METSÄNTUTKIMUSLAITOKSEN JULKAISUJA

COMMUNICATIONES
INSTITUTI FORESTALIS FENNIAE

MEDDELANDEN FRÅN SKOGSFORSKNINGSINSTITUTET I FINLAND
MITTEILUNGEN DER FORSTLICHEN FORSCHUNGSANSTALT IN FINNLAND
PUBLICATIONS OF THE FINNISH FOREST RESEARCH INSTITUTE
PUBLICATIONS DE L'INSTITUT DE RECHERCHES FORESTIÉRES DE LA FINLANDE

82

HELSINKI 1975

METSÄNTUTKIMUSLAITOKSEN JULKAISUJA

COMMUNICATIONES
INSTITUTI FORESTALIS FENNIAE

MEDDELANDEN FRÅN SKOGSFORSKNINGSINSTITUTET I FINLAND
MITTEILUNGEN DER FORSTLICHEN FORSCHUNGSANSTALT IN FINNLAND
PUBLICATIONS OF THE FINNISH FOREST RESEARCH INSTITUTE
PUBLICATIONS DE L'INSTITUT DE RECHERCHES FORESTIÉRES DE LA FINLANDE

82

HELSINKI 1975

COMMUNICATIONES

INSTITUTI FORESTALIS FENNIAE

82

82.1 Nikkilä, Heikki & Rikkonen, Pentti & Heiskanen, Veijo. 1974. Suomalaisen kuitupuun pinotiheys ja siihen vaikuttavat tekijät. *Summary:* The relative solid content of Finnish pulpwood and the factors affecting it ..... 1— 91

82.2 Reunala, Aarne. 1974. Structural change of private forest ownership in Finland. *Seloste:* Yksityismetsänomistuksen rakennemuutos ..... 1— 70

82.3 Juutinen, Paavo. 1974. Über die in den männlichen Blütenkätzchen der Rauh- und Moorbirke vorkommenden *Argyresthia*-Arten (Lepidoptera: Argyresthiidae) *Seloste:* Raudus- ja hieskoivun hedenorkoissa esiintyvistä *Argyresthia*-lajeista (Lepidoptera: Argyresthiidae) ..... 1— 30

82.4 Selby, Ashley. 1975. Afforestation of fields in Finland: Agricultural background and recent achievements. *Seloste:* Peltojen metsitys Suomessa ..... 1— 51

82.5 Palo, Matti & Nissilä, Olli. 1975. Waste paper recycling: Economic and ecological prospects. *Seloste:* Keräyspaperin käytön ekonomiset ja ekologiset perusteet ja mahdollisuudet ..... 1—106

SUOMALAISEN KUITUPUUN PINOTIHEYS JA SIIHEN VAIKUTTAVAT TEKIJÄT

HEIKKI NIKKILÄ, PENTTI RIKKONEN
JA VEIJO HEISKANEN

SUMMARY

THE RELATIVE SOLID CONTENT OF FINNISH PULPWOOD
AND THE FACTORS AFFECTING IT

HELSINKI 1974

ISBN 951-40-0109-5

Helsinki 1974. Valtion painatuskeskus

ALKUSANAT

Pinomittausta ja sen kehittämistä on tutkittu meillä vv. 1972—73 intensiivisesti erityisesti Pinomittauksen kehittämisryhmän toimesta. Tämän ryhmän suorittamien tutkimusten tulokset on julkaistu ennakkotiedonantoina kymmenessä monisteessa (Heiskanen 1972 a, 1972 b, 1972 c, 1972 d, 1972 e, Nikkilä ja Heiskanen 1972, Nikkilä 1972 b, 1972 c, Rikkonen 1972 a, 1972 b) ja osa tärkeimmistä tuloksista on jo esitetty myös Folia Forestalia-sarjan tutkimuksina (Heiskanen 1973 a, 1973 b, 1973 c, Heiskanen ja Riikonen 1973). Yksi osa tutkimuksesta käsitteli kuitupuupinojen keskimääräistä pinotiheyttä ja siihen vaikuttavia tekijöitä, joita koskevat tiedot on julkaistu Rikkosen (1972 a, 1972 b) toimesta ennakkotiedonantoina. Eri tekijöiden vaikutusta koskevia laskelmia jatkettiin syksyllä 1972 ja niiden sekä mainittujen ennakkotietojen perusteella laadittiin, samoin syksyllä 1972, Mittausneuvoston asettaman työryhmän toimesta kiintomittausohje (Uudistuva puutavaran mittaus II. 1973). Se on ollut marraskuusta 1972 alkaen Mittausneuvoston suosittelemana kokeilumielessä käytössä koko maassa.

Näiden ennakkotietojen perusteella julkaisi Metsäntutkimuslaitos tammikuussa 1973 päätöksen puutavaran mittauksessa käytettävistä muuntoluvuista (Folia Forestalia 172).

Esillä olevassa julkaisussa esitetään pinotiheyttä ja siihen vaikuttavia tekijöitä koskevat tärkeimmät tulokset 2 m ja 3 m tavaroiden osalta pinomittauksen kehittämistutkimuksen mukaisina. Työnjako tutkimusta tehtäessä on ollut se, että tutkimussuunnitelma on tehty Pinomittauksen kehittämisryhmässä Heiskasen johdolla, alkuperäinen laskentatyö Rikkosen johdolla ja lopulliset laskelmat Nikkilän toimesta. Käsikirjoitus on Heiskasen ja Nikkilän yhdessä osittain Rikkosen aiempien julkaisujen pohjalta laatima.

Tässä yhteydessä meillä on mieluisa velvollisuus esittää kiitoksemme seuraaville tutkimustyötä erityisesti edistäneille henkilöille: toimitusjohtaja Väinö Niku, metsänhoitaja Matti Ylinen, valtiotiet. kand. Arja Winter, metsät. ylioppilas Jorma Riikonen, metsät. ylioppilas Leif Niemi ja metsäteknikko Pentti Savilampi sekä Pinomittauksen kehittämisryhmän muut jäsenet, mittausryhmien johtajat sekä laskentatöihin osallistunut Metsäntutkimuslaitoksen metsäteknologian tutkimusosaston henkilökunta.

Helsinki 1974-05-18

Heikki Nikkilä, Pentti Rikkonen ja Veijo Heiskanen

SISÄLLYSLUETTELO

Alkusanat Sivu

1. Johdanto ... 5
2. Tutkimusmenetelmä ... 7
   21. Tutkimuspinojen valinta ... 7
   22. Suoritetut mittaukset ... 8
3. Tutkimusaineisto ... 12
4. Tutkimustulokset ... 17
   41. Mittauksen vaikutus pinotiheyteen ... 17
      411. Kehysmitan mittaustapa ... 17
      412. Mittausryhmän mittauksen ja tarkastusmittauksen vertailua ... 19
      413. Muita tekijöitä ... 20
   42. Pinon ominaisuuksien vaikutus ... 20
      421. Ladonta ... 20
         4211. Ladontatapa ... 20
         4212. Ladontaluokka ... 25
         4213. Uudelleen ladonta ... 29
      422. Vieraat esineet ... 33
      423. Lumi ja jää ... 35
      424. Pinon suuruus ... 35
      425. Pinon ikä ... 36
      426. Mittauspaikka ... 38
      427. Kauppatapa ... 38
      428. Omistajaryhmä ... 39
      429. Muita tekijöitä ... 40
   43. Kuitupuun ominaisuuksien vaikutus ... 41
      431. Keskiläpimitta ... 41
      432. Läpimittojen erotus ja hajonta ... 44
      433. Sekoittuminen ... 45
      434. Tyvipölkkyjen osuus ... 46
      435. Mutkaisuus ... 49
      436. Karsinta ... 53
      437. Lehtipuusekoitus ... 57
      438. Muita tekijöitä ... 60
   44. Pinotiheyden vaihtelua selittävät mallit ... 61
      441. Yleistä ... 61
      442. Malleihin sisältyvät muuttujat ... 62
      443. Mallit ... 65
      444. Mallien arvostelu ... 66
   45. Keskimääräisiä pinotiheyksiä ... 70
   46. Käytännön sovellutuksia ... 72
   47. Tiivistelmä ... 77
Kirjallisuutta ... 83
Summary ... 87
Liitteet — *Appendices* ... 93

1. JOHDANTO

Vuonna 1972 tehtiin Pinomittauksen kehittämisryhmän toimesta laaja kuitupuun pinomittausta koskeva tutkimus. Tämä pinomittauksen kehittämistutkimus jakautui kahteen vaiheeseen, kuten Heiskasen (1973 a) julkaisussa on selostettu. Tutkimuksen I vaiheessa selvitettiin koearvioinnein pinon mittauksen sekä tyhjän tilan vähennyksen, pinotiheysluvun, ns. pinotiheystekijäin ja hylkyvähennysten arvioinnin tarkkuutta. Tämä tapahtui 64 näytepinon mittausten ja arviointien avulla. Kokeisiin osallistui kaikkiaan 149 metsäammattimiestä. Tutkimuksen tämän osan organisaation, menetelmän ja tulosten osalta viitataan Heiskasen (1973 a, 1973 b ja 1973 c) tutkimusselosteisiin.

Pinomittauksen kehittämistutkimuksen nyt esillä olevan II vaiheen päätarkoituksena on suomalaisen 2—3 metrisen kuitupuun keskimääräisen pinotiheyden ja sen vaihteluun vaikuttavien tekijäin selvittäminen maan eri puolilta kerätyn aineiston perusteella. Tämä selvitys katsottiin tarpeelliseksi sen vuoksi, että kuitupuun laatu ja tekotapa sekä pinojen laatu ja pinoamistapa ovat muuttuneet aiempien laajojen pinotiheystutkimusten ajoista. Nykyaikaisista pinoista onkin saatavissa tietoja vain Nikkilän (1972 a) verraten suppeasta lehtipuupinoja koskevasta julkaisemattomasta selvityksestä. Pinomittauksen kehittämisryhmän tuloksia koskevat ennakkotiedot on myös julkaistu monisteina (Rikkonen 1972 a, 1972 b). Useissa yhteyksissä on muutoinkin korostettu konepinojen pinotiheyden alhaisuutta sekä tällaisten pinojen mittauksen vaikeuksia (Arnkil 1966, v. Schoultz 1968, Heiskanen 1968, Finne 1970, Hemmi 1970). Myös pinomittauksen yleiset vaikeudet ja pinotiheyden arviointi, mm. tyhjäntilan vähennys ovat olleet esillä viimeaikaisessa kirjallisuudessa (esim. Pertovaara 1964, Hemmi 1967, 1970, Finne 1967, Leinonen ja Rikkonen 1971, Ylinen 1972). Samoja ongelmia käsiteltiin myös Heiskasen em. tutkimuksissa. Pinotiheyteen vaikuttavia tekijöitä ovat valottaneet mm. Jalava 1929, Aro 1931, 1958, 1959, Wuoti 1938, 1940, Ronkanen 1942, Saari et al. 1942, Makkonen 1957, 1958, 1959, 1965, Hellman 1959, Pertovaara 1960, 1964, Nisula 1963, 1967, Mähönen 1964, Hemmi 1965, 1966, 1967. Monissa näistä on pinomittausta ja pinotiheyksiä tutkittu pitämällä tavoitteena eri yhteyksissä

tarvittavien muuntolukujen selvittämistä. Tällaisista tutkimuksista mainittakoon ennen kaikkea Aron, Makkosen ja Hemmin työt.

Ulkomailla, nimenomaan Ruotsissa, on pinomittauksen kaikkinainen kehittäminen ollut vilkkaan tutkimustoiminnan kohteena. Tärkeimpiä tutkimuksia ovat Sydsvenska virkesföreningenin v. 1955, Virkesmätningsrådetin v. 1960 ja Skogsstyrelsenin v. 1957 tekemät alustavat selvitykset sekä Nylinderin ja Petersonin (1967) ja Karlssonin (1971) laajat pinotiheyden mittaamista ja arviointia koskevat tutkimukset. Lisäksi mainittakoon Nylinderin (1957, 1958, 1959, 1964) selvitykset eri puutavaralajien pinotiheyksistä sekä Eklundin (1948, 1953) vastaavanlaiset työt. Myös uranuurtava komiteanmietintö »Vid virkesmätning erforderliga relationstal» vuodelta 1923 antaa vieläkin käyttökelpoisia tietoja eri puutavaralajien pinotiheyksistä.

Pinomittausta ja pinotiheyksiä jossakin määrin meikäläisiä vastaavissa olosuhteissa on tutkittu myös Norjassa. Sikäläisistä tutkimuksista mainittakoon seuraavat: Klem ja Halvorsen (1963), Myhrer ja Wibstad (1965) ja Arvesen (1966).

Esillä olevasta aineistosta on tarkoitus keskimääräislukujen lisäksi tutkia myös eri pinotiheystekijöiden vaikutusta pinotiheyteen. Tällaisina pinotiheystekijöinä otettiin tutkittavaksi seuraavat: keskiläpimitta, sekoittuminen, läpimittojen erotus (ja hajonta), tyvipölkkyjen osuus, mutkaisuus, ladonta, karsinta, vieraat esineet sekä lumi ja jää. Lisäksi tulevat selvitettäviksi pölkyn pituuden ja puulajin vaikutus. Pinotiheystekijäin vaikutusta on jo alustavasti selvitetty pinomittauksen kehittämistutkimuksen I vaiheen aineistosta (Rikkonen 1972 a). Ko. aineistosta saadaan myös tukea keskimääräisiä pinotiheyslukuja tutkittaessa.

Nyt esillä olevan tutkimuksen pääaineistoa kerättäessä kiinnitettiin erityistä huomiota siihen, että aineistoa saataisiin maan kaikista osista. Tämä katsottiin tarpeelliseksi mahdollisten alueellisten eroavuuksien selvittämiseksi ja aineiston alueellisen edustavuuden varmistamiseksi. Aineiston edustavuus onkin sen keräämisessä pyritty varmistamaan mahdollisimman hyvin. Tutkimuksen I vaiheen pinot olivat sitä vastoin koearvioinnin suorituksen tarkoituksenmukaisuutta silmälläpitäen valittuja ja osittain sitä varten tehtyjä pinoja, joten niitä ei ole voitu yhdistää II vaiheen aineistoon.

Esillä olevasta aineistosta tutkitaan myös mittausryhmien johtajien arviointituloksia eräiden tunnusten osalta, jolla tavoin saadaan lisätietoja arviointien tarkkuudesta.

2. TUTKIMUSMENETELMÄ

21. Tutkimuspinojen valinta

Tutkimuspinojen valinnassa meneteltiin seuraavasti:

— Etelä-Suomen alueella asetettiin tavoitteeksi saada mitatuksi n. 300 pinoa ja Pohjois-Suomessa n. 200 pinoa. Puulajeittain oli tavoiteltu pinomäärä taulukon 1 mukainen.

— Kummallakin suuralueella asetettiin osa-alueille tavoitekiintiö puulajeittain pinotavaran hakkuusuunnitteen (Huttunen 1971) osoittamassa suhteessa. Tavoitekiintiöt näkyvät taulukosta 1.

— Tutkimuspinojen alueellinen määrittäminen kullakin osa-alueella tapahtui peruskartan karttalehtiä (mittakaava 1 : 20 000) käyttäen. Karttalehden neljänneksistä oli A-osa pinta-alan perusyksikkönä, jonka alueelle asetettiin tavoitteeksi 3—7 pinon kiintiöt. Ne näkyvät alla olevasta asetelmasta.

	Mä	Ku	Leh
Etelä-Suomi		Pinoja, kpl	
Alue 1	2	2	1
2	2	2	3
3	1	1	2
Pohjois-Suomi			
Alue 4	1	1	1
5	1	1	1

Pinojen määrät kiintiöissä eroavat siis toisistaan. Kiintiöt muodostettiin sovittelussa, jossa vaatimuksena oli, että pinojen määrän tuli olla kullakin osa-alueella sama kaikissa pinta-alayksiköissä samalla kun puulajien suhteet pysyivät kokonaiskiintiön mukaisina. Koska pidettiin mahdollisena, että pystykaupoissa ja hankintakaupoissa tehtävien pinojen pinotiheydet saattoivat poiketa toisistaan, haluttiin varmistaa, että niitä tuli aineistoon likimäärin oikeassa suhteessa. Aineiston kerääjille annetun ohjeen mukaan tuli Pohjois-Suomen alueella olla n. $\frac{2}{3}$ pystykauppojen pinoja ja n. $\frac{1}{3}$ hankintakauppojen pinoja. Etelä-Suomessa vastaava tavoite oli puolet kumpaakin kauppatyyppiä.

Ne karttalehdet, joiden alueella pinoja mitattiin, määritettiin arpomalla käyttäen kuitenkin sellaista menettelyä, jonka avulla pinot jakautuivat osa-alueen eri puolille. Lisäksi eri osa-alueille määritettiin varakarttalehdet siltä varalta, ettei pinoja löytynyt riittävästi varsinaisilta karttalehdiltä. Arpomalla määritettiin kullekin ryhmälle vielä kolme lisäkarttalehteä. Kullakin karttalehdellä tapahtui pinojen valinta kahdella eri tavalla. *Pystykauppapinot* alueella luetteloitiin ja luettelosta *arvottiin* tutkimuspinot. *Hankintakauppapinoja* kerättiin ns. *tiemenetelmällä*. Tässä meneteltiin siten, että suorinta tietä majapaikalta karttalehden alueelle tultaessa mitattiin ensimmäiset tien varressa olleet pinot. Kiintiön täyttämiseksi jatkettiin matkaa karttalehdellä siten, että seuraavasta tienhaarasta käännyttiin vasemmalle ja seuraavasta oikealle, jälleen vasemmalle jne. Siltä varalta, ettei pinoja karttalehden osalta löytynyt kiintiön edellyttämää määrää, annettiin yksityiskohtaiset ohjeet kiintiön täyttämiseksi. Näitä erityisohjeita jouduttiin soveltamaan kuitenkin hyvin harvoin.

Koepinoille asetettiin eräitä vaatimuksia, jotka katsottiin tarpeellisiksi aineiston ominaisuuksien määrittelyn kannalta. Pinojen tuli täyttää seuraavat ehdot:

— Tavaran tuli olla määräpituista 2 m:n, 2.2 m:n, 2.4 m:n tai 3 m:n tavaraa. Seassa sai kuitenkin olla ns. apumittoja.

— Lehtipuun tai vieraan puulajin sekoitus sai olla korkeintaan 10 %. Lehtipuupinoissa ei eri lehtipuulajeille asetettu rajoituksia, mutta kaikki aineistoon sisältyvät lehtipuupinot ovat voimakkaasti koivuvaltaisia.

— Pino ei saanut olla ylivuotinen.

— Pinon minimikoko oli 2—2.4 m:n tavaralle 10 p-m^3 ja 3 m:n tavaralle 15 p-m^3. Yli 20 p-m^3:n pinosta mitattiin vain 20 p-m^3 kaikissa tavaran pituusluokissa. Mitattava osa erotettiin muusta pinosta katkaisemalla pino uudelleen latomalla.

22. Suoritetut mittaukset

Mittausryhmän tehtäviin kuuluivat seuraavat mittaukset ja arvioinnit:

— Yleistietojen merkintä.
— Pinon kehysmitan mittaaminen
  — — puutavaran mittaussäännön mukaisesti (virallinen kehysmitta)
  — — ns. ruotsalaisen tavan mukaisesti (todellinen kehysmitta).
— Tyhjän tilan arviointi.
— Pinotiheysluvun arviointi.
— Pinotiheystekijäin arviointi.
— Hylkyvähennysten arviointi.

— Pölkyttäinen kiintomitan mittaus ja siihen liittyen lisämääritykset koepölkyistä.

— Pinojen uudelleen ladonta keskinkertaista ladontatapaa käyttäen.

— Uudelleen ladottujen pinojen kehysmitan mittaukset.

Esillä olevan tutkimusongelman kannalta on tarpeetonta esittää tyhjän tilan vähennystä koskevia ohjeita, koska tätä kysymystä ei käsitellä (ks. Heiskanen 1973 a).

Yleistietoina merkittiin jokaisesta pinosta muistiin seuraavat tiedot:

— Puulaji

— Mittaajan nimi

— Pinon tunnukset

— Pinoamisaika kuukauden tarkkuudella

— Kauppatapa, hankinta- vai pystykauppa

— Puutavaralaji, josta merkittiin muistiin, oliko kyseessä runko- vai latvuspinotavara vaiko molempien sekoitus, sekä oliko tavara lajittelematonta vai lajiteltua.

— Ladontatapa ja sen arvostelu, missä erotettiin käsin tehty pino, hyvä konepino ja huono konepino sekä muu. Huonoksi katsottiin konepino, jossa pölkyt ovat sekaisin, jossa on hakkuutähteitä sekä oksia ja jossa pinojen sivut ovat hyvin epätasaiset. »Muu» tarkoittaa esim. puskulevyllä tehtyä kasaa.

— Karsinnasta merkittiin ylös jokin seuraavista vaihtoehdoista: kirveskarsinta, moottorisahakarsinta ja kummatkin pinnanmyötäisesti sekä tynkäkarsinta.

— Pääpuut

— Aluspuut.

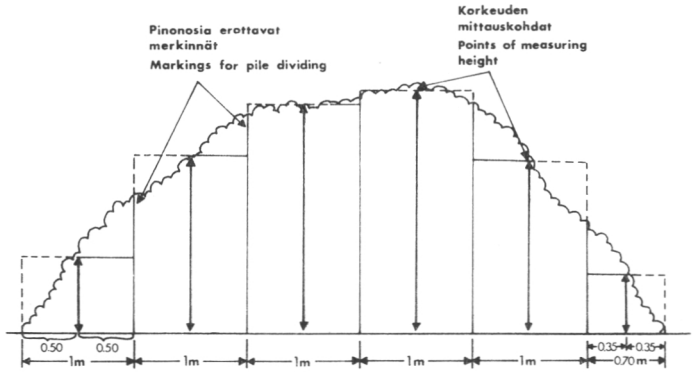
Vielä piirrettiin jokaisesta pinosta kaaviokuva.

Pinon kylkitiheyden mittaukset suoritettiin myös, mutta niitä koskeviin ohjeisiin ei ole tässä yhteydessä syytä puuttua (ks. Nikkilä 1972 b).

Pinon ns. virallinen kehysmitta määritettiin, kuten mainittiin, puutavaran mittaussäännön mukaisesti siten, että tavaran pituutena käytettiin sen nimellistä pituutta.

Pinon pituudet mitattiin pinon molemmilta puolilta korkeuden puolivälistä pinon pohjan suunnassa senttimetrin tarkkuudella. Pinon korkeudet mitattiin seuraavin välimatkoin pinon molemmilta puolilta sentin tarkkuudella: alle 5 metrin pituisissa pinoissa 1 m:n välein, 5—20 metrin pituisissa pinoissa 2 m:n välein ja yli 20 metrin pinoissa 3 m:n välein. Ensimmäinen mittauskohta asetettiin puolen mittausvälin etäisyydelle pinon päästä.

Ruotsalaisen järjestelmän mukaan määritettiin ns. todellinen kehysmitta seuraavasti (kuva 1).



Kuva 1. »Ns. ruotsalainen» pinon kehysmitan mittaustapa.
Fig. 1. So-called Swedish method of measuring gross volume.

»Pinon pituus mitataan maan tasalta ulommaisen pölkyn ulkoreunasta toisen pään ulommaisen pölkyn ulkoreunaan desimetrin tarkkuudella.

Pinon korkeudet mitataan pinon molemmilta puolilta. Alle 5 metrin pinoissa väli on 50 cm, ja sitä pitemmissä 100 cm. Ensimmäinen mittauskohta on puolen mittausvälin etäisyydellä pinon alkupäästä. Mittaukset suoritetaan samalla tavoin pinon molemmilta puolilta. Pinoa ei siis 'kierretä'.»

P i n o t i h e y s l u k u arvioitiin jokaisesta pinosta alkuperäisen ladonnan mukaisena silmävaraisesti prosentin tarkkuudella (H e i s k a n e n 1973 b).

P i n o t i h e y s t e k i j ö i n ä arvioitiin seuraavat tunnukset liitteessä 1 esitettyjen 3—5 luokkaisten luokitusten mukaisesti: keskiläpimitta, läpimittojen erotus, pölkkyjen sekoittuminen, tyvipölkkyjen osuus, lehtipuun osuus, mutkaisuus, ladonta, karsinta, vieraat esineet sekä lumi ja jää. Kaikki nämä arvioinnit tehtiin alkuperäisestä pinosta. Pinotiheyteen vaikuttavina tekijöinä voidaan myös tarkastella ladontatapaa ja kauppatapaa sekä pinon ikää.

Pinotiheyksien ym. tietojen laskemista varten määritettiin pölkkyjen kiintomitat seuraavia ohjeita noudattaen:

»— Pölkystä mitataan läpimitta todellisen pituuden puolivälistä kuoren päältä vaakasuorassa suunnassa 1 cm:n alenevaa luokitusta käyttäen. Jos mittauskohdassa on oksapaisuma tai muu paksunnos, mitataan kaksi läpimittaa paksunnoksen molemmilta puolilta sen vaikutusalueen ulkopuolelta. Näiden läpimittain keskiarvo on pölkyn paksuus.

— Mutkaisuus määritetään kolmessa luokassa. Luokat ovat seuraavat: 1. Suora tai likipitäen suora, 2. Lievästi lenko tai mutkainen, 3. Hyvin lenko tai mutkainen.

Joka 10:s pölkky on koepölkky. Asemaa, keskusläpimittaa ja mutkaisuutta koskevien tietojen lisäksi koepölkyistä tehdään seuraavat merkinnät:

— Tyvi- ja latvaläpimitat mitataan samalla tavalla kuin keskusläpimitta. Mittaukset suoritetaan 5 cm:n etäisyydeltä kummastakin päästä. Jos mittauskohdassa on oksapaisuma tai muu paksunnos siirretään mittauskohtaa latvassa tyveen päin ja tyvessä latvaan päin siihen, missä paksunnoksen vaikutus loppuu.»

Kiintomittaa laskettaessa korjattiin keskeltämittauksen antama tulos koepölkkyjen mittaustulosten perusteella tarkkaa todellista kiintomittaa vastaavaksi. Eri läpimittaluokissa ja puulajeissa käytetyt korjauskertoimet nähdään liitteestä 2 (vrt. Heiskanen 1973 c).

»— Mutkaisuus merkitään myös mutkaisuuden mittana alenevaa sentin luokitusta käyttäen.

— Karsinnan laatu arvostellaan kolmessa luokassa: 1. Ei oksantynkiä, 2. Joitakin lyhyitä oksantynkiä (< 1 cm), 3. Paljon lyhyitä tai pitkähköjä tynkiä.

— Pölkyn pituus mitataan pölkyn sahauspintojen välisenä etäisyytenä 1 cm:n alenevalla luokituksella.»

Maa jaettiin mittausten suorittamista varten viiteen alueeseen, jotka ilmenevät kuvista 2, 3 ja 4. Jokaiseen alueeseen asetettiin yhdysmies, jonka tehtävänä olivat käytännön järjestelyt, sekä mittaustöitä varten yksi tai kaksi mittausryhmää. Näiden ryhmien koulutus suoritettiin perusteellisesti. Ensin järjestettiin kaksipäiväinen koulutustilaisuus pääpiirtein saman ohjelman mukaan kuin koemittaajienkin koulutuspäivät. Lisäksi mittausryhmien johtajat osallistuivat toiminta-alueensa koulutus- ja mittaustilaisuuksiin (vrt. Heiskanen 1973 a).

Ryhmien toimintaa valvoi metsäteknikko Pentti Savilampi Metsäntutkimuslaitoksesta. Hän suoritti myös tarkastusmittauksia samoin menetelmin kuin ryhmänjohtajatkin.

3. TUTKIMUSAINEISTO

Tutkimusaineiston pinojen jakautuminen maan eri osiin näkyy kuvista 2, 3 ja 4. Jakautumaa tarkasteltaessa on huomattava, että Pohjois-Suomen alueella on pinoja hakkuupoistumaan nähden suhteellisesti enemmän kuin Etelä-Suomen alueella. Aineiston kokonaismäärä (taulukko 1) ylittää asetetun tavoitteen. Sen suhteellinen jakautuminen puulajien ja osa-alueiden kesken ei ole täysin tavoitteen mukainen, mutta kuitenkin sitä tyydyttävän lähellä. Yli 2 metriä pitkää tavaraa esiintyy verraten vähän, joten sen osalta pitkälle menevien johtopäätösten teko on vaikeata. Alueen 5 (Lappi) kuusipinoista on kuitenkin valtaosa 3-metristä tavaraa.

Taulukko 1. Tutkimusaineisto osa-alueittain.
Table 1. Investigation material by sub-areas.

Alue *Area*	2-m Pinoja kpl *Piles pcs*	2.2- ja 2.4-m Pinoja kpl *Piles pcs*	3-m Pinoja kpl *Piles pcs*	Yhteensä Pinoja kpl [1] *Piles pcs*
		Mänty — *Pine*		
1	35	—	5	40 (34)
2	22	2	3	27 (27)
3	26	—	1	27 (29)
4	34	—	—	34 (27)
5	36	—	—	36 (33)
Etelä-Suomi — *South Finland*	83	2	9	94 (90)
Pohjois-Suomi — *North Finland*	70	—	—	70 (60)
Koko maa — *Total*	153	2	9	164 (150)
		Kuusi — *Spruce*		
1	34	—	6	40 (36)
2	21	4	2	27 (30)
3	23	—	4	27 (24)
4	35	—	—	35 (38)
5	8	—	14	22 (22)
Etelä-Suomi — *South Finland*	78	4	12	94 (90)
Pohjois-Suomi — *North Finland*	43	—	14	57 (60)
Koko maa — *Total*	121	4	26	151 (150)
		Lehtipuu — *Broadleaved*		
1	24	—	2	26 (16)
2	38	2	—	40 (47)
3	39	13	—	52 (57)
4	34	—	—	34 (31)
5	53	—	1	54 (49)
Etelä-Suomi — *South Finland*	101	15	2	118 (120)
Pohjois-Suomi — *North Finland*	87	—	1	88 (80)
Koko maa — *Total*	188	15	3	206 (200)

[1]) Suluissa olevat luvut tarkoittavat tavoitteeksi asetettuja pinomääriä. — *Numbers in the*

Alue *Area*	2-m Pinoja kpl *Piles pcs*	2.2- ja 2.4-m Pinoja kpl *Piles pcs*	3-m Pinoja kpl *Piles pcs*	Yhteensä Pinoja kpl[1]) *Piles pcs*
Kaikki puulajit — *Total*				
1	93	—	13	106 (86)
2	81	8	5	94 (104)
3	88	13	5	106 (110)
4	103	—	—	103 (96)
5	97	—	15	112 (104)
Etelä-Suomi — *South Finland*	262	21	23	306 (300)
Pohjois-Suomi — *North Finland*	200	—	15	215 (200)
Koko maa — *Total*	462	21	38	521 (500)

Käsin ladottujen pinojen osuus näkyy alueittain seuraavasta asetelmasta.

Alue 1	74.5	%
2	74.5	»
3	85.8	»
4	59.2	»
5	43.8	»
E-S (1—3)	78.4	»
P-S (4—5)	51.2	»
Yhteensä	67.2	%

Käsin ladottujen pinojen osuutta voidaan pitää suurena, kun verrataan sitä esim. I vaiheen aineistoon. Kysymyksessä on kuitenkin pinojen lukumäärän suhde. Se ei kuvaa ladontamenetelmien tosiasiallista osuutta, mikäli koneella tehdyt pinot ovat keskimäärin käsin tehtyjä suurempia, kuten on otaksuttavissa.

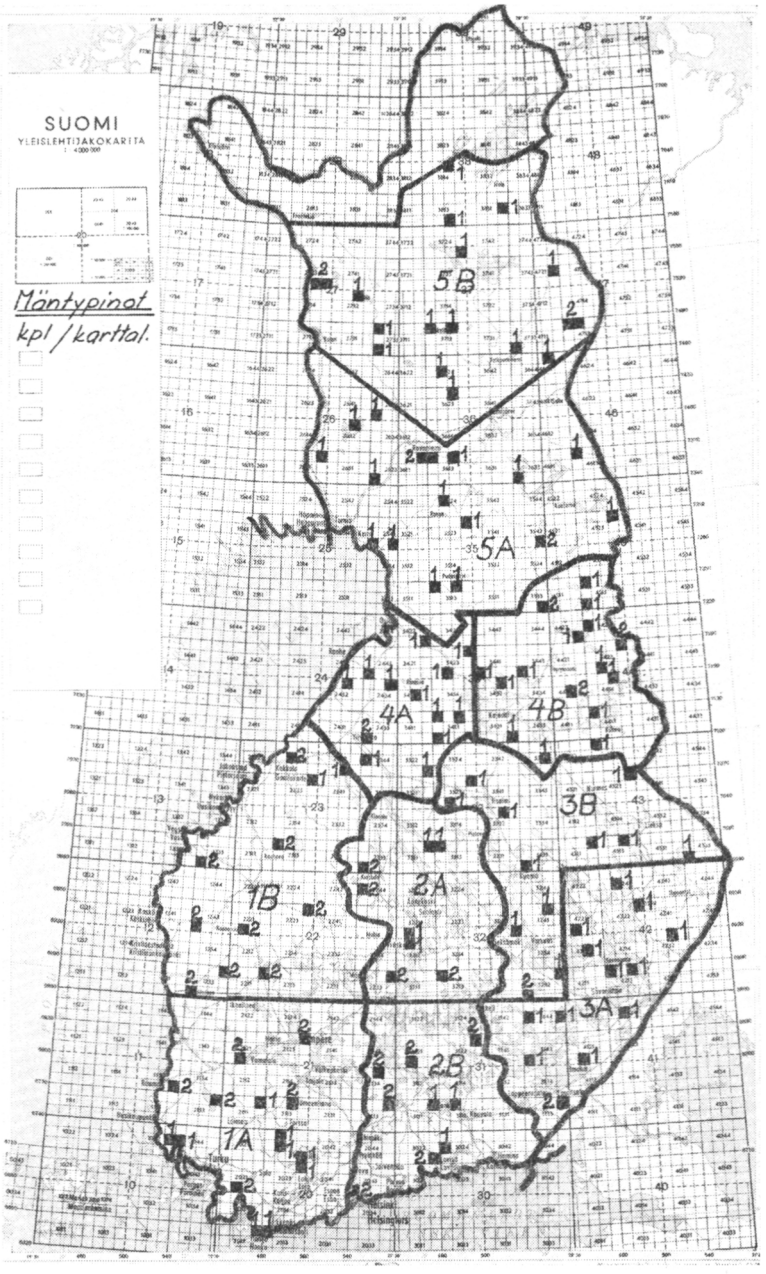
Joitakin pinojen keskimääräisiä ominaisuuksia eri alueilla on esitetty taulukossa 2.

Taulukko 2. Keskimääräisiä tietoja eri osa-alueilla mitatuista 2.0—2.2 m:n kuitupuupinoista

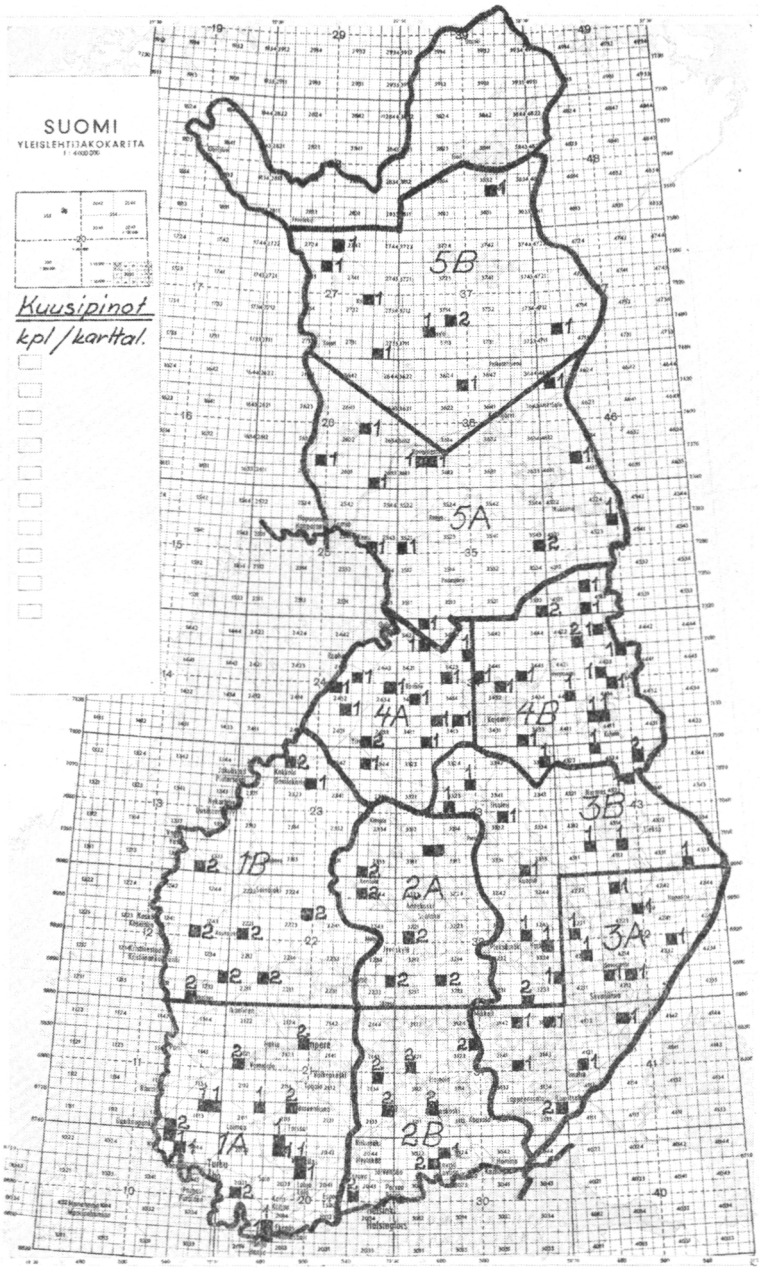
Table 2. Average information on 2.0—2.2-m pulpwood piles measured in different subareas.

Osa alue *Area*	Pinoja *Piles*	Yht. p-m³ *Piled cu.m.*	P-m³/ pino *Piled cu.m./ pile*	Vaihtelurajat *Limits of variation* max	Vaihtelurajat *Limits of variation* min	Keskiläpimitta, cm *Mean diameter* $\bar{x}$	Keskiläpimitta, cm *Mean diameter* vaihtelu *variation* max	Keskiläpimitta, cm *Mean diameter* vaihtelu *variation* min
Havupuu — *Conifer*								
1	68	1 166.1	16.9	26.2	9.0	11.4	18.6	8.0
2	46	768.2	16.7	27.0	9.9	11.1	16.6	8.0
3	49	720.3	14.7	21.4	10.3	11.4	16.5	8.6
4	68	1 094.8	16.1	22.5	10.4	11.6	16.0	8.7
5	43	731.0	17.0	28.4	9.4	13.1	19.9	9.6
Yht. — *Total*	274	4 480	16.3	28.4	9.0	11.6	19.9	8.0
Lehtipuu — *Broadleaved*								
1	24	3 720.0	15.5	20.5	10.0	10.8	12.9	7.8
2	40	684.0	17.1	25.0	10.2	11.3	18.2	7.9
3	40	632.0	15.8	20.3	10.0	11.7	18.9	7.3
4	33	570.9	17.3	22.0	10.8	11.3	13.7	9.3
5	52	889.2	17.1	40.6	9.1	12.4	17.8	9.0
Yht. — *Total*	189	3 148	16.7	40.6	9.1	11.6	18.9	7.3

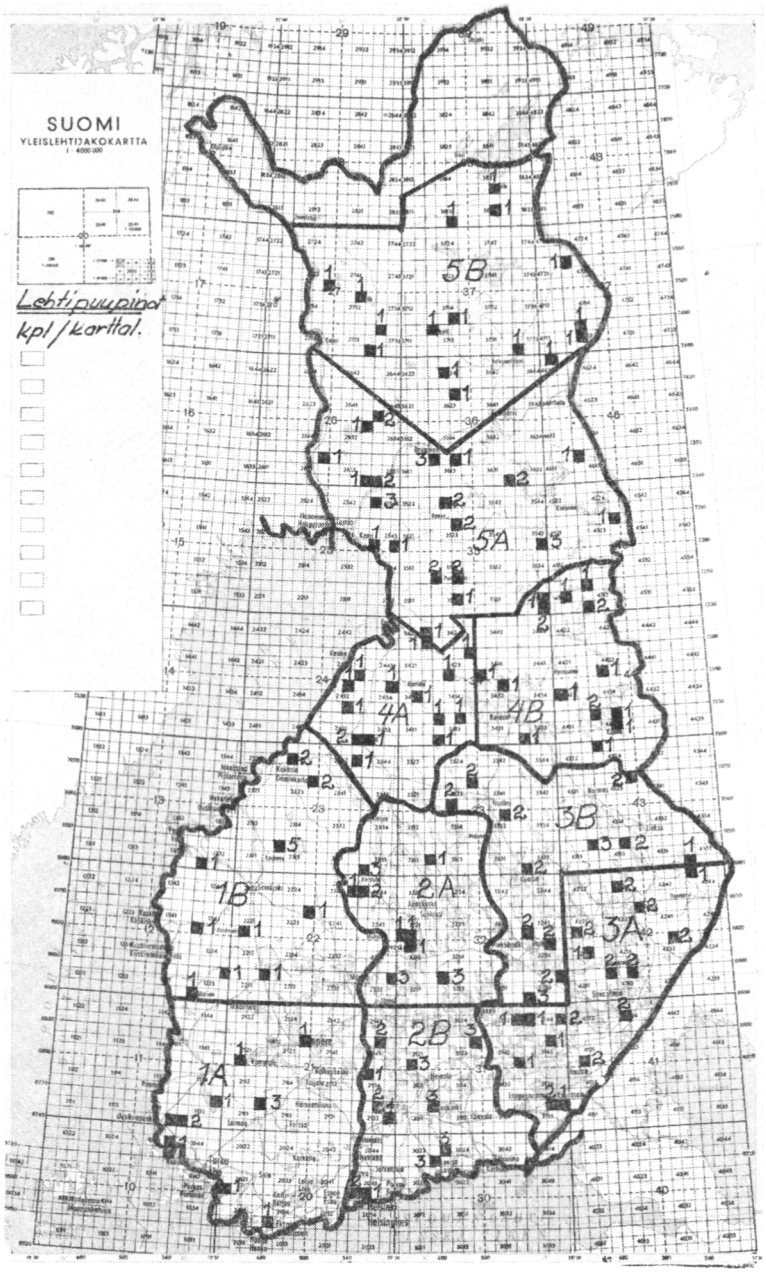
braces are the aims.



Kuva 2. Mäntypinojen alueittainen jakautuminen.
Fig. 2. Regional distribution of pine piles.



Kuva 3. Kuusipinojen alueittainen jakautuminen.
Fig. 3. Regional distribution of spruce piles.



Kuva 4. Lehtipuupinojen alueittainen jakautuminen.
Fig. 4. Regional distribution of broadleaved piles.

4. TUTKIMUSTULOKSET

41. Mittauksen vaikutus pinotiheyteen

411. Kehysmitan mittaustapa

Pääosasta pinoja mitattiin pinomitta sekä puutavaran mittaussäännön mukaan että Ruotsissa käytännössä olevan mittaustavan mukaan, kuten tutkimusmenetelmää selostettaessa mainittiin. Mittaussäännön mukaista

Taulukko 3. Kehysmitan mittaustavan vaikutus pinotiheyteen tutkimusalueittain
Table 3. Effect of the gross volume measuring method on the relative solid content by sub-areas.

Alue *Area*	Pinoja *Piles pcs*	Virallinen *Official relative solid content*			Todellinen *Accurate relative solid content*			Ero % *Difference %*
		$\bar{x}$	s	v %	$\bar{x}$	s	v %	
Mänty — *Pine*								
1	40	65.0	4.7	7.2	64.8	4.5	6.9	—0.3
2	27	66.0	3.9	5.9	66.0	3.9	5.9	0
3	27	63.9	3.7	5.8	64.1	3.5	5.5	+0.3
4	34	67.1	4.9	7.3	67.6	4.8	7.1	+0.7
5	36	63.8	5.0	7.8	64.0	5.1	8.0	+0.3
Etelä-Suomi — *South Finland*	94	65.0	4.2	6.5	64.9	4.1	6.3	—0.2
Pohjois-Suomi — *North Finland*	70	65.4	5.2	8.0	65.5	5.2	7.9	+0.2
Koko maa — *Total*	164	65.2	4.6	7.0	65.3	4.6	7.0	+0.2
Kuusi — *Spruce*								
1	40	66.0	4.4	6.7	66.4	4.0	6.0	+0.6
2	27	66.8	2.9	4.3	67.1	2.6	3.9	+0.4
3	27	64.4	3.6	5.6	64.7	3.5	5.4	+0.5
4	35	65.9	4.7	7.1	66.1	4.5	6.8	+0.3
5	22	63.6	3.7	5.8	63.9	3.8	5.9	+0.5
Etelä-Suomi — *South Finland*	94	65.8	3.9	5.9	66.1	3.0	5.4	+0.5
Pohjois-Suomi — *North Finland*	57	65.0	4.5	6.9	65.3	4.3	6.6	+0.5
Koko maa — *Total*	151	65.5	4.1	6.2	65.8	3.9	5.9	+0.5
Lehtipuu — *Broadleaved*								
1	26	55.4	4.9	8.8	55.7	4.6	8.2	+0.5
2	40	57.8	4.2	7.3	58.0	4.2	7.2	+0.3
3	52	56.2	4.3	7.6	56.3	4.3	7.6	+0.2
4	34	56.2	4.2	7.5	56.1	4.3	7.7	—0.2
5	54	56.4	4.7	8.3	56.6	4.6	8.1	+0.4
Etelä-Suomi — *South Finland*	118	56.6	4.5	8.0	56.7	4.4	7.8	+0.2
Pohjois-Suomi — *North Finland*	88	56.3	4.5	8.0	56.4	4.5	8.0	+0.2
Koko maa — *Total*	206	56.5	4.5	8.0	56.6	4.4	7.8	+0.2

Taulukko 4. Kehysmitan mittaustavan vaikutus pinotiheyteen eri pinotyypeissä.
Table 4. Effect of the gross volume measuring method on the relative solid content of different types of pile.

Alueryhmä *Area*	Puulaji *Tree species*	Pinoja *Piles pcs*	Pinotiheys *Relative solid content*						Ero *Difference* %
			virallinen *Official*			todellinen *Accurate*			
			$\bar{x}$	s_x	v %	$\bar{x}$	s_x	v %	
Molemmat pääpuut — *Both end poles*									
Etelä-Suomi — *South Finland*	Mä	16	63.9	4.1	6.4	64.0	4.1	4.6	+0.2
Pohjois-Suomi — *North Finland*	*Pine*	11	66.9	3.7	5.5	67.7	3.9	5.8	+1.2
Yhteensä — *Total*		27	65.1	4.1	6.3	65.5	4.4	6.7	+0.6
Etelä-Suomi — *South Finland*	Ku	16	65.1	4.5	6.9	65.7	4.4	6.7	+0.9
Pohjois-Suomi — *North Finland*	*Spruce*	7	67.5	4.2	6.2	67.5	4.2	6.2	0
Yhteensä — *Total*		23	65.8	4.5	6.8	66.3	4.3	6.5	+0.8
Etelä-Suomi — *South Finland*	Le	18	55.6	4.7	8.5	55.6	4.8	8.6	0
Pohjois-Suomi — *North Finland*	*Broad-*	9	56.2	5.7	10.1	56.3	5.9	10.5	+0.2
Yhteensä — *Total*	*leaved*	27	55.8	5.1	9.1	55.8	5.1	9.1	0
Toinen pääpuu — *One end pole*									
Etelä-Suomi — *South Finland*	Mä	45	64.8	4.4	6.8	65.1	4.1	6.3	+0.5
Pohjois-Suomi — *North Finland*	*Pine*	37	65.3	3.8	5.8	65.6	4.0	6.1	+0.5
Yhteensä — *Total*		82	65.0	4.2	6.5	65.3	4.0	6.1	+0.5
Etelä-Suomi — *South Finland*	Ku	40	65.1	4.0	6.1	65.4	3.6	5.5	+0.5
Pohjois-Suomi — *North Finland*	*Spruce*	36	65.0	4.4	6.8	65.3	4.4	6.7	+0.5
Yhteensä — *Total*		76	65.1	4.2	6.5	65.4	4.0	6.1	+0.5
Etelä-Suomi — *South Finland*	Le	54	57.1	4.0	7.0	57.4	4.0	7.0	+0.5
Pohjois-Suomi — *North Finland*	*Broad-*	44	56.6	4.4	7.8	56.6	4.4	7.8	0
Yhteensä — *Total*	*leaved*	98	56.9	4.2	7.4	57.0	4.2	7.4	+0.2
Ei pääpuita — *No end poles*									
Etelä-Suomi — *South Finland*	Mä	33	65.8	4.0	6.1	65.2	4.0	6.1	—0.9
Pohjois-Suomi — *North Finland*	*Pine*	22	64.9	7.4	11.4	65.0	7.3	11.2	+0.2
Yhteensä — *Total*		55	65.4	5.6	8.6	65.1	5.5	8.4	—0.5
Etelä-Suomi — *South Finland*	Ku	38	66.7	3.3	4.9	67.0	3.2	4.8	+0.4
Pohjois-Suomi — *North Finland*	*Spruce*	14	63.7	4.5	7.1	64.2	4.1	6.4	+0.8
Yhteensä — *Total*		52	65.9	3.9	5.9	66.3	3.6	5.4	+0.6
Etelä-Suomi — *South Finland*	Le	46	56.3	4.9	8.7	56.5	4.5	8.0	+0.4
Pohjois-Suomi — *North Finland*	*Broad-*	35	55.9	4.4	7.9	56.2	4.5	8.0	+0.5
Yhteensä — *Total*	*leaved*	81	56.1	4.7	8.4	56.4	4.5	8.0	+0.5

kehysmittaa nimitetään tässä tutkimuksessa v i r a l l i s e k s i k e h y s m i t a k s i ja ruotsalaisen menetelmän mukaista t o d e l l i s e k s i k e h y s m i t a k s i, kuten edellä mainittiin. Todellisen pinomitan mukaan on saatu keskimäärin 0.2—0.5 % suurempi pinotiheys kuin ns. virallista mittaustapaa käytettäessä, mikä nähdään taulukosta 3. Todellinen kehysmitta on siis ollut vastaavasti virallista kehysmittaa pienempi. Eri osa-alueilla ja

eri puulajeilla ilmenee jossakin määrin eri suuntaisia eroja. Kehysmitan mittaustavan vaikutus pinotiheyteen on katsottava jokseenkin merkityksettömäksi.

Vertailtavista mittaustavoista voidaan ruotsalaista menetelmää pitää periaatteessa tarkempana pienempien korkeuden mittausvälien vuoksi erityisesti pääpuuttomilla pinoilla (vrt. Heiskanen 1973 a). Taulukon 4 hajontaluvut tukevat tätä käsitystä, sillä todellisten pinotiheyksien pinojenväliset variaatiokertoimet ovat olleet yleensä joko yhtä suuret tai pienemmät kuin virallisten pinotiheyksien vastaavat tunnukset. Joitakin poikkeuksia toki esiintyy nimenomaan molemmilla pääpuilla varustetuissa pinoissa. Niissä onkin virallisen pinotiheyden hajonta männyllä ja lehtipuulla pienempi kuin todellisen pinotiheyden hajonta. Muissa, siis vaikeasti mitattavissa pinotyypeissä suhde on päinvastainen.

412. Mittausryhmän mittauksen ja tarkastusmittauksen vertailua

Metsäntutkimuslaitoksen edustajan suorittamat tarkastusmittaukset kohdistuivat osittain alkuperäisestä pinosta ja osittain uudelleen latomisen jälkeisestä pinosta mitattuihin kehysmittoihin. Osa koskee lisäksi virallista ja osa todellista kehysmittaa. Alustava selvitys osoitti kuitenkin, että tarkastusmittaustulokset voitiin mittaustavoittain yhdistää.

Taulukon 5 mukaan tarkastusmittaajan ja ryhmien tulokset poikkeavat toisistaan verraten vähän. Huomattavampaa eroa on todettavissa vain alueen 5 siis, Pohjois-Suomen ryhmien osalta, mutta eroon saattaa olla syynä

Taulukko 5. Tarkistusmittausten tuloksia.
Table 5. Results of control measurements.

Alue/Ryhmä *Area/group*	Pinoja kpl *Piles pcs*	Kehysmitta, p-m³ *Piled cu.m.*		Ero % *Difference*
		Ryhmä *Group*	Tarkistaja *Control*	
1/1	5	82.3	82.2	+0.1
1/2	11	147.0	147.7	—0.5
2/1	3	55.1	54.5	—1.1
2/2	10	165.4	166.4	—0.6
3/1	9	135.3	134.6	+0.5
3/2	6	96.0	96.1	—0.1
4/1	14	229.2	230.7	—0.7
4/2	14	249.9	247.6	+0.9
5/1	4	75.8	77.5	—2.2
5/2	5	95.4	98.1	—2.8
Etelä-Suomi — *South Finland*	44	681.1	681.5	±0.0
Pohjois-Suomi — *North Finland*	37	650.3	653.9	—0.6
Koko maa — *Total*	162	1 331.4	1 335.4	—0.3

aineiston vähäisyys. Tämän tarkastelun valossa voidaan kehysmitan määrittämisen tutkimuksessa katsoa olleen tarkkaa ja yhdenmukaista eri ryhmien välillä. Edellä todettu mittausmenetelmien välinen vähäinen ero tukee myös tätä käsitystä. On lisäksi syytä korostaa, että tarkastusmittaaja on saanut tulokseksi suuremman kehysmitan kuin ryhmänjohtajat keskimäärin. Tämä merkitsee, että Metsäntutkimuslaitoksen tarkastusmittausten mukaan olisi tulokseksi saatu alhaisemmat pinotiheydet kuin nyt saadut.

Yleinen käsitys on käytännön mittausten osalta se, että tarkastusmittaajat saavat jonkin verran pienemmän tuloksen kuin varsinaiset mittaajat ovat saaneet (esim. Nylinder 1972). Pinossa mitattavan tavaran osalta tämän saa aikaan ensinnäkin pinojen painuminen (esim. Heiskanen ja Riikonen 1973) sekä alkuperäiseen mittaustulokseen mahdollisesti vaikuttaneet kaupalliset intressit. Kumpikaan näistä tekijöistä ei ole vaikuttanut käsillä olevan tutkimuksen mittauksiin. Mainittakoon, että tarkastusmittaus tehtiin yleensä viikon kuluessa alkuperäisen tutkimusmittauksen jälkeen.

413. Muita tekijöitä

Mittauksellisista seikoista saattaa vaikuttaa saatavaan mittaustulokseen lisäksi mittaajan työnantaja siten, että ostajan edustaja mittaa kehysmitan pienemmäksi kuin myyjän edustaja. Vähäistä tällaista tendenssiä esiintyi pinomittauksen kehittämistutkimuksen koetilaisuuksissa (vrt. Heiskanen 1973 a). Tutkimuksen esillä olevan vaiheen mittauksissa ei vastaavaa suuntausta ollut nähtävissä, kuten tarkastusmittausten tulokset osoittavat. On kuitenkin mahdollista, että käytännön mittauksissa työnantajan edun tavoittelua saattaa esiintyä.

Mittaustulokseen vaikuttaa myös mittausvälineiden laatu ja tarkoituksenmukaisuus, mutta tätä vaikutusta ei voida tutkimustuloksin osoittaa. Niiden merkitys lienee kuitenkin vähäinen.

42. Pinon ominaisuuksien vaikutus

421. Ladonta

4211. Ladontatapa

Kuten tutkimusmenetelmää selostettaessa todettiin, erotettiin tutkimuksessa ladontatavan perusteella neljä pinotyyppiä; nimittäin käsin tehty pino (käsipino), hyvä konepino ja huono konepino sekä muu. Viimeksimai-

nittuja ei kuitenkaan sisältynyt lainkaan tutkimusaineistoon. Esimerkkejä näistä pinotyypeistä nähdään kuvista 5, 6 ja 7.

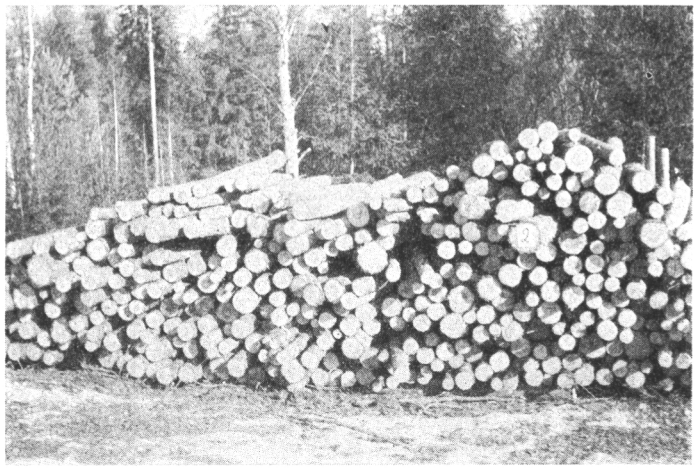
Tutkimusaineistoa esiteltäessä mainittiin jo, että suurin osa aineistosta oli käsipinoja. Etelä-Suomessa niiden osuus oli 78.4 %, Pohjois-Suomessa 51.2 % ja koko maassa 67.2 %. Puulajien välillä on tässä suhteessa melko selviä eroja, mikä on otettava ladontatavan vaikutuksen tarkastelun pohjaksi. Kuvassa 8 on esitetty aineiston lopulliseen analysointiin hyväksytty-



Kuva 5. Käsinladottu pino.
Fig. 5. Manually stacked pile.



Kuva 6. Hyvä koneella ladottu pino.
Fig. 6. Mechanically well stacked pile.



Kuva 7. Huono koneella ladottu pino.
Fig. 7. Mechanically poorly stacked pile.

jen 2.0—2.2 m näytepinojen jakautuminen käsipinoihin, hyviin konepinoihin ja huonoihin konepinoihin. Koko maa on käsitelty yhdessä. Kuva osoittaa, että käsipinojen osuus on kaikissa puulajeissa suurin. Konepinoja esiintyy vähiten kuusiaineistossa.

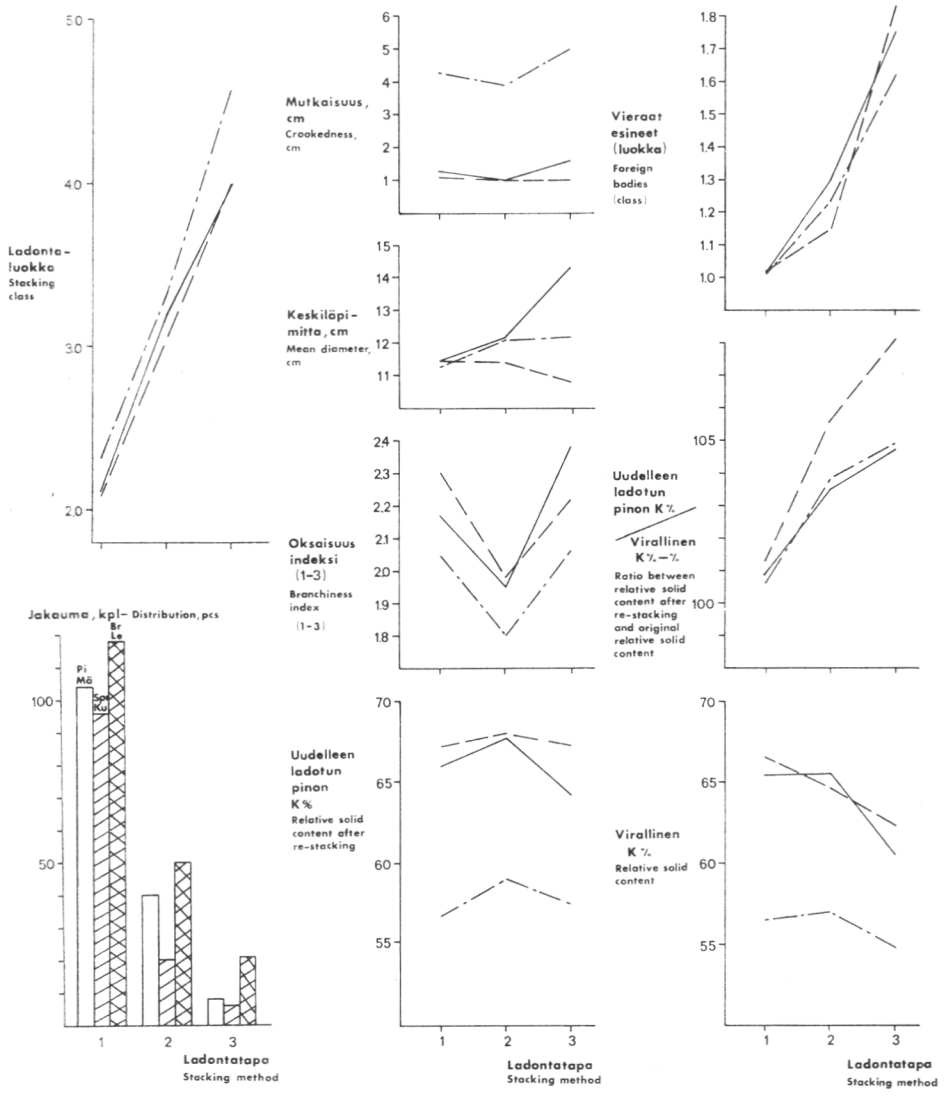
Yhdistettäessä kaikki konepinot yhteen saadaan seuraavan asetelman mukainen jakautuma.

	Käsipinoja		Konepinoja	
	kpl	%	kpl	%
Mänty	104	68.4	48	31.6
Kuusi	96	78.7	26	21.3
Lehtipuu	118	62.4	71	37.6
Yhteensä	318	68.7	145	31.3

Kuvasta 8 nähdään eri tavoin ladottujen pinojen pinotiheydet sekä pinojen keskimääräisiä ominaisuuksia. Keskimääräiset pinotiheydet tilastollisine tunnuksineen on esitetty myös seuraavassa asetelmassa.

	Käsipinot		Hyvät konepinot		Huonot konepinot	
	$\bar{x}$	s_x	$\bar{x}$	s_x	$\bar{x}$	s_x
Mänty	65.4	4.3	65.5	3.4	61.5	3.6
Kuusi	66.5	3.8	64.6	4.0	62.3	4.7
Lehtipuu	56.5	4.6	57.0	4.2	54.8	3.7

Mainittakoon myös, että kaikkien konepinojen keskimääräiset pinotiheysluvut olivat seuraavat: mänty 64.8, kuusi 64.1, lehtipuu 56.4. Nämä luvut osoittavat, että konepinojen pinotiheys on ollut mäntypinoissa 0.6,



Kuva 8. Näytepinojen jakauma ja ominaisuuksia puulajeittain ja ladontatavoittain. (Mä —, Ku — —, Leht — - —; Käsipino = 1, Konepino = 2, Huono konepino = 3).
Fig. 8. Distribution of sample piles and properties by tree species and stacking methods. (Pine —, Spruce — —, Broadleaved — - —; Manually stacked pile = 1, mechanically stacked pile = 2, mechanically poorly stacked pile = 3).

kuusipinoissa 2.4 ja lehtipuupinoissa 0.1 prosenttiyksikköä pienempi kuin käsipinojen pinotiheys. Erot ovat kuusipinoissa tilastollisesti melkein merkitseviä. Muiden puulajien kone- ja käsipinojen tiheyksien erotus ei ole mer-

kitsevä. Konepinojen eri luokkia tarkasteltaessa havaitaan, että männyssä ja lehtipuussa hyvien konepinojen keskimääräinen pinotiheys on suurempi kuin käsipinojen tiheys. Huonot konepinot jäävät sitä vastoin kaikissa puulajeissa tiheydeltään muiden erotettujen ladontatyyppien alle. Kuusipinoista myös hyvät konepinot ovat olleet keskimäärin harvempia kuin käsipinot.

Käsi- ja konepinojen vähäiset tiheyserot vaikuttavat yllättäviltä, sillä monissa muissa tutkimuksissa ja kirjoituksissa on korostettu konepinojen hyvin heikkoa pinotiheyttä käsipinoihin verrattuna (Arnkil 1966, v. Schoultz 1968, Heiskanen 1968, Finne 1970 ja Hemmi 1972). Nikkilän (1972 a) mukaan käsinladottujen 2 m lehtipuupinojen keskimääräinen pinotiheys oli 58.7 ja konepinojen vain 55.6 eli 3.1 prosenttiyksikköä edellistä pienempi. Eroja pinoamistapojen välillä ilmeni kuitenkin vain sellaisissa pinoissa, joissa ei ollut aluspuita. Edellämainittu ero aluspuilla varustetuissa pinoissa oli vähäinen. Nylinderin ja Petersonin (1967) suorittamassa kokeessa oli kourakuormaimella tehdyn pinon pinotiheysluku n. 2 prosenttiyksikköä pienempi kuin käsinladotun pinon tiheysluku.

Kuvan 8 perusteella voidaan eri tavoin tarkastella ladottujen pinojen ominaisuuksia ja niiden mahdollista vaikutusta saatuihin tuloksiin.

— Oksaisuusindeksi on hyvissä konepinoissa pienin, mistä on pääteltävissä että oksaisuuden merkitys harvuutta aiheuttavana tekijänä on näissä pinoissa pienempi kuin muissa. Sama suunta on havaittavissa kaikissa puulajeissa.

— Keskiläpimitat eri ladontatyypeissä ovat myös erilaiset. Kuusipinoissa pölkkyjen läpimitta pienenee siirryttäessä käsipinoista huonoihin konepinoihin, mikä voinee osittain selittää sen, että kuusipinoissa ladontatavan vaikutus pinotiheyteen vaikuttaa selvimmältä. Mänty- ja lehtipuupinoissa sitä vastoin pölkkyjen keskiläpimitta on käsipinoissa pienin ja huonoissa konepinoissa suurin.

— Mutkaisuudessa erot ovat vähäisiä. Hyvät konepinot ovat kuitenkin kaikissa puulajeissa sisältäneet keskimäärin suorempia pölkkyjä kuin käsipinot. Kuusipinoissa huonojen konepinojen pölkkyjen mutkaisuus on suunnilleen sama kuin hyvien konepinojen, mutta muissa puulajeissa pinon tiheyttä pienentävä mutkaisuus on ollut suurin huonoissa konepinoissa.

— Vieraiden esineiden määrää kuvaavat arvioidut luokat osoittavat, että käsipinoissa on ollut vieraita esineitä vähiten ja huonoissa konepinoissa eniten. Vieraita esineitä esiintyy käsipinoista 2 %:ssa, konepinoista 24 %:ssa ja huonoista konepinoista 63 %:ssa. Tämä seikka vaikuttaa ko. rajoissa kuitenkin vain vähän pinotiheyteen.

Kaikkien konepinojen ja käsipinojen vertailu puutavaran ominaisuuksien kannalta osoittaa, että konepinot ovat olleet oksaisuuden ja läpimitan puolesta parempia kuin käsipinot. Mutkaisuudessa ei ole paljonkaan eroja.

Sen sijaan vieraiden esineiden määrä on konepinoissa suurempi kuin käsipinoissa.

Käsi- ja koneladonnan pinotiheyslukujen eroihin palataan jäljempänä uudelleenladonnan yhteydessä.

4212. Ladontaluokka

Ladontaluokka määritettiin silmävaraisesti viidessä luokassa, kuten tutkimusmenetelmää selostettaessa mainittiin. Luokka 1 tarkoittaa tiheimmin ladottua pinoa ja luokka 5 harvimmin ladottua (liite 1).

Kuvassa 9 on esitetty eri puulajien pinojen jakautuminen ko. ladontaluokkiin. Siitä havaitaan verraten selviä eroavuuksia puulajien välillä Kuusipinot ja mäntypinot muistuttavat ladontaluokkajakautumaltaan paljon toisiaan, vaikka kuusipinojen ladonta onkin arvioitu hivenen mäntypinojen ladontaa paremmaksi. Lehtipuupinoissa ladontaluokka on arviointien mukaan huomattavasti heikompi kuin havupuupinoissa, mikä ilmenee myös seuraavista ladontaluokkien keskiarvoista:

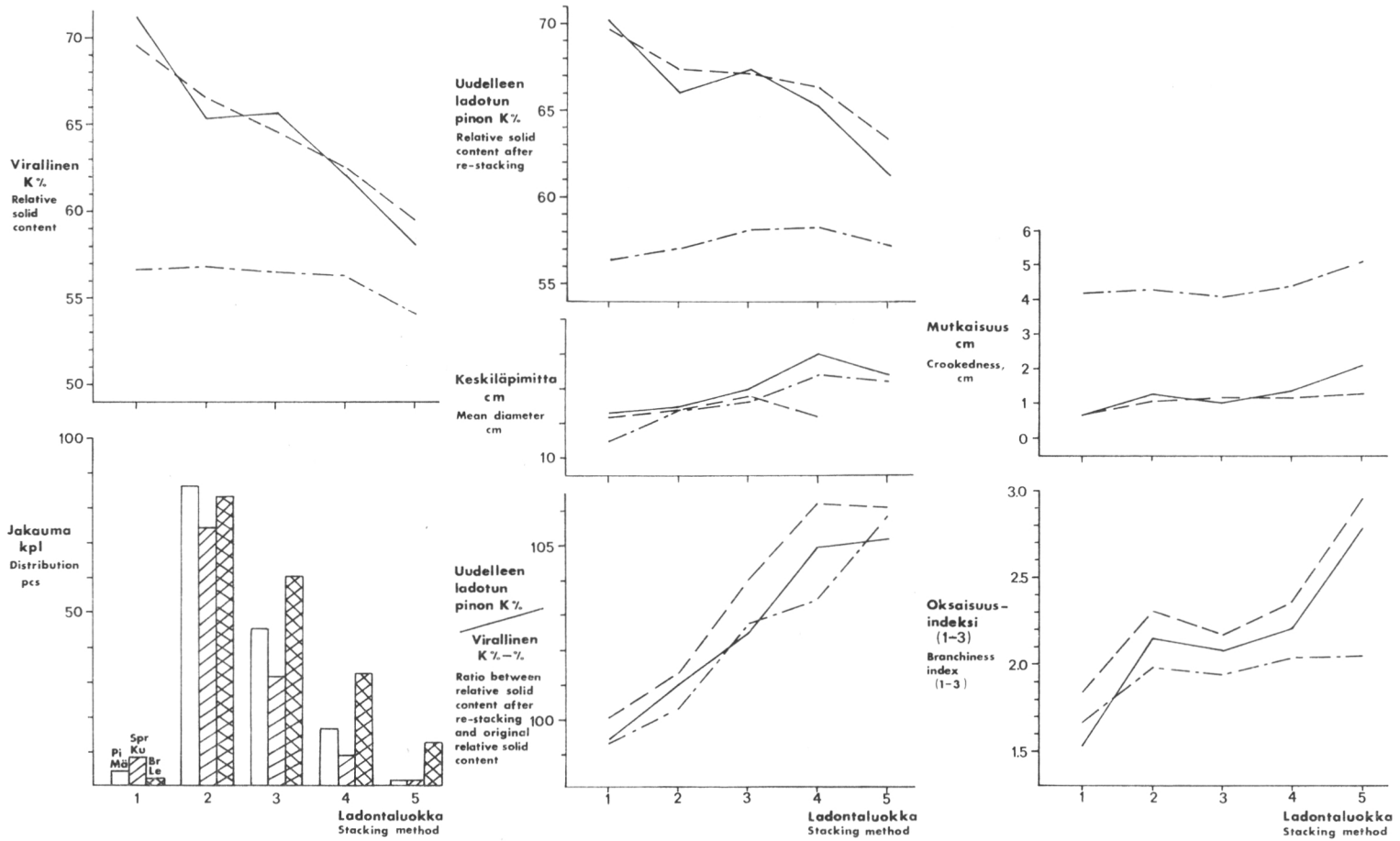
Mänty	2.5
Kuusi	2.3
Lehtipuu	2.8

Lehtipuiden ladonnan heikoksi arviointi johtuu ilmeisesti pölkkyjen mutkaisuudesta, jonka vuoksi pinot näyttävät harvoilta ja ladonta heikolta. Ei näet ole mitään syytä olettaa itse ladonnan olevan lehtipuilla heikompaa kuin havupuilla. Väitettä tukee myös se, että lehtipuupinojen pinomitta pieneni uudelleenladottaessa samalla tavalla kuin havupuupinojenkin. Vastaavanlaisia tuloksia eri puulajien välisestä ladontaluokkien eroavuuksista saatiin myös Heiskasen (1973 a) mukaan koearvioinneissa.

Ladontaluokan vaikutus pinotiheyteen sekä eri luokkiin kuuluvien pinojen keskimääräisiä ominaisuuksia nähdään kuvasta 9. Pinotiheyden osalta voidaan todeta seuraavaa.

Havupuissa pinotiheys alenee erittäin selvästi ladontaluokan huonotessa. Kummassakin puulajissa suunta on lähimain sama. Ladontaluokan vaikutus pinotiheyteen on suoraviivaisena seuraava. Asetelmassa on esitetty ladontaluokan korrelaatio (R) pinotiheyden suhteen.

	R	Vaikutus/luokka
Mänty	—0.258	—1.36 prosenttiyksikköä
Kuusi	—0.405	—2.07 »
Lehtipuu	—0.116	..
Yhteensä	—0.328	—1.59 prosenttiyksikköä



Kuva 9. Näytepinojen jakauma ja ominaisuuksia puulajeittain ja ladontaluokittain. (Mä —, Ku — —, Leht — · —; Erittäin hyvä = 1, Erittäin huono = 5).

Fig. 9. Distribution of sample piles and properties by tree species and stacking classes. (Pine —, Spruce — —, Broadleaved — · —; Very good = 1, Very poor = 5).

Lehtipuupinoissa ladontaluokan vaikutus pinotiheyteen on saatujen tulosten mukaan varsin vähäinen. Luokissa 1—4 pinotiheydet ovat kuvan 9 mukaan suunnilleen samat, kun taas luokan 5 pinotiheys on jo selvästi muita heikompi.

Seuraavassa asetelmassa on esitetty eri ladontaluokkien keskimääräiset pinotiheydet. Niihin liittyvät hajonnat nähdään liitteestä 3.

Ladonta-luokka	Havupuu kpl	Havupuu pino tiheys	Havupuu suhde	Lehtipuu kpl	Lehtipuu pino-tiheys	Lehtipuu suhde
I	12	69.9	107.0	2	56.6	100.0
II	160	65.9	100.9	83	56.8	100.4
III	76	65.3	100.0	60	56.6	100.0
IV	24	62.3	95.4	32	56.3	99.5
V	2	58.9	90.2	12	54.1	95.6

Suhdeluvuista (luokka 3 = 100) ilmenee, että havupuissa yhden luokan muutos ladonnassa merkitsee 2—4 prosenttiyksikön muutosta pinotiheydessä. Lehtipuissa vastaavaa pinotiheyden muutosta ei ole havaittavissa lukuunottamatta 4. ja 5. luokan väliä. Tarkasteltaessa kuitenkin uudelleenladonnan vaikutusta kuvasta 9 havaitaan, että lehtipuullakin luokitus on varsin hyvin onnistunut, vaikkei luokkien ero näykään suoraan pinotiheyksistä.

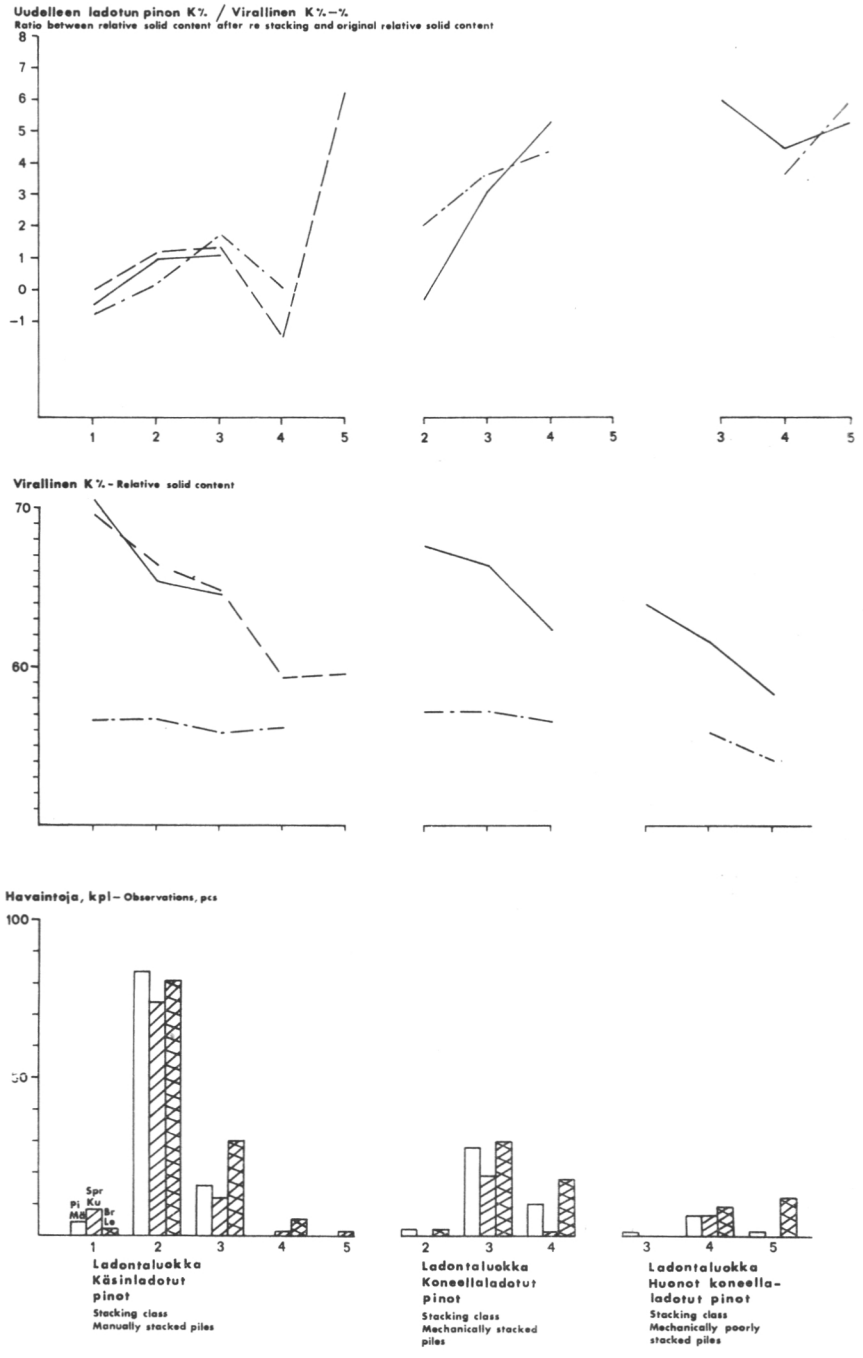
Nylinder ja Peterson (1967) jakoivat tutkimuksessaan 3 m tavaraa sisältävät käsipinot ladonnan mukaan hyviin ja normaaleihin ja saivat männyllä ja kuusella tiheyksien eroksi 2.2 prosenttiyksikköä. Koivulla ero oli vain 1.4 yksikköä.

Rikkosen (1972 b) mukaan ladontaluokan vaikutus oli havupuissa suunnilleen samaa suuruusluokkaa kuin esillä olevassa aineistossa. Lehtipuupinoissa ladontaluokan vaikutus osoittautui käytännöllisesti katsoen yhtä suureksi kuin havupuupinoissakin, kuten seuraavasta asetelmasta nähdään.

Ladonta-luokka	Havupuu pino-tiheys	Havupuu suhde	Lehtipuu pino-tiheys	Lehtipuu suhde
II	69.7	106.1	60.3	106.7
III	65.7	100.0	56.5	100.0
IV	63.5	96.6	54.1	95.8

Karlsson (1971) on käsitellyt kaikki pinot yhdessä ja jakanut tulosten perusteella pinot seitsemään ladontaluokkaan. Hänen mukaansa siirtyminen luokasta toiseen merkitsee 1 prosenttiyksikön muutosta pinotiheydessä.

»Uudistuva puutavaran mittaus»-kirjasessa on ladonta käsitelty neljässä luokassa, jotka on nimetty seuraavasti: I Tiivis, II Keskinkertainen, III Harva ja IV Erittäin harva. Lehtipuupinoissa on luokan muutoksen vaikutus 1 prosenttiyksikkö paitsi siirryttäessä III luokasta IV luokkaan, jossa se on 2 prosenttiyksikköä. Havupuupinoissa ladontaluokan vaikutus on läpi



Kuva 10. Näytepinojen jakauma ja ominaisuuksia puulajeittain ja ladontaluokittain ladontatapojen sisällä. (Mä —, Ku — —, Leht — - —; Käsipino vas, Konepino kesk, Huono konepino oik, Erittäin hyvä = 1, Erittäin huono = 5).

Fig. 10. Distribution of sample piles and their properties by tree species and stacking classes among the stacking methods. (Pine —, Spruce — —, Broadleaved — - —; Manually stacked pile ceft, Mechanically stacked pile middle, Mechanically poorly stacked pile right, Very good = 1, Very poor = 5).

koko asteikon 2 prosenttiyksikköä. Se vastaakin aika hyvin nyt saatua tulosta.

Ladontaluokan vaikutusta tarkasteltaessa on syytä tutkia myös kuhunkin ladontaluokkaan sisältyvien pinojen muita pinotiheyteen vaikuttavia ominaisuuksia. Ne on esitetty kuvassa 9. Kuvasta nähdään, että oksaisuus, mutkaisuus ja pölkkyjen keskiläpimitta seuraavat ladontaluokkaa siten, että kaikkien sanottujen tunnusten lukuarvo, mitta tai indeksi, kasvaa ladontaluokan huonotessa. Tämä merkitsee, että keskiläpimitta on nostanut ja oksaisuus sekä mutkaisuus alentanut huonoihin ladontaluokkiin kuuluvien pinojen tiheyttä hyvin ladottujen pinojen tiheyteen verrattuna.

Tarkasteltaessa miten eri luokkien pinojen tiheys on uudelleenladonnan yhteydessä muuttunut voidaan todeta, että luokitus on varsin hyvin onnistunut, so. mitä huonompaan ladontaluokkaan pinot on viety sitä enemmän niiden tiheys on uudelleenladottaessa suurentunut (vrt. luku 4213).

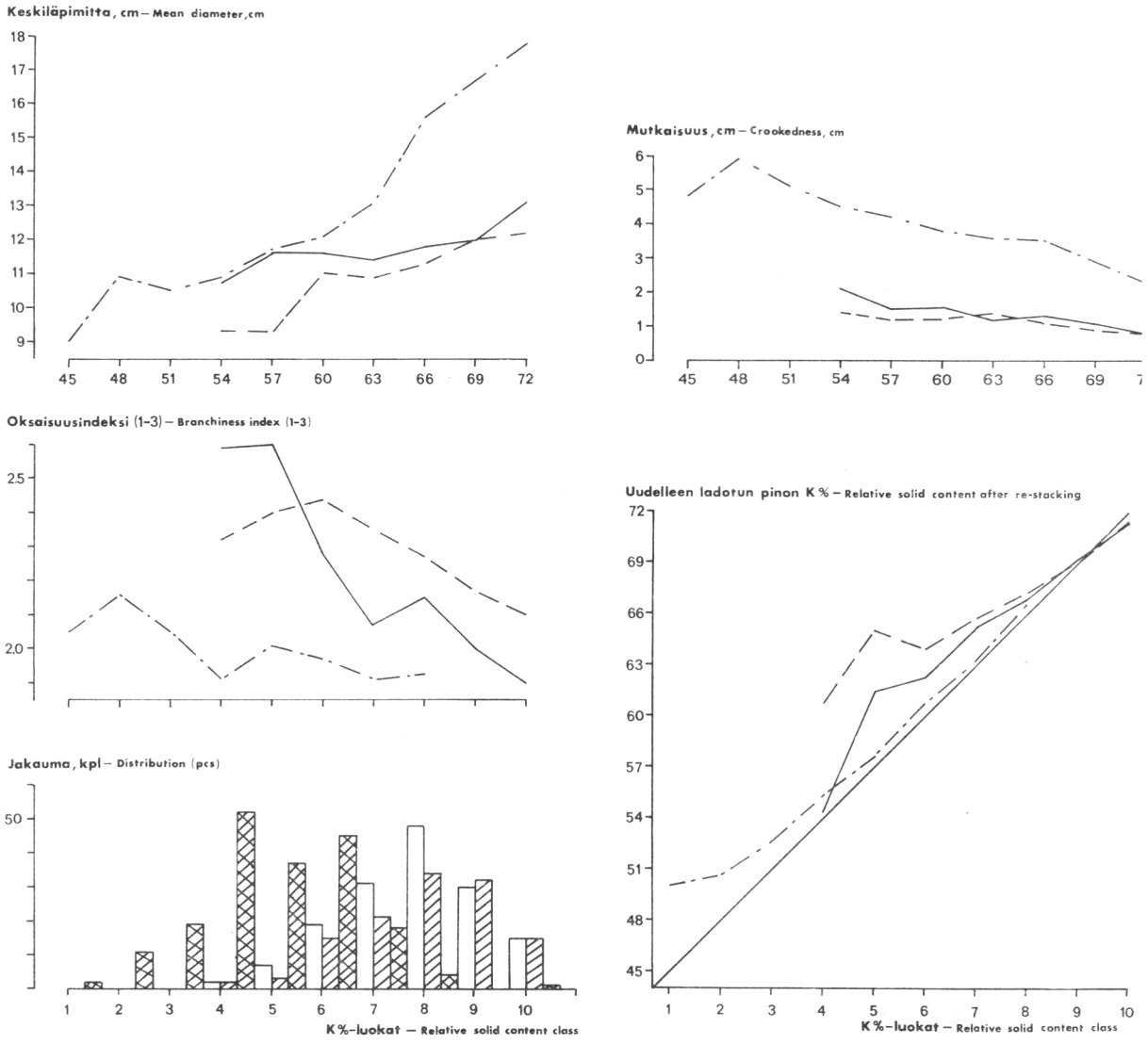
Ladontaluokan vaikutusta pinotiheyteen voidaan tutkia myös erikseen käsi- ja erikseen konepinoista. Näytepinot jakautuivat eri luokkiin ladontatavoittain kuvan 10 osoittamalla tavalla. Siinä ilmenee jo selviä eroja eri tapojen välillä siten, että huonosti koneella ladottujen pinojen yleisin luokka on 4., tavallisten koneella ladottujen 3. ja käsin ladottujen 2. luokka. Eri ladontatapojen eroavuutta kuvaavat myös seuraavat keskimääräiset ladontaluokat:

	Käsi-pinot	Hyvät konepinot	Huonot konepinot
Mänty	2.1	3.2	4.0
Kuusi	2.1	3.0	4.0
Lehtipuu	2.3	3.3	4.6

Ladontaluokan vaikutus pinotiheyteen nähdään kuvasta 10. Siihen on otettu mukaan kussakin tapauksessa vain ne puulajit, joista on riittävästi havaintoja eri ladontaluokista. Myös näin erotellussa aineistossa näkyy arvioidun ladontaluokan vaikutus pinotiheyteen erittäin selvänä etenkin havupuissa. Lehtipuissa ei silmävaraisesti arvioitu ladontaluokka kuvaa lainkaan pinotiheyttä käsinladotuissa pinoissa. Tavallisissa konepinoissa erot eri ladontaluokkien välillä ovat hyvin vähäiset. Huonosti koneella ladotuissa lehtipuupinoissa luokan 5 pinotiheys on huomattavasti luokan 4 pinotiheyttä alhaisempi.

4213. Uudelleen ladonta

Esillä olevan tutkimuksen kannalta on tärkeää tietää, millä tavoin pinon kehysmitta ja vastaavasti pinotiheys muuttuu uudelleen ladottaessa. Se osoittaa tietyllä tavalla myös pinon kehysmitan luotettavuuden kaupallisena mittayksikkönä.



Kuva 11. Näytepinojen jakauma ja ominaisuuksia puulajeittain ja kiintomittaprosenttiluokittain. (Mä —, Ku — —, Leht — - —).

Fig. 11. Distribution and properties of sample piles by tree species and solid measure percentage classes. (Pine —, Spruce — —, Broadleaved — - —).

Mittausryhmille annetun ohjeen mukaan tuli uudelleen ladonnan olla vähintään yhtä hyvää kuin alkuperäisessä pinossa. Määräys katsottiin tarpeelliseksi, koska jouduttiin käsittelemään toisten omistamia pinoja. Ladonnan ei tämän huomioon ottaen tarvitse siis olla yhdenmukaista. Kaikki uudelleen latomiset suoritettiin käsin mittausryhmän toimesta. Ladonnan laatua voidaankin pitää vähintään keskinkertaisena.

Kuvan 11 mukaan pinotiheys on yleensä suurentunut uudelleen ladonnan jälkeen. Uudelleen ladonnan vaikutusta kuvaavat myös seuraavat keskimääräiset suhteelliset pinotiheydet, joita laskettaessa alkuperäistä tiheyttä on merkitty luvulla 100.

		Käsipinot	Suht. pinotiheys Konepinot
Etelä-Suomi	Kuusi	101.2	106.2
»	Mänty	101.1	104.5
»	Lehtipuu	101.4	105.8
Pohjois-Suomi	Kuusi	100.5	104.6
»	Mänty	100.2	103.4
»	Lehtipuu	98.8	102.9

Odotusten mukaisesti käsin ladotuilla pinoilla on pinotiheyden muutos ollut selvästi pienempi kuin koneella ladotuilla. Tulokset osoittavat myös, että Pohjois-Suomessa pinotiheyden muutokset ovat olleet kummassakin ladontatavassa pienempiä kuin Etelä-Suomessa.

Vastaavanlaisia tuloksia kone- ja käsipinojen eroavuuksista uudelleen ladonnassa on saatu monissa aiemmissa selvityksissä. Hemmi (1970) mainitsee konepinojen painuneen uudelleen latomisen yhteydessä keskimäärin 5—6 % (vrt. Heiskanen 1973 a).

Nikkilä (1972 a) on todennut, että alunperin koneella ladottujen lehtipuupinojen kehysmitta oli uudelleen ladonnan jälkeen 93.4 % ja käsinladottujen 98.1 % alkuperäisestä kehysmitasta. Pinotiheydet ovat siis suurentuneet konepinoissa 6.6 % ja käsipinoissa vain 1.9 %. Nikkilän mukaan aluspuuttomien pinojen pinotiheys kasvaa uudelleen latomisen johdosta enemmän kuin aluspuullisten pinojen. Tämä johtuu lähinnä aluspuuttomien pinojen alunperin heikommasta tiheydestä ja siitä, että pinoihin uudelleen ladonnan yhteydessä pantiin säännönmukaista pinoamista helpottavat aluspuut.

Myös Makkosen (1958, 1960) mukaan kehysmitta pienenee ja pinotiheys suurenee uudelleen ladonnan johdosta, kun kyseessä on käsinladottu kuorellinen tavara. Huolellisesti käsinladotut kuorellisen tavaran pinot saattavat kuitenkin paisuakin uudelleen ladonnassa (Finne 1970). Sitä vastoin kuoritun tavaran uudelleen pinoaminen johtaa Makkosen mukaan yleensä alkuperäistä suurempaan kehysmittaan.

Esillä olevasta aineistosta on selvitetty myös uudelleen ladonnan vaikutus hyvissä ja huonoissa konepinoissa erikseen. Keskimääräiset pinotiheydet suhteessa alkuperäisiin keskiarvoihin nähdään kuvasta 8. Siitä havaitaan, että uudelleen ladonnan pinotiheyttä suurentava vaikutus on suurin huonoissa konepinoissa. Eri puulajit eroavat toisistaan niin, että kuusipinoissa uudelleen ladonta parantaa pinotiheyttä selvästi eniten.

Ladonnan laadun eli ladontaluokan vaikutus uudelleen ladonnan aiheuttamaan pinotiheyden muutokseen on myös perin selvä, kuten kuvasta 9 ja seuraavasta asetelmasta havaitaan.

Ladonta-luokat		Mänty	Kuusi	Lehti-puu
I	alkuperäinen pinotiheys	70.6	69.6	56.6
	uudelleen ladottu pinotiheys	70.1	69.6	56.3
	ero %	— 0.7	0.0	— 0.5
II	alkuperäinen pinotiheys	65.4	66.6	56.8
	uudelleen ladottu pinotiheys	66.0	67.4	57.0
	ero %	+ 0.9	+ 1.2	+ 0.4
III	alkuperäinen pinotiheys	65.7	64.6	56.6
	uudelleen ladottu pinotiheys	67.3	67.1	58.1
	ero %	+ 2.4	+ 3.9	+ 2.6
IV	alkuperäinen pinotiheys	62.2	62.5	56.3
	uudelleen ladottu pinotiheys	65.2	66.3	58.2
	ero %	+ 4.8	+ 6.1	+ 3.4
V	alkuperäinen pinotiheys	58.2	59.6	54.1
	uudelleen ladottu pinotiheys	61.2	63.3	57.2
	ero %	+ 5.2	+ 6.2	+ 5.7

Asetelman mukaan ladontaluokkaan 1 kuuluvien tiheiksi ladottujen pinojen pinotiheys on pysynyt ennallaan tai jonkin verran pienentynyt (vrt. Finne 1970). Muissa luokissa on tapahtunut kehysmitan pienenemistä ja vastaavasti pinotiheyden suurenemista. Kuvatunlaiset tulokset osoittavat myös, että ladontaluokka on pystytty arvioimaan keskimäärin verrattain luotettavasti. Todettakoon vielä, että tässäkin tapauksessa eli siis jokaisessa luokassa erikseen on uudelleen ladonnan pinotiheyttä suurentava vaikutus ollut selvin kuusipinoissa.

Vieraiden esineiden vaikutus on myös selvä uudelleen ladonnasta aiheutuvaan pinotiheyden muutokseen. Se nähdään seuraavasta asetelmasta, jossa on esitetty uudelleen ladonnan mukainen pinotiheys verrattuna alkuperäisen pinon pinotiheyteen (= 100).

	Vieraat esineet, lk		
	1	2	3
	Suht. uudelleen ladottu pinotiheys		
Mänty	101.5	104.1	..
Kuusi	102.2	103.6	105.7
Lehtipuu	101.8	103.6	..

Vieraiden esineiden asetelmasta nähtävä vaikutus kuvastuu jo kone- ja käsipinojen eroavuuksissa. Vieraita esineitä sisältäneet pinot olivat ja ovat käytännössäkin miltei poikkeuksetta konepinoja, joiden pinotiheyden suuri muuttuminen uudelleen ladonnan yhteydessä johtuu osaksi juuri vieraista esineistä.

Uudelleen ladonnan vaikutusta voidaan tarkastella myös tiheysluokittain. Kuvasta 11 nähdään odotetusti, että mitä harvempi pino on alunperin ollut, sitä enemmän sen tiheys on sekä absoluuttisesti että suhteellisesti kasvanut uudelleenladonnan yhteydessä. Uudelleen ladonnan aiheuttaman muutoksen yhteyttä pinotiheyteen selvittää myös kuva 22 (s. 59).

422. Vieraat esineet

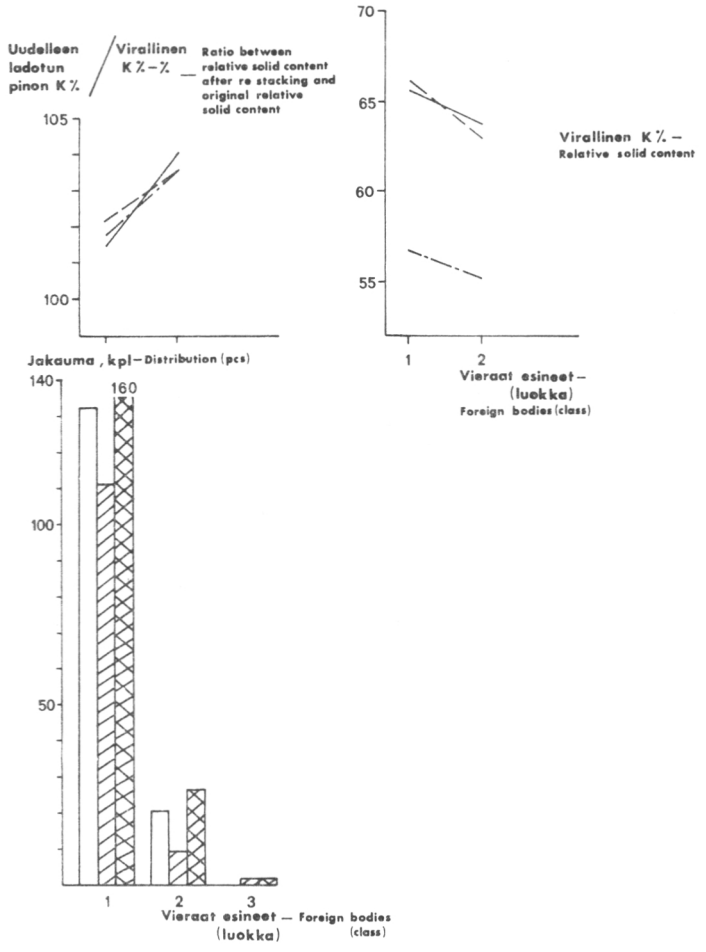
Pinoissa, nimenomaan koneellisesti ladotuissa pinoissa on melko usein vieraita esineitä, kuten oksia, sammalta yms., jotka tietenkin vaikuttavat pinotiheyttä alentavasti. Niiden vaikutuksen selvittämiseksi arvioitiin jokaisesta pinosta vieraiden esineiden määrä kolmessa luokassa, niinkuin alussa mainittiin. Luokka 1 tarkoittaa sitä, että pinossa ei ole lainkaan vieraita esineitä ja luokka 3 sitä, että vieraita esineitä on runsaasti (ks. liite 1).

Kuvasta 12 nähdään näytepinojen jakautuminen eri luokkiin. Se osoittaa, että suurin osa pinoista on kuulunut luokkaan 1. Sen osuus on ollut yli 80 %. Luokkaan 3 kuuluvia pinoja on esiintynyt vain satunnaisesti, eikä niille voidakaan laskea keskimääräistä pinotiheyslukua. Muiden erotettujen luokkien keskimääräiset pinotiheydet olivat seuraavat:

Puulaji	Vieraiden esineiden lk pinotiheys 1.	2.
Mänty	65.5	63.7
Kuusi	66.2	63.0
Lehtipuu	56.7	55.6

Kaikissa puulajeissa on siis vieraiden esineiden vaikutus suunnilleen samanlainen sovelletun luokituksen puitteissa.

Tulosten mukaan siirtyminen luokasta toiseen merkitsee eri puulajeissa 1—3 prosenttiyksikön pienenemistä pinotiheysluvussa. Luokkien väliset erot johtunevat osaksi myös eri ladontatapojen välisistä eroista (vrt. 4211). Nylinder ja Peterson (1967) ovat pitäneet tässä kohdassa tarpeellisena luokitusta 0—10 %:iin, kun lumi ja jää yhdistetään vieraisiin esineisiin. Karlsson (1971) luokitti nämä pinotiheyteen vaikuttavat tekijät viiteen luokkaan, mutta luokkiin 4 ja 5 ei hänen tutkimusaineistossaan osu-



Kuva 12. Näytepinojen jakauma ja ominaisuuksia puulajeittain vieraiden esineiden määrää kuvaavissa luokissa. (Mä —, Ku — —, Leht — · —; Ei vieraita esineitä = 1, Hiukan vieraita esineitä = 2, Runsaasti vieraita esineitä = 3).

Fig. 12. Distribution and properties of sample piles by tree species into classes indicating the amount of foreign bodies. (Pine —, Spruce — —, Broadleaved — · —; No foreign bodies = 1, Some foreign bodies = 2, Numerous foreign bodies = 3).

nut yhtään pinoa. Kolmen parhaan luokan pinotiheysluvut olivat lumettomana aikana 64.6, 64.4 ja 63.4. Kyseessä olivat käsinladotut pinot. K a r l s s o n ehdottaa myös käytännössä sovellettavaksi viisijakoista luokitusta, jossa yhden luokan muutos merkitsee 1 prosenttiyksikön muutosta pinotiheydessä.

Uudessa kokeiltavana olevassa suomalaisessa pinomenetelmässä suoritetaan vieraiden esineiden ja lumen ja jään huomioonottaminen tekemällä cm-vähennys pinonosien korkeudesta (Uudistuva puutavaran mittaus . . .).

Rikkosen (1972 a) mukaan korrelaatiokerroin vieraita esineitä kuvaavan luokan ja pinotiheyden välillä oli 0.784 (Sy.x = 0.040).

423. Lumi ja jää

Lumen ja jään vaikutusta pinotiheyteen koetettiin selvittää kolmijakoisella luokituksella, joka on esitetty liitteessä 1.

Lunta ja jäätä esiintyi kuitenkin pinoissa niin vähän, ettei vaikutuksen suuruusluokista päästy käsitykseen. Tekijän ilmeneminen vaikuttaa pinotiheyttä alentavasti ja vaikutus saattaa erikoisolosuhteissa olla huomattavakin (Nylinder ja Peterson 1967, Karlsson 1971).

Rikkosen (1972 a) aineistoon sisältyi kaikkiin lumi- ja jääluokkiin kuuluvia pinoja. Eri puulajien pinotiheydet olivat luokittain seuraavat:

	Lumi- ja jää-luokka		
	1	2	3
	Pinotiheys		
Havupuu	68.0	65.8	64.2
Lehtipuu	58.2	55.8	—

Luokkien 1 ja 2 väliset erot ovat varsin selvät ja johtuvat pääasiassa lumen ja jään erilaisesta määrästä.

Muissa tutkimuksissa tämä tekijä on yhdistetty vieraisiin esineisiin (ks. luku 412). Se onkin satunnaisesti esiintyvä ominaisuus, mutta se vaikuttaa selvästi pinotiheyteen, kuten edellä esitettiin. Myös monissa kirjoituksissa on korostettu pinossa olevan lumen ja jään pinotiheyttä pienentävää vaikutusta. Se on otettu huomioon myös voimassa olevassa puutavaran mittaussäännössä (Puutavaran . . . 1969). Uudessa kokeiltavana olevassa pinomenetelmässä lumen ja jään vaikutus eliminoidaan jo kehysmitassa cm-vähennyksenä korkeudenmittaushavainnoista (Uudistuva . . .).

424. Pinon suuruus

Pinon suuruuden vaikutusta pinotiheyteen ei tutkimusaineistosta pystytä laskemaan, sillä pinojen koon vaihtelu pyrittiin saamaan mahdollisimman vähäiseksi, kuten tutkimusmenetelmää selostettaessa mainittiin.

Aineistosta voitiin silti laskea keskiarvot eri pinon korkeuksille, jotka luvut kuitenkin sisältävät myös muiden tekijöiden vaikutuksen. Keskiarvo-

jen mukaan alle 1 m:n korkuiset havupuupinot olivat harvempia kuin muut pinot. Lehtipuissa ei pinon korkeudella ollut lainkaan vaikutusta pinotiheyteen (vrt. Rikkonen 1972 a). Asiaa on myös syytä tarkastella muiden tutkimusten ja kirjoitusten valossa.

Pinon pituudella ei tutkimusten mukaan ole vaikutusta pinotiheyteen (Nylinder 1957, 1972). Myös pinon korkeudella on Nylinderin (1972) mukaan vain vähäinen vaikutus. Erään hänen referoimansa tutkimuksen mukaan oli 1.5 metriä korkeiden pinojen tiheysluku vain ¼ yksikköä suurempi kuin 1 metrin korkuisten pinojen tiheysluku. Asia erikseen on, että kehysmittauksen virheet ovat hyvin pienissä pinoissa suuremmat kuin suurissa pinoissa.

Jalava (1929) ja Aro (1931) ovat tarkastelleet pinon suuruuden vaikutusta hyvin monipuolisesti ja tulleet siihen tulokseen että pinon suuruudella ei ole sanottavaa vaikutusta pinotiheyteen (vrt. Vid virkesmätning . . . 1923). Sen pinon tiheyden lisäyksen, jonka puiden paino korkeassa pinossa aiheuttaa, tasoittaa pinon korkeudesta aiheutuva huonompi ladonta pinon yläosissa.

Pertovaara (1957, 1958) sitä vastoin on esittänyt, että pinojen reunojen tiheys on selvästi pienempi kuin keskiosien, mistä johtuu, että pienet pinot ovat harvempia kuin suuret. Myös Mäkelä (1970) toteaa, että pienissä erissä tapahtuva mittaus antaa suuremman tuloksen (pienemmän pinotiheyden) kuin mitattaessa sama erä suurissa varastopinoissa. On kuitenkin korostettava, että tällainen pinon suuruuden vaikutus ei ole itsestään selvä verrattaessa erillisiä puutavaraeriä toisiinsa. Suuret pinot ovat usein koneella ladottuja ja saattavat olla siitä syystä pienikokoisia pinoja harvempia (esim. Nikkilä 1972 a).

425. Pinon ikä

Pinossaoloaika eli pinon ikä vaikuttaa aina kehysmittaa pienentävästi ja pinotiheyttä suurentavasti. Puutavaran mittauskomitea toteaa ongelmasta seuraavaa. »Pinon kokokin vaihtelee pölkkyjen kuivumisesta aiheutuvan kutistumisen ja pinon mekaanisen painumisen johdosta siten, että pinon myöhemmät mittaukset antavat miltei aina pienemmän pinomitan kuin aiemmin saman pinon mittauksessa saadut tulokset.» Nylinder (1960) on osoittanut, että vasta kuorittua tuoretta kuitupuuta sisältävä pino pieneni heinäkuusta syyskuuhun n. 1 %. Wuoti (1933) sai tulokseksi, että hyvin huolellisesti ladottua kuorittua tavaraa sisältävä pino laskeutui huhtikuusta lokakuuhun vain 0.8 %. Onkin ilmeistä, että pinon painuminen ei johdu yksinomaan puun kutistumisesta vaan myös ladonnan hyvyydestä. Harvat pinot saattavat painua varastointiaikana paljon. Myös pinon sisällä

Taulukko 6. Pinossaoloajan vaikutus pinotiheyteen.
Table 6. Effect of the in-pile time on relative solid content.

Pinon ikä, kk *In-pile time months*	Mänty *Pine*		Kuusi *Spruce*		Lehtipuu *Broadleaved*	
	kpl *pcs*	pinotiheys *relative solid content*	kpl *pcs*	pinotiheys *relative solid content*	kpl *pcs*	pinotiheys *relative solid content*
0	5	62.6	5	68.4	9	58.6
1	13	65.3	17	64.6	22	57.2
2	32	66.3	31	66.6	44	56.9
3	49	65.0	37	65.2	52	56.1
4	27	64.8	31	64.7	31	55.4
5	13	64.8	13	66.6	15	55.6
6	10	64.0	8	64.7	13	56.3
7	6	67.3	5	64.2	8	59.6
8	2	63.7	1	71.4	3	56.6
9	2	58.3	—	—	7	53.8
10	4	67.2	3	61.3	—	—
11	1	68.3	—	—	1	55.1
12	—	—	—	—	1	53.6

olevan lumen ja jään sulaminen pienentää usein pinon kehysmittaa varsin huomattavasti.

Esillä oleva aineisto ei osoita lainkaan pinotiheyden riippuvuutta pinossaoloajasta, niinkuin taulukosta 6 nähdään. Pinon pinotiheyteen vaikuttaakin yhtä aikaa niin monta tekijää, että pinon iän vaikutus peittyy muiden tekijöiden vaikutukseen. Lisäksi on huomattava, että esillä olevassa tutkimuksessa mitattujen pinojen pinossaoloaika vaihteli varsin vähän. Aineistoon ei esimerkiksi sisältynyt lainkaan ylivuotisia pinoja. Nikkilä (1972 a) on saanut korrelaation pinon iän ja pinotiheyden välillä negatiiviseksi.

Asia muuttuu aivan toiseksi, jos seurataan samojen pinojen iän vaikutusta saataviin mittoihin, mihin edellä siteerattu puutavaranmittauskomitean päätelmäkin viittaa. Osasta aineistoa selvitettiin yhteensä 138 pinon mittojen muuttuminen uudelleen pinoamisesta autoon kuormaukseen saakka. Näiden pinojen pinotiheys oli suurentunut ko. 2—7 kuukauden aikana keskimäärin seuraavasti (Heiskanen ja Riikonen 1973). Lukuihin sisältyvät myös mahdollisesti esiintyneet mittausvirheet.

Mäntypinot	1.47 %
Kuusipinot	0.39 »
Lehtipuupinot	1.34 »
Keskimäärin	1.15 »

Joissakin tapauksissa pinon painuminen ja pinotiheyden suureneminen oli usean prosentin suuruinen.

426. Mittauspaikka

Mittauspaikan osalta on puutavaran mittauksen ja pinotiheyden kannalta tärkeätä selvittää maassa olevien pinojen ja ajoneuvossa olevien pinojen eroavuudet. Osasta tutkimusaineistoa mitattiinkin kehysmitta myös autokuljetuksen eri vaiheissa, ja tulokset on julkaistu Heiskasen ja Riikosen (1973) tutkimuksessa. Ko. osatutkimuksessa suoritettiin kaikkiaan seitsemän mittausta 138 pinosta seuraavasti:

1. Alkuperäinen kehysmitta, joka on sama kuin esillä olevassa tutkimuksessa käytettävä mitta.
2. Kehysmitta uudelleen pinoamisen jälkeen.
3. Kehysmitta maassa juuri ennen autoon kuormausta.
4. Kehysmitta auton lavalla heti kuormauksen jälkeen ennen kuljetusta.
5. Kehysmitta auton lavalla kuljetuksen jälkeen.
6. Tehtaan bruttomitta.
7. Tehtaan nettomitta.

Koko aineiston alunperin käsin ja alunperin koneella ladottujen pinojen suhteelliset pinotiheydet olivat eri vaiheissa seuraavat, kun kaikissa vertailuissa alkuperäisen kehysmitan mukaista pinotiheyttä merkitään luvulla 100:

Mittausvaihe	Käsipinot	Konepinot
	Suht. pinotiheys	
1	100.0	100.0
2	101.0	104.5
3	102.2	106.4
4	99.2	104.7
5	100.6	106.1
6	100.0	105.4
7	101.5	106.4

Vastaavanlaisia tietoja on esitetty myös Puutavaran mittauskomitean mietinnössä (vrt. Puutavaran . . . 1965).

427. Kauppatapa

Kauppatavan eli latojan vaikutusta voidaan tarkastella sen perusteella, onko latomisen suorittanut myyjä (hankintakauppa ja käsikauppa) tai ostaja (pystykauppa). Keskiarvojen esittäminen eri kaupoille on tarpeetonta, koska edellämainitut ryhmät poikkeavat nimenomaan ladontatavaltaan toisistaan. Mahdolliset erot pinotiheyksissä aiheutuvat myös pääasiassa ladontatavasta. Seuraavassa asetelmassa on esitetty eri ladontatapojen osuus

mitatuista pinoista pysty- ja hankintakaupoissa. Mahdolliset erot pinotiheyksissä aiheutuvat myös pääasiassa ladontatavasta. Seuraavassa asetelmassa on esitetty eri ladontatapojen osuus mitatuista pinoista pysty- ja hankintakaupoissa.

	Kauppatapa					
	Hankinta			Pysty		
	kpl	%		kpl	%	
Käsipinoja						
Mänty	60	58		44	42	
Kuusi	57	59		39	41	
Lehtipuu	72	61		46	39	
Yhteensä	189	59	96 %	129	41	48 %
Konepinot						
Mänty	2	5		38	95	
Kuusi	2	10		18	90	
Lehtipuu	3	6		47	94	
Yhteensä	7	6	4 %	103	94	39 %
Huonot konepinot						
Mänty	1	12		7	88	
Kuusi	0	0		6	100	
Lehtipuu	0	0		21	100	
Yhteensä	1	3	△ %	34	97	13 %
Kaikki	197	42	100 %	266	57	100 %

Hankintapinot ovat olleet miltei sataprosenttisesti käsinladottuja, kun taas pystykauppojen pinoista yli puolet on ollut koneellisesti ladottuja. Näiden tietojen perusteella voidaan päätellä, että hankintakauppojen pinojen tiheys on jonkin verran suurempi kuin pystykauppojen. Ero ei ole kuitenkaan suuri, kuten ladontatapojen vertailu luvussa 4 211 osoitti. Pystykauppojen osuus on Pohjois-Suomessa ollut tässä aineistossa suurempi kuin Etelä-Suomessa, mikä ilmenee seuraavasta asetelmasta.

	Etelä-Suomi				Pohjois-Suomi			
	Hankinta		Pysty		Hankinta		Pysty	
	kpl	%	kpl	%	kpl	%	kpl	%
Havupuu	81	50	82	50	41	37	70	63
Lehtipuu	46	44	58	56	29	36	56	66
Yhteensä	127	48	140	52	70	36	126	64

Jakauma on jokseenkin samanlainen kuin asetettu tavoite.

428. Omistajaryhmä

Omistajaryhmällä tarkoitetaan tässä yhteydessä lähinnä myyjää tai toimittajaa. Siis esimerkiksi jaotus yksityiset—yhtiöt—metsähallitus on omis-

tajaryhmittäinen. Eri omistajaryhmiltä tulevan pinotavaran tiheydessä ei havaittu merkittäviä eroja. Eri omistajaryhmiltä eri alueilla tulevat pinot poikkeavat jonkinverran ominaisuuksiltaan mm. ladontatavaltaan, mutta mitään selvää suuntaa tällä poikkeamalla ei ole. Poikkeamat, jos niitä esiintyy, johtuvat kauppatavasta, jonka vaikutus otettiin esille edellisessä luvussa. Se, että jonkin omistajaryhmän toimittamat kuitupuut ovat järeämpiä kuin jonkin toisen, tulee esille pinotavaran järeyden vaikutusta tarkasteltaessa.

429. Muita tekijöitä

Muista pinokohtaisista pinotiheyteen vaikuttavista tekijöistä on tärkein aluspuiden olemassaolo tai puuttuminen, jota Nikkilä (1972 a) on tarkastellut tutkimuksessaan. Hänen tuloksensa osoittavat, että aluspuilla varustettujen koneellisesti ladottujen lehtipuupinojen pinotiheys on suurempi kuin aluspuuttomien, kuten seuraava asetelma osoittaa:

	Konepinot	Käsipinot pinotiheysluku	Yhteensä
Aluspuulliset	58.1	58.5	58.4
Ilman aluspuita	54.0	60.0	55.1

Joissakin vanhemmissa keskieurooppalaisissa tutkimuksissa on todettu, että jos pitkän pinotavaran pinossa on vain yksi pääpuu kummassakin päässä, saadaan korkeampi pinotiheys kuin jos kummassakin päässä on rinnakkain kaksi tukea (vrt. Jalava 1929, Aro 1931).

Kehysmittauksen tuloksen tarkkuuteen ja siten myös saatavan pinotiheysluvun luotettavuuteen vaikuttaa melko selvästi pinotyyppi, siis se onko pinossa pääpuut vai ei. Pääpuullisten pinojen mittaustulokset vaihtelevat eri miehillä huomattavasti vähemmän kuin ilman pääpuita olevien kasojen mittaustulokset (Heiskanen 1973 a).

Pinotyypin vaikutus itse pinotiheyteen on esitetty seuraavassa asetelmassa (vrt. Rikkonen 1972 b).

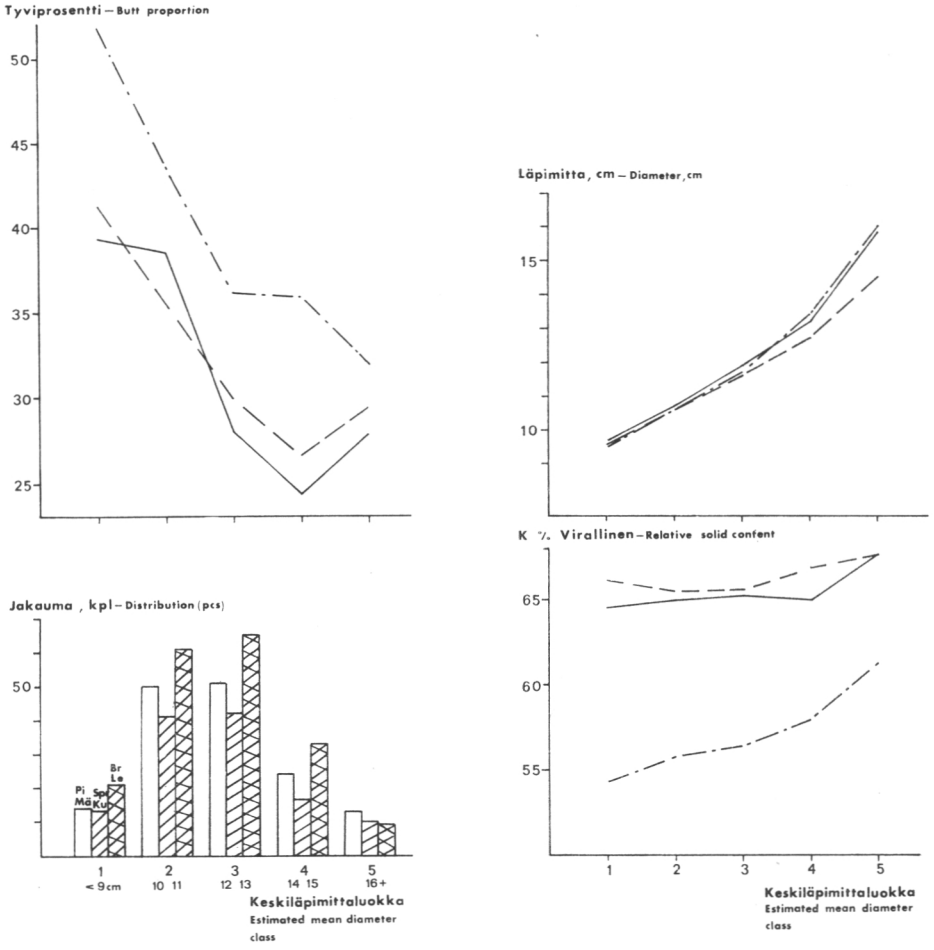
	Mänty	Kuusi pinotiheys	Lehtipuu
Molemmat pääpuut	65.5	66.3	55.8
Toinen pääpuu	65.3	65.4	57.0
Ei pääpuuta	65.1	66.3	56.6

Luvuista ilmenee, että kuvattujen pinotyyppien pinotiheydet eivät eroa systemaattisesti toisistaan.

43. Kuitupuun ominaisuuksien vaikutus

431. Keskiläpimitta

Pinossa olevien pölkkyjen läpimitta ei sinänsä vaikuttaisi pinotiheyteen, mutta pölkkyjen järeyteen liittyvät muut ominaisuudet kuten tyvien osuus, mutkaisuus ja oksaisuus aiheuttavat sen, että läpimitta yksinäänkin selittää huomattavan osan pinotiheyden hajonnasta.



Kuva 13. Näytepinojen jakauma ja ominaisuuksia puulajeittain arvioiduissa läpimittaluokissa. (Mä —, Ku — —, Leht — · —; ≤ 9 = 1, 10—11 = 2, 12—13 = 3, 14—15 = 4, 16+ = 5).

Fig. 13. Distribution and properties of sample piles by tree species in estimated diameter classes. (Pine —, Spruce — —, Broadleaved — · —; ≤ 9 = 1, 10—11 = 2, 12—13 = 3, 14—15 = 4, 16+ = 5).

Käsillä olevassa tutkimuksessa pölkkyjen läpimitta sekä arvioitiin että mitattiin. Arviointi suoritettiin viiteen luokkaan (liite 1). Kuten kuvasta 13 nähdään, arviointi on onnistunut verraten hyvin nimenomaan keskimmäisissä luokissa. Sitä kuvaavat myös seuraavat arvioidun ja mitatun läpimitan väliset korrelaatiot:

Puulaji	Korrelaatiokerroin
Mänty	0.773
Kuusi	0.735
Lehtipuu	0.754
Yhteensä	0.753

Arvioidun läpimittaluokan vaikutus pinotiheyteen on kuvan 13 mukaan selvä. Eri luokkien keskimääräiset pinotiheydet hajontoineen on esitetty liitteessä 3. Lehtipuulla vaikutus on huomattavasti voimakkaampi kuin havupuulla. Arvioidun läpimittaluokan ja pinotiheyden korrelaatiot ja läpimitan vaikutus pinotiheyteen olivat seuraavan asetelman osoittamat:

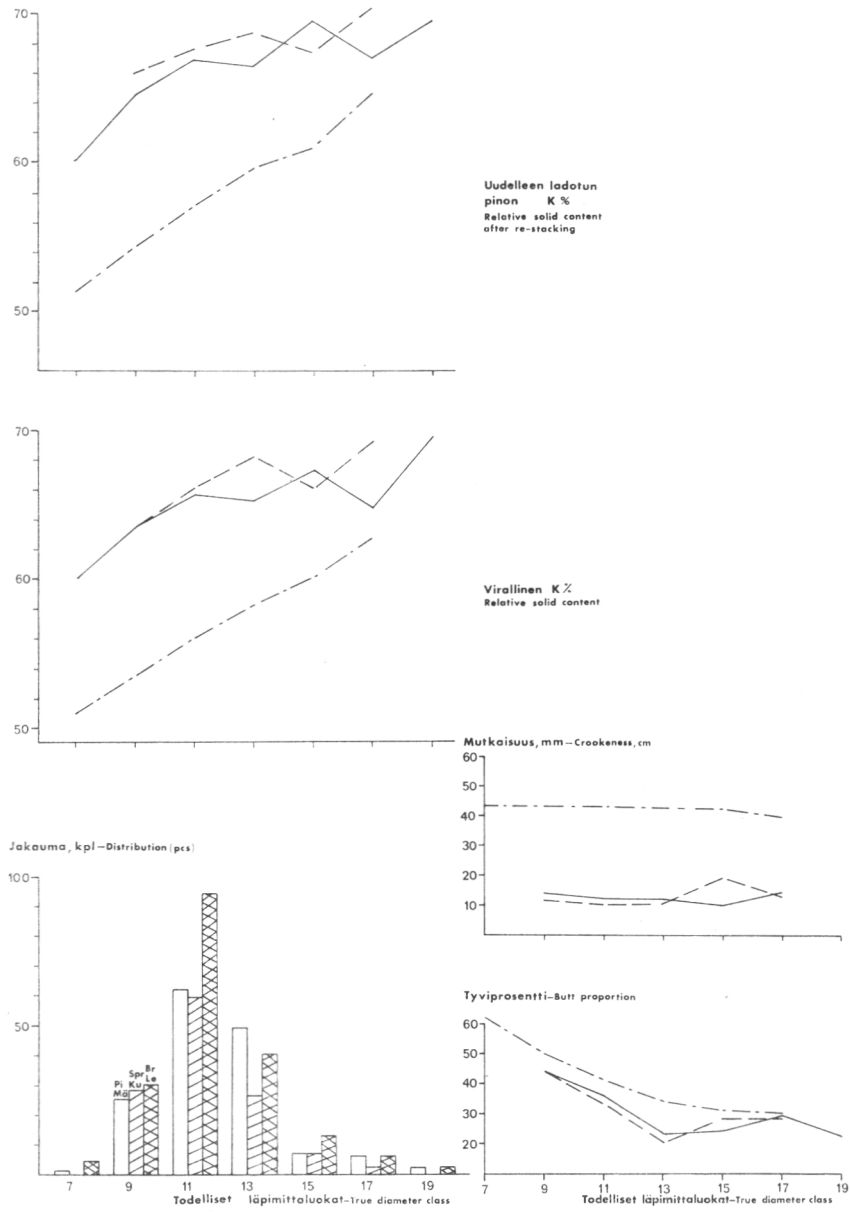
	Korrelaatio-kerroin	Vaikutus/luokka
Mänty	0.135	0.634 prosenttiyksikköä
Kuusi	0.121	— »
Lehtipuu	0.319	1.251 »
Yhteensä	0.161	0.932 »

Mitatulla läpimitalla oli kuitenkin selvempi vaikutus pinotiheyteen. Edelläesitettyjä vastaavat luvut mitatulle läpimitalle olivat seuraavat:

	Korrelaatio-kerroin	Vaikutus/läpimitan cm
Mänty	0.223	0.497 prosenttiyksikköä
Kuusi	0.365	0.838 »
Lehtipuu	0.486	1.225 »
Yhteensä	0.265	10.724 prosenttiyksikköä/ läpimitan logaritmiyksikkö

Viimeksimainittu on noin 2.5—0.5 prosenttiyksikköä/cm läpimitasta riippuen. Kaikille puulajeille yhdessä esitetty luku osoittaa, että läpimitan vaikutus on vähenevä, so. järeissä luokissa ei yhden cm:n muutos läpimitassa aiheuta yhtä suurta muutosta pinotiheydessä kuin ohuissa läpimittaluokissa. Karlssonin (1971) mukaan 3 m kuitupuun pinotiheys saavuttaa maksiminsa 27.4 cm:ssä. Hänen aineistossaan esiintyy pinojen keskiläpimittoja 8—38 cm:iin; valtaosa on kuitenkin yli 12 cm:n. Hän suositteleekin nelijakoista luokitusta, jossa koko vaihteluvälillä vaikutus on 4 prosenttiyksikön luokkaa.

Pölkkyjen läpimitan ja pinotiheyden välinen riippuvuus on osoitettu myös monissa aiemmissa tutkimuksissa (esim. Aro 1931, Jalava 1929,



Kuva 14. Näytepinojen jakauma ja ominaisuuksia puulajeittain todellisissa läpimittaluokissa. (Mä —, Ku — —, Leht — - —).

Fig. 14. Distribution and properties of sample piles by tree species in true diameter classes. (Pine —, Spruce — —, Broadleaved — - —).

Saari et al. 1939, Eklund 1948, Hellman 1959, Mähönen 1964, Nikkilä 1972 a. Yleensä läpimittajakautuma ei ole ollut kovin laaja, ja tuloksena onkin tavallisesti ollut, että pinotiheys suurenee pölkyn läpimitan kasvun myötä. Wuoti (1940) sai mm. kuusitukeista tehdyn pinotavaran pinotiheydeksi peräti 78, kun normaalin puun tiheytenä pidettiin siihen aikaan lukua 72.

Myös erilaisia tuloksia on saatu. Edellä mainittiin jo Karlssonin tulos. Eklund (1953) tutki läpimitan mukaan lajiteltua kuusikuitupuuta ja sai tulokseksi, että pinotiheys oli suurimmillaan pölkkyjen läpimitan ollessa 10—15 cm. Nylinderin ja Petersonin (1967) mukaan vastaavanlaisessa lehtipuutavarassa maksimipinotiheys saavutettiin 10—20 cm:n paikkeilla, ja kuuselle lähellä 30 cm:ä. Männyllä ei pinotiheys alentunut vielä yli 30 cm:n läpimitassakaan. Heidän mukaansa lajittelemattoman havukuitupuun pinotiheys ei saavuttanut maksimia 20 cm:ään mennessä. (vrt. Nylinder 1960).

Käsillä olevassa aineistossa yli puolessa pinoista pölkkyjen keskiläpimitta on alle 12 cm:n ja läpimitan vaikutus on tämän johdosta huomattavasti jyrkempi kuin Karlssonin mukaan. Kuten kuvasta 14 nähdään, on läpimitan vaikutus muita tekijöitä huomioon ottamatta havupuulla noin 9 prosenttiyksikköä ja lehtipuulla noin 12 prosenttiyksikköä koko vaihteluvälillä, 7—17 cm. Nämä arvot eivät kuitenkaan suoraan kuvaa läpimitan vaikutusta vaan niissä on mukana osittain ainakin tyvien osuuden vaikutusta, kuten kuvasta 14 ilmenee. Myös ladonta on mukana vaikutuksessa siten, että kuusella pienissä läpimittaluokissa esiintyy enemmän konepinoja kuin suurissa. Muilla puulajeilla tilanne on päinvastainen (ks kuva 8). Läpimitan vaikutusta selkiyttää kuitenkin muiden tekijöiden etenkin mutkaisuuden ja ladonnan huomioonottaminen, mihin palataan luvussa 44.

Rikkosen (1972 a) mukaan läpimitan vaikutus oli havupuulla noin 1 prosenttiyksikkö senttimetriä kohden ja lehtipuulla suurinpiirtein samanverran. Tulos vastaa nyt saatua, sillä kun kaikki puulajit yhdistetään, on läpimitan vaikutus tässäkin aineistossa suoraviivaisena likimain 1 yksikkö senttimetriä kohden.

432. Läpimittojen erotus ja hajonta

Läpimittojen erotuksen luokittelu aineiston keruun yhteydessä epäonnistui, sillä miltei kaikki havainnot menivät samaan luokkaan.

Läpimitan hajonta korreloi vahvasti pinotiheyden kanssa varsinkin lehtipuun osalta. Korrelaatio ei ole kuitenkaan yhtä vahva kuin läpimitan ja pinotiheyden välinen korrelaatio. Hajonnan pinotiheyttä kuvaava vaikutus

johtuu suurelta osin siitä, että hajonta on sitä suurempi mitä järeämpiä pölkyt ovat.

Aineistosta saatiin läpimitan hajonnalle seuraavat korrelaatiot pinotiheyteen ja järeyteen.

	Korrelaatiokertoimet	
	Pinotiheys	Järeys (läpim. cm)
Mänty	0.033	0.812
Kuusi	0.120	0.756
Lehtipuu	0.445	0.768
Yhteensä	0.139	0.782

Toisin sanoen pinotiheyden vaihtelun selittäminen pölkkyjen läpimitan hajonnan avulla ei onnistu, jos mallissa jo käytetään läpimittaa selittäjänä.

Karlsson (1971) on saanut läpimitan hajonnan merkitseväksi pinotiheyden vaihtelun selittäjäksi. Tosin vaikutus on vain 2 prosenttiyksikköä koko vaihteluvälillä.

Rikkonen (1972 a) mukaan läpimitan hajonta ei selittänyt pinotiheyden vaihtelua.

Läpimittaan liittyy teoriassa kysymys läpimitan mukaan lajiteltujen ja läpimitaltaan lajittelemattomien pölkkyjen muodostamien pinojen pinotiheyksistä. Nylinderin (1960, 1972) mukaan on lajiteltujen pinojen tiheys jonkin verran lajittelemattomien pinojen tiheyttä pienempi.

433. Sekoittuminen

Eri kokoisten pölkkyjen sekoittuminen arvioitiin pinojen mittausten yhteydessä kolmessa luokassa (hyvä—keskinkertainen—huono) (liite 1).

Pinotiheyksien keskiarvot eri luokissa olivat seuraavat.

Puulaji	Sekoittumisluokka 1	2	3
		Pinotiheysluku	
Mänty	65.7	65.4	64.4
Kuusi	66.4	65.7	66.2
Lehtipuu	54.8	57.0	58.0

Pinotiheyteen vaikuttavana tekijänä sekoittuminen peittyy suurimmaksi osaksi muihin tekijöihin. Havupuilla kuitenkin sekoittumisen paraneminen suurentaa pinotiheyttä jonkin verran. Lehtipuulla näyttää sen sijaan sekoittumisen huonontuminen lisäävän pinotiheyttä. Tämä saattaa johtua siitä, että lehtipuun järeäpölkkyiset pinot ovat olleet melko tasaläpimittaista tavaraa, mutta suorempia pölkkyjä sisältävinä kuitenkin tiheämpiä kuin paremmin sekoittuneet pinot.

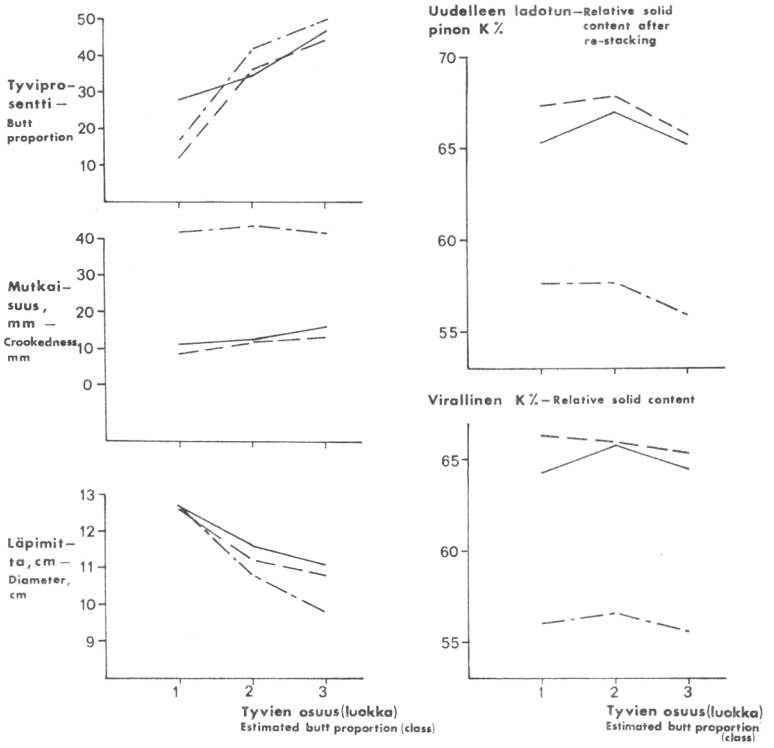
Arvioidun sekoittumisluokan korrelaatio pinotiheyden suhteen on havupuilla negatiivinen ja heikko. (Kuusi —0.090 ja mänty —0.020). Lehtipuilla korrelaatio on voimakkaampi ja positiivinen (R = 0.252).

K a r l s s o n (1971) käytti sekoittumisen kuvaamiseen läpimitan hajontaa, ja kuten edellä todettiin, sai vaikutukseksi noin 2 prosenttiyksikköä koko vaihteluvälillä.

R i k k o n e n (1972 a) sai sekoittumisen koko vaikutukseksi havupuulla 2 prosenttiyksikköä silloin, kun muut tekijät oli huomioitu. Lehtipuulla sekoittuminen ei selittänyt hänen mukaansa pinotiheyden hajontaa.

434. Tyvipölkkyjen osuus

Tyvipölkkyjen osuus arvioitiin kolmessa luokassa (liite 1), ja se laskettiin myös täsmällisesti pölkkyjen mittauksen yhteydessä. Tyvien-osuus-



Kuva 15. Näytepinojen ominaisuuksia puulajeittain arvioiduissa tyviosuusluokissa. (Mä —, Ku — —, Leht — - —; < 20 % = 1, 20—40 % = 2, > 40 % = 3).

Fig. 15. Properties of sample piles by tree species in estimated butt proportion classes. (Pine —, Spruce — —, Broadleaved — - —; < 20 % = 1, 20—40 % = 2, > 40 % = 3).

luokittain ei pinotiheydellä näytä olevan mitään selvää suuntaa. Luokitus lienee ollut hieman liian karkea. Pinotiheydet olivat luokittain seuraavat:

Puulaji	Tyvien osuus lk 1 <20 %	2 20—40 % pinotiheys	3 <40 %
Mänty	64.3	65.8	64.5
Kuusi	66.3	65.9	65.4
Lehtipuu	56.0	56.6	55.6

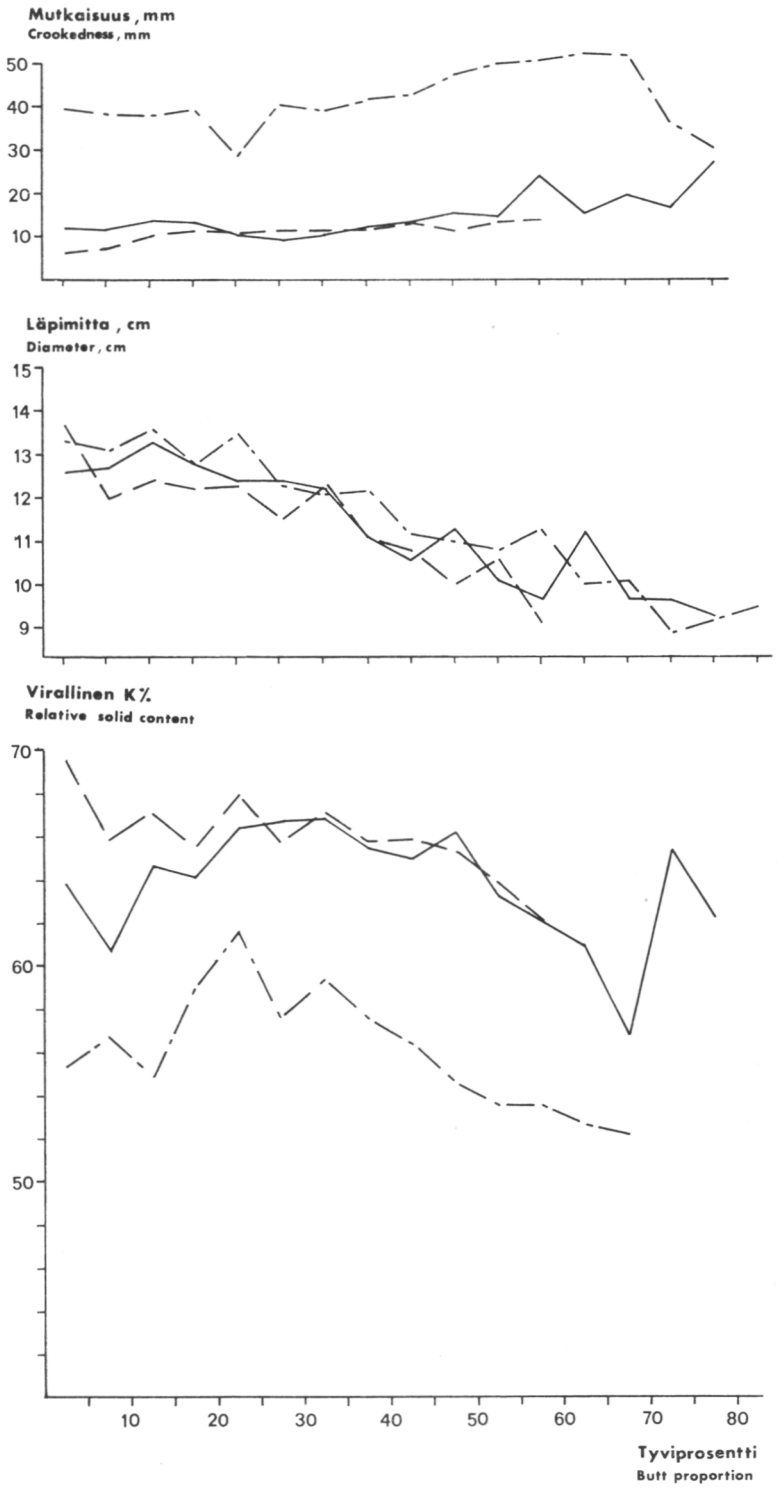
Luokkien korrelaatiot ovat pinotiheyden suhteen hyvin heikot, niinkuin yllä olevasta asetelmastakin voi päätellä. Kuvasta 15 nähdään pinojen muitakin ominaisuuksia tyviosuusluokittain. Siitä havaitaan, että tyviprosentin arviointi ei ole onnistunut kovinkaan hyvin, vaikka eri luokkien tyviprosentit eroavatkin selvästi toisistaan.

Todellinen tyvien osuus vaihteli puulajeittain. Havupuulla tyvien osuus oli keskimäärin n. 32 % ja lehtipuulla n. 40 %. Todellisella tyvien osuudella oli melko vahva korrelaatio pinotiheyteen mäntypinoja lukuunottamatta, mikä ilmenee seuraavan asetelman korrelaatiokertoimista.

Puulaji	Korrelaatiokerroin
Mänty	—0.047
Kuusi	—0.331
Lehtipuu	—0.358
Yhteensä	—0.354

Kuten kuvasta 16 nähdään on tyvien osuuden vaikutus epäselvä pienillä tyviosuuksilla, kuitenkin 30 prosentista eteenpäin vaikutus on melko selvä. Samanlaista kehitystä havaitaan myös pölkkyjen keskiläpimitassa ja mutkaisuudessa, jotka melko tarkasti seuraavat tyviprosentin kasvua, läpimitta pienentyen ja mutkaisuus suurentuen. Mutkaisuuden mittaustavasta johtuen mutkaisuus selittää tyviosuudenkin vaikutuksen pinotiheyteen. Mutkaisuutta mitattaessa näet otettiin huomioon myös tyvilaajeneman suuruus. Läpimitta ja tyviosuus ovat myös vahvassa riippuvuudessa keskenään, ja näin ollen läpimitan käyttäminen selittäjänä vie myös osan tyviprosentin selityskyvystä. Tyvien osuuden korrelaatiot mutkaisuuteen ja läpimittaan olivat seuraavat:

	Korrelaatiokertoimet läpimitta	mutkaisuus
Mänty	—0.428	0.331
Kuusi	—0.520	0.293
Lehtipuu	—0.421	0.318
Yhteensä	—0.431	0.363



Kuva 16. Näytepinojen ominaisuuksia puulajeittain todellisissa tyviosuusluokissa. (Mä —, Ku — —, Leht — - —).

Fig. 16. Properties of sample piles by tree species in true butt proportion classes. (Pine —, Spruce — —, Broadleaved — - —).

Karlsson (1971) suosittelee tyvien osuuden arviointiin kolmea luokkaa, joille hän sai vaikutukseksi pinotiheyteen 2 prosenttiyksikköä koko vaihteluvälillä.

Rikkonen (1972 a) sai tyvien osuuden vaikutukseksi havupuulle n. 4 prosenttiyksikköä eli luokiteltuna Karlssonin mukaan vaikutus pinotiheyteen olisi samansuuruinen kuin tämän saama vaikutus. Lehtipuulla ei tyvien osuus vaikuttanut pinotiheyteen. Nylinder ja Peterson (1967) toteavat, että varsinkin kuusipinoissa tyvipölkkyjen osuus vaikuttaa pinotiheyttä pienentävästi. Sama vaikutus ilmenee myös pinotiheys/kylkitiheyssuhteessa (Nikkilä 1972 b).

435. Mutkaisuus

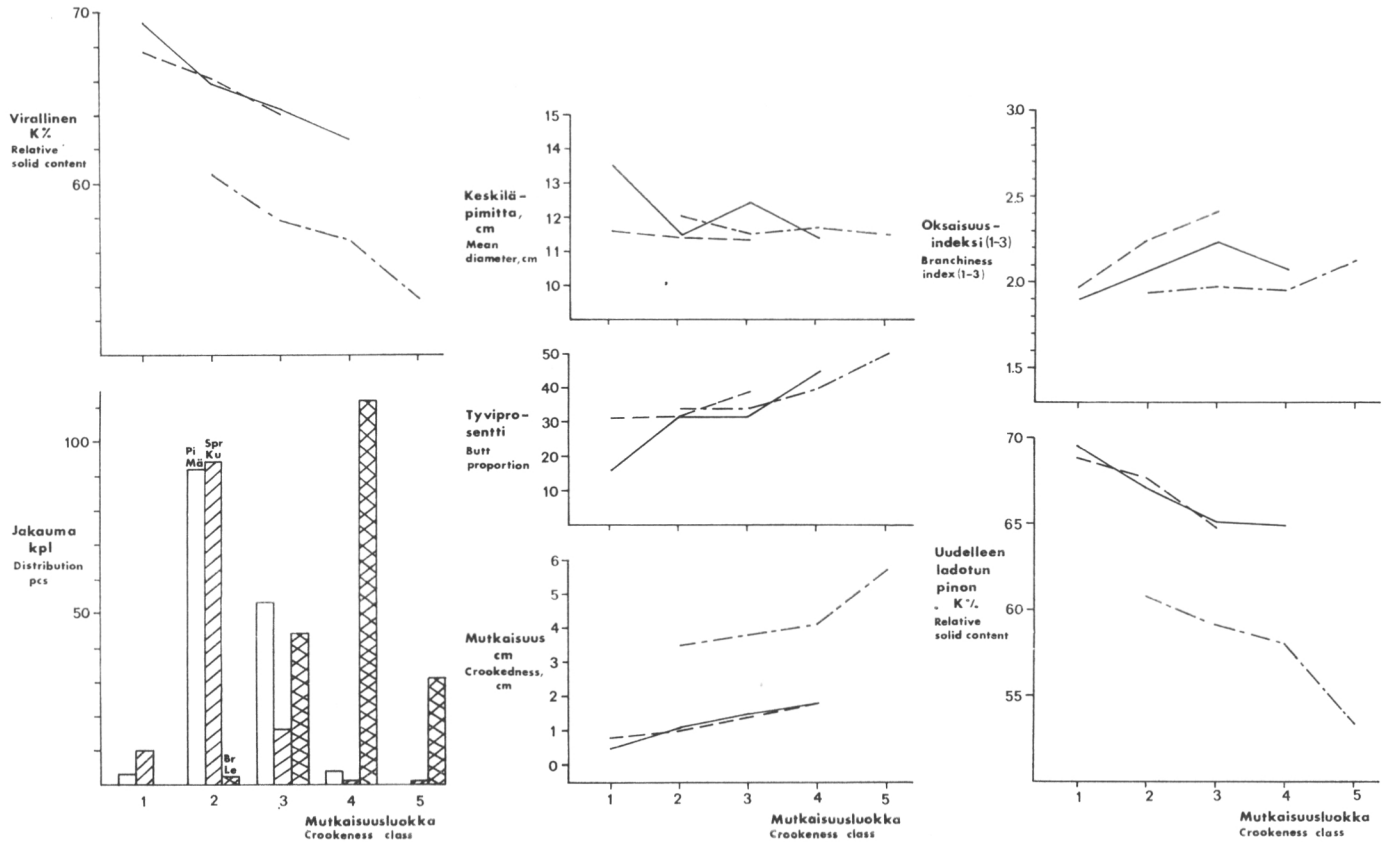
Pinossa olevien pölkkyjen mutkaisuus arvioitiin viidessä luokassa (liite 1). Lisäksi määritettiin mutkaisuuden määrä mittaamalla se koepölkyistä tutkimusmenetelmää selostettaessa esitetyllä tavalla.

Eri puulajien pinojen jakautuminen mutkaisuusluokkiin nähdään kuvasta 17, josta havaitaan eri puulajien eroavan selvästi toisistaan. Lehtipuupinot kuuluvat luokkiin 2—5 yleisimmän luokan ollessa 4. Havupuupinoista valtaosa on luokitettu 2. luokkaan, mutta männyssä myös 3. luokka on verraten yleinen. Huonoimmissa luokissa on havupuupinoja vain aivan satunnaisesti. Vastaavanlaisia jakautumia saatiin tutkimuksen 1. vaiheen koearvioinneissa (Heiskanen 1973 a, Rikkonen 1972 a).

Mutkaisuuden mitta sentteinä osoittaa riippuvuutta arvioidusta mutkaisuusluokasta erikseen kussakin puulajissa sekä kaikissa yhteensä, kuten havaitaan kuvasta 17. Ohjeiden mukaan havu- ja lehtipuun mutkaisuus arvioitiin erikseen siten, että keskimmäinen luokka vastasi puulajiryhmän luontaista keskimääräistä mutkaisuutta, mikä näkyykin hyvin kuvasta 17.

Mutkaisuusluokan vaikutus pinotiheyteen on kuitenkin hyvin selvä ja suoraviivainen kaikissa puulajeissa, kuten kuvasta 17 ilmenee. Korrelaatiokertoimien arvot ja tekijän suoraviivainen vaikutus olivat seuraavat puulajeittain:

	Korrelaatiokerroin	Vaikutus/luokka
Mänty	—0.236	—1.22 prosenttiyksikköä/lk
Kuusi	—0.222	—1.20 »
Lehtipuu	—0.316	—1.93 »
Yhteensä	—0.695	—1.45 »



Kuva 17. Näytepinojen jakauma ja ominaisuuksia puulajeittain arvioiduissa mutkaisuusluokissa.
(Mä —, Ku — —, Leht — - —; Suora = 1, Erittäin mutkainen = 5).

Fig. 17. Distribution and properties of sample piles by tree species in estimated crookedness classes.
(Pine —, Spruce — —, Broadleaved — - —; Straight = 1, Very crooked = 5).

Tasoittamattomat pinotiheysluvut olivat seuraavat eri mutkaisuusluokissa (vrt. liite 3).

	Mutkaisuusluokka				
	1	2	3	4	5
	Pinotiheysluku				
Mänty	69.5	67.7	65.1	64.9	—
Kuusi	68.8	67.1	64.8	—	—
Lehtipuu	—	60.7	59.1	58.0	53.4

Tulosten mukaan siis yhden luokan muutos mutkaisuudessa aiheuttaa havupuupinoissa 1—2 prosenttiyksikön muutoksen pinotiheydessä. Vastaava muutos on lehtipuupinoissa keskimäärin suurempi. Rikkosen (1972 a) mukaan korrelaatiokerroin mutkaisuuden ja pinotiheyden välillä oli 0.842 ($S_{y \cdot x} = 0.034$). Eri luokkien pinotiheysluvut olivat hänen mukaansa seuraavat.

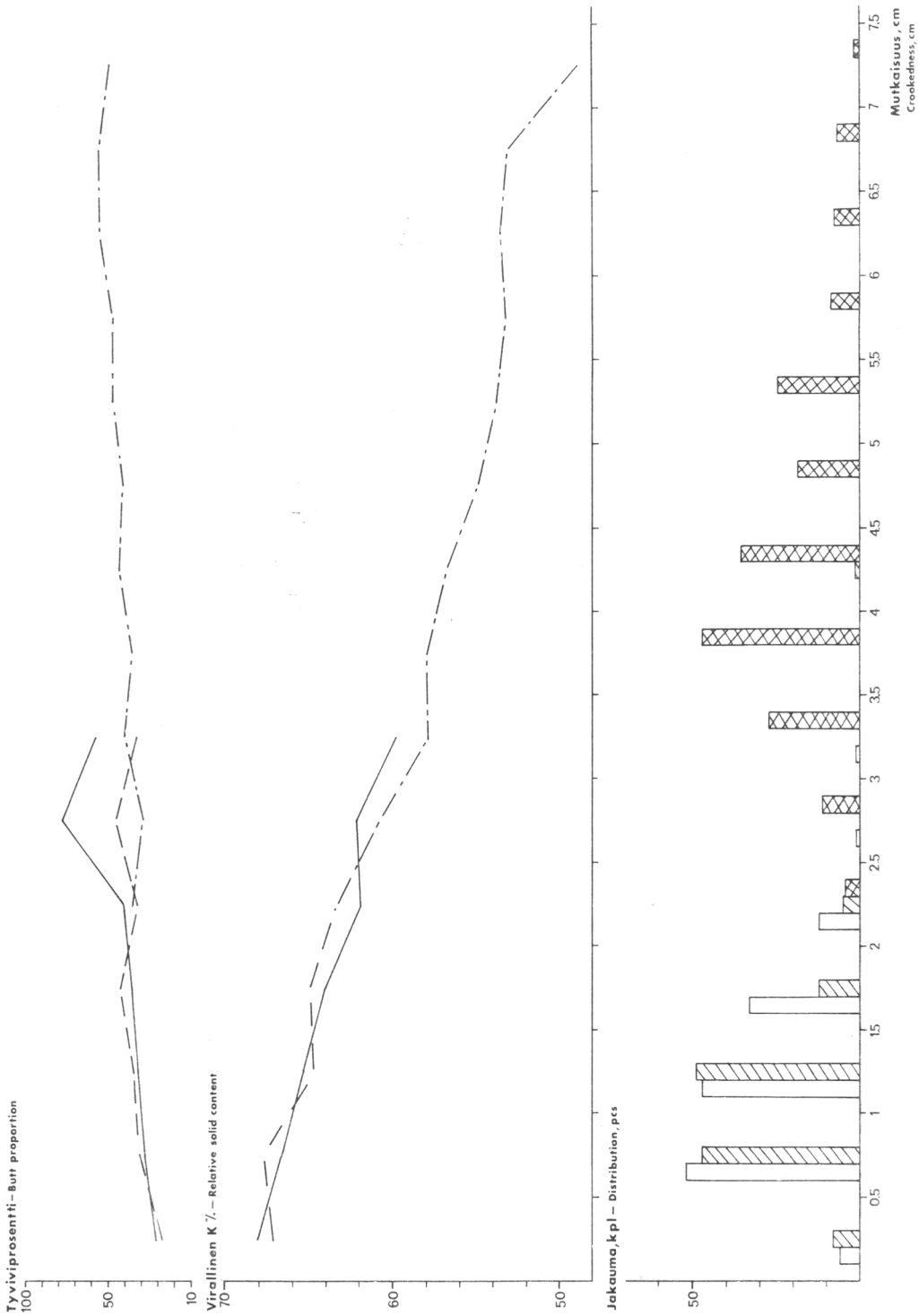
Mutkaisuusluokka	Havupuut	Lehtipuut
	Pinotiheysluku	
1	72.5	—
2	67.5	—
3	64.0	59.0
4	—	57.5
5	—	49.5

Tulos vastaa siis hyvin nyt saatua tulosta. Voidaankin todeta, että mutkaisuuden vaikutus pinotiheyteen on käytetyn luokituksen puitteissa erittäin selvä.

Mitatun mutkaisuuden ja pinotiheyden välinen riippuvuus nähdään kuvasta 18 puulajeittain. Vastaavat korrelaatiokertoimen arvot ja tekijän suoraviivainen vaikutus ovat seuraavat:

	Korrelaatio-kerroin	Vaikutus/mutkaisuuden cm
Mänty	—0.384	—2.1 prosenttiyksikköä/cm
Kuusi	—0.342	—2.7 »
Lehtipuu	—0.534	—2.3 »
Yhteensä	—0.788	—2.3 »

Nämä tulokset osoittavat, että mitattu mutkaisuus osoittaa pinotiheyden suuruuden varsin hyvin kussakin puulajissa erikseenkin. Näin on laita nimenomaan lehtipuissa, joissa mutkaisuuden lukuarvo vaihtelee erittäin laajalla alueella. Havupuussa korrelaatio on hieman heikompi. Jos sitä vastoin yhdistetään kaikki puulajit, on mutkaisuuden ja pinotiheyden välinen korrelaatio hyvin vahva. Voidaankin todeta, että mutkaisuus on itse asiassa ainoa ominaisuus, jonka kannalta lehtipuupinot eroavat havupuupinoista. Se onkin tekijä, joka selittää lehtipuupinojen heikon pinotiheyden. Itse



Kuva 18. Näytepinojen jakauma ja ominaisuuksia puulajeittain todellisissa mutkaisuusluokissa.
(Mä —, Ku — —, Leht — - —).

Fig. 18. Distribution and properties of sample piles by tree species in true crookedness classes.
(Pine —, Spruce — —, Broadleaved — - —).

mutkaisuuden vaikutus pinotiheyteen on kaikilla puulajeilla samaa suuruusluokkaa (kuva 18).

Rikkonen (1972 a) on myös saanut tulokseksi hyvin vahvan riippuvuuden mitatun mutkaisuuden ja pinotiheyden välillä. Regressiosuoran yhtälö on seuraava, kun kaikki puulajit käsitellään erottelemattomina:

$y = 0.7041 - 0.0309x$, jossa
y = pinotiheys ja
x = mutkaisuus (cm).

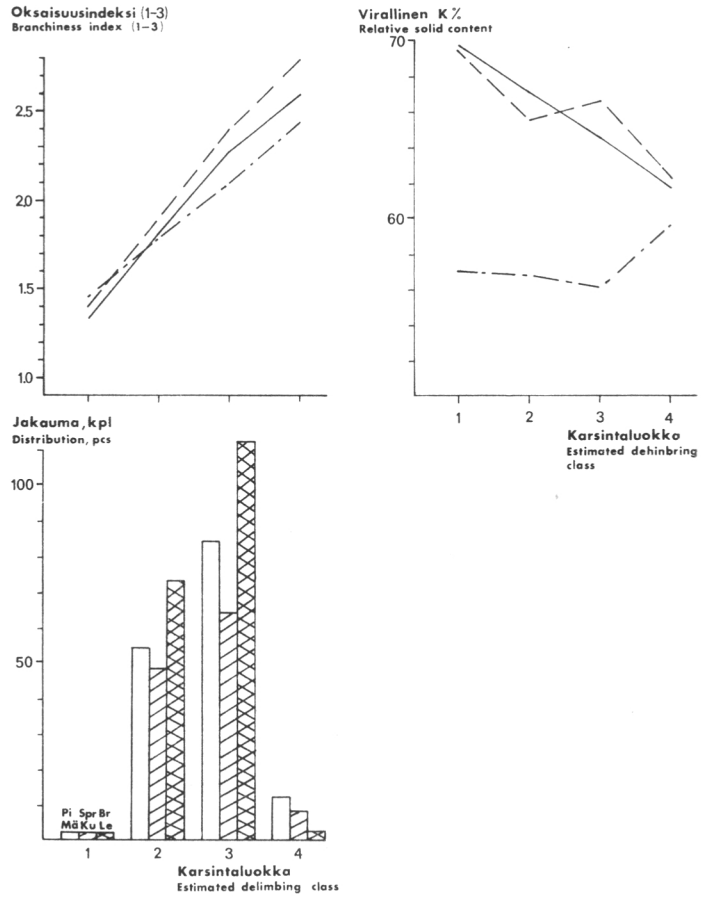
Myös monissa muissa tutkimuksissa on käsitelty mutkaisuuden ja pinotiheyden suhdetta. Makkonen (1965) erotti 2-m koivupaperipuussa kolme mutkaisuusluokkaa ja sai eri luokille seuraavat pinotiheysluvut, kun kussakin pinossa kaikki pölkyt kuuluivat ko. luokkaan: I 69.3, II 64.1 ja III 60.9. Lajittelemattoman tavaran pinotiheysluku oli 63.4. Nylinder ja Peterson (1967) esittävät pinotiheyksiä pinossa olevien mutkaisten pölkkyjen lukumäärän funktiona. Perusaineiston mukaan riippuvuus on kaikilla puulajeilla verraten heikko. Selvin on mutkaisuuden vaikutus kuusessa ja erittäin mutkaisessa koivussa. Mutkaisuuden huomioon ottamiseksi pinomitasta kiintomittaan pyrittäessä Nylinder ja Peterson ehdottavat käyttöön viisijakoisen luokituksen. Siinä on luokkien 1—2 ja 2—3 väli yksi prosenttiyksikkö ja muut välit 2 prosenttiyksikköä.

Karlssonin (1971) mukaan mutkaisuus on toiseksi merkittävin pinotiheyteen vaikuttavista tekijöistä. Pinon pölkkyjen keskimääräisen mutkaisuuden lisääntyessä 0:sta 70 mm:iin pienenee pinotiheys hänen mukaansa n. 7 prosenttiyksiköllä. Myös arvioitujen mutkaisuusluokkien ja pinotiheyden välillä vallitsee hyvin voimakas riippuvuus. Hän ehdottaa käytettäväksi seitsenjakoista luokitusta, jossa luokkien väli mutkaisuudessa on 9.7 mm. Yhden luokan muutos vaikuttaa yhden prosenttiyksikön verran pinotiheyteen. Sekä Nylinderin ja Petersonin että Karlssonin ehdottamat luokitukset on tarkoitettu kaikille puulajeille.

Uudessa suomalaisessa pinomenetelmässä on päädytty nelijakoiseen mutkaisuusluokitukseen. Havupuupinoissa vaikuttaa yhden luokan muutos yhden prosenttiyksikön ja lehtipuupinoissa kaksi prosenttiyksikköä pinotiheyttä muuttavasti (vrt. Uudistuva . . .). Jos kaikki puulajit olisi yhdistetty olisi mutkaisuus pitänyt jakaa ainakin kymmeneen luokkaan (ks. kuva 24), mikäli haluttaisiin päästä pieniin luokkaväleihin.

436. Karsinta

Karsinnan laatu arvioitiin silmävaraisesti jokaisesta pinosta neljässä luokassa, kuten tutkimusmenetelmää selostettaessa mainittiin (ks. liite 1).



Kuva 19. Näytepinojen jakauma ja ominaisuuksia puulajeittain arvioiduissa karsintaluokissa. (Mä —, Ku — —, Leht — · —; Pinnanmyötäinen = 1, Erittäin huono = 4)

Fig. 19. Distribution and properties of sample piles by tree species in estimated delimbing classes. (Pine —, Spruce — —, Broad-leaved — · —; Well delimbed = 1, Very poorly delimbed = 4).

Kuvasta 19 nähdään pinojen jakautuminen eri luokkiin. Se osoittaa, että kaikissa puulajeissa ovat keskimmäiset luokat 2 ja 3 yleisimpiä, mikä ilmenee myös seuraavista eri puulajien keskiarvoisista luokista:

Puulaji	Karsinta-luokka
Mänty	2.7
Kuusi	2.6
Lehtipuu	2.6

Mainittakoon, että Heiskasen (1973 b) mukaan myös kehittämistutkimuksen 1. vaiheessa suoritetuissa koearvioinneissa osoittautuivat samat luokat yleisimmiksi (vrt. Rikkonen 1972 a).

Karsintaluokan ja pinotiheyden välistä riippuvuutta osoittavat kuvaajat nähdään kuvasta 19. Korrelaatiokertoimien arvot ja tekijän vaikutus pinotiheyteen suoraviivaisena ovat seuraavat:

	Korrelaatiokerroin	Vaikutus/luokka
Havupuu	—0.254	—1.10 prosenttiyksikköä
Lehtipuu	—0.057	—

Tulokset osoittavat, että arvioitu karsintaluokka kuvaa pinotiheyttä varsin hyvin havupuissa, joissa luokan muutos aiheuttaa n. 1 prosenttiyksikön muutoksen pinotiheyteen. Lehtipuupinoissa karsintaluokan ja pinotiheyden välinen riippuvuus on hyvin heikko. Eri karsintaluokkien tasoittamattomat pinotiheydet nähdään myös seuraavasta asetelmasta.

Karsintaluokka	Mänty	Kuusi	Lehtipuu
	Pinotiheydet		
I	69.7	69.4	57.0
II	67.0	65.5	56.9
III	64.5	66.6	56.2
IV	61.8	62.3	59.5

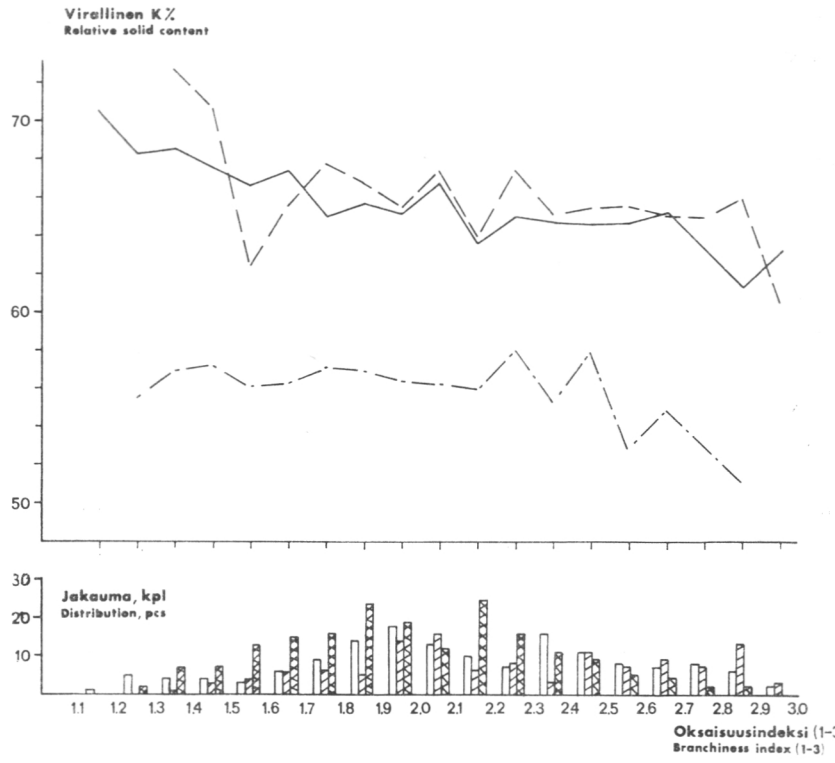
Liitteessä 3 nähdään karsintaluokkien pinotiheydet ja hajonnat puulajeittain.

Karsinnan laatua ja pölkkyjen oksaisuutta tutkittiin myös ns. oksaisuusindeksin avulla. Tämä indeksi laskettiin koepölkkyjen oksaisuusluokkien keskiarvona (ks. luku 22). Kuvassa 19 esitetään oksaisuusindeksit karsintaluokittain. Se osoittaa, että kaikissa puulajeissa on ko. tunnuksilla hyvin selvä ja vahva keskinäinen riippuvuussuhde. Sama asia selviää myös seuraavan asetelman korrelaatiokertoimista.

Puulaji	Korrelaatiokerroin
Havupuu	0.644
Lehtipuu	0.484
Yhteensä	0.588

Luvut osoittavat että havupuulla arvioinnit ovat olleet yhdenmukaisia. Lehtipuulla sen sijaan karsinnan laadun arvostelu eri tavoilla on ollut epävarmempaa tekijän pienemmän vaikutuksen vuoksi.

Oksaisuusindeksin mukainen pinojen jakauma ja vaikutus pinotiheyteen tasoittamattomana selviää kuvasta 20.



Kuva 20. Näytepinojen jakauma ja ominaisuuksia puulajeittain oksaisuusindeksi luokissa. (Mä —, Ku — —, Leht — - —).

Fig. 20. Distribution and properties of sample piles by tree species in branchiness index classes. (Pine —, Spruce — —, Broadleaved — - —).

Pinotiheyden ja oksaisuusindeksin väliset korrelaatiokertoimet ja indeksin vaikutus pinotiheyteen ovat seuraavat eri puulajeilla.

	Korrelaatiokerroin	Vaikutus/indeksiyksikkö
Mänty	—0.312	—3.18 prosenttiyksikköä
Kuusi	—0.174	—2.98 »
Lehtipuu	—0.088	—1.52 »

Tämän tuloksen voidaan katsoa osoittavan, että oksaisuusindeksi kuvaa karsinnan vaikutusta pinotiheyteen varsin hyvin. Mainittakoon, että Rikkosen (1972 a) mukaan kaikkien puulajien yhteinen karsintaluokan ja oksaisuusindeksin välinen korrelaatiokerroin oli 0.545.

Karsinnan vaikutusta pinotiheyteen on käsitelty myös monissa muissa tutkimuksissa. Yleensä on vain todettu, että pitkät oksantyngät heikentävät pinotiheyttä (esim. Aro 1931, Puutavaran ... 1966). Varsinaisia

tutkimustuloksia löydetään sitä vastoin verraten vähän. Nylinder ja Peterson (1967) esittävät viisiluokkaisen karsintaluokituksen (erittäin hyvä—erittäin huono), jossa yhden luokan muutos merkitsee 1 prosenttiyksikköä pinotiheydessä. Luokkien 4 ja 5 väli on kuitenkin 2 prosenttiyksikköä.

Karlssonin (1971) mukaan oksaisuusindeksi oli kolmanneksi tärkein pinotiheyteen vaikuttavista tekijöistä. Hänen luokituksessaan oli kolme luokkaa, jotka oli määritelty jäljellä olevien oksantynkien pituuden perusteella. Tulosten perusteella hän päätyi nelijakoiseen luokitukseen, jossa luokan muutos merkitsee 1 prosenttiyksikön muutosta pinotiheyteen ja esittää samaa arvosteluasteikkoa havu- ja lehtipuille.

Rikkosen (1972 a) mukaan korrelaatiokerroin karsintaluokan (sama luokitus kuin esillä olevassa tutkimuksessa) ja pinotiheyden välillä on havupuilla 0.806 ($S_{y \cdot x} = 0.035$) ja lehtipuilla hyvin pieni ja merkiltään negatiivinen. Siirtyminen 2. luokasta 3. luokkaan merkitsi hänen mukaansa havupuissa 3—4 prosenttiyksikön muutosta pinotiheyteen. Lehtipuupinoissa vaikutus oli nolla. Vaikutuksen suuruus havupuun keskimmäisten luokkien välillä johtuu lähinnä siitä että nämä olivat yleisimmin käytetyt luokat, so. ääritapauksetkin ovat ryhmittyneet niihin.

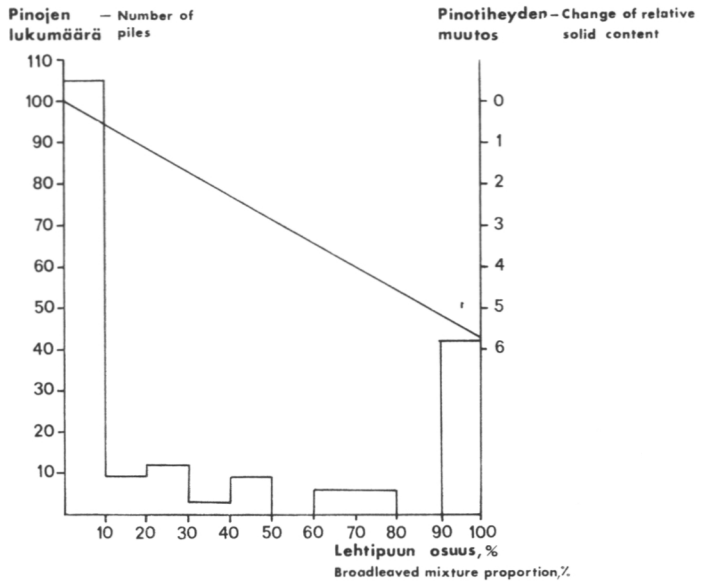
Uudistuva puutavaran mittaus-kirjasessa käytetään nelijakoista luokitusta, jossa otetaan huomioon sekä luontainen oksaisuus että karsinnan laatu. Havupuissa luokan muutos merkitsee 2 prosenttiyksikköä pinotiheydessä. Lehtipuissa vastaava muutos merkitsee 1 prosenttiyksikön muutosta pinotiheyteen.

437. Lehtipuusekoitus

Lehtipuisen kuitupuun pinotiheys on yleensä selvästi pienempi kuin havupuisen kuitupuun pinotiheys, kuten myös esillä olevan tutkimuksen tulokset osoittavat. Siten myös lehtipuun osuus sekapinoissa vaikuttaa hyvin selvästi pinotiheyteen. Ongelmaa ei ole voitu selvittää esillä olevasta aineistosta, vaan sitä on tarkasteltava ruotsalaisten tutkimustulosten valossa.

Nylinder ja Peterson (1967) ovat esittäneet havupuu—lehtipuusekapinojen pinotiheydestä, että esim. 50 prosentin koivusekoitus antaa pinotiheydeksi 3-metrisessä mäntypinossa 71 ja 5 prosentin sekoitus 75. Kuusipinoissa lehtipuusekoituksen vaikutus on suunnilleen samanlainen. Mainittakoon lisäksi, että mänty- ja kuusikuitupuun sekoittaminen keskenään ei vaikuta sanottavasti pinotiheyteen.

Myös koivukuitupuun sekoittaminen sekahavupuun kanssa vaikuttaa voimakkaasti pinotiheyttä alentavasti. Voimakkain vaikutus ilmenee kuusivaltaisissa pinoissa (Nylinder ja Peterson 1967). He ehdottavat,



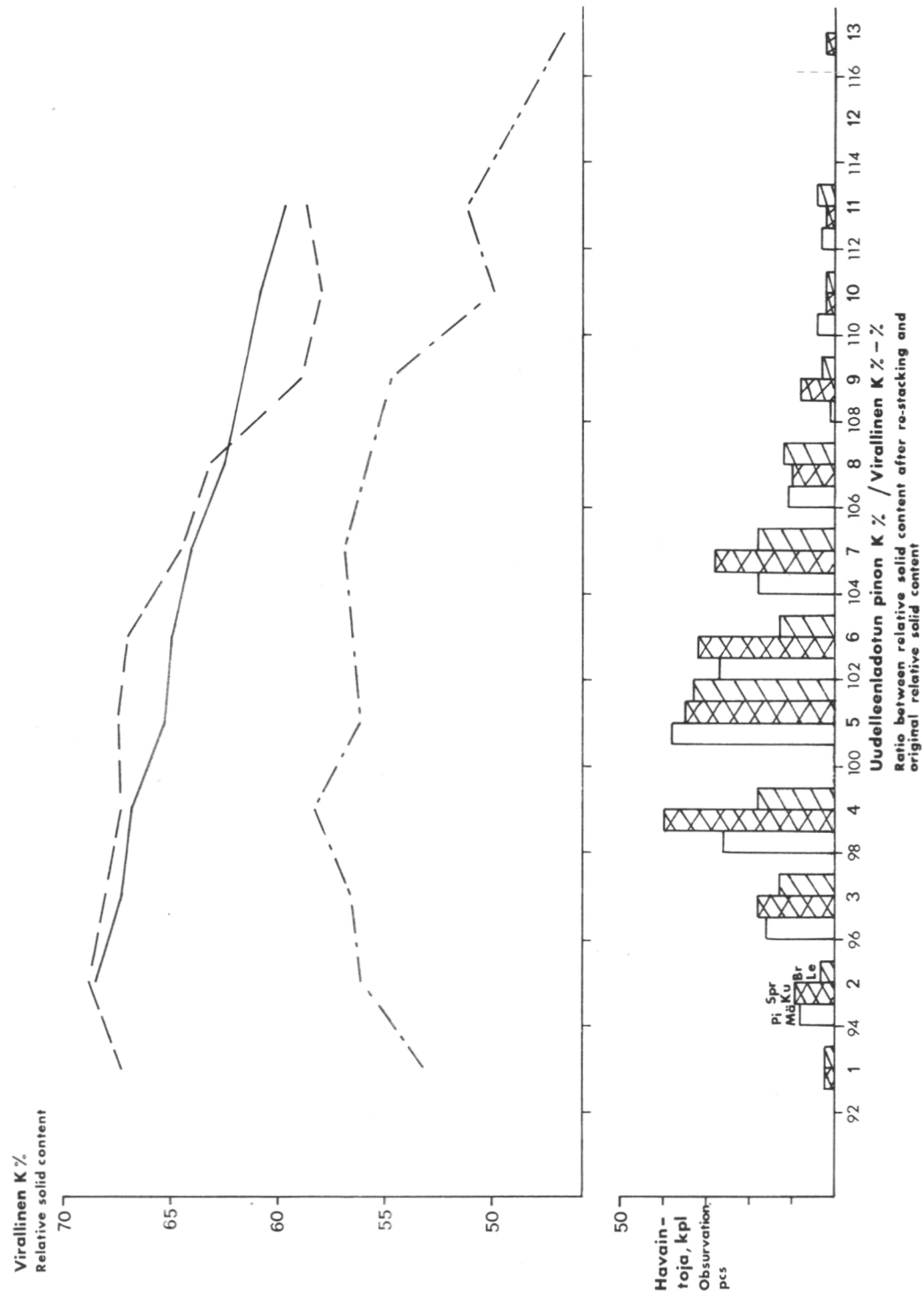
Kuva 21. Lehtipuusekoitusosuuksien jakauma ja vaikutus pinotiheyteen Karlsonin (1971) aineistossa.

Fig. 21. Distribution of broadleaved mixture proportions and their effect on relative solid content in Karlsson's (1971) material.

että käytännön mittauksissa olisi koivusekoitus otettava huomioon siten, että 20 %:n lisäys aiheuttaisi aina pinotiheysluvun alenemisen 1 prosentti yksiköllä.

Karlssonin (1971) mukaan lehtipuusekoitus vaikuttaa pinotiheyteen voimakkaammin kuin muut tutkitut ominaisuudet. Tämä osuus määritettiin prosentteina kiintomitasta. Karlssonin saamat tulokset on esitetty kuvassa 21, josta nähdään havaintojen lukumäärä pylväsdiagrammeina ja sekoituksen vaikutus suorana viivana. Tämän kuvaajan perusteella Karlsson esittää, että käytännön mittauksessa käytettäisiin seuraavaa taulukkoa lehtipuusekoituksen huomioon ottamisessa:

Lehtipuun osuus kuutiomäärästä, %	Vaikutus kiintomitta-prosenttiin
— 10	0
— 25	1
— 40	2
— 60	3
— 80	4
— 95	5
—100	6



Kuva 22. Pinotiheys uudelleenladonnan yhteydessä tapahtuneen pinotiheyden suhteellisen muutoksen funktiona.
(Mä —, Ku — —, Leht —·—).

Fig. 22. Relative solid content as a function of the relative change in relative solid content after re-stacking.
(Pine —, Spruce — —, Broadleaved —·—).

Tämä osoittaa, että Ruotsissa on saatu havupuun ja lehtipuun pinotiheyksien eroksi vain 6 prosenttiyksikköä, kun taas esillä olevan aineiston mukaan se on peräti 9 prosenttiyksikköä, kuten jäljempänä esitetään (ks. myös Rikkonen 1972 b). Ruotsalaisten verraten laajaan aineistoon perustuva selvitys ei tältäkään osin ole sovellettavissa meikäläisiin olosuhteisiin. Tärkeimpänä eroihin vaikuttavana tekijänä ovat Ruotsin ankarammat laatuvaatimukset erityisesti mutkaisuuden osalta. Mutkaisuudenhan todettiin edellä olevan sen tekijän, joka miltei yksinomaisesti aiheuttaa lehtipuupinojen alhaisen pinotiheyden havupuupinoihin verrattuna.

Suomalaisessa mittausohjeessa ei ole otettu kantaa lehtipuusekoitukseen, koska pinot ovat meillä suurimmaksi osaksi yhden puulajin muodostamia (Uudistuva . . .). Meillä ei ole myöskään tietoja siitä, millä tarkkuudella lehtipuusekoitus pystytään pinoista arvioimaan. Ruotsissa on todettu, että arvioinnin keskimääräinen poikkeama on 5—6 % oikeasta arvosta (Karlsson 1971).

438. Muita tekijöitä

Muita puutavaran ominaisuuksia, joilla saattaa olla vaikutusta pinotiheyteen, ovat mm. pölkyn pituus ja puulaji, joiden vaikutukseen palataan keskimääräisiä pinotiheyslukuja tarkasteltaessa, sekä kapeneminen, kuorinta-aste ja halkaisu.

Kapenemisen vaikutuksen ilmoittaa Nylinder (1972) erittäin vähäiseksi. Välillisesti kapenemisella on kuitenkin pinotiheyttä pienentävä vaikutus, sillä kapenemisen ja oksaisuuden välillä vallitsee positiivinen korrelaatio.

Kuorinnan merkityksestä saadut tulokset ovat jossain määrin ristiriitaisia. Puutavaran mittauskomitean mietinnössä todetaan, että kuorellista tavaraa sisältävän pinon tiheys on jonkin verran pienempi kuin kuorittua tavaraa sisältävän pinon tiheys, mikäli tavara on huolimattomasti karsittua. Nylinderin (1972) mukaan lajittelemattoman mäntykuitupuun pinotiheys on ennen kuorintaa suurempi kuin kuorinnan jälkeen. Kuusessa suhde on päinvastainen. Nylinder mainitsee myös, että koneellisesti kuorittuun puutavaraan jää usein kuoren palasia, mikä pienentää pinotiheyttä.

Halkaiseminen pienentää pinotiheyttä, kuten monissa tutkimuksissa on osoitettu (esim. Aro 1931, Nylinder 1972).

Makkonen (1958) on todennut, että harvennetuista metsiköistä hakatun koivukuitupuun pinotiheys on suurempi kuin harventamattomista hakatun. Ero johtuu pölkkyjen järeyden ja suoruuden vaihteluista.

Nikkilä (1972 a) mainitsee, että paras pinotiheys saatiin käsinkarsituille ja käsinladotuille runkotavarapinoille.

Mainittakoon myös, että Heiskanen ja Koivulehto (1964) saivat apumittoina tehdyn 2.2 m koivukuitupuun pinotiheysluvuksi 58.7 kun samoilla työmailla normaalin 2.2 m kuorellisen tavaran keskimääräiset pinotiheydet olivat 64.6 ja 63.1.

Kuten edellä taulukoista 3 ja 4 ilmeni, eivät keskimääräiset pinotiheysluvut eroa aineiston mukaan maan eri osien välillä. Monissa aiemmissa tutkimuksissa on kuitenkin saatu hyvinkin selviä eroavuuksia pinojen maantieteellisen sijainnin mukaisesti. Aiemmat suomalaiset viralliset pinotiheysluvut olivat havupuille samat Pohjois- ja Etelä-Suomessa (FF 57). Käsillä oleva aineisto kuitenkin osoittaa, että pinotiheyden hajonta on ollut Pohjois-Suomessa kussakin 2 m tavaralajissa suurempi kuin Etelä-Suomessa. Se ilmenee seuraavan asetelman todellisten pinotiheyksien hajonnasta (vrt. Rikkonen 1972 a).

	Etelä-Suomi		Pohjois-Suomi	
	x	v %	x	v %
Mänty	64.9	6.3	65.5	7.9
Kuusi	66.1	5.4	65.3	6.6
Lehtipuu	56.7	7.8	56.4	8.0

Tämä johtunee siitä, että Pohjois-Suomessa esiintyy järeämpiä pölkkyjä sisältäviä pinoja kuin Etelä-Suomessa, mutta toisaalta myös kaikkein pieniläpimittaisinta ja mutkaisinta tavaraa sisältäviä pinoja.

44. Pinotiheyden vaihtelua selittävät mallit

441. Yleistä

Kuten taulukosta 7 nähdään, on pinotiheyden vaihtelu voimakasta (variaatiokerroin 6—8 %). Tämä merkitsee vastaavaa epätarkkuutta pinon kiintomitan määrittämisessä valtakunnallisten keskimääräislukujen avulla. Toisaalta voidaan aineistosta todeta, ettei tarkkuus oleellisesti parane osa-alueittaisia tai muutoin ryhmiteltyjä lukuja käyttämällä. Pinon kiintomittaus voisi näin ollen olla hyväksyttävän tarkkaa vain pinokohtaisella, pinon ja puutavaran ominaisuuksiin perustuvalla menetelmällä. Sellaisen kehittäminen voi tapahtua matemaattisen mallin avulla. Karlsson (1971) luettelee hyvälle, käytäntöäkin palvelevalle mallille asetettavina vaatimuksina seuraavia.

1. Malliin sisältyvien muuttujien tulisi olla suhteellisen halvalla ja tarkasti mitattavissa tai arvioitavissa.

2. Mallin pitäisi selittää huomattava osa pinotiheyden varianssista (väh. 50 %).

Taulukko 7. 2.0—2.2 metrisen kuitupuun tärkeimpiä pinotiheyteen vaikuttavia ominaisuuksia puulajeittain.

Table 7. Most important properties of 2.0—2.2-m pulpwood that affect relative solid content, by tree species

Ominaisuus *Property*	Puulaji — *Tree species*								
	Mänty *Pine*			Kuusi *Spruce*			Lehtipuu *Broadleaved*		
	$\bar{x}$	s	v %	$\bar{x}$	s	v %	$\bar{x}$	s	v %
Pinoja, kpl — *Piles, pcs*	152			122			189		
Pinotiheys, virallinen, % — *Official relative solid content*	65.2	4.1	6.3	66.0	4.0	6.1	56.5	4.4	7.8
Uudelleen ladottu pinotiheys % virallisesta tiheydestä — *Relative solid content after re-stacking/official relative solid content*	101.8	3.8	3.7	102.3	4.5	4.4	102.0	4.3	4.2
Keskiläpimittä, cm — *Mean diameter*	11.2	2.0	17.8	11.4	1.7	14.9	11.6	2.0	17.2
Läpimitan hajonta, cm — *Standard deviation of diameter*	3.8	1.1	28.9	3.5	1.0	28.6	3.7	1.0	27.0
Tyvien osuus, % — *Butt proportion*	31.9	14.6	45.8	32.6	14.7	45.1	40.2	14.1	35.1
Mutkaisuus, mm — *Crookedness*	12.4	5.5	44.4	11.0	5.2	47.3	43.1	10.8	25.1
Oksaisuusindeksi — *Branchiness index*	2.1	0.4	19.0	2.2	0.4	18.2	2.0	0.3	15.0

3. Selittämättä jääneen hajonnan ja poikkeamien tulisi olla riippumattomia puulajista ja pinotiheydestä. Toisin sanoen malliin ei saisi sisältyä systemaattisia virheitä.

4. Kertoimien pitäisi olla riittävän suuria ja tilastollisesti merkitseviä.

Lisäksi useimpien analyysimenetelmien käyttämisen ja mallien tulkittavuuden ehtona on, että malliin sisältyvät tekijät ovat tilastollisesti selitettävän tekijän kannalta merkitseviä, eivätkä korreloi huomattavasti keskenään.

Näin monen vaatimuksen ehdoton täyttäminen samalla kun luodaan käyttökelpoinen malli ei voi täysin onnistua (Karlsson 1971), mutta verraten vähilläkin tekijöillä päästään malliin, joka tyydyttävästi täyttää asetetut ehdot.

442. Malleihin sisältyvät muuttujat

Edellä olevista luvuista (41, 42 ja 43) on jo käynyt selväksi, että pinotiheyteen vaikuttavat hyvin monet tekijät. Kaikkien jollakin tavoin vaikuttavien tekijöiden »pakottaminen» pinotiheyttä selittävään malliin tekee kuitenkin mallin tulkittavuuden ja käyttökelpoisuuden kyseenalaiseksi. Tämä johtuu tekijöiden keskinäisistä korrelaatioista, so. useampi eri tekijä kuvaa samaa muutosta pinotiheydessä. Esimerkiksi tyvien osuuden vaikutus näkyy mutkaisuuden mittaustavasta johtuen myös mutkaisuuden vaikutuksena, kuten aiemmin mainittiin.

Samoin on todettu, että varsinkin arvioidut pinotiheystekijät korreloivat keskenään ja menevät osittain päällekkäin. Liitteestä 4 selviää alueittain eräiden luokitusten ja vastaavasti mitattujen ominaisuuksien keskiarvot ja hajonnat. Siitä selviää miksi luokiteltujen muuttujien käyttö selittäjinä on varsin hankalaa. Vaikka arvioinnit ovatkin yleisesti onnistuneet varsin hyvin, ovat eri ryhmänjohtajat kuitenkin tulkinneet laadittuja luokituksia eri tavoin ja myös keskiarvot ovat asettuneet eri kohdille, osittain todellisista arvoista riippumatta. Käyttämällä alueittaisia korjauksia saadaan keskiarvojen heilahtelun vaikutus korjatuksi, mutta sen sijaan tulkinnan erilaisuus hämärtää tekijöiden keskinäisiä korrelaatioita. Edelläesitetty ei kumoa tekijöiden arviointimahdollisuuksia, (Karlsson 1971, Heiskanen 1973 b) sillä tutkimusvaiheessa käytettävissä olevat arviointiperusteet olivat vielä verraten heikot ja epämääräiset ja mittamiesten koulutus mm. tästä syystä riittämätön. Edelläesitetyistä syistä katsottiin varmemmaksi käyttää malleissa miltei yksinomaan mitattuja tekijöitä.

Parhaan ja käyttökelpoisimman mallin antaviksi tekijöiksi muodostuivat mitattu keskiläpimitta, pölkkyjen mitattu mutkaisuus, pinon ladonta ja pölkkyjen karsinnan laatua kuvaava indeksi. Myös puulajille jäi jonkin verran selitysarvoa kaikki puulajit sisältävässä yhteismallissa. Edellämainittujen sekä eräiden muiden pinon ja puutavaran ominaisuuksien keski-

Taulukko 8. Malleihin sisältyvien tekijöiden korrelaatiot. Kaikki puulajit.
Table 8. Correlation matrix for factors included in the regression models. All tree species.

	Puulaji *Tree species*	Keskiläpimitta *Mean diameter*	Log keskiläpimitta *Logarithm of mean diameter*	Ladonta *Relative change in relative solid content after re-standing*	Karsinta *Branchiness index*	Mutkaisuus *Crookedness*	Pinotiheys *Relative solid content*
Puulaji [1] — *Tree species*	1.000						
Keskiläpimitta, cm — *Mean diameter*	—0.004	1.000					
Log keskiläpimitta — *Logarithm of mean diameter*	—0.008	0.993	1.000				
Ladonta [2] — *Relative change in relative solid content after re-stacking*	—0.010	—0.030	—0.032	1.000			
Karsinta (oksaisuusindeksi) — *Branchiness index*	—0.242	0.166	0.156	—0.117	1.000		
Mutkaisuus, mm — *Crookedness*	0.886	0.007	—0.002	—0.042	—0.126	1.000	
Pinotiheys (virallinen), % — *Relative solid content*	—0.728	0.252	0.265	—0.261	0.057	+0.788	1.000

[1]) Havupuu = 0, lehtipuu = 1 — *Conifer = 0, Broadleaved = 1.*
[2]) Uudelleen ladotun pinon tiheys prosenttia alkuperäisestä tiheydestä. — *Relative solid content after re-stacking/in per cent of the initial solid content.*

arvot, hajonnat ja korrelaatiot pinotiheyden suhteen nähdään puulajeittain taulukoista 7, 8, 9 ja 10.

Pölkkyjen läpimitta on pinon kaikkien pölkkyjen mitattu aritmeettinen keskiläpimitta, joka havupuulla antoi parhaan mallin käyräviivaisena (logaritmisena), kun taas lehtipuulla suoraviivainen läpimitta oli lähes yhtä hyvä kuin logaritminenkin.

Mutkaisuus on koepölkyistä mitattujen mutkaisuusarvojen keskiarvo pinottain millimetreinä pölkkyä kohti.

Ladontaa kuvasi parhaiten ja samalla objektiivisimmin pinotiheyden muutos uudelleen ladonnan yhteydessä.

Taulukko 9. Malliin sisältyvien tekijöiden korrelaatiot. Havupuu.

Table 9. Correlation matrix for factors included in the regression models. Conifer.

	Keskiläpimitta *Mean diameter*	Log. keskiläpimitta *Logarithm of mean diameter*	Ladonta *Relative change in relative solid content after re-stacking*	Karsinta *Branchiness index*	Mutkaisuus *Crookedness*	Pinotiheys *Relative solid content*
Keskiläpimitta, cm — *Mean diameter*	1.000					
Log. keskiläpimitta — *Logarithm of mean diameter*	0.993	1.000				
Ladonta [1]) — *Relative change in relative solid content after re-stacking*	—0.094	—0.105	1.000			
Karsinta (oksaisuusindeksi) — *Branchiness index*	0.153	0.144	—0.110	1.000		
Mutkaisuus, mm — *Crookedness*	0.010	—0.003	—0.024	0.202	1.000	
Pinotiheys (virallinen), % — *Relative solid content*	0.267	0.289	—0.515	—0.236	—0.372	1.000

Taulukko 10. Malliin sisältyvien muuttujien korrelaatiot. Lehtipuu.

Table 10. Correlation matrix for factors included in the regression models. Broadleaved.

	Keskiläpimitta *Mean diameter*	Ladonta *Relative change in relative solid content after re-stacking*	Karsinta *Branchiness index*	Mutkaisuus *Crookedness*	Pinotiheys *Relative solid content*
Keskiläpimitta, cm — *Mean diameter* ...	1.000				
Ladonta [1]) — *Relative change in relative solid content after re-stacking*	0.057	1.000			
Karsinta (oksaisuusindeksi) — *Branchiness index*	0.204	—0.147	1.000		
Mutkaisuus, mm — *Crookedness*	0.034	—0.112	0.233	1.000	
Pinotiheys (virallinen), % — *Relative solid content*	0.486	—0.233	—0.088	—0.534	1.000

[1]) Uudelleen ladotun pinon tiheys prosenttia alkuperäisestä tiheydestä. — *Relative solid content after re-stacking/in per cent of the initial solid content.*

K a r s i n t a a kuvaamaan käytettiin koepölkyistä arvioitujen karsinta-indeksien pinottaisia keskiarvoja. Edellämainitut tekijät sisältävät jo niin suuren osan mallin ulkopuolelle jäävien tekijöiden selityskyvystä, etteivät muut tekijät enää täytä malliin hyväksymiseen vaadittavia kriteereitä.

443. Mallit

Mallien laskemiseen on käytetty valikoivaa reggressioanalyysiä, jonka periaatteita ei tässä yhteydessä ole syytä kerrata.

Lopullinen malli on laskettu sekä havupuulle että lehtipuulle. Myös kaikille puulajeille yhdessä on laskettu malli. Jos kaikki pinotiheyteen vaikuttavat tekijät olisi pystytty tarkasti mittaamaan, ei puulajeihin enää tarvitsisi kiinnittää huomiota, vaan yhteinen malli selittäisi puulajeittaisen vaihtelun, kuten K a r l s s o n k i n (1971) toteaa. Tekijöiden epätarkasta mittauksesta ja erilaisesta vaihtelualueesta puulajeittain johtuu, että puulajeittaiset mallit pystyvät hivenen paremmin selittämään pinotiheyden vaihtelua kuin kokonaismalli.

Seuraavassa on esitetty asetelma kolmen eri mallin kertoimista.

Kokonaismalli 1)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	93.936			
logaritmi keskiläpimitasta (cm)	10.724	0.838	12.80	3
mutkaisuus, mm	— 0.232	0.017	—13.99	1
karsinta (oksaisuusindeksi 1—3)	— 2.217	0.343	— 6.46	4
ladonta [1])	— 0.438	0.031	—13.94	2
puulaji [havupuu-lehtipuu (0-1)]	— 2.271	0.600	— 3.79	5

Havupuun malli 2)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	102.279			
logaritmi keskiläpimitasta (cm)	7.135	1.113	6.41	3
mutkaisuus, mm	— 0.251	0.032	— 7.77	2
karsinta (oksaisuusindeksi 1—3)	— 2.534	0.412	— 6.15	4
ladonta [1])	— 0.516	0.041	—12.44	1

Lehtipuun malli 3)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	91.178			
keskiläpimitta, cm	1.125	0.099	12.44	2
mutkaisuus, mm	— 0.230	0.018	—12.69	1
karsinta (oksaisuusindeksi 1—3)	— 1.517	0.580	— 2.61	4
ladonta [1])	— 0.354	0.045	— 7.86	3

[1]) Pinon uudelleen ladonnan jälkeen mitatun tiheyden suhde prosentteina alkuperäiseen tiheyteen.

Kuten mallista 1 nähdään, jää puulajille muiden selittäjien huomioonottamisen jälkeen vain vaatimaton, mutta merkitsevä selitysosuus. Pinotiheyden vaihtelua selittävät tekijät pystyvät siis miltei täysin selittämään myös puulajien väliset erot. Tämä osoittaa myös, että mittaukset on tehty suhteellisen tarkasti.

444. Mallien arvostelu

Mallit voidaan arvostella sen mukaan, miten ne täyttävät luvussa 441 mainitut ehdot. Tärkeintä on todeta miten paljon pinotiheyden hajonnasta mallit selittävät. Seuraavassa asetelmassa on esitetty pinotiheyden hajonnat neliösummina puulajeittain keskiarvojen ympärillä sekä jäännösneliösummat mallien käytön jälkeen.

Hajonta	Mänty	Kuusi	Havupuu yhteensä	Lehtipuu	Kaikki yhteensä
keskiarvon ympärillä	2 576	1 945	4 555	3 653	17 459
Malli 1. jäännösneliösummat	1 444	678		1 381	3 616
selitetty varianssi-prosentti	44.0 %	65.2 %		62.2 %	79.3 %
Mallit 2 ja 3 jäännösneliösummat			2 148	1 246	3 394
selitetty varianssi prosentti			52.8 %	65.9 %	80.6 %

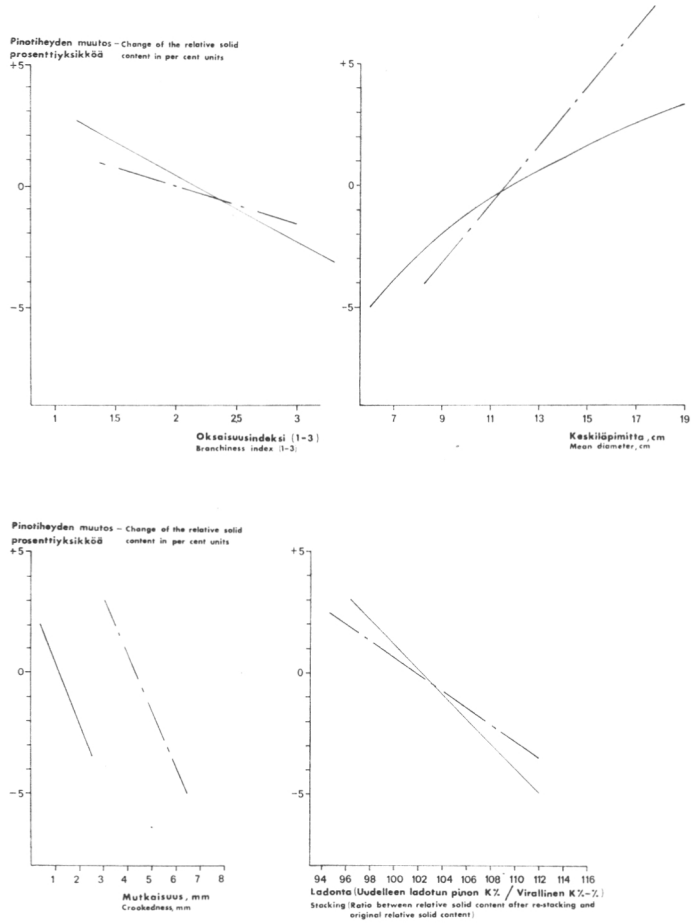
Kokonaismallilla 1 ja malleilla 2 ja 3 saavutetuilla tuloksilla ei ole juuri mitään eroa. Lopullisena mallina voitaisiin siis käyttää kaikkien puulajien yhteistä mallia.

Karlsson (1971) päätyy aivan samanlaiseen tulokseen ja päätyykin suosittelemaan käytännön malliksi kokonaismallia joidenkin tekijöiden osalta kokemusperäisillä luvuilla täydennettynä.

Jäännöspoikkeamien tarkastelu osoittaa kuitenkin, etteivät poikkeamat ole riippumattomia puulajista eivätkä pinotiheydestäkään. Malli 1 yliarvioi alhaiset pinotiheydet ja aliarvioi korkeat pinotiheydet. Tilanne on hieman parempi mallien 2 ja 3 osalta, vaikka sama suunta on niidenkin yhteydessä havaittavissa. Suuremmat ja samalla systemaattiset poikkeamat alhaisten ja korkeiden pinotiheyksien kohdalla johtuvat ensinnäkin siitä, että yleensäkin mallit toimivat parhaiten sillä alueella, josta on eniten havaintoja so. lähellä keskimääräisiä arvoja ja toiseksi malliin sisältymättömät vaikuttajat aiheuttavat poikkeamia varsinkin äärialueilla. Juuri tämän vuoksi olisi perusteltua ottaa käytännössä huomioon muitakin kuin malliin sisältyviä tekijöitä esim. kokemusperäisiä lukuja käyttäen.

K a r l s s o n (1971) suosittelee käytettäväksi kokemusperäisiä lukuja niiden tekijöiden osalta, jotka eivät sovi tilastolliseen malliin. Hänen mallistaan on kuitenkin poissa ladonnan vaikutus, joka tunnetusti on suuri ja niinollen se on pakko ottaa huomioon. Lisäksi hän ehdottaa lumen ja jään sekä vieraiden esineiden huomioonottamista kokemusperäisiä lukuja käyttäen.

Virheen poistamiseksi äärialueilla voitaisiin meilläkin esim. tyvipölkkyjen osuus ja pölkkyjen sekoittuminen ottaa huomioon. Käytettyjen lukujen sopivuus olisi kuitenkin testattava. Kokemusperäisten tekijöiden lisäämistä vastaan voidaan esittää ainakin kaksi väitettä. Ensinnäkin muiden kuin jo

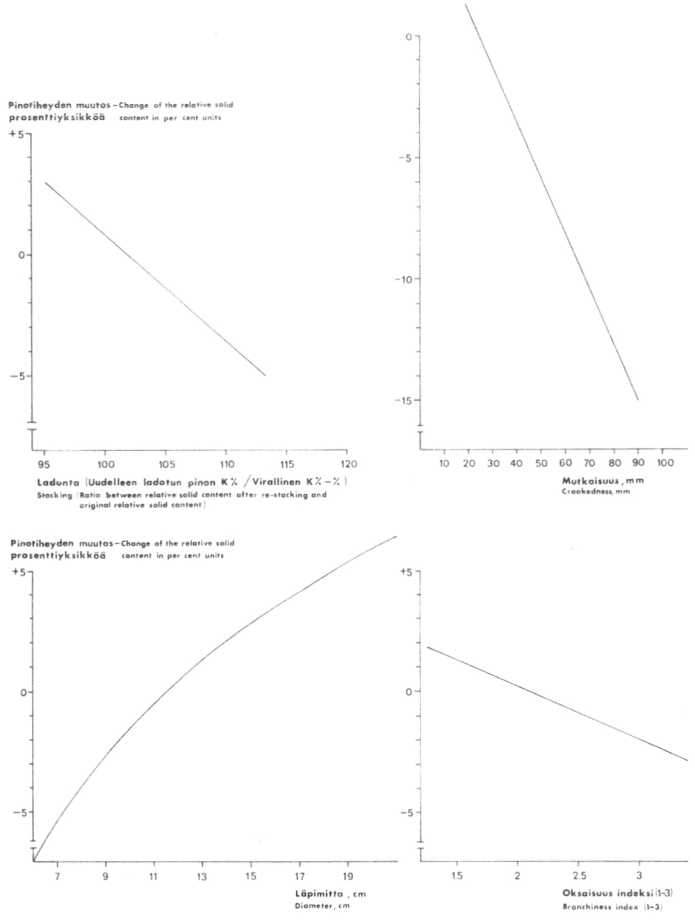


Kuva 23. Testattuihin malleihin sisältyvien muuttujien vaikutus pinotiheyteen. (Havupuu —, Lehtipuu — - —).

Fig. 23. Effect on relative solid content of variables contained in the models tested. (Coniferous —, Broadleaved — - —).

huomioonotettujen tekijöiden vaikutus on suhteellisen pieni ja toiseksi tekijöiden välisten korrelaatioiden vuoksi tulevat nämä ulkopuoliset tekijät jo huomioon otetuksi, so. jos tekijöitä lisättäisiin olisi vaikutusten päällekkäisyyden vaara entistä suurempi. Joillakin toisilla malleilla voidaan näennäinen selitysaste saada suuremmaksi kuin nyt lasketuilla. Esimerkiksi ottamalla huomioon oksaisuusindeksin alueittaiset arviointierot nousee edellämainittujen mallien selitysaste 5—10 prosenttia.

Keskimäärin antavat kaikki kehitetyt mallit tarkkoja tuloksia, niinkuin näinkin hyvin selittäviltä malleilta voidaan odottaa. Mallit on kuvattu myös graafisesti kuvissa 23 ja 24.



Kuva 24. Testattuun kokonaismalliin sisältyvien muuttujien vaikutus pinotiheyteen.

Fig. 24. Effect on relative solid content of variables contained in the total model tested.

Mallien voidaan katsoa hyvin täyttävän luvussa 441 asetetuista vaatimuksista ehdot 2 ja 4. Ne toisin sanoen selittävät suuren osan, yli 50 % pinotiheyden vaihtelusta, ja kertoimia voidaan pitää riittävän suurina ja ne ovat tilastollisesti merkitseviä. Sen sijaan vaatimukseen 3 nähden jää hiukan toivomisen varaa nimenomaan äärialueilla. Vaatimus 1 eli se, että malliin sisältyvien muuttujien tulisi olla suhteellisen halvalla tai tarkasti mitattavissa tai arvioitavissa, ei näissä malleissa tule täytetyksi. Kuten edellä mainittiin, pyrittiin valitsemaan selittäjiksi mitattavia tekijöitä ennen kaikkea siitä syystä, että mittamiesten arviointikyky vaihteli eri alueilla eikä arviointikyky täyttänyt koulutuksen puutteellisuuden takia riittäviä tarkkuusvaatimuksia. Aiemmin tehdyt tutkimukset ovat kuitenkin viitanneet siihen, että tarkoituksenmukaisella koulutuksella saadaan eri pinotiheystekijöiden arvioinnissa esiintyvät karkeat virheet eliminoiduksi (Karlsson 1971, Heiskanen 1973 b).

Käytäntöön soveltuvassa mallissa olisi senvuoksi käytettävä eri selittäjien kohdalla seuraavia helposti mitattavia tai arvioitavia selittäjiä.

Tutkimuksessa käytetty	Käytäntöön soveltuva
Mitattu keskiläpimitta	Arvioitu keskiläpimitta
Mitattu mutkaisuus	Arvioitu mutkaisuus
Uudelleen ladonnan vaikutus pinotiheyteen	Arvioitu ladontaa kuvaava luokka
Oksaisuusindeksi	Karsinnan laatua kuvaava luokka

Käytännössä kokeiltavana oleva Mittausneuvoston suosittama pinossa olevan kuitupuun kiintomittausmenetelmä perustuu juuri edellä esitettyihin luokituksiin ja se vastaa pääosin nyt laskettuja lopullisia tutkimustuloksia (vrt. Uudistuva . . .). Käytännön menetelmässä on jo otettu huomioon äärialueilla havaittu epätarkkuus suurentamalla mm. oksaisuuden vaikutusarvoja. On näet havaittu, että käytetty karsintaluokitus ei riitä kuvaamaan karsinnan laadun vaikutusta havupuupinojen pinotiheyteen. Sen vuoksi on havupuun karsinnalle ja oksaisuudelle otettu yksi luokka lisää. Tämäkään luokka ei vielä riitä tynkäkarsitulle tavaralle. Eroavuuksia nyt saatuun tulokseen on aiheutunut myös siitä, että läpimitan vaikutuksen nollakohta on muutettu käytännön menetelmässä 11.5 cm:stä 11 cm:iin.

Lisäksi on syytä todeta, että käytännön menetelmää laadittaessa on käytetty hyväksi myös Pinomittauksen kehittämistutkimuksen ensimmäisen vaiheen tuloksia (Rikkonen 1972 a). Kun käytännön menetelmä perustuu arvioitaviin tunnuksiin, ovat ensimmäisen vaiheen tulokset sikäli käyttökelpoisia ja tarkoituksenmukaisia, että jokaisesta pinosta ja sen pinotiheystekijöistä on käytettävissä parinkymmenen ammattimiehen arvio- ja mittaustulokset (ks. Heiskanen 1973 a). Eräissä nyt tehdyn tutkimuksen tulosten epäselvissä kohdissa tukeuduttiin osittain myös Karls-

sonin (1971) Ruotsissa saamiin tuloksiin. Mitkään esillä olevan tutkimuksen tuloksista eivät kuitenkaan viittaa siihen, että käytännön kokeilumenetelmä olisi siinä sovellettujen pinotiheys- eli kiintomittatekijöiden osalta systemaattisesti virheellinen tai harhaanjohtava. Päinvastoin kaikki nyt saadut tulokset tukevat käytännön menetelmän laadinnassa laskettujen eri tekijöiden vaikutuksen oikeellisuutta.

45. Keskimääräisiä pinotiheyksiä

Metsäntutkimuslaitos on käsillä olevan tutkimuksen tulosten perusteella vahvistanut seuraavat keskimääräiset muuntoluvut (pinotiheysluvut) koko maassa (Folia Forestalia 172).

Puutavaralaji, jonka pinomittaa muunnetaan	Puulaji	
	Havupuu	Lehtipuu
	Muuntokerroin	
2-m kuorellinen	0.66	0.57
3-m kuorellinen	0.64	0.54

Niillä muunnetaan keskimääräisessä tilanteessa pinomitta (kehysmitta) kiintomitaksi. Käsillä olevassa tutkimuksessa on käynyt selväksi, että pinokohtainen muuntoluku vaihtelee hyvin paljon mm. pölkkyjen keskiläpimitan, karsinnan ja mutkaisuuden sekä pinon ladonnan mukaan. Keskimääräinen muuntoluku on siis yksittäisen mittauserän kohdalla hyvin epätarkka. Keskimääräisten muuntolukujen käyttökelpoisuutta yleisessä tapauksessa kuvaavat myös näiden keskiarvojen virherajat. Käsillä olevassa aineistossa on keskiarvot saatu havupuulle ± 1.1 ja lehtipuulle ± 1.7 prosentin tarkkuudella (P = 100). Tämä merkitsee, että havupuun muuntoluku on välillä 65—67 prosenttia ja lehtipuun 55—59 prosenttia. Esimerkin vuoksi ajateltakoon, mitä tapahtuu jos mitataan satunnaisesti 25 pinoa kumpaakin puulajia, ja muuntamisessa käytetään saatuja keskimääräisiä lukuja. Tällöin niiden pinojen todellinen muuntoluku on jokatapauksessa havupuulla välillä 63.5—68.5 ja lehtipuulla välillä 52—62 siis virherajat ovat n. ± 4 % ja n. ± 5 %.

Edelläesitetystä voidaan päätellä, että tarkkojen muuntolukujen laskeminen on mahdotonta ja etteivät keskimääräiset muuntoluvut sovi yksittäisten erien mittaustuloksen muuntamiseen kiintomitaksi.

Käsillä olevan tutkimuksen aineistoon ei sisältynyt 3 metriä pitempää tavaraa ja 3 metristäkin suhteellisen vähän. Muille kuin kahden ja kolmen metrin sekä näiden välillä oleville pituuksille ei voitu esittää muuntolukuja. Mainittakoon kuitenkin, että Mittausneuvosto on sopimusluonteisesti suosittanut käytettäväksi muille kuitupuulajeille seuraavia muuntolukuja (Eripituisten . . .).

»Pinomenetelmä ei ole tarkoitettu kolmea metriä pitemmän puutavaran mittaukseen, vaan tulisi näillä puutavaralajeilla käyttää muita kiintomittausmenetelmiä.

Jos kuitenkin pinomenetelmän käyttö osoittautuu pitkän puutavaran mittauksessa välttämättömäksi, tulisi käyttää seuraavassa esitettäviä arviolukuja.

4-, 5- ja 6-metristä kuitupuuta voidaan kussakin tapauksessa erikseen sopien mitata myös pinomenetelmällä, jolloin keskimääräisinä eli III kiintomittaluokan kiintomittaprosentteina käytettäköön seuraavia.

Pituus	Havukuitupuu		Lehtikuitupuu	
	III k-lk.	Ero 2-metriseen	III k-lk.	Ero 2-metriseen
4 m	61	—5	52	—5
5 m	60	—6	50	—7
6 m	59	—7	49	—8

Muiden kiintomittaluokkien kiintomittaprosentit saadaan vähentämällä esitetyt erotukset vastaavista 2-metrisen kuitupuun kiintomittaluokkien kiintomittaprosenteista.

Pinomenetelmän käyttö pitkällä puutavaralla ei kiintomittaprosentin määrittämisen osalta perustu tutkimuksiin. Koska kuitenkin on erittäin todennäköistä, että pinotiheystekijäin vaikutukset ovat pitkällä puutavaralla saman suuntaisia kuin lyhyellä, voidaan kiintomittaluokan ja -prosentin määrittämisen pinokohtaisesti odottaa antavan tarkemman tuloksen kuin keskimääräisen luvun käyttäminen.»

Metsäntutkimuslaitoksessa onkin aloitettu pitkän pinotavaran mittausta koskeva tutkimus, jonka valmistuttua saataneen myös 4 m kuitupuun pinotiheysluvut varmistetuiksi.

Vertailun vuoksi esitetään seuraavassa myös entiset viralliset muuntoluvut sekä näiden lukujen vahvistamisen jälkeen tehtyjen tutkimusten tulokset. (Vanha virallinen muuntoluku = 100).

Tutkimus	Mänty		Kuusi		Lehtipuu	
	K %	suhde	K %	suhde	K %	suhde
1.	72	100	73	100	64	100
2.	66.9	93	67.0	92	56.5	88
3.					57.2	89
4.	66	92	66	90	57	89

1. Metsäntutkimuslaitoksen . . . 1969
2. Rikkonen 1972 a
3. Nikkilä 1972 a
4. Käsillä oleva tutkimus

Vertailu osoittaa muuntolukujen alentuneen havupuulla keskimäärin 8—10 % ja lehtipuulla 11 %.

46. Käytännön sovellutuksia

Kuten alkusanoissa ja johdannossa todettiin, on tutkimusaineiston ja tutkimuksen ennakkotulosten perusteella jo laadittu Mittausneuvoston toimesta menetelmä, joka tähtää kuorellisen kiintomitan määrittämiseen pinotiheystekijöiden avulla. Menetelmän pääpiirteet ovat seuraavat (Uudistuva . . .).

Ensin mitataan pinon pituus, korkeus ja leveys. Näiden avulla saadaan pinon kehyskuutiomäärä eli kehysmitta. Sitten määritetään pinotiheystekijöiden luokat eli keskiläpimittaluokka, ladontaluokka, oksaisuus- ja karsintaluokka sekä mutkaisuusluokka. Pinotiheystekijäluokkien perusteella määräytyy pinon kiintomittaluokka ja kiintomittaprosentti ja pinon kiintokuutiomäärä lasketaan kertomalla kehysmitta kiintomittaprosentilla.

Pinon pituuden, korkeuden ja leveyden mittaamiseen ei tässä yhteydessä ole syytä puuttua. Eri pinotiheystekijöiden luokat on määritelty em. ohjeessa seuraavasti.

K e s k i l ä p i m i t a n luokituksessa käytetään 2 cm:n tasaavia luokkia, jotka ovat seuraavat:

Luokka, cm	Luokkarajat, cm
9	— 9.9
11	10.0—11.9
13	12.0—13.9
15	14.0—15.9
17	16.0+

Läpimittaluokka on se luokka, johon pinossa olevien pölkkyjen läpimittojen aritmeettinen keskiarvo sijoittuu. Luokan määritys tapahtuu joko

— mittaamalla pölkkyjen päiden läpimittoja pinon kyljestä ja laskemalla niiden keskiarvo, tai

— määrittämällä silmävaraisesti keskiarvoa edustava pölkyn pää ja mittaamalla sen läpimitta.

Läpimittaluokan määrityksessä ei tehdä eroa pölkyn tyvi- ja latvapäiden välillä.

P i n o n l a d o n t a l u o k k a määritetään silmävaraisen tarkastelun perusteella. Luokat ja niiden määritelmät ovat:

Luokka I Tiivis. Pölkyt tiiviisti lomittain.

Luokka II Keskinkertainen. Jonkin verran pölkkyjä ristikkäin, pölkkyjen välissä ladonnasta aiheutuneita rakoja.

Luokka III Harva. Monet pölkyt ristikkäin, pölkkyjen välissä isoja ladonnasta aiheutuneita rakoja.

Luokka IV Erittäin harva. Erittäin runsaasti pölkkyjä ristikkäin. Pinon kyljessä isoja ladonnasta aiheutuneita aukkoja.

P i n o n p ö l k k y j e n k a r s i n t a- j a o k s a i s u u s l u o k k a a määritettäessä otetaan huomioon pölkyissä mittaushetkellä olevien oksan-

tynkien ja oksakyhmyjen määrä. Tähän vaikuttavat sekä runkojen oksaisuus että karsinnan laatu. Oksattomista tai vähäoksaisista rungoista valmistettu puutavara kuuluu yleensä parempiin karsinta- ja oksaisuusluokkiin kuin runsasoksaisista rungoista valmistettu puutavara.

Luokat ja niiden määritelmät ovat:

Luokka I Oksaton. Hyvin pinnanmyötäisesti karsittu puutavara.
Luokka II Keskimääräinen. Pinnanmyötäisesti karsittu puutavara, joitakin lyhyitä oksantynkiä voi esiintyä.
Luokka III Oksainen. Huonosti karsittu puutavara, oksantynkiä esiintyy siellä täällä.
Luokka IV Erittäin oksainen. Erittäin huonosti karsittu puutavara, oksantynkiä esiintyy runsaasti.

P i n o n p ö l k k y j e n m u t k a i s u u s l u o k k a a määritettäessä on vertailuperustana p u u l a j i n l u o n t a i n e n m u t k a i s u u s. Luokat ja niiden määritelmät ovat:

Luokka I Suora. Pölkyt ovat suoria.
Luokka II Keskimääräinen. Pölkyt edustavat puulajin keskimääräistä luontaista mutkaisuutta.
Luokka III Mutkainen. Pölkyt ovat mutkaisia. Pinossa on pölkkyjen mutkaisuudesta aiheutuvaa reikäisyyttä.
Luokka IV Erittäin mutkainen. Pölkyt ovat erittäin mutkaisia. (Voi esiintyä yleensä vain lehtipuulla Pohjois-Suomessa.)

Kunkin pinotiheystekijän luokan vaikutus kiintomittaprosenttiin käy ilmi seuraavasta asetelmasta. Vaikutus on määritelty erikseen havupuulle ja lehtipuulle.

			Vaikutus kiintomittaprosenttiin	
	2 cm:a tasaava luokitus		Havupuu	Lehtipuu
1. Keskiläpimittaluokka	9 ja alle		—3	—3
	11		0	0
	13		+2	+2
	15		+3	+4
	17 ja yli		+4	+6
2. Ladontaluokka	I	Tiivis	+2	+1
	II	Keskinkertainen	0	0
	III	Harva	—2	—1
	IV	Erittäin harva	—4	—3
3. Karsinta ja oksaisuusluokka	I	Oksaton	+2	+1
	II	Keskimääräinen	0	0
	III	Oksainen	—2	—1
	IV	Erittäin oksainen	—4	—2
4. Mutkaisuusluokka	I	Suora	+1	+2
	II	Keskimääräinen	0	0
	III	Mutkainen	—1	—2
	IV	Erittäin mutkainen	(—2)	—4

Kun mitattavan pinon pinotiheystekijät on luokiteltu, otetaan em. asetelmasta näiden luokkien vaikutus kyseessä olevan puulajin kohdalta. Vaikutusarvot lasketaan yhteen plus- ja miinusmerkit huomioon ottaen. Seuraavasta asetelmasta nähdään, mihin kiintomittaluokkaan ja kiintomittaprosenttiin edellä mainitulla tavalla laskettu summa johtaa.

Havupuu					Lehtipuu				
Pinotiheystekijäin vaikutus kiintomittaprosenttiin, yhteensä	Kiintomittaluokka	k % 2 ja 2.2 m	2.4 m	3 m	Pinotiheystekijäin vaikutus kiintomittaprosenttiin, yhteensä	Kiintomittaluokka	k % 2 ja 2.2 m	2.4 m	3 m
+ 5 · · · +9	I	72	71	69	+ 6 · · · +10	I	64	63	61
+ 2 · · · +4	II	69	68	66	+ 3 · · · + 5	II	61	60	58
— 1 · · · +1	III	66	65	63	— 2 · · · + 2	III	57	56	54
— 6 · · · —2	IV	62	61	59	— 6 · · · — 3	IV	53	52	50
—13 · · · —7	V	57	56	54	—12 · · · — 7	V	48	47	45

Erittäin tärkeä käytännön ongelma on se, millä tavoin menetelmä ottaa huomioon pinotiheysluvun kokonaisvaihtelun. Suositetun menetelmän käyttämässä kiintomittaluokituksessa on viisi luokkaa, kuten edellä esitettiin. Niissä ovat rajaluokkien arvot 2 m tavaran osalta seuraavat:

Havupuu ..... 57 ja 72 %
Lehtipuu ..... 48 ja 64 %

Tutkimusaineiston mukaan keskiarvot olivat havupuulla 66 ja lehtipuulla 57 ja vastaavat hajonnat prosentteina keskiarvosta 6.3 ja 7.8. Tämä merkitsee, että hajonnan sisälle sopivat pinot, joiden pinotiheysluku on havupuilla välillä 53—78 ja lehtipuilla välillä 44—70. Todelliset pienimmät ja suurimmat arvot olivat havupuulla 52.4 ja 73.7 sekä lehtipuulla 45.7 ja 70.0. Viiden harvimman ja viiden tiheimmän pinon keskimääräiset pinotiheysluvut olivat havupuilla 54.7 ja 73.3 sekä lehtipuulla 47.7 ja 66.7. Luvut osoittavat, että uudessa menetelmässä sopii raja-arvojen sisälle suurin osa pinoista. Erittäin tiheät ja erittäin harvat pinot eivät kuitenkaan tule tällaisessa luokitellussa järjestelmässä oikein arvostelluksi. Tähän pääsemiseksi on kaksi kehittämismahdollisuutta (Heiskanen 1973 d).

1. Muutetaan pinotiheystekijäin arviointiin perustuva menetelmä siten, että tulos otetaan luokittamattomana. Tällä tavoin saadaan Mittausneuvoston suositteleman menetelmän pinotiheyslukujen raja-arvot esim. 2 m havupuupinoissa nykyisten 57 %:n ja 72 %:n sijasta 53 %:iin ja 75 %:iin ja lehtipuupinoissa 45 %:iin ja 65 %:iin.

2. Siirrytään pinotiheystekijäin arviointiin perustuvasta menetelmästä pinotiheysluvun silmävaraiseen arviointiin, jolloin mitattavien pinojen pinotiheyden todelliset vaihtelut voidaan huomioida koko laajuudessaan.

Uudella menetelmällä on muitakin heikkouksia, jotka kaikki perustuvat sen arvioluonteisuuteen. Menetelmä näet edellyttää voimaperäistä koulutusta, sillä vain hyvin koulutetut mittamiehet voivat välttää mittauksissaan karkeat virheet (Karlsson 1971, Heiskanen 1973 a, b ja c). Lisäksi arvioluonteisuudesta johtuu, että mittaustulosten tarkistaminen on vaikeata. Siitä syystä on yritettävä löytää tarkoituksenmukaisia pinossa olevan tavaran kiintomitan tarkistusmenetelmiä, jotka täyttävät kaikilta kohdiltaan objektiiviselle menetelmälle asetettavat vaatimukset Heiskasen (1973 d) mukaan kyseeseen voivat tulla pinotavaran kiintomittauksessa seuraavat menetelmät pinotiheystekijäin arviointiin perustuvan menetelmän lisäksi.

Kehysmittausta vaativat menetelmät:

— Muunnetaan keskimääräisellä pinotiheysluvulla.

— Arvioidaan tyhjätila ja saatu nettopinomitta muunnetaan keskimääräisellä pinotiheysluvulla.

— Muunnetaan silmävaraisesti arvioidulla pinotiheysluvulla.

— Määritetään muuntamiseen tarvittava pinotiheysluku kylkitiheyden mittaamisen avulla (= kylkitiheysmenetelmä).

Menetelmät, joissa ei tarvita kehysmittausta

— Jokainen pinossa oleva pölkky mitataan keskusläpimitan, tyvi- ja latvaläpimittojen tai latvaläpimitan perusteella (= kappalettainen mittaus).

— Otetaan osa pinossa olevista pölkyistä mitattavaksi ja niiden perusteella määritetään koko mitattavan erän kiintomitta (= kappaleotanta).

— Määritetään koko mitattavan erän paino ja koepölkyistä otetaan tilavuus painonäytteet, joiden avulla paino muunnetaan kiintomitaksi (= tilavuuspaino-otanta).

— Määritetään kiintomitta mitattavan erän syrjäyttämän vesimäärän mittaamisen avulla (= ksylometrimittaus).

— Määritetään kiintomitta Arkimedeen lain perusteella eli punnitsemalla mitattava puuerä veteen upotettuna ja ilmassa (= upotusmittaus).

Edellä esiteltyjä mittausmenetelmiä toisiinsa vertailtaessa voidaan ne jakaa usealla eri tavalla vertailun pohjaksi. Aluksi on syytä jakaa menetelmät sen mukaan joudutaanko suorittamaan subjektiivisia arviointeja vai ei. Tällöin saadaan subjektiivisia päätelmiä edellyttävien menetelmien ryhmä seuraavaksi:

— tyhjän tilan arviointia käyttävä menetelmä

— pinotiheysluvun silmävaraista arviointia käyttävä menetelmä

— pinotiheysluvun arviointia pinotiheystekijöiden avulla käyttävä menetelmä.

Kaikki nämä menetelmät voidaankin sulkea pois mahdollisen tarkistusmenetelmän valinnassa. Ne voivat palvella kuitenkin perusmittausmenetel-

mänä, kuten Mittausneuvoston suosittaman uuden menetelmän antamat kokemukset ja käsillä olevan tutkimuksen tulokset ovat osoittaneet. Toinen jakojärjestelmä on jako keskiarvoisuuteen tai jokaisen pinon erityisominaisuudet huomioon ottaviin menetelmiin. Keskiarvoihin yksinomaan perustuu keskimääräisen pinotiheysluvun käyttö muuntotehtävissä. Se ei tietenkään voi olla tarkistusmenetelmänä eikä myöskään käytännön kuitupuun mittauksen perusmenetelmänä.

Kolmanneksi voidaan vielä jäljelle jääneitä menetelmiä tarkastella sen perusteella, mitataanko niissä kaikki pölkyt tai koko erä vai noudatetaanko otantamittausta. Sellaisia menetelmiä, jotka periaatteessa antavat tulokseksi hyvin tarkan pinon kiintomitan ovat seuraavat:

1. Kappalettainen mittaus joko keskusläpimittaan tai latva- ja tyviläpimittoihin perustuvana.
2. Ksylometrimittaus
3. Mittaus Arkimedeen lakiin perustuvilla laitteilla eli upotusmittareilla.

Ensimmäinen näistä tavoista on kaikkialla sovellettavissa, mutta sen kustannukset lienevät niin korkeat, ettei se totaalisena voi tulla lainkaan kyseeseen pinossa jo olevan kuitupuun mittauksessa. Se on siis hylättävä yksinomaan kustannussyistä, vaikka voimassa oleva puutavaran mittaussääntö tunteekin menetelmän.

Ksylometrimittaus tuntuu tällä hetkellä vielä aivan teoreettiselta käytännön sovellutusten kannalta. On odotettava Pohjois-Suomessa tehtävistä kokeiluista saatavia kokemuksia. Parhaassakin tapauksessa ksylometrimenetelmä voi kuitenkin olla ainoastaan paikallinen tarkistusmenetelmä. Jos nyt käynnissä olevat kokeilut johtavat jatkokehittelyihin innostaviin tuloksiin, on ensi tilassa selvitettävä riittävällä aineistolla ksylometrimittauksen ja kappalettaisen kiintomittauksen väliset mahdolliset erot.

Upotusmittaus on jo käytännössä ratkaistu A. Ahlström Osakeyhtiön ja Kone Oy:n laittein. Ne ovat tarkkoja, mutta niiden käyttömahdollisuudet ovat paikallisesti ja omistajan mukaan rajoitettuja. Jotta niitä voitaisiin käyttää edes paikallisesti pinomittauksen tarkistuksessa, on ensi tilassa tutkittava niiden antaman kuutiotuloksen ja kappalettaisen stereometrisen mittauksen antamien tuloksien erot.

Vielä käsittelemättä olevat menetelmät perustuvat otantaan. Tällaisia menetelmiä ovat seuraavat:

1. Tilavuuspaino-otanta.
2. Kylkitiheysmenetelmä.
3. Kappaleotanta.

Punnitseminen on välillinen keino kiintomitan määrittämiseksi. Mm. tästä syystä se ei voi tarkkuudessa kilpailla muiden tähän ryhmään kuuluvien kanssa. Sitä ei myöskään voi soveltaa kuin keskitetyillä mittauspaikoilla.

Kylkitiheys- ja kappaleotantamenetelmät ovat sellaisia, että niitä voidaan soveltaa missä tahansa. Tosin kylkitiheyden tarkka toteaminen käy nopeasti päinsä vain kalliilla laitteilla, mutta ympyränäytteiden mittaus voidaan suorittaa verraten halvalla kaikissa olosuhteissa. Kuitenkin menetelmä on parhaassakin tapauksessa niin vaivalloinen, että pinossa olevan tavaran perusmittausmenetelmäksi siitä ei ole. Sama koskee myös kappaleotantaa, joka on teoriassa parempi menetelmä kuin kylkitiheyden kautta kiintomittaan pyrkiminen. Se on kuitenkin vielä enemmän aikaa vievä, koska se edellyttää kaikkien pinossa olevien pölkkyjen lukumäärän määrittämisen.

Tarkastelun ja vertailujen perusteella on todettava, että pinossa olevan kuitupuun mittauksessa on siis edelleenkin pitäydyttävä pinotiheystekijäin tai pinotiheysluvun arviointilinjalla. Nyt kokeiltavana olevaa menetelmää voidaan kehittää. Ko. subjektiivisiin arviointeihin perustuvan menetelmän antamien tulosten tarkistamiseen sopivia yleismenetelmiä ovat kappalemittaus, kylkitiheysmenetelmä ja kappaleotanta. Kahta jälkimmäistä on edelleen kehitettävä ja tutkimuksin selvitettävä niissä tarvittavat perustiedot, mm. otoksen suuruus. Erikoistapauksiin voidaan suositella myös ksylometrija upotusmittauksia. Niiden osalta on selvitettävä saatujen tulosten suhde stereometrisin menetelmin saatavaan kiintomittaan.

Pinotiheystekijöiden arviointiin perustuva menetelmä edellyttää mittamiehiltä varsin suurta pätevyyttä. Tähän liittyy siten kysymys puolueettomien, erittäin hyvin koulutettujen mittamiesten käytöstä, joka varmasti parantaisi tulosten luotettavuutta (vrt. Leinonen ja Rikkonen 1972). Järjestelmää tutkitaan parhaillaan Mittausneuvostossa.

Arviointeihin perustuvan menetelmän kitkaton käytäntöön soveltaminen edellyttää myös, että valistusmenettely on joustava. Saattaakin olla asiallista tutkia nopeasti toimivan osapuolten välisen valistusorgaanin aikaansaamista myös tarkistusmittausten käyttöön liittyvänä.

47. Tiivistelmä

Käsillä oleva tutkimus perustuu Pinomittauksen kehittämisryhmän toimesta vuonna 1972 kerättyyn laajaan yli 500 pinoa käsittävään aineistoon (taulukko 1), jonka perusteella tarkastellaan eri pinotiheystekijäin vaikutusta pinotiheyteen sekä 2—3 metrisen kuitupuun keskimääräisiä pinotiheyksiä. Tulosten perusteella laaditaan myös pinotiheyttä kuvaavia tilastollisia malleja. Mainitun aineiston lisäksi käsitellään eräiden tutkimuksessa selvittämättä jääneiden pinotiheystekijöiden vaikutusta kirjallisuuden perusteella, jotta pinotiheyskysymyksestä saataisiin mahdollisimman täydellinen kuva.

Tutkimusmenetelmässä kiinnitettiin erityistä huomiota näytteenottoon ja siinä noudatettiin seuraavia periaatteita.

Tavoitekiintiö asetettiin eri alueille puulajeittain hakkuusuunnitteen osoittamassa suhteessa (Huttunen 1971, ks. taulukko 1). Mitattavat pinot etsittiin eri osa-alueille arvotuilta karttalehdiltä (peruskartta 1 : 20 000 osa 17) kahdella eri menetelmällä. Pystykauppapinot ko. karttalehden osa-alueella luetteloitiin ja näistä arvottiin mitattavat pinot. Hankintakauppapinot kerättiin ns. tiemenetelmällä, so. edettiin karttalehdellä esiintyvässä tieverkossa annettujen ohjeiden mukaan ja mitattiin kohdalle tulevia pinoja kunnes karttalehden kiintiö oli täynnä. Edellinen kahtiajako tehtiin, koska oletettiin, että hankinta- ja pystykauppojen pinojen tiheydet saattaisivat poiketa toisistaan. Pystykauppapinojen tavoiteosuus oli Pohjois-Suomessa $^2/_3$ ja Etelä-Suomessa $^1/_2$.

Mittausryhmän tehtäviin kuuluivat seuraavat mittaukset ja arvioinnit:

— Yleistietojen merkintä (kaikki pinosta ilman mittauksia käytettävissä oleva tieto)

— Pinon kehysmitan mittaus kahdella tavalla: mittaussäännön mukaan ja ns. ruotsalaisen tavan mukaan (ks. kuva 1)

— Tyhjän tilan vähennyksen arviointi (Heiskanen 1973 a)

— Pinotiheysluvun silmävarainen arviointi prosenttiyksikön tarkkuudella.

— Pinotiheystekijäin arviointi (ks. liite 1)

— Hylkyvähennysten arviointi (Heiskanen 1973 c)

— Pölkyttäinen kiintomittaus ja siihen liittyvät lisämääritykset koepölkyistä. Jokaisen pölkyn vaakasuora keskusläpimitta 1 cm:n alenevalla luokituksella paksunnosten vaikutus eliminoiden, jokaisen pölkyn mutkaisuus kolmessa luokassa: 1. suora tai likipitäen suora, 2. lievästi lenko tai mutkainen, 3. hyvin lenko tai mutkainen. Joka 10:s pölkky oli koepölkky, josta mitattiin tai arvioitiin: tyvi- ja latvaläpimitat samoin kuin keskusläpimitta 5 cm:n etäisyydeltä pölkyn päästä, mutkaisuus senttimetrin alenevin luokin, karsinnan laatu kolmessa luokassa: 1. ei oksantynkiä, 2. joitakin lyhyitä oksantynkiä (< 1 cm), 3. paljon lyhyitä tai pitkähköjä oksantynkiä. Koepölkyn pituus mitattiin päältä sahauspintojen etäisyytenä 1 cm:n alenevin luokin.

Maa jaettiin mittauksen suorittamista varten viiteen alueeseen, jotka selviävät kuvista 2, 3 ja 4. Jokaisessa alueessa toimi yhdysmies ja yksi tai kaksi mittausryhmää.

Pinotiheyteen vaikuttavat tekijät on jaettu mittauksesta, pinon ominaisuuksista ja puutavaran ominaisuuksista johtuviin tekijöihin.

Mittauksesta johtuvista tekijöistä voidaan mainita, että virallisen mittaustavan ja ruotsalaisen mittaustavan mukaisten pinotiheyksien erot ovat vähäiset (taulukko 3). Vaikeasti mitattavissa pinotyypeissä ruotsalainen mittaustapa antaa luotettavammat tulokset (taulukko 4). Mittausryhmän

ja tarkastusmittaajan tulokset poikkesivat vain vähän toisistaan siten, että tarkistusmittaus antoi tulokseksi suuremman kehysmitan ja siis pienemmän pinotiheyden kuin tutkimusryhmien mittaus (taulukko 5).

Pinon ominaisuuksista on ladonta yksi tärkeimmistä pinotiheyden kannalta tarkasteltaessa. Sen merkityksestä antavat tulokset seuraavia tietoja.

Ladontatavan kannalta jaettiin pinot käsipinoihin, hyviin konepinoihin ja huonoihin konepinoihin. Käsipinojen ja hyvien konepinojen erot olivat vähäiset ja eri puulajeissa erisuuntaiset. Huonot konepinot olivat kaikissa puulajeissa selvästi harvimmat. Kaikkien konepinojen keskimääräinen pinotiheys oli mäntypinoissa 0.6, kuusipinoissa 2.4 ja lehtipuupinoissa 0.1 prosenttiyksikköä pienempi kuin käsipinojen pinotiheys. Erojen pienuus johtuu osittain siitä, että konepinojen puutavara oli etenkin mänty- ja lehtipuupinoissa järeämpää ja paremmin karsittua kuin käsipinoissa (kuva 8).

Ladontaluokan (liite 1) vaikutus pinotiheyteen on havupuupinoissa keskimäärin 1.6 prosenttiyksikköä, mäntypinoissa 1.4 ja kuusipinoissa 2.1 prosenttiyksikköä. Lehtipuupinoissa ei ladontaluokalla ole luokkien 1 ja 4 välillä sanottavaa vaikutusta pinotiheyslukuun. Viides luokka on muita selvästi harvempi. Kun tarkastellaan uudelleen ladonnan vaikutusta eri luokissa, havaitaan kuitenkin, että myös lehtipuupinoissa pinotiheys on suurentunut sitä enemmän mitä huonommaksi ladonta on alkuperäisessä pinossa arvioitu (Kuvat 9 ja 10).

Uudelleen ladonta on keskimäärin suurentanut pinotiheyttä kuva 11. Käsipinoissa uudelleen ladottu pinotiheys oli korkeintaan 1.4 % suurempi ja konepinoissa 2.9—6.2 prosenttia suurempi kuin alkuperäinen pinotiheys.

Vieraiden esineiden vaikutus arvioitiin kolmessa luokassa, joista vain kahteen ensimmäiseen saatiin riittävästi aineistoa. Tuloksista ilmenee, että 2. luokkaan kuuluvien pinojen tiheys oli kaikissa puulajeissa pienempi kuin 1. luokkaan kuuluvien tiheys (kuva 12).

Lumen ja jään vaikutusta ei saatu selville. Rikkosen (1972 a) aineistossa ko. vaikutus on kuitenkin selvä käytetyn kolmijakoisen luokituksen puitteissa.

Pinon suuruuden vaikutusta ei pystytty täysin selvittämään, mutta tulosten ja kirjallisuuden mukaan arvostellen se on hyvin vähäinen.

Pinossa oloajan eli pinon iän vaikutus on tulosten mukaan erittäin vähäinen. Osasta pinoja mitattiin kehysmitta kuitenkin useamman kerran ja havaittiin, että niiden pinotiheys oli suurentunut 2—7 kuukaudessa hieman yli 1 %:lla.

Mittauspaikan vaikutusta tarkastellaan Heiskasen ja Riikosen (1973) tutkimuksen perusteella.

Kauppatavan vaikutus pinotiheyteen ilmenee siten, että hankintapinot ovat olleet miltei 100 prosenttisesti käsin ladottuja, kun taas pystykauppojen pinoista oli yli 50 % konepinoja.

Omistajaryhmällä ei ole ilmeisesti vaikutusta pinojen pinotiheyteen.

Aluspuilla varustettujen konepinojen pinotiheys on Nikkilän (1972 a) mukaan suurempi kuin aluspuuttomien koneella tehtyjen pinojen tiheys. Pääpuiden olemassaololla ei sitävastoin ole vaikutusta pinotiheyteen.

Puutavaran ominaisuuksista on eniten tarkasteltu läpimitan, läpimittojen erotuksen ja hajonnan sekä sekoittumisen, tyvipölkkyjen osuuden, mutkaisuuden ja karsinnan vaikutusta.

Läpimitan vaikutus arvioiduissa luokissa osoittautui varsin vähäiseksi, vain n. 1 %:ksi luokkaa kohden. Mitattu läpimitta kuvasi paremmin pinotiheyden vaihtelua. Keskimäärin sen vaikutus oli pienimmissä läpimittaluokissa 2.5 prosenttiyksikköä/cm ja järeimmissä luokissa enää vain 0.5 yksikköä. Aineistosta ei saatu selville läpimitan vaikutuksen kulminaatiopistettä, kuten eräissä ruotsalaisissa tutkimuksissa (Kuvat 13 ja 14).

Läpimittojen erotuksen vaikutusta ei pystytty selvittämään. Läpimitan hajonta sitä vastoin korreloi vahvasti pinotiheyden mutta vielä vahvemmin läpimitan kanssa.

Eri kokoisten pölkkyjen sekoittuminen, joka arvioitiin kolmessa luokassa, ei vaikuttanut havupuissa lainkaan pinotiheyteen. Lehtipuupinoissa oli tiheys suurin huonosti sekoittuneissa pinoissa. Korrelaatio oli kaikissa tapauksissa heikko.

Tyvipölkkyjen osuus luokiteltuna korreloi hyvin heikosti pinotiheyden kanssa. Luokitus lienee ollut liian karkea. Todellinen tyvien osuus osoitti melko voimakasta korrelaatiota pinotiheyteen mäntypinoja lukuunottamatta. Tyvien osuuden ja läpimitan välillä vallitsee melko vahva negatiivinen ja sen sekä mutkaisuuden välillä positiivinen riippuvuussuhde (kuvat 15 ja 16).

Pinossa olevien pölkkyjen mutkaisuus määritettiin arvioimalla viidessä luokassa ja mittaamalla koepölkyistä mutkaisuuden määrä sentteinä. Mutkaisuusluokkajakautuman kannalta puulajit erosivat siten toisistaan, että lehtipuupinoissa oli 4. luokka yleisin ja havupuupinoissa 2. luokka. Mutkaisuuden mitta ja mutkaisuusluokka olivat riippuvuussuhteessa keskenään kuitenkin siten, että lehtipuupinoissa tietty luokka osoitti suurempaa mutkaisuutta kuin havupuupinoissa.

Mutkaisuusluokan vaikutus pinotiheyteen oli käytetyn luokituksen puitteissa hyvin selvä, yli 1 %-yksikkö luokkaa kohden. Mitatun mutkaisuuden ja pinotiheyden välinen korrelaatio oli vieläkin vahvempi. Yhden senttimetrin muutos mutkaisuudessa merkitsee yli 2 prosenttiyksikön muutosta pinotiheyteen (kuvat 17 ja 18).

Karsinnan laatu määritettiin arvioimalla neljässä luokassa ja arvioimalla koepölkkyjen oksantynkien määrän ja pituuden perusteella ns. oksaisuusindeksi. Pinot jakautuivat kaikissa puulajeissa karsintaluokkiin suunnilleen samalla tavoin. Korrelaatio karsintaluokan ja oksaisuusindeksin välillä oli melko vahva, havupuupinoissa vahvempi kuin lehtipuupinoissa.

Karsintaluokka selittää havupuupinoissa pinotiheyden vaihtelua melko hyvin. Yhden luokan muutos aiheuttaa hieman yli 1 %:n muutoksen pinotiheyteen. Lehtipuupinoissa ei vastaavaa riippuvuutta ollut havaittavissa (Kuva 19).

Oksaisuusindeksi korreloi pinotiheyden kanssa jonkin verran vahvemmin kuin karsintaluokka. Sen vaikutus indeksiyksikköä kohden on havupuupinoissa n. 3 prosenttiyksikköä ja lehtipuupinoissa n. 1.5 prosenttiyksikköä (kuva 20).

Tutkimustulosten mukaan lehtipuupinojen pinotiheys on huomattavasti havupuupinojen pinotiheyttä alhaisempi. Siten myös sekapinojen pinotiheys pienenee lehtipuusekoituksen suuretessa, kuten mm. ruotsalaiset tutkimustulokset ovat osoittaneet (kuva 21).

Muista pinotiheyteen vaikuttavista tekijöistä mainittakoon kapeneminen, kuorinta ja halkaiseminen (esim. Nylinder 1972).

Maan eri osien välillä ei havaittu eroavuuksia pinotiheyksissä, mutta kunkin puulajin pinotiheyksien hajonta oli Pohjois-Suomessa suurempi kuin Etelä-Suomessa.

Pinotiheyden vaihtelua selittäviä malleja kehiteltäessä todettiin, että arvioitujen pinotiheystekijäin soveltaminen malleissa oli vaikeaa mittausryhmien johtajien toisistaan poikkeavien tulkintojen takia. Parhaan ja käyttökelpoisimman mallin antaviksi tekijöiksi osoittautuivat pölkkyjen mitattu keskiläpimitta, pölkkyjen mitattu mutkaisuus, pinon ladonnan laatu, jota kuvataan pinotiheyden suhteellisella muutoksella uudelleen ladonnan yhteydessä, ja pölkkyjen karsinnan laatua kuvaava oksaisuusindeksi.

Mallien laskemiseen käytettiin valikoivaa regressioanalyysiä. Seuraavassa on esitetty kehitettyjen kolmen mallin kertoimet asetelmana.

Kokonaismalli 1)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	93.936			
logaritmi keskiläpimitasta (cm)	10.724	0.838	12.80	3
mutkaisuus, mm	— 0.232	0.017	—13.99	1
karsinta (oksaisuusindeksi 1—3)	— 2.217	0.343	— 6.46	4
ladonta [1])	— 0.438	0.031	—13.94	2
puulaji	— 2.271	0.600	— 3.79	5
havupuu—lehtipuu (0—1)				

Havupuun malli 2)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	102.279			
logaritmi keskiläpimitasta (cm)	7.135	1.113	6.41	3
mutkaisuus, mm	— 0.251	0.032	— 7.77	2
karsinta (oksaisuusindeksi 1—3)	— 2.534	0.412	— 6.15	4
ladonta [1])	— 0.516	0.041	—12.44	1

[1]) Pinon uudelleen ladonnan jälkeen mitatun tiheyden suhde prosentteina alkuperäiseen tiheyteen.

Lehtipuun malli 3)

tekijä	reggressio-kerroin	kertoimen keskivirhe	t-arvo	selitys-järjestys
vakio	91.178			
keskiläpimitta, cm	1.125	0.099	12.44	2
mutkaisuus, mm	— 0.230	0.018	—12.69	1
karsinta (oksaisuusindeksi 1—3)	— 1.517	0.580	— 2.61	4
ladonta [1])	— 0.354	0.045	— 7.86	3

Mallien tarkastelu osoitti, että malli 1 selittää 44.0 % männyn, 65.2 % kuusen, 62.2 % lehtipuun ja 79.3 % kaikkien puulajien pinotiheyden varianssista. Mallit 2 ja 3 selittävät havupuulla 52.8 %, lehtipuulla 65.9 % ja kaikilla puulajeilla 80.6 % pinotiheyden varianssista.

Keskimäärin esitetyt mallit antavat hyviä tuloksia. Luonnollisista syistä kuitenkin äärialueilla syntyy virheitä varsinkin kaikkien puulajien yhteisissä malleissa (kuvat 23 ja 24).

Malleissa esiintyvät muuttujat eivät sellaisenaan ole helposti mitattavissa tai arvioitavissa. Sen vuoksi ne on käytäntöä varten korvattava luokitetuilla muuttujilla esim. seuraavalla tavalla:

Tutkimuksessa käytetty	Käytäntöön soveltuva
Mitattu keskiläpimitta	Arvioitu keskiläpimitta
Mitattu mutkaisuus	Arvioitu mutkaisuus
Uudelleen ladonnan vaikutus pinotiheyteen	Arvioitu ladontaa kuvaava luokka
Oksaisuusindeksi	Karsinnan laatua kuvaava luokka

Käytännössä tähän päästään luokittelemalla mitattu ominaisuus tarpeelliseen määrään luokkia havaintojakauman perusteella ja määrittelemällä nämä luokat myös suusanallisesti.

Tämän tutkimuksen aineistoon perustuva edellä kuvatulla tavalla laadittu menetelmä on jo käytännössä kokeiltavana (ks. Uudistuva . . .). Esillä olevan tutkimuksen tulokset viittaavat siihen, että tämä käytännön kokeilumenetelmä ottaa hyvin huomioon pinotiheyden vaihtelut. Tällaisen arviointiin perustuvan menetelmän soveltaminen vaatii onnistuakseen perusteellisen koulutuksen. Erimielisyyksien selvittämiseen ja tarkistusmittauksiin on oltava käytettävissä riittävän hyvä tarkistusmenetelmä. Kovin vähätöistä ja helppoa tarkistusmenetelmää ei tällä hetkellä ole olemassa, mutta tarkoitukseen soveltuvat tietyin rajoituksin kappalemittaus, kylkitiheysmenetelmä, ksylometri- ja upotusmittaus ja erilaiset otantamenetelmät.

[1]) Pinon uudelleen ladonnan jälkeen mitatun tiheyden suhde prosentteina alkuperäiseen tiheyteen.

KIRJALLISUUSLUETTELO

Arnkil, J. E. 1966. Kourakuormaajalla ladotun pinon tiheydestä. Metsähall. tekn.tied. n:o 65.

Aro, P. 1958. Pohjois-Suomen 2 m kuusi- ja mäntypaperipuiden pinotiheydestä, kuorimishäviöstä ja kuutiosuhteista. Metsäntutk.lait. Julk. 50.8.

—»— 1931. Tavallisimpien suomalaisten pinopuutavarain pinotiheys. Metsäntutk.lait. Julk. 14.5.

—»— 1959. Nippujen kuutiotaulukot 2 m ja 4 m kuusipaperipuille. Metsäntutk.lait. Julk. 51.5.

—»— Korpela, T. ja Nisula, P. 1958. Tutkimuksia kuusiohutpuun ja koivupaperipuun kuorimishäviöstä. Metsäntutk.lait. Julk. 50.2.

—»— ja Rikkonen, P. 1966. Havusahatukkien latvamuotoluvut. Metsäntutk. lait. Julk. 61.7.

Arvesen, A. 1966. Barking av 2- og 3-meter kubb med traktormontert barkemaskin. Driftsteknisk rapport nr. 5. Det norske Skogforsksøksvesen. ss. 423—451. Saertryklo av Tidsskrift for Skogbruk nr. IV. 1965. Vollebekk.

Eklund, B. 1948. Undersökningar över fastmasseprocenter, åtgongstal mm. vid mätning av 2- och 3-meters tali och granmassaved. — Medd. från Statens Skogsforskningsinstitut. Band 37 : 1.

—»— 1953. Om volymen och antalet bitar per m^3t hos travar av dimensionsblandad och dimensionssorterad 2-meters massaved av gran. Meddelande från statens skogsforskningsinstitut. Serier uppsatser nummer 28.

Eripituisten kuitupuutavaroiden mittaus pinomenetelmällä. 1973. Mittausneuvoston moniste.

Finne, B. 1967. Koetuloksia tilavuuden mittauksesta pinosta otetun kappalenäytteen perusteella. Uittoteho r.y. tied. 225.

—»— 1970. Puunkorjuun koneellistumisen vaikutus pinotilavuuden mittaukseen. Uittoteho r.y. tied. 244.

Hallert, B. 1967. Elementär felteori för mätningar.

Halvorsen, B. 1969. Forholdet mellom fastmasseprosent og foredlingsverdi hos 3 m kubb av gran og furu. — Tidskrift for Skogsbruk. 77-Hefte III.

Heiskanen, V. 1968. Pinomittauksen ja teknillisen kiintomitan mittauksen tarkkuudesta. Suomen Metsänhoitajaliitto ry. Moniste.

—»— 1972 a. Pinomittauksen kehittämistutkimus II. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Tutkimusmenetelmä ja -aineisto. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

—»— 1972 b. Pinomittauksen kehittämistutkimus III. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Pinomitan mittaaminen ja tyhjän tilan arviointi. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

—»— 1972 c. Pinomittauksen kehittämistutkimus IV. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Pinotiheysluvun arviointi. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

Heiskanen, V. 1972 d. Pinomittauksen kehittämistutkimus V. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Pinotiheystekijäin arviointi. Metsäntutkimuslaitos. Metsäteknologian tutkimusoasto. Moniste.

—»— 1972 e. Pinomittauksen kehittämistutkimus VI. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Hylkyvähennysten arviointi. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

—»— 1973 a. Pinon kehysmitan mittaus ja tyhjän tilan vähennyksen arviointi ja niiden tarkkuus. Folia Forestalia 169.

—»— 1973 b. Pinotiheysluvun ja pinotiheystekijäin arviointi ja sen tarkkuus. Folia Forestalia 170.

—»— 1973 c. Hylkypölkkyjen osuuden arviointi pinomittauksessa. Folia Forestalia 171.

—»— 1973 d. Kiintomitan määrittäminen pinosta. Eri menetelmien tarkastelua. Moniste.

—»— ja Koivulehto, P. 1964. Tutkimus 2.2 m ja 4.4 m koivupaperipuun pinotiheydestä ja kuorimishukasta VK-16 kuorimakoneella kuorittaessa. Pienpuualan Toimikunnan julkaisu 170.

—»— ja Riikonen, J. 1973. Kuitupuun kehysmitta ja pinotiheys autokuljetuksen eri vaiheissa. Folia Forestalia 182.

Hellman, E. 1959. Paperipuun keskiläpimitan ja pinotiheyden suhde. Suomen Puutalous 9.

Hemmi, L. 1965. Paperipuun pinotiheysmittauksia Kemijoella 1965. Uittoteho ry:n tiedotus 214.

—»— 1967. Jatkotutkimus paperipuun pinotiheyksistä Kemijoella 1966. Uittoteho ry:n tiedotus 235.

—»— 1967. Havaintoja Ruotsissa käyttöön otetuista raakapuun mittausmenetelmistä. Uittoteho ry:n tiedotus 236.

—»— 1970. Kouraladottujen pinojen mittauksesta Pohjois-Suomessa. Moniste.

Huttunen, T. 1971. Suomen puunkäyttö, poistuma ja metsätase vuosina 1969—71. Folia Forestalia 127.

Jalava, M. 1929. Pyöreän pinopuutavaran mittaamisesta. Metsäntutk.lait. Julk. 13.8.

Karlsson, J. 1971 b. Mätning av massaved i travat mått. Skogshögskolan. Inst. för Virkeslära. Rapporter Nr R 73.

Klem, G. og Halvorsen, B. 1963. Målmetoder for bestemmelse av fasmasseprosenter i kubblag. Medd. fra Det norske Skogforsøksvesen. Nr. 66. Vollebekk.

Kungl. Skogsstyrelsen, 1967. Virkesmätningsföreskrifter. — Cirkulär Vm nr 1.

Leinonen, E. ja Rikkonen, P. 1971. Pinomittauksen kehittäminen Ruotsissa käynnissä olevan tutkimuksen perusteella. Pinomittauksen kehittämisryhmä. Moniste.

Makkonen, O. 1957. Aisattujen 2-m koivupaperipuiden kuorettoman kiintokuutiomäärän ja pinokuutiomäärän suhde Keski-Suomessa. Metsätehon tiedotus 132.

—»— 1958. Pinotiheystutkimuksia. Metsätehon julkaisu 39.

—»— 1959. Pinotiheys mäntypaperipuiden laaturyhmän tunnuksena. Metsätehon tiedotus 155.

—»— 1960. Kuorimattomien 2.4 m:n koivupaperipuiden ja 2m:n koivupolttorankojen pinotiheysmittauksia. Metsätehon tiedotus 173.

—»— 1965. Koivupaperipuiden mutkaisuuden vaikutuksesta pinotiheyteen. Metsätehon tiedotus 241.

Matérn, B. 1955. Okulärbedömning av massaved. — Sydsvenska virkesföreningen. Opublicerat arbete.

Metsäntutkimuslaitoksen päätös puutavaran mittauksessa käytettävistä muuntoluvuista ja kuutioimistaulukoista. 1969. Folia Forestalia 57.

Metsäntutkimuslaitoksen päätös puutavaran mittauksessa käytettävistä muuntoluvuista ja kuutioimistaulukoista 2 päivänä toukokuuta 1969 annetun päätöksen muuttamisesta. 1973. Folia Forestalia 172.

Myhrer, K. og Wibstad, K. 1965. Målemetoder for bartrekubb. SSFF. Transportutvalget. Oslo.

Mähönen, E. 1964. Pinotiheyden riippuvuus pölkkyjen läpimitasta. Folia Forestalia 3.

Nikkilä, H. 1972 a. 2-m ja 2.2 m koivupaperipuun pinotiheys Tehdaspuu Oy:n hankinta-alueella 1971. Konekirjoite Metsäntutkimuslaitoksessa.

—»— 1972 b. Pinomittauksen kehittämistutkimus VIII. Kylkitiheyden ja pinotiheyden välinen riippuvuus. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

—»— 1972 c. Pinomittauksen kehittämistutkimus IX. Kylkitiheyden pinon sisäinen hajonta. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

—»— ja Heiskanen, V. 1972. Pinomittauksen kehittämistutkimus I. Kylkitiheydestä ja sen mittaamisesta. Kirjallisuuskatsaus. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

Nisula, P. 1963. Pinotiheystutkimuksia. Pienpuualan Toimikunnan tiedotus 97.

—»— 1967. Koivupaperipuun pinotiheydestä ja kuutiosuhteista. Metsäntutk.lait. Julk. 62.7. Eripainos.

Nylinder, P. 1957. Undersökningar över fastmasseprocenter skador mm. hos tremeters massaved i östra Värmland. Skogshögskolan, Inst. för Virkeslära R 12.

—»— 1958. Fastmasseprocenter hos boardved, ribb och baker samt flis. — Skogshögskolan, Inst. för Virkeslära. R 16.

—»— 1959. Fastmasseprocenter hos några klenvirkessortiment. Skogshögskolan. Inst. för Virkeslära. R 21.

—»— 1964. Studier över antalet 3-meters massavedbitar per m^3t. Skogshögskolan. Inst. för Virkeslära. R 45.

—»— 1972. Virkesmätning. Skogshögskolan. Institutionen för Virkeslära. Kompendium nr. 5.

—»— & Peterson, O. 1967. Relativa fastvolymen hos tremeters massaved av tall, gran och björk. — Skogshögskolan Inst. för Virkeslära. R 59.

Person, O. 1960. Virkesmätningsrådets lövmassautredning; redogörelse för bearbetning av mätresultat. — Opublicerat arbete.

Pertovaara, H. 1960. Pitkän pinotavaran pinotiheysmittauksia Pohjois-Suomessa. Uittotehon tiedotus 183. Rovaniemi.

—»— 1964. Tasapituisen paperipuun pinotiheys- ja kuutiointimittauksia Pohjois-Suomessa. Uittotehon tiedotus 209.

Puutavaranmittauslaki 1969. Pieni lakisarja 58. Valtion painatuskeskus.

Rikkonen, P. 1970. Valmiin puutavaran mittaus. Tapion taskukirja 16. uudistettu painos.

—»— 1972 a. Pinomittauksen kehittämistutkimls VII. Pinomittauksen tarkkuus ja sen parantamismahdollisuudet. Pinotiheystekijäin vaikutus pinotiheyteen. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

Rikkonen, P. 1972 b. Pinomittauksen kehittämistutkimus X. Suomalaisen kuitupuun pinotiheys. Metsäntutkimuslaitos. Metsäteknologian tutkimusosasto. Moniste.

Ronkanen, A. J. 1942. Runkojen koon vaikutus pinon kuutiosisältöön. Metsätal. Aikak.l. 7—8.

Saari, E., Keltikangas, V. ja Wuoti, E. 1939. Kuusi- ja mäntypaperipuiden pinotiheys ja kuorimishukka. Metsätal. Aikak.l. 1. Helsinki.

Schoultz, H. von. 1968. Paperipuiden pinotiheys konekuormaajalla tehdyissä autokuormissa. Konekirjoite.

Uudistuva puutavaran mittaus II. Kuitupuu. Mittausneuvosto. 1973.

Vid virkesmätning erforderliga relationstal 1923. Statens offentliga utredningar.

Virkesmätningsrådet, 1967. Rikskoder för virkesredovisning. — N:o 2/67.

Wuoti, E. 1933. Kuusipaperipuun kutistumisesta ja kutistumisen osuudesta pinon painumiseen. Acta Forestalia Fennica 39.6.

—»— 1938. Eräs tutkimus erimittaisten paperipuiden kiintokuutiosuhteista. Yksityismetsänhoitajayhdistyksen vuosikirja XI ss. 185—92. Helsinki.

—»— 1940. Kuusisahapuista valmistettujen paperipuiden pinotiheys. Suomen Paperi- ja Puutavaralehti 1940:22.

Ylinen, M. 1972. Pinojen tilalle ovat tulleet kasat. Miten käy pinomittauksen. Teollisuuden metsäviesti 6.

SUMMARY

The present study is based on a large material of over 500 piles collected in 1972 by the Pile Measurement Development Group (Table 1). This material was used to investigate the effect of certain factors on the relative and average relative solid content of 2—3-m pulpwood. Statistical models illustrating relative solid content were prepared from the results. In addition, the effect of some relative solid content factors, not examined in the study, was analysed on the basis of the literature in order to obtain as complete a picture as possible of the relative solid content problem of pulpwood piles.

Special attention was paid in the investigation method to sampling in which the following principles were observed. The target quota was fixed for different districts by three tree species (pine, spruce and broadleaved species, mostly pine) in ratio to the allowable cut (H u t t u n e n 1971, See Table 1). The piles to be measured were sought by two methods from map sheets for the different sub-areas drawn by lot (master map 1 : 20 000). Stumpage sale piles in the sub-area of the map sheet in question were listed and the piles to be measured were drawn by lot from among them. Delivery sale piles were collected by the so-called road method, i.e., the measurers moved along the road network shown on the map sheet according to the instructions given and measured any piles they encountered until the map sheet quota was completed. The above-mentioned division into two by sales method was made on the assumption that the relative solid contents in stumpage and delivery sales might differ. The target proportion of stumpage sale piles was $\frac{2}{3}$ in North and $\frac{1}{2}$ in South Finland.

The tasks of the measuring group included the following measurements and estimates:

— Noting general data (all information available on the pile without measurements)

— Measuring of the gross volume of the pile in two ways: by the Finnish measuring rule and by the so-called Swedish method (see Fig. 1)

— Estimation of the deduction of empty space (cf. H e i s k a n e n 1973 a)

— Visual estimation of the relative solid content to the nearest per cent unit

— Estimation of relative solid content factors (see Appendix 1)

— Estimation of the deduction for waste bolts (cf. H e i s k a n e n 1973 c)

— Measurement of solid volume by bolts and in the same connection additional determinations of sample bolts (cross-section middle diamter of each bolt in descending steps of 1 cm to eliminate the effect of thickenings, the crookedness of each bolt in three classes): 1. Straight or practically straight; 2. Slight sweep or crookedness; 3. Considerable sweep or crookedness. Every 10th bolt was a sample bolt for which the following measurements or estimates were made: butt and top diameter and middle diameter 5 cm from the bolt end, crookedness in descending classes of 1 cm, quality of delimbing in three classes: 1. No branch stubs; 2. Some short branch stubs (<1 cm in length); 3. Many short or fairly long branch stubs. The length of the sample bolt

was measured from above at the distance of cross-cuttings in descending classes of 1 cm.

The country was divided into five areas for the measuring (Figs. 2, 3 and 4). Each area had one liaison man and one or two measuring groups.

The factors affecting relative solid content are divided into factors caused by measuring, by pile qualities and by pulpwood properties.

Of the factors due to measuring, the differences between the solid content according to the official method and the Swedish method were small (Table 3). The Swedish measuring method gave more reliable results for pile types that are difficult to measure (Table 4). The results of the measuring group and the control measurer differed little; the control measurement gave a higher gross volume and thus a lower relative solid content than the measurement of the measuring groups (Table 5).

S t a c k i n g is one of the most important pile characteristics for relative solid content. The results give the following information concerning its importance.

Piles were distributed by method of stacking into manually stacked, mechanically well stacked and mechanically poorly stacked piles. The differences between manually stacked piles and mechanically well stacked piles were small and different for individual tree species. Mechanically poorly stacked piles were clearly the sparsest for all tree species. The mean relative solid content of all mechanically stacked piles was 0.6 per cent units smaller than that of manually stacked piles for pine, 2.4 for spruce and 0.1 for hardwoods piles. The smallness of the differences is due partly to the larger size of the timber in the mechanically than manually stacked piles, especially pine and broadleaved piles; the logs of the mechanically stacked piles were also better delimbed (Fig. 8).

The effect of the stacking class (Appendix 1) on the relative solid content was an average of 1.6 per cent units for coniferous piles, 1.4 for pine and 2.1 for spruce piles. The stacking class had no noteworthy effect on the relative solid content between classes 1 and 4 in broadleaved piles. The fifth class was distinctly sparser than the others. However, re-examination of the effect of stacking in different classes showed that the relative solid content increased also in broadleaved piles the poorer the stacking was estimated to be in the original pile (Figs. 9 and 10).

R e - s t a c k i n g increased the relative solid content on average. The re-stacked relative solid content of manually stacked piles was at the most 1.4 % greater and of mechanically stacked piles 2.9—6.2 % greater than the original relative solid content (Fig. 11).

The effect of f o r e i g n b o d i e s was estimated in three classes for only two of which sufficient material was obtained. The relative solid content of piles of class 2 was smaller for all tree species than the solid content of piles belonging to class 1 (Fig. 12).

The effect of s n o w a n d i c e was not established. This effect was elicited, however, in R i k k o n e n's (1972 a) material within the tripartite classification used.

It was not possible to establish fully the effect of p i l e s i z e, but it is very small according to the results and the literature.

The effect of the i n - p i l e t i m e, i.e. of the age of the pile, was very small according to the results obtained. However, the gross volume of the piles was measured several times and their relative solid content was found to have grown by a little over 1 % in 2—7 months.

The effect of the measuring site is reviewed on the basis of the study conducted by H e i s k a n e n and R i i k o n e n (1973).

The effect of the mode of sale on the relative solid content was manifest: almost 100 % of the delivery sale piles were manually stacked, whereas over 50 % of the stumpage sale piles were mechanically stacked.

The relative solid content of piles was obviously unaffected by the ownership group to which they belonged.

Nikkilä (1972 a) reported that the relative solid content of mechanically stacked piles was greater if they had pile foundations than if they had not. In contrast, the relative solid content was not affected by the use of end poles.

The timber properties which were paid the greatest attention were diameter, difference and deviation and mixture of diameters, and the proportion, crookedness and delimbing of butt logs.

The effect of diameter in the estimated classes was fairly small, only approx. 1 % per class. The measured diamter illustrated the variation of relative solid content better. Its effect was 2.5 per cent units/cm on average in the smallest diameter classes and no more than 0.5 units in the larger classes. Unlike some Swedish studies, this material did not reveal the point of culmination of the effect (Figs. 13 and 14).

The effect of the difference between diameters proved impossible to establish. Deviation of diameters, on the other hand, correlated strongly with relative solid content and even more strongly with diameter.

Mixture of bolts of different sizes, which was graded in three classes, did not affect the relative solid content at all for conifers. The solid content was greatest in the badly mixed piles of broadleaved species. The correlation was weak in all the cases.

The proportion of butt bolts correlated very weakly with the relative solid content. The classification was probably too crude. The true proportion of butts showed a fairly strong correlation with relative solid content except in pine piles. There was a fairly strong negative correlation between the proportion of butts and diameter and a positive correlation between the proportion of butts and crookedness (Figs. 15 and 16).

The crookedness of the bolts in a pile was graded by estimation into five classes and by measuring the crookedness in centimetres from the sample bolts. The tree species differed in their distribution into crookedness classes; class 4 was the commonest in broadleaved piles and class 2 in coniferous piles. The degree of crookedness and crookedness class were correlated, however; a certain class in the broadleaved piles displayed greater crookedness than in coniferous piles.

The effect of the crookedness class on relative solid content was very distinct within the classification used, over 1 per cent unit per class. The correlation between the measured crookedness and relative solid content was even stronger. A change of 1 cm in crookedness resulted in a change of over two per cent units in the relative soli dcontent (Figs. 17 and 18).

The quality of delimbing was graded by estimation into four classes and by estimating the so-called branchiness index from the quantity and length of branch stubs. The distribution of the piles into delimbing classes was roughly the same for all tree species. The correlation between the delimbing class and branchiness index was fairly strong, stronger for coniferous than for broadleaved piles.

The delimbing class explained the variation of relative solid content in coniferous piles fairly well. A change of one class caused a change of slightly over 1 % in the relative solid content. No corresponding correlation was observed in broadleaved piles (Fig. 19).

There was a somewhat stronger correlation between the branchiness index and relative solid content than between it and delimbing class. Its effect per index unit

was about 3 per cent units for coniferous piles and about 1.5 per cent units for broadleaved piles (Fig. 20).

According to the results, the relative solid content is considerably lower in broadleaved piles than in coniferous piles. The relative solid content of mixed piles also decreases, therefore, when the broadleaved mixture increases, as the Swedish investigation results show (Fig. 21).

Other factors influencing relative solid content are taper, barking and splitting (e.g. Nylinder 1972).

No differences were observed in the relative solid contents between the different parts of the country, but the deviation in the relative solid contents of each tree species was greater in North than in South Finland.

When models explaining the variation of relative solid content were developed it was found that application of the estimated relative solid content factors was difficult because of the diverging interpretations of the chiefs of the measuring groups. The factors giving the best and most useful model were the measured middle diameter of the bolts, measured crookedness of the bolts, the quality of stacking which emerges from the relative change in relative solid content after re-stacking, and the branchiness index which describes the quality of delimbing of the bolts.

Selective regression analysis was used in the calculation of the models. The coefficients of the three models formulated are tabulated below.

Total model 1)

factor	regression coefficient	standard error of coefficient	t-value	order of explanation
constant	93.936			
logarithm of mean diameter (cm)	10.724	0.838	12.80	3
crookedness, mm	— 0.232	0.017	—13.99	1
delimbing (branchiness index 1—3)	— 2.217	0.343	— 6.46	4
stacking [1]	— 0.438	0.031	—13.94	2
tree species coniferous- broadleaved (0-1)	— 2.271	0.600	— 3.79	5

Pine and spruce model 2)

factor	regression coefficient	standard error of coefficient	t-value	order of explanation
constant	102.279			
logarithm of mean diameter (cm)	7.135	1.113	6.41	3
crookedness, mm	— 0.251	0.032	— 7.77	2
delimbing (branchiness index 1—3)	— 2.534	0.412	— 6.15	4
stacking [1]	— 0.516	0.041	—12.44	1

Broadleavel moded 3)

factor	regression coefficient	standard error of coefficient	t-value	order of explanation
constant	91.178			
mean diameter, cm	1.125	0.099	12.44	2
crookedness, mm	— 0.230	0.018	—12.69	1
delimbing (branchiness index 1—3)	— 1.517	0.580	— 2.61	4
stacking [1]	— 0.354	0.045	— 7.86	3

[1]) Per cent of relative solid content measured after re-stacking of the pile in ratio to the original relative solid content.

Model 1 explains 44.0 of the variance in the relative solid content of pine, 65.2 % of that of spruce, 62.2 % of that of broadleaved (birch) and 79.3 % of that of all tree species. Models 2 and 3 explain 52.8 % of the variance in the relative solid content of coniferous, 65.9 % for broadleaved and 80.6 % for all tree species.

The models presented give good results on the whole. However, errors arise for natural reasons in the extreme areas, especially in models common to all tree species (Figs. 22, 23 and 24).

The variables appearing in the models are not easy to measure or estimate as such. They must therefore be substituted in practice by classified variables in e.g. the following way:

Used in the investigation	Suitable for practical use
Measured middle diameter	Estimated middle diameter
Measured crookedness	Estimated crookedness
Effect of re-stacking on relative solid content	Estimated class illustrative of stacking
Branchiness index	Class illustrative of quality of delimbing

This is achieved in practice by grading a measured property into the necessary number of classes on the basis of the observation distribution and by defining these classes also orally.

A method based on the material of the present study and devised as described above is already being tried experimentally (See Uudistuva . . .). The present results indicate that this practical experimental method takes good account of the variations in relative solid content. To succeed, the application of such a method based on estimation requires thorough training. There must be available a sufficiently good control method to settle differences of opinion and for control measurements. There is no control method today that involves little work and is easy to perform. But suitable for the purpose with certain limitations are unit measurement, face density measurement, xylometry, measuring by immersion in water, and various sampling methods.

Liite 1

Pinotiheyteen vaikuttavien tekijöiden arviointi

Keskiläpimitta arvioidaan viidessä (1—5) luokassa: 1. Hyvin pieni ≤ 9 cm, 2. Pieni 10—11 cm, 3. Normaali 12—13 cm, 4. Suuri 14—15 cm, 5. Hyvin suuri 16 + cm.

Suurimpien ja pienimpien pölkkyjen läpimittojen erotus arvioidaan kolmessa (1—3) luokassa: 1. Erotus ≤ 9 cm, 2. Erotus 10—16 cm, 3. Erotus ≥ 17 cm.

Eri kokoisten pölkkyjen sekoittuminen pinossa arvioidaan kolmessa luokassa (1—3): 1. Sekoittuminen hyvä, 2. Keskinkertainen, 3. Huono.

Tyvipölkkyjen osuus kiintomitasta arvioidaan kolmessa (1—3) luokassa 1. Tyvipölkkyjä alle 20 %, 2. Tyvipölkkyjä 20—39 %, 3. Tyvipölkkyjä yli 40 %.

Lehtipuun osuus kiintomitasta arvioidaan havupuupinoissa kolmessa (1—3) luokassa: 1. Sivupuulajia alle 20 %, 2. Sivupuulajia 20—39 %, 3. Sivupuulajia yli 40 %.

Mutkaisuus arvioidaan viidessä (1—5) luokassa: 1. Pölkyt erittäin suoria, 2. Pölkyt suoria, 3. Pölkyt suoruudeltaan keskinkertaisia, 4. Pölkyt mutkaisia, 5. Pölkyt erittäin mutkaisia.

Ladonta arvioidaan neljässä (1—4) luokassa: 1. Hyvä, 2. Keskinkertainen, 3. Huono, 4. Erittäin huono.

Vieraiden esineiden määrä (hakkuutähteet) arvioidaan kolmessa luokassa (1—3): 1. Ei esiinny, 2. Esiintyy jonkin verran, 3. Esiintyy paljon.

Lumen ja jään määrä arvioidaan myös kolmessa luokassa (1—3): 1. Ei esiinny, 2. Esiintyy jonkin verran, 3. Esiintyy paljon.

Appendix 1

Evaluation of factors affecting relative solid content

Mean diameter will be evaluated in five classes. 1. Very small ≤ 9 cm, 2. Small 10—11 cm, 3. Normal 12—13 cm, 4. Large 14—15 cm, 5. Very large 16+ cm.

Difference between largest and smallest diameter will be evaluated in three classes. 1. Difference ≤ 9 cm, 2. Difference 10—16 cm, 3. Difference ≥ 17 cm.

Admixture of different size of bolts will be evaluated in three classes. 1. Admixture good, 2. Admixture medium, 3. Admixture bad.

Butt proportion of solid volume will be evaluated in three classes. 1. < 20 %, 2. 20—40 %, 3. > 40 %.

Broadleaved mixture proportion in conifer piles will be evaluated in three classes. 1. < 20 %, 2. 20—39 %, 3. > 40 %.

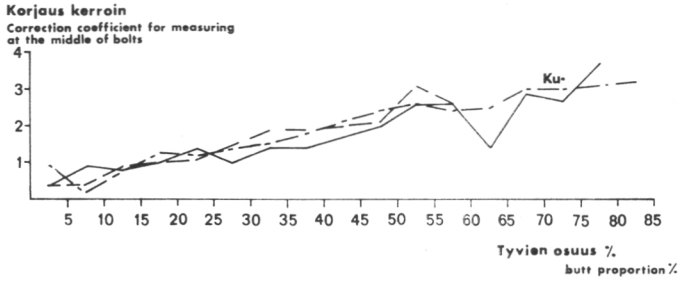
Crookedness will be evaluated in five classes. 1. Bolts extremely straight, 2. Bolts straight, 3. Medium class, 4. Crooked bolts, 5. Very crooked bolts.

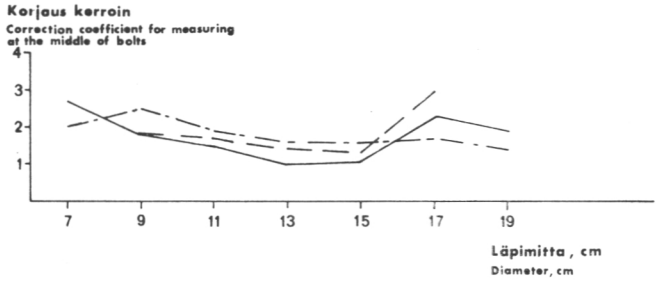
Stacking will be evaluated in five classes. 1. Good, 2. Medium, 3. Bad, 4. Very bad.

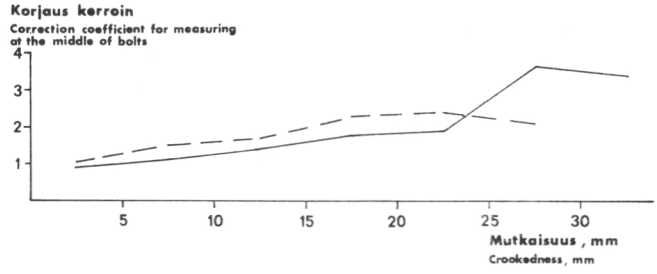
Appearing of foreign bodies will be evaluated in three classes. 1. No foreign bodies, 2. A little foreign bodies, 3. Much foreign bodies.

Appearing of snow and ice will be evaluated in three classes. 1. No snow and ice, 2. A little snow and ice, 3. Much snow and ice.

Liite 2
Appendix 2







Liite 3
Appendix 3

Pinotiheydet, hajonnat ja havaintomäärät mutkaisuus-, ladonta-, karsinta- ja keskiläpimittaluokissa

Relative solid content, its standard deviation and number of piles by some classifications

	Mutkaisuusluokat — *Crookedness class*									
	1.		2.		3.		4.		5.	
Mänty — *Pine*	3	69.5 4.2	92	65.8 6.0	53	64.3 6.6	4	62.6 4.9		
Kuusi — *Spruce*	10	67.7 6.1	94	66.1 6.1	16	64.1 5.4	1	65.5 —	1	61.9 —
Lehtipuu — *Broad-leaved*			2	60.6 4.6	44	57.8 8.4	112	56.7 7.2	31	53.4 6.5
	Ladontaluokat — *Stacking class*									
Mänty — *Pine*	4	70.6 3.8	86	65.4 6.5	45	65.7 5.4	16	62.2 4.6	1	58.2 —
Kuusi — *Spruce*	8	69.6 4.1	74	66.6 5.4	31	64.6 6.2	8	62.5 7.2	1	59.6 —
Lehtipuu — *Broad-leaved*	2	56.6 8.9	83	56.8 8.3	60	56.6 7.6	32	56.3 7.0	12	54.1 7.0
	Karsintaluokat — *Delimbing class*									
Mänty — *Pine*	2	69.7 1.6	54	67.0 5.6	84	64.5 6.1	12	61.8 6.1		
Kuusi — *Spruce*	2	69.4 6.8	48	65.5 7.2	64	66.6 4.9	8	62.3 4.9		
Lehtipuu — *Broad-leaved*	2	57.0 9.7	73	56.9 7.5	112	56.2 4.5	2	59.5 6.6		
	Keskiläpimittaluokat — *Mean diameter class*									
Mänty — *Pine*	14	64.5 4.8	50	65.0 6.4	51	65.2 6.1	24	65.0 7.1	13	67.7 6.6
Kuusi — *Spruce*	13	66.1 5.6	41	65.4 6.0	42	65.6 6.3	16	66.9 6.0	10	67.6 6.1
Lehtipuu — *Broad-leaved*	21	54.3 6.6	61	55.8 7.1	65	56.4 7.8	33	58.0 6.2	9	61.3 11.2

Liite 4
Appendix 4

Arvioitujen ja mitattujen tekijöiden vertailu alueittain
Comparison between estimated and measured factors

Havupuu — *Conifer*

Alue *Area*	Pinoja, kpl *Piles, pcs*	Läpimitta — *Diameter*				Karsinta — *Delimbing*			
		luokka *class*		todellinen *real*		luokka *class*		oksaisuusindeksi *index*	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1	68	2.6	1.0	11.4	1.9	2.8	0.5	2.4	0.3
2	46	2.2	0.9	11.1	1.6	2.8	0.5	2.3	0.4
3	49	2.9	1.0	11.4	1.8	2.9	0.7	2.4	0.4
4	68	3.0	1.1	11.6	1.6	2.1	0.5	1.8	0.3
5	43	3.2	1.2	13.1	2.1	3.0	0.5	2.2	0.4
		Ladonta — *Stacking* [1]				Mutkaisuus — *Crookedness*			
		luokka *class*				luokka *class*		todellinen *real*	
1		2.3	0.5	102.4	5.0	2.1	0.3	1.24	0.4
2		2.3	0.8	102.5	3.5	2.2	0.6	1.24	0.4
3		2.5	0.8	101.1	3.1	2.2	0.4	1.35	0.6
4		2.4	0.8	102.7	4.3	2.0	0.6	0.90	0.6
5		2.8	0.9	100.8	3.7	3.0	0.5	1.27	0.5
		Tyvien osuus — *Butt proportion*							
1		1.9	0.4	31.9	15.5				
2		1.9	0.6	32.4	16.0				
3		1.9	0.8	29.5	14.3				
4		1.9	0.5	35.0	14.5				
5		1.7	0.5	31.2	12.0				

Lehtipuu — *Broadleaved*

Alue *Area*	Pinoja, kpl *Piles, pcs*	Läpimitta — *Diameter*				Karsinta — *Delimbing*			
		luokka *class*		todellinen *real*		luokka *class*		oksaisuusindeksi *index*	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1	24	2.5	1.2	10.9	1.7	2.5	0.5	2.1	0.3
2	40	2.4	1.0	11.3	1.9	2.6	0.6	2.1	0.3
3	40	2.8	0.8	11.7	2.3	2.8	0.4	2.2	0.3
4	33	2.9	0.8	11.3	1.1	2.0	0.4	1.6	0.2
5	52	2.9	1.2	12.4	2.1	2.9	0.4	2.0	0.3
		Ladonta — *Stacking* [1]				Mutkaisuus — *Crookedness*			
		luokka *class*				luokka *class*		todellinen *real*	
1		2.8	0.9	103.6	6.2	3.5	0.5	3.95	0.9
2		2.9	1.0	103.2	4.0	4.0	0.6	4.08	1.1
3		2.7	0.8	101.9	3.4	3.6	0.5	4.28	0.7
4		2.5	0.7	102.4	4.0	3.8	0.7	4.12	1.0
5		3.1	1.1	100.0	3.7	4.4	0.6	4.79	1.3
		Tyvien osuus — *Butt proportion*							
1		2.1	0.4	40.8	9.2				
2		2.0	0.5	34.2	13.6				
3		2.0	0.6	30.8	13.6				
4		2.0	0.3	43.4	8.9				
5		2.0	0.2	49.6	12.8				

[1]) Uudelleen ladotun pinon tiheys prosenttia alkuperäisestä tiheydestä. — *Relative solid content after re-stacking/in per cent of the initial solid content.*

STRUCTURAL CHANGE OF PRIVATE FOREST OWNERSHIP IN FINLAND

AARNE REUNALA

Seloste

YKSITYISMETSÄNOMISTUKSEN RAKENNEMUUTOS

HELSINKI 1974

ISBN 951-40-0139-7

Helsinki 1974. Valtion painatuskeskus

FOREWORD

This study was begun at the end of 1969 with the encouragement of my teachers Päiviö Riihinen and Lauri Heikinheimo, and the five years taken to complete it have proved very stimulating and, also, very difficult.

It is impossible to name all the people who have given their assistance and support through this project, but I cannot avoid mentioning the wonderful personnel of the Department of Forest Economics in the Finnish Forest Research Institute, being in addition to Lauri Heikinheimo, Matti Heikinheimo, Vuokko Heikkilä, Veli-Pekka Järveläinen, Anita Korvenranta, Maija Kuusijärvi, Matti Palo, Rakel Seppälä, Risto Seppälä, Nora Sepulveda, Brita Sjöstrand, Maija-Liisa Soveri, Ilpo Tikkanen, Hannu Vehviläinen and Kaija Westin, who all helped me in various phases of the study. All the others in the department have also given their share to the creation of the warm and stimulating atmosphere, which has been an essential aid to my work.

Several others have also been kind and helpful. Aake Kuntonen and Väinö Rantonen conducted the interviews, André-Clément Decouflé, Kauko Hahtola, Kullervo Kuusela, N. A. Osara and Leo Törnqvist, in addition to some others already mentioned, read the preliminary manuscript and made me really think over this study once again.

During the busy nights of the final formulation and correcting of the study I thought with gratitude those persons, who made the rapid completing possible: Lauri Heikinheimo, Matti Palo, Risto Seppälä and Leo Törnqvist who checked the manuscript without any delay, Ashley Selby who checked the English text at very short notice, and Raija-Riitta Enroth and Marja Nikkanen, who gave the very necessary practical aid.

I remember many other people with affection and to them also I express my sincere gratitude.

Economically I have been in a lucky position: the Academy of Finland has paid my salary since May 1970, and I have received scholarships from the Foundation for Research in Natural Resources in Finland, the Finnish Cultural Foundation, the Niemi Foundation and the Society of Forestry in Finland. I warmly thank these institutions for their support.

Helsinki, November 1974

Aarne Reunala

CONTENTS

Page

Foreword 3

0. Summary 7

1. Introduction 10
   11. Importance of private forestry 10
   12. Development of private forest ownership in Finland 14

2. Problem 17

3. Private forest ownership structure in the Province of Keski-Suomi in 1945—1970 22
   31. Research method 22
   32. Private forest ownership structure in Keski-Suomi in 1970 24
   33. Structural change in 1945—1970 26
      331. Result of change 26
      332. Mechanism of change 30
      333. Private forest ownership change as an open system 33

4. Future private forest ownership structure 37
   41. How to get information about the future 37
      411. General remarks 37
      412. Forecasting 38
      413. Planning 40
      414. Prospective approach 42
   42. Choice of method 44
   43. Prospect for private forest ownership change in 1970—2000 47
      431. Forest ownership of farmers 47
         4311. Heavy tendencies in agriculture 47
         4312. Prospect for decrease of farmers' forest land area 51
      432. Prospect for increase of State and forest industry company forests 53
      433. Prospect for increase of non-farmers' forest land area 55
      434. Prospect for private forest ownership structure in 1980 and 2000 .. 57

5. Discussion 58

References 63

Seloste 68

Appendix 71

0. SUMMARY

Productive forest land covers 61 % of Finland's total land area. The main forest owner groups are private forest owners, the State and forest industry companies. Private forest owners (individual persons, heirs and family companies) form the largest group, they owned 12.2 million hectares of forest land in 1964—70, or 65 % of the total forest land area. Their share of the growing stock was 71 % and of the annual increment 78 %. Some 350 000 private forest owners held at least 2 hectares of forest land in 1969.

A forestry objective, although never explicitely stated by any authority, has since the beginning of 1960s been that of increasing the intensity of timber production. This objective is especially difficult to achieve in private forests with 350 000 individual decision-makers. Several laws and an organization of Forestry Boards exist, silvicultural and forest improvement programmes have been made in order that private forest-owners may approach this objective. In the late 1960s first signs of a new difficulty were observed: an increasing part of the private forest holdings, traditionally owned by farmers, was observed to be owned by *non-farmer forest owners*, with the main part of their living coming from other professions than farming; and who, according to a number of observations, were less interested in intensive timber production or timber sales than farmers.

The *aim of this study* was to acquire relevant information for forest policy concerning private forest ownership structure. Three different tasks were derived from this aim:

— to acquire information about the number of non-farmer forest owners and forest land area in their ownership in 1970,
— to describe and analyze the past change in private forest ownership structure, and
— to find out information about future private forest ownership structure relevant to forest policy decisions.

Data for the two first tasks were obtained by interviewing private forest owners in the province of Keski-Suomi. The sample contained 510 private forest holdings (over 10 hectares of forest land); a questionnaire was pre-

pared, and owners were interviewed by two experienced interviewers between October 1970 and January 1971. According to this sample non-farmers owned 24 % of private forest holdings (over 10 ha) and 20 % of the private forest land area. With additional information from other studies it was estimated that *in Keski-Suomi 30 % of the number of all private forest holdings and 20 % of the total private forest land area belonged to non-farmers in 1970.*

From 1945 to 1970 the *forest land area of non-farmers in Keski-Suomi increased from 8 % to 20 %* of the total private forest land area. Inheritance or purchase from parents or relatives was as the mechanism for 57 % of this increase, purchase on the free market accounted for 20 %, farmer's change of occupation for 18 % and settlement activities for the remaining 5 %. When original reason for forest ownership change in the case of farmer's change of occupation was inheritance, a conclusion was made that *inheritance was as channel for 75 % of the increase of non-farmers' forest land area.*

A systems approach was used to analyze the change in more detail. The *private forest ownership system* was shown to have changed mainly because of the urbanization process in society. The changing behaviour of forest owners was as an output of the system. From the viewpoint of forest policy, only the output of the system can be regarded as dominable (which can be affected by forest policy measures), whereas inputs to the system and inner structure of the system are dominant for forest policy but dominable for general societal policy.

Whilst the two first tasks of the study deal mainly with problems of measurement and description, the third part deals with problems of methodology. There are three different approaches towards information concerning the future: forecasting, prospect and planning. *Forecasting* is generally understood as continuing the underlying process (trend) to the future, *prospect* means the description of the horizon for a plan (or for a decision), and *planning* means above all activity concerned with dominable phenomena.

Theoretically all these concepts are deficient, no definite boundaries between forecasting, planning and prospects exist. Prospective approach was chosen for this study for two reasons: It was hoped to avoid the mere idea of continuing the underlying process (in forecasting) and the term planning was considered to be unsuitable because forest ownership system is mostly dominant for forest policy. Typical to the prospective approach and normative planning is the consideration of values and norms. How these considerations should be made, is, however, unclear.

A prospect for private forest ownership structure in 1980 and 2000 was made in several steps. First, the decrease of farmers' forest area was appraised on the basis of agricultural forecasts made. Secondly, the amount of the area left over by farmers to be bought by the State and forest industry companies was appraised. Thirdly, the remaining forest land area was divided

between inheritance and purchases of non-farmers and purchases of farmers, and finally all these estimates were aggregated together. *According to this prospect non-farmers' share of private forest lands will be in 1980 34 % and in 2000 44 %*. The total private forest land area will decrease from 12.2 million hectares in 1970 to 11.4 million hectares in 2000.

It must be stressed that this prospect is by no means a prophecy of what will really happen in the future. Development in agriculture and in the agricultural population structure was taken as a heavy tendency, but questions were raised about its possible or desirable change in the future. The increase of State and forest industry forests in the future depends on considerations concerning the right to forest ownership. The increase of non-farmers' forests depends mainly on the question of the right of inheritance. Thus around the numerical estimates made there is a region of uncertainty that cannot be accurately estimated.

The value of the prospect for forest policy seems useful from two viewpoints: first a heavy tendency seems to exist in the 1970s and, although not so strongly, for the 1980s and beyond, according to which non-farmers' share of private forest land area increases continuously. Secondly, consideration of values and norms in connection with making the prospect is supposed to give valuable aid for forest policy decision-makers.

Another approach to the problem in question might have been to treat forest ownership structure, not on the level of forest policy, but on the level of general societal policy, to which private forest ownership system is dominable. By defining the »best» forest ownership structure, considering the possibilities of changing present ownership structure towards the »best» one, a plan might have been made to achieve the »best» structure. However, private forest ownership change can still be considered of minor significance compared with general societal policy, thus the choice of prospective approach seems justified.

1. INTRODUCTION

11. Importance of private forestry

Finland is a country of forests. *Forest land* comprises of 61 % of the total land area of Finland (K u u s e l a 1972, p. 12). Forest land is defined as land used for timber growing, where the annual average growth, under the most favourable conditions and with a rotation time of 100 years, is at least 1 m^3/ha (with bark); on *poorly productive forest land* the increment is 0.9—0.1 m^3/ha (K u u s e l a 1972, p. 9). By *forest* we generally understand an area growing trees outside habited areas (M a k k o n e n 1974, p. 11). Typical of Finland is the small number of tree species: three main species (pine, spruce and birch) are dominant on 95 % of forest land area (K u u s e la 1972, p. 23).

Forests have been important for the Finnish population throughout the history. In old times main services of forests were game, fuelwood and timber for construction purposes. Fields were made out of the best forest lands, and forests were burnt for the purpose of shifting cultivation. Forests have as well served as Finland's main natural resource for industrial use: since the 17th century for making tar, later for making charcoal, since the beginning of the 19th century for sawn timber and in the 20th century for the rapid expansion of mechanical and chemical forest industries (H e l a n d e r 1949). The role of forests as an important part of the ecosystem must not either be forgotten.

A typical feature of the Finnish forestry is as well the large private forest ownership. By *private forest owners* we mean individual persons, heirs or family companies. In 1964—70 private forest owners owned 12.2 million hectares of forest land which is 65.5 % of the total forest land area. Other forest owner groups in Finland are the State (23.6 % of the forest land area), companies (7.4 %), which comprise mainly of forest industry companies, *communes* and *church* (1.9 %) and *corporations* (1.8 %) by which is meant foundations, cooperatives, other enterprises than companies and farms, and other corporations (K u u s e l a 1972, p. 10—16). Forest ownership and its development in Finland is treated more closely in the next section. Here

it is sufficient to mention that there are several owner groups the largest of which is private owners. This special situation explains many of the characteristics of the Finnish forestry and forest policy in the 20th century.

When Finland entered the 20th century its forests were largely in poor silvicultural condition [1]). The cutting method mainly used had been selective cutting, the largest trees had been cut to be used by the sawmills, and trees of poor quality or of small dimension were left in the forest. No measures to regenerate forest were used. The value of »good» forest was, however, understood as early as in the 16th century, when burning forests for the purpose of shifting cultivation was restricted. In a Decree of 1647 it was ordered that peasants were only allowed to use timber in their farms, not to sell it. The concept of »good» forest grew more apparent in the 19th century when devastation of forests occured in large areas and fear for ending of timber became more general. A Forestry Decree was set up in 1851 to restrict the sawmilling of timber, but with new technology in the woodworking industries, timber cutting increased continuously. Committees were set up to study the aims and means of forest policy, and the *1886 Forestry Law* was enacted to prevent the devastation of forests. This Law was an important step in the Finnish forestry: it was clearly stated that forests were Finland's main natural resource and care had to be taken to maintain them in good condition. This principle came into practice very slowly, however, because of deficiencies in the institutional setting. It was not an easy task to create an organisation capable of giving advice and orders to the large number of private owners.

An administrational organisation of Provincial Forestry Boards was created according to the *1917 Forestry Decree*. After the university level education of foresters had begun in the latter half of the 19th century, forestry experts became available for the purpose of promoting private forestry. By *promotion of private forestry* we understand, in Finland, activities to give private forest owners information and guidance of good silviculture, and technical and economical aid to practice good forestry. The Provincial Forestry Boards were not, however, considered efficient enough in the radically changing rural population structure. The number of independent private forest owners increased by 170 000 during the period 1901 to 1929, in consequence of an effort to decrease the grave social problems in the rural areas of Finland. The large increase of individual decision-makers in forestry was considered to threaten the progress so far achieved. Thus a new *Law Concerning Private Forests* was passed in 1928. In this Law, a new promotional organisation was created with District Forestry Boards and two Central Forestry Boards, one for the Finnish speaking districts and the other

[1]) In this brief historical presentation I follow Helander (1949).

for the Swedish speaking districts. The organisation, as well as the main drinciples of the Law Concerning Private Forests, still hold in the Finnish forestry. The main tasks of this promotional organisation were to prevent forest devastation, to promote the use of better cutting methods and to ensure the reforestation of cutting areas. In this context it is worth mentioning that the *national forest inventories* began in Finland during the 1920s thus giving useful information for forest policy makers, and especially for the promotion of private forestry.

Since the latter half of the 1950s the problem-setting of forest policy got a new dimension. After World War II the strong growth of forest industries continued and timber removals occasionally exceeded the allowable cut (H u t t u n e n 1974, p. 15). Exports of wood-based products had been, at the beginning of the 20th century, about 70 % of total exports. The proportion reached its peak of 90 % just after World War II, but since then, notwithstanding the remarkable growth of forest industries, the percentage has been declining and was in 1960 somewhat under 60 %, and in 1970 about 55 % (Suomen kansantalouden . . . 1972, K u u s e l a 1974, p. 30). In spite of the declining relative importance of forest industries to the Finnish national economy, the need to try to increase its capacity was continuously felt. Forests were Finland's most important natural resource, and when the Timber Trends Studies (FAO 1953, 1964) forecasted growing demand for wood-based products, a proposal for *dynamic forest policy* made in the first Timber Trends Study (FAO 1953, p. 306) was accepted in Finland. Dynamic forest policy meant man's active participation in forestry aiming at the intensification of timber production.

The views in forest policy changed from that of a guardian to that of a promoter. Several committees in the 1960s sought possibilities for a more intensive forestry. Practical steps were taken after a proposal for the financing of the increasing forest improvement works was made in the MERA-programme in 1964. Although the *objectives of forestry* have never been explicitely stated by any State or governmental authority, the idea of increasing timber production by more intensive forest improvement and silvicultural activities seems to have been generally accepted. This is shown for example by the fact that the MERA-programmes were revised and improved in 1966 and 1969.

Finnish forestry programmes of the 1960s are discussed by H e i k i n h e i m o and P a l o (1972). The main part of forest improvement work has been carried out in private forests, a natural consequence of the forest ownership distribution. Table 1.1. shows forest improvement work in private forests in 1950, 1960 and 1970. A remarkable increase has occurred in all activities except seeding.

Table 1.1. Forest improvement work made by District Forestry Boards, Forest Management Associations and Forest Improvement Districts in 1950, 1960 and 1970 in Finland. Source: Tapion vuosikirja 1971, p. 122

Year	Seeding and planting			Care of seedling stands	Forest fertilization	Forest drainage	Construction of forest roads, km
	Seeding	Planting	Total				
	1 000 hectares						
1950	16.3	3.5	19.8	25.0	—	7.2	7
1960	12.3	18.7	31.0	52.6	—	79.8	354
1970	15.1	74.2	89.3	92.0	73.9	204.3	2 136

The number of private forest owners having at least 2 hectares of forest land was 352 000 in 1969. The average size of forest holdings belonging to one owner was about 35 hectares (SVT III: 68, 1971). *Forest holding* here means one woodlot or several woodlots belonging to the same owner and in the same commune, the combined area of which (the area of forest land and poorly productive forest land) is a minimum of two hectares (SVT XVII A : 5, 1974, p. 79). Private forests are generally situated in the southern part of Finland on best soils and in the best climate conditions. Some other facts stress the importance of private forests: private forests cover 65 % of total forest land area, their share of the *growing stock* in 1964—1970 was 71 % and of the annual *increment* of the growing stock it was 78 % (K u u s e l a 1972, p. 42, 58).

Most private forest holdings have traditionally belonged to farmers. By *farmer* we mean usually a person who cultivates arable land and has economic and legal responsibility of the farm (L ö n n s t e d t 1974). Normally a farmer owns his farm, but he may have rented all or part of the land that he cultivates. For the purpose of this study still one addition has to be made: in this study a farmer is supposed to get the main part of his living from farming (forest incomes included), thus so-called *part-time farmers* who get their main living from other occupations are not considered as farmers. In 1969, of the 352 000 private forest owners 279 000 owned at least 2 hectares of arable land. The average size of a private farm in 1959 was 9 hectares of arable land and 30 hectares of forest land (productive and poorly productive) (SVT III: 53, 1962; SVT III: 68, 1971). Forests have in Finland been always considered as a necessity for a farm because agriculture only very seldom can give a sufficient level of income to a farmer and his family. Only with exceptionally large areas of arable land a family could manage without forests, but the scattered structure of Finnish soils and the social structure of the rural population have in most cases prevented the establishing of such farms.

The importance of forests to farmers' private economies has been considerable. From their own forest they have been able to get *fuelwood* and *construction wood* needed on the farm. They have been able to *sell timber* and get *labour income* by working in the forest. In 1965 about 20 % of labour income from their own estate came from forest work (I h a m u o t i l a 1968, p. 105). According to the sample of J ä r v e l ä i n e n (1974) farmers got in 1971 28 % of the total net income of their estate from the forest.

12. Development of private forest ownership in Finland

Private forest ownership has long roots in Finland. In the 16th and 17th centuries the kings declared that forests, not then belonging to private persons, were the property of the Crown. In a Forest Decree of 1734 it was ordered that borderlines were to be made between private and State forests. The official demarcation of lands began in the 1770s and it has been continued up to the present time (H e l a n d e r 1949).

It is possible to give only a rough idea of forest ownership structure for times before the first Agricultural Census (1929) and the first national forest inventory (1921—1924). One remarkable change in the private forest ownership can be observed. At the end of the 19th century over 80 % of the population getting its living from agriculture were farmless (H e l a n d e r 1949, p. 285), peasants, who cultivated little fields and had to pay rent to the landowner, or agricultural workers. In some cases the relationship between peasant and landowner was good and continued without difficulties from one generation to another, but generally the large number of landless rural population caused severe social problems. A land reform was carried out, and O s a r a (1935, p. 24—26) estimated that the number of new, independent farms increased by 170 000 from 1901 to 1929. Newly established farms were small, their average forest area was only 11 hectares.

Detailed numerical data on forest ownership exist only for the 20th century. According to the *national forest inventories* the ownership of forest land has developed as shown in Figure 1.1. In 1920 private forest owners owned 55 % of forest land area, in 1970 (1964—70) their share had increased to 65 %. The main reduction occurred in the area of State owned forests. This change is mainly explained by *settlement* activities after World War II, when 400 000 refugees from Karelia had to be given a livelihood. By a special law (Maanhankintalaki 1945) about 2.2 million hectares of forest land were acquired for them, mainly from State owned lands, but some also from forest company lands and from large private farms (V e n n a m o 1968, p. 272).

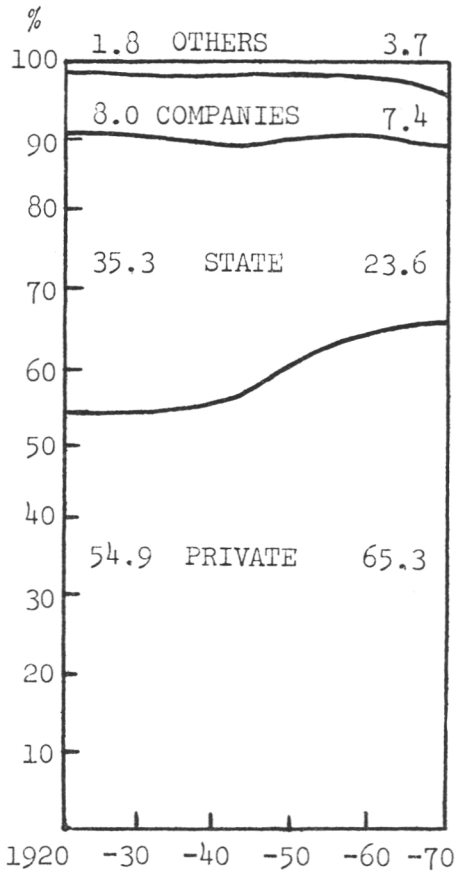


Figure 1.1. Ownership of forest land in 1920—1970 by forest owner groups. Source: Kuusela 1972, p. 91.

Forest inventories give no estimate on the number of private forest owners. According to the *Agricultural Censuses* (SVT 45.3, 1954; III: 55, 1962; III: 66 & 68, 1969) *the number of farms* owning some forest land has developed as follows (figures are rounded):

Year	Number of farms with forest
1929	238 000
1950	315 000
1959	337 000
1969	279 000

Farms included in the 1969 statistics had to have at least one hectare of arable land and two hectares of forest land (productive and poorly produc-

tive). In previous censuses the minimum size of the farm varied and may not even have been stated clearly. However, it may be concluded that the number of farms with forest increased from 1929 to 1959 by about 100 000, since that the number of farms has begun to decrease.

The total number of private forest holdings (with a minimum of 2 ha of productive and poorly productive forest land) was in 1959 and 1969 361 000 and 352 000 respectively (SVT III: 55, 1962; III: 68, 1969). During this 10-year period the decrease in the number of forest holdings was about 10 000, at the same time the decrease in the number of private farms with forest, as was seen above, was about 60 000. This difference reflects the main theme of this study, the structural change of private forest ownership.

Developments in private forest ownership reflect the general ideas governing society. In the latter half of the 19th century the first ideas of *liberalism* came to Finland, and the benefits of this ideology were soon reflected in the rapid development of industry, trade and culture (W a r i s 1968, p. 12). Liberalism stresses the defects that State or any other authority may cause to society when giving too strict orders. Free human will is considered as the main factor of development. From this background it is easy to understand that at the beginning of the 20th century, when the rural problems had to be solved, a solution was seen in private forest ownership and increasing the number of private owners. Other solutions, such as common forests or forest cooperatives, were not considered, except as theoretical constructions. S a a r i (1928 p. 15), for example, came to the conclusion that from the viewpoint of efficient forestry small private forest ownership was the most unfavourable type of ownership. Such opinions were, however, regarded as theoretical and impractical.

It may not be wrong to say that since the beginning of the 20th century this *commitment to private forest ownership* has governed in Finnish society. This was seen during the settlement activities after World War II, but even more clearly in the new Law Concerning Land Use (Suomen Asetuskokoelma 1958, n:o 353, Maankäyttölaki). According to this Law 850 000 hectares of forest land of the State was still transferred to private ownership in 1959—1969 (H o l o p a i n e n 1971), although the continuing decreasing of the agricultural population was clearly seen.

Commitment to private forest ownership has not, however, been complete. It was already mentioned that the State, forest industry companies and other owner groups have always owned a considerable part of Finland's forests. Their share of the forest area has been declining during this century but, along with the rapid change of society, there are the first signs of reverse development: the National Board of Forestry (the State) began to buy forests in 1969 and has ever since been buying about 20 000 hectares of private forests annually (R e u n a l a 1974).

2. PROBLEM

The increase in the capacity of Finnish forest industries during the past twenty years has been rapid. In 1955 the consumption of industrial wood was 27 million m^3 including bark, in 1973 it reached 50 million m^3 (H u t t u n e n 1974, p. 25). This remarkable increase, a principal factor in the growth of the Finnish national economy (for example K u u s e l a 1974, p. 25—37) has been possible because of major changes in the composition of total drain (decreasing fuelwood consumption and roundwood exports), increasing use of roundwood residues, increasing roundwood imports and increasing allowable cut. The increase of annual allowable cut was about 4 million m^3 from 1960 to 1973 (H u t t u n e n 1974, p. 44), and it is explained by more intensive forest improvement and silviculture practiced according to MERA-programmes.

The annual increment of Finland's forests is actually 47 million m^3 without bark (about 55 million m^3 including bark, according to H u t t u n e n 1974, p. 15). With improved silviculture, more intensive forest improvement and more intensive land-use the theoretical maximum increment that can be achieved in a period of 80 years is 88 million m^3. Although in practice it may not be reasonable to strive towards this maximum, substancial advantages to the national economy can be achieved by more intensive forestry (K u u s e l a 1974, p. 74).

The intensification of forestry is not a simple task because of the existence of the large number of private forest owners, who act as *independent decision-makers* concerning forestry in their forest holding. It is evident that these 350 000 decision-makers have a variety of *different objectives* they try to strive for, and quite often their objectives and general objectives of forestry do not fit together. Practicing »good» forestry may be said to have been a general objective in Finland during this century although the contents of »good» forestry has never been clearly defined. This general objective has been approached mainly in a negative, restrictive way: in the Law Concerning Private Forests (1928, 1 §) it was stated that »forest may not be devastated», and the same statement still exists in the renewed Law Concerning Private Forests (Suomen Asetuskokoelma 1967 no. 412). The new Law Con-

cerning Forest Administration (Suomen Asetuskokoelma 1966 no. 465) reflects, however a change towards positive definition of »good» forestry stating that (1 §) »efforts must be made to handle the forests in such a way that economically favourable and growing yield of timber will be permanently ensured and the land's production capacity utilized as well as possible». The creation of the promotional system of Forestry Boards can also be regarded as an attempt to reduce the contradictions between the general objectives and the individual objectives.

During this century attempts to reduce these contradictions have been successful, the silvicultural quality of forests has been continuously improving (for example K u u s e l a 1972, p. 89). All contradictions have not, however, been eliminated, it is, for example, estimated that 19 % of the forest lands are still low-yielding (K u u s e l a 1972, p. 78). In this rapidly changing world it cannot even be expected that all contradictions could be abolished. Objectives of society and objectives of private persons are changing, thus a continuous need exists to regulate changes in a way that objectives adequately fit together.

A remarkable change in forestry objectives has occurred in recent years: besides the objective of more intensive timber production, environmental and ecological aspects are given increasing weight. P a l o (1974, p. 6) defines forest system as »one which is concerned with making, distributing and consuming the goods and services of the forest». By goods and services are understood all the benefits, not only economic, of forests to mankind. It is, however, stressed that environmental and ecological objectives are not necessarily in contradiction with the objective of more intensive timber production (K u u s e l a 1974, p. 104—120).

Differences in private forest owners' objectives have been clearly noticed in several studies regarding the attitudes and behaviour of forest owners (for example R i i h i n e n 1963, H a h t o l a 1967 a, 1967 b, R i i h i n e n 1970, H a h t o l a 1971 a, 1971 b, J ä r v e l ä i n e n 1971, 1974, V i r t a 1971, S e p p ä l ä 1974). Economic and social environment, individual farm backgrounds, regional conditions and individual factors have been shown to have influence on forest owners' silvicultural behaviour. The purpose of these studies has been to find better tools to enable forest policy to solve the problem of different objectives.

The rapid change of society has brought a new dimension to this problem. The change from agricultural to industrial society has been exceptionally fast in Finland, according to J u t i k k a l a (1968, p. 218—219) it was more rapid in the 1940's than in the history of any other European country. In 1900 12 % of the Finnish population lived in towns, in 1973 the figure was 57 %. The share of population in the primary industries (agriculture

and forestry) was in 1900 about three-quarters, in 1970 about one-fifth (Lento 1951, p. 49, Raivio 1960, p. 35, Suomen ... 1973, p. 47). This radical change in the structure of the population is reflected in the structure of private forest ownership. Traditionally, nearly all private forest owners have been farmers, but in the late 1960s it was remarked that an increasing amount of forests belonged to persons of other professions and who often lived in towns. In the following the term *non-farmer forest owners* (or simply non-farmers) is used for those private forest owners, who earn the main part of their living from occupations other than farming. Not only the existence of the new owner group was noticed but special concern was given to some observations that their *silvicultural attitudes* might be unfavourable for the general objective of more intensive forestry (for example Helsingin Sanomat 13. 2. 1970, 6. 6. 1970, Heikkerö 1970, Kähönen 1970, Holopainen 1971). It was observed that some non-farmers were not interested in timber growing but in recreation, and some others in speculative cutting even against the rules of the Law Concerning Private Forests. The increasing number of non-farmers was seen as a threat to more intensive forestry.

The private forest owner is the decision-maker concerning the intensity of his forestry, but in recent years his behaviour has become significant in another matter also: in *timber-selling*. With new technology in timber harvesting and transporting, the forest system is much more sensitive to fluctuations in timber-sales than before, and these fluctuations can cause considerable damage to forest industry, forest machine and transport contractors and forest workers.

In a study made by Hahtola et al. (1973) the hypothesis concerning non-farmers' unfavourable attitudes and behaviour (compared to farmers) was partially verified. Non-farmers were observed to cut less than the allowable cut thus giving rise to timber savings. Non-farmers were also observed to sell timber less regularly than farmers. In contrast with these negative statements is non-farmers' active use of the professional aid, which seems to be bigger than that of farmers (Järveläinen 1974, Reunala and Tikkanen 1972). As a conclusion of these observations it can be stated that *the existence of non-farmers brings up new difficulties to the achievement of forestry objectives.*

The practical importance of these observations depends on two things: how unfavourable the attitudes and behaviour of non-farmers really are, and what is the number of non-farmers and the area of forest land in their ownership. When considering forestry objectives, it is important to notice that they are situated somewhere in the future, thus their realisation depends not only on the *present* but mainly on the *future* behaviour and number of non-farmers.

The purpose of forest policy is to strive for forestry objectives. Thus information about the present forest ownership structure but also some information about the future is needed in order to carry out efficient forest policy.

The aim of this study is to acquire relevant information for forest policy concerning private forest ownership structure. The first task derived from this aim is

— *to acquire information about the present number of non-farmer forest owners and forest land area in their ownership.*

The concept of present causes here a problem typical to all research of changing phenomena: the present is disappearing all the time into the past and so the research results inevitably lag behind the actual present. In order to avoid confusion, present is here understood to mean the year 1970.

The second task might be stated as the need to forecast change in private forest ownership structure. A *forecast* is defined as »a quantitative estimate of some specified future condition or event, made as a result of rational study and analysis of available pertinent data» (IUFRO . . . 1971, p. 3). There are also a number of other definitions, for example J a n t s c h (1967, p. 15) defines forecast as »a probabilistic statement, on a relatively high confidence level, about the future». In this case, however, the use of the concept »forecast» is considered unsuitable with regard to acquiring some information about the future forest ownership structure and this is for two reasons. First there is no general theory of forecasting (for example J a n t s c h 1967, p. 17) thus it is unclear what is the real meaning of a forecast, a numerical estimate of a future event, and how it can be used to aid policy-making. Secondly, there exist two other approaches to policy-making and future, they are called *planning* and *prospect* (they are defined in section 41.), and it depends on the phenomenon concerned which kind of approach is the most suitable. All these approaches have, however, one point in common, and it is the careful gathering and analyzing of past and present data of the phenomenon (for example R u b i n 1969, p. 293, O z b e k h a n 1969, p. 133—135, D e c o u f l é 1972, p. 36, Prospective . . . 1972, p. 38, de J o u v e n e l 1972, p. 146). So, independent of the final approach of making appraisal of the future private forest ownership structure, the second task of this study can be defined as

— *to describe and analyze the past change in private forest ownership structure.*

After these two tasks have been fulfilled, the final question of getting information about the future can be treated. At this stage, before detailed information of private forest ownership structure is available, it is not possible to decide which approach to use in estimating the possible future num-

ber and forest land area of non-farmers, the forecasting, planning or prospective approach. Therefore the third task of the study is defined generally as

— *to find out information about future private forest ownership structure relevant to forest policy decisions.*

Already at this point it can be stressed that relevant information does not necessarily consist of some numerical estimates only.

The first two tasks, which can be called as *descriptive*, are handled in Chapter 3. This part of the study is based on a sample of private forest owners in the province of Keski-Suomi, the results presented apply only to this province of Finland. Methodological problems are mainly those of measuring.

The third task regarding the *future* private forest ownership structure is dealt with in Chapter 4. It is based on the results obtained in Chapter 3. as well as information from other sources. The questions how information can be obtained about the future and what kind of information is relevant for forest policy are treated in detail in sections 41. and 42. Two restrictions of Chapter 4. can already be mentioned: consideration of the problem is made on the level of the *whole country*, and time perspective will be up to year 2000. Problems dealt with are thus those of the *long range*. By long range is understood a time period during which the whole system can change, while in short range changes are supposed to occur only within the system (J a n t s c h 1969 a, p. 29). Usually long range means a time period of over 5 years (V i r k k u n e n 1973, p. 21). The latter restriction means that the large number of short range forecasting methods (see for example T ö r n q v i s t 1974, p. 62—88) are left out of consideration.

3. PRIVATE FOREST OWNERSHIP STRCUTURE IN THE PROVINCE OF KESKI-SUOMI IN 1945—1970

31. Research method

Existing data in the files of the Agricultural Census, tax authorities and land registers might have given a rough picture about the present number of non-farmer forest owners. Concerning past development of private forest ownership structure sufficient information was not, however, available in existing statistics and files. The same lack of statistics concerning ownership changes was observed in 1966 by a State Committee (Komiteanmietintö 1966: B 98, p. 55). This necessitated the use of a *sample* of private forest holdings and an *interview* of the owners. The interview was considered useful, not only for finding out the past ownership development, but also for the precise defining of the profession of the owner. The division of forest owners to farmers and non-farmers is essential task of this study, thus the value of results depend largely how well this division is made. By interview the definition of profession can be made according to the same criteria with all forest owners.

With limited economic rescources available it was not possible to take whole Finland as study area, thus a province was considered as the next best solution. Very clear criteria for the choice of the province were not found. The decision was finally made for the province of Keski-Suomi (Keski-Suomen lääni), which is situated in the central part of Finland. In Keski-Suomi there are both strong industrialized towns and less developed, poor rural communes. The structure of Keski-Suomi is thus more variable than that of many other provinces, and it can be supposed that from this viewpoint Keski-Suomi is a rather good »sample» of whole Finland.

A sample of private forest holdings was drawn from the files of the 1969 Agricultural Census. The *population were all private forest holdings with at least 10 hectares of forest land.* Before the sampling procedure the *size of the sample* was decided. Basic information was that in 1959 the approximate number of farmers was 12 500 and that of non-farmers 4 100. Using an equation presented by Cochran (1963, p. 75) it was estimated (with the

assumption of 50 % proportions for farmers and non-farmers, leading to maximum size of the sample) that sample of 375 forest holdings would give the proportion of non-farmers within margin of error of 5 % and with risk of 5 % that the true proportion is outside this margin. The number of non-farmers in a sample of 375 was expected to remain under one hundred, and this was considered as too little to get reliable results from the non-farmers' group. In order to estimate proportions with a 5 % margin of error and a 10 % risk *within* the group of non-farmers a sample of 250 was needed. A sample needed for farmers with the same reliability was 260.

Thus three separate samples were drawn with simple random sampling. First a sample was drawn until the number of farmers totalled 260, and the number of forest holdings in the *main sample* was 338. After this only those forest holdings in the file of non-farmers were drawn until the total number was 510. Thus it was expected to get, besides the main sample, a *sample of farmers* (260) and a *sample of non-farmers* (250).

The interviews revealed that quite a large number of entries in the files of the Agricultural Census regarding professional status were false. Many of those marked as farmers were in fact non-farmers and vice-versa. The true distribution of the sample according to profession of the owner was:

Farmers	309
Non-farmers	196
Owner not interviewed	1
Forest company	4
Total	510

Thus the number of farmers became larger than was intended.

A *questionnaire* was prepared and tested, two forest technicians with previous experience in interviewing made the interviews. Instruction was given to them during three days before the beginning of data collecting. During the interview procedure from October 1970 to January 1971 contacts with the interviewers were frequent.

The questionnaire is given in Appedix 1. Questions deal with basic information concerning forest owner and his forest holding, with variables possibly correlating to ownership change, and last with former owners of forest holding in 1945—1970.

Forest owners were almost without exceptions positive towards the interview. In the *main sample* of 338 forest holdings, which is the most important sample for the purpose of this study, information was obtained from all but one forest holding. The distribution of the main sample according to data gathered was the following:

The forest owner was interviewed and owners between 1945—1970 were ascertained	327
The forest owner was *not* interviewed but owners between 1945—1970 were ascertained	
— adolescent owner	3
— owner ill	1
— owner abroad	2
— owner refused information	1
— owner was not met	1
— holding sold to forest company	2
Forest owner was *not* interviewed and owners in 1945—1970 were *not* ascertained	1
Total	338

Analysis of the material did not cause difficult problems. As it was mentioned earlier, this part of the study is descriptive and problems are thus mainly those of measurement and description. Forest owner's profession was chosen as the variable describing the private forest ownership structure, and in the interviews profession could be measured in a reliable way. Description is simply made with the aid of percentage distributions.

Only a minor part of the data collected is used in this study. This part consists of information concerning forest owner's profession, the main differences between the groups of farmers and non-farmers, and the mechanism of the structural change in 1945—1970. The rest of the data has been left out, because it is not as essential background for this study and because it has been presented in an earlier, separate report (R e u n a l a 1972).

32. Private forest ownership structure in Keski-Suomi in 1970

The distribution of private forests according to forest holding size in Keski-Suomi is shown in Table 3.1. Forest holdings larger than 10 hectares account for nearly 80 % of the number of forest holdings and 97 % of the private forest land area. This shows that almost all timber production in

Table 3.1. Number and forest land area of private forest holdings in District Forestry Board of Keski-Suomi in 1969. Source: SVT III : 68, 1971.

Size of forest holdings, hectares	Forest holdings		Forest land area	
	Number	%	Hectares	%
2.00—9.99	4 776	22	24 100	3
10.00—	17 318	78	801 700	97
Total	22 094	100	825 800	100

Table 3.2. Distribution of private forest holdings (over 10 ha) by forest owner's profession in 1970 according to the sample.

Owner group	Forest holdings		Forest land area	
	Number	%	Hectares	%
Farmers	255	76	10 467	80
Non-farmers	80	24	2 584	20
Total	335	100	13 051	100

private forests occur in forest holdings of size of 10 hectares or more. Therefore the decision to restrict the sample to forest holdings bigger than 10 hectares seems to have been justified.

According to the sample, in 1970 non-farmers owned *24 % of the number of private forest holdings* (over 10 ha) and *20 % of the private forest land area* (Table 3.2.).

In the 1969 Agricultural Census the total number of private forest holdings of over 10 hectares (in the same area) was 17 318. Thus the number of non-farmers' forest holdings in Keski-Suomi was approximately 4 150. The forest land area of non-farmers was 20 % of 801 700 hectares, or 160 000 hectares.

The sample did not contain small forest holdings of less than 10 hectares of forest land. When some information was also available concerning their distribution, it seemed useful to try to construct a picture of the ownership structure of all private forests in Keski-Suomi. Data from eastern and central Finland (S e p p ä l ä 1974) shows that non-farmers' share of forest

Table 3.3. Number and forest land area of all private forest owners in Keski-Suomi in 1969 by forest owner's profession. Estimate based on 1969 Agricultural Census, sample of this study, V i r t a (1971) and S e p p ä l ä (1974).

Size of forest holding	Farmers		Non-farmers		Total	
	Number of forest holdings					
	Number	% [1]	Number	% [1]	Number	%
≤ 10 ha	2 388	50	2 388	50	4 776	100
> 10 ha	13 179	76	4 139	24	17 318	100
Total	15 567	70	6 527	30	22 094	100
	Forest land area					
	Hectares	% [1]	Hectares	% [1]	Hectares	%
≤ 10 ha	14 460	60	9 640	40	24 100	100
> 10 ha	642 960	80	158 740	20	801 700	100
Total	657 420	80	168 380	20	825 800	100

[1]) rounded figures.

holdings smaller than 10 hectares was 55 %. Virta (1971, p. 16) found that in western Finland non-farmers' share of the number of forest holdings of size 5—9.99 hectares was 33 %. If we appraise that 50 % of the number of private forest holdings smaller than 10 hectares and 40 % of their area belonged to non-farmers in Keski-Suomi, we get the distribution shown in Table 3.3. According to this appraisal *30 % of all private forest holdings and 20 % of the total private forest land area in Keski-Suomi belonged to non-farmers in 1970.*

The total private forest land area in Keski-Suomi obtained in the 1969 Agricultural Census (825 800 hectares) was considerably smaller than that obtained and checked in connection with the national forest inventory in 1965, 982 800 hectares (Uusvaara 1969, p. 23). The latter estimate is to be considered the better, being closer to the correct area because of deficiencies in the Agricultural Census (SVT XVII A : 1 1969, p. 40). According to the forest inventory estimate, the total forest land area of non-farmers was, in 1970, in Keski-Suomi about 200 000 hectares.

What are these non-farmers like as compared to farmers? The most significant differences (with 0.1 % risk) found between these two groups are presented in Table 3.4. Whereas farmers live in the *countryside* and mostly on their *farm* to which the forest holding in the sample belongs, almost half of non-farmers live in *towns*. There is an interesting difference in *sex* distributions, 16 % belonging to the group of farmers are female while the share of females is more than one-third within non-farmers' group. Non-farmers have considerably more *education* than farmers. *Purchase* on the free market was a considerably more frequent way of acquiring forests with non-farmers than with farmers. The average *age* of farmers, 52 years, was significantly higher than that of non-farmers, 44 years. Farmers have also, in the average, owned their forest holding for a longer time than non-farmers. The average *size* of farmers' forest holdings in the sample was 42 hectares, considerably bigger than the 33 hectares of non-farmers. Considering such differences, it is not surprising that the silvicultural and timber-selling behaviour of non-farmers differs from that of farmers, as was noticed in Chapter 2.

33. Structural change in 1945—1970

331. Result of change

The description of change in private forest ownership structure is based on the main sample of 338 forest holdings. With the last page of the questionnaire an image of the history of forest holding and its owners was obtained

Table 3.4. Significant [1]) (with 0.1 % risk) differences of variables of farmers and non-farmers, based on the independent samples of farmers (n = 308) and non-farmers (n = 174).

Variable	Farmers	Non-farmers
	%	
Home-place		
Countryside	94	58
Town	6	42
Total	100	100
Sex		
Male	78	19
Female	16	81
Total	100	100
Education		
Primary school or less	84	64
More than primary school	16	36
Total	100	100
The way of acquiring ownership		
Inheritance or purchase from parents or relatives	82	72
Purchase from the free market	8	25
Other	10	3
Total	100	100
	Years	
Age		
Average age, years	52	44
Ownership		
Average length of forest ownership, years	17	13
	Hectares	
Size of forest holding		
Average size, hectares	42	33

[1]) Significance was calculated using t-test with the following formula (V a s a m a & V a r t i a 1972, p. 621): $t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{\delta_1^2}{n_1} + \frac{\delta_2^2}{n_2}}}$, where $\bar{x}$ = average, δ^2 = variance, n = sample size.

The same formula for proportions is $t = \frac{p_1 - p_2}{\sqrt{\frac{p_1 q_1}{n_1} + \frac{p_2 q_2}{n_2}}}$.

in the years 1945—1970. Besides the name, profession and ownership time of each owner the way of obtainement of the forest (inheritance, purchase, settlement, other) was mentioned (see Appendix 1). This information was

Table 3.5. Development of forest land area owned by non-farmers in Keski-Suomi in 1945—1970, according to the sample used.

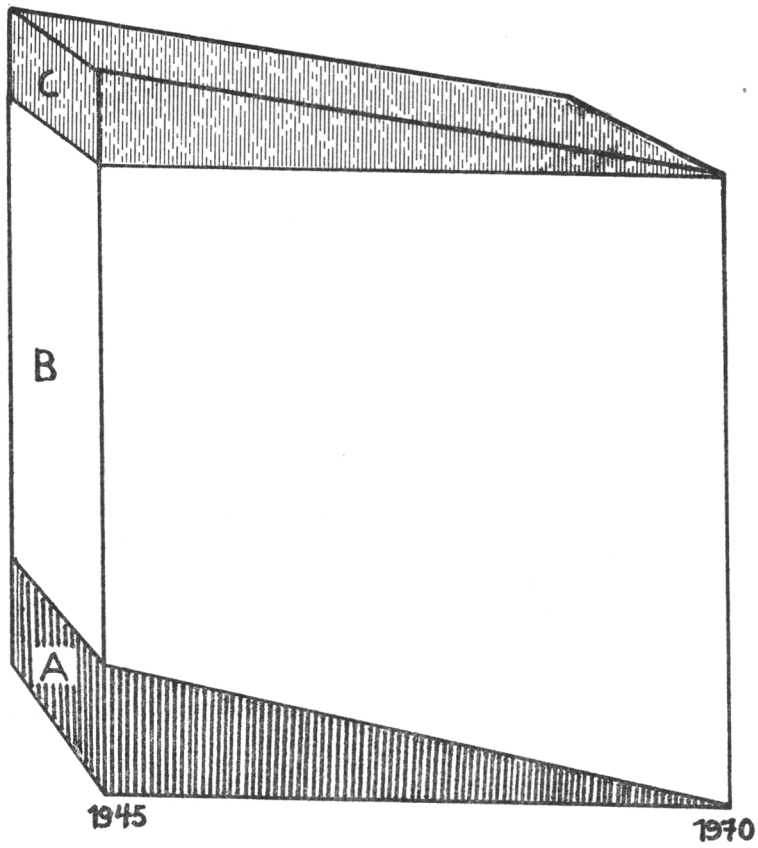
Year	Non-farmers		Total	
	Hectares	Per cent of total	Hectares	ratio 1970 = 100
1	2	3	4	5
1945	1 015	8.4	12 112	93
1950	1 043	8.3	12 597	97
1955	1 214	9.5	12 839	98
1960	1 552	12.0	12 958	99
1965	2 078	15.9	13 068	100
1970	2 584	19.8	13 051	100

obtained from all but one forest holding, thus the data consist of 337 forest holdings.

The forest land area of non-farmers has, according to the sample, developed in Keski-Suomi as presented in Table 3.5. *From 1 015 hectares, equal to 8.4 % of the total private forest land area in 1945, it increased to 2 584 hectares, 19.8 %, in 1970.* There has thus occured a considerable increase during the study period. The sample was, however, drawn in 1970, and thus it is strictly taken representative only for the 1970 situation. Feasibility of the time-series for the earlier years must thus be checked.

In Table 3.5. (column 5) it is observed that 7 % of the private forest land area of 1970 belonged 25 years earlier to other than private owners. During the study period private owners had got *additional forest lands* from other forest owner groups. But it is also possible that during this period private owners had *sold* some amounts of forest land to others. These possibilities are schematically presented in Figure 3.1. During the period 1945—1970 the ownership of some forests (A) was transferred from other forest owners to private owners, some forests (B) have continuously belonged to private owners, and, finally, some forests (C) that in 1945 were owned by private persons, were sold before 1970 to other owner groups. The larger the amount of C, the less representative is the time-series in Table 3.5.

Information on sales of forest land from private persons to others is not directly available. Some reasoning can, however, be made. According to the forest inventories private forest land area in Keski-Suomi increased from 1952 to 1965 by 75 000 hectares (Ilvessalo 1957, p. 13, Ilvessalo 1959, p. 35, Usvaara 1969, p. 23). The only way for private owners to get forests after 1952 from the State or forest companies has been according to the Laws concerning land acquisition (Asutuslaki 1935, Maanhankintalaki 1945, Maankäyttölaki 1958). Without legal requisition the State and forest companies have not relinguished any of their forests. Statistics available show that transfers of land ownership in Keski-Suomi in the imple-



A = owned by others in 1945, transferred before 1970 to private owners

B = privately owned in 1945 and in 1970

C = privately owned in 1945, transferred before 1970 to other owners

Figure 3.1. Schematic figure of development of private forest area in Keski-Suomi from 1945 to 1970.

mentation of land acquisition laws were in 1952—1965 about 50 000—60 000 hectares (K u l h a 1963, SVT XXX: 1967, Asutustoiminnan . . .). We can therefore conclude: the increase of private forest area was 75 000 hectares, the only way for this increase was land acquisition, statistics on land acquisition show an increase of about the same magnitude or somewhat less, thus *considerable sales of private forest lands to other ownergroups may not have occurred* and *the time-series in Table 3.5. can therefore be considered as representative for the whole period 1945—1970.*

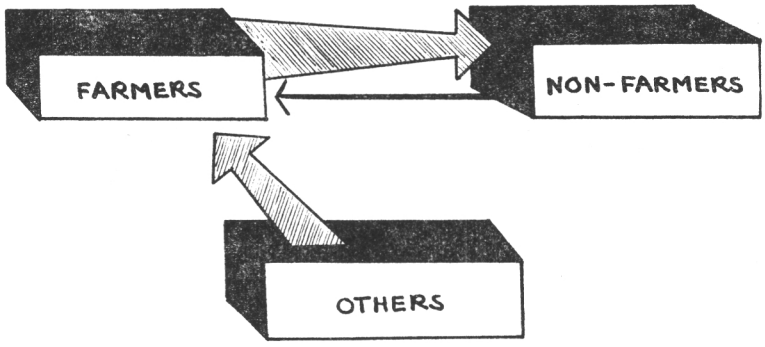


Figure 3.2. Schematic figure of main changes in forest ownership since 1945.

332. Mechanism of change

The share of private forest land area owned by non-farmers increased in 1945—1970 from 8 % to 20 %. Principles of this change can be illustrated as in Figure 3.2. The group of farmers has received additional forests from the group of other forest owners (mainly the State and forest industry companies) in connection with settlement activities. A certain part of forests belonging to farmers has been transferred to non-farmer ownership. Probably a negligible part of non-farmers' forests has returned back to farmers' ownership. There may be small arrows from the farmer and non-farmer groups to the group of others, because in recent years some private owners have sold their forest holdings to the State and forest industry companies (R e u n a l a 1974). It was just at the end of 1960s when these sales grew to considerable amounts.

Principally these changes of ownership group can occur in the following ways:

by — inheritance
— purchase from parents or relatives
— purchase on the market
— settlement activities
— change of forest owner's occupation.

Purchase from parents or relatives was mentioned separately from free market purchase because there are essential differences in the purpose of purchase. Normally purchase between relatives is arranged in order to maintain the main part of the farm as an entity, purchase has in such a case the role of arranging the inheritance between children. In some cases, also, purchase may be preferred in order to avoid inheritance taxes. Purchase from parents or relatives can thus be considered as inheritance which, for practical reasons, is carried out in the form of purchase.

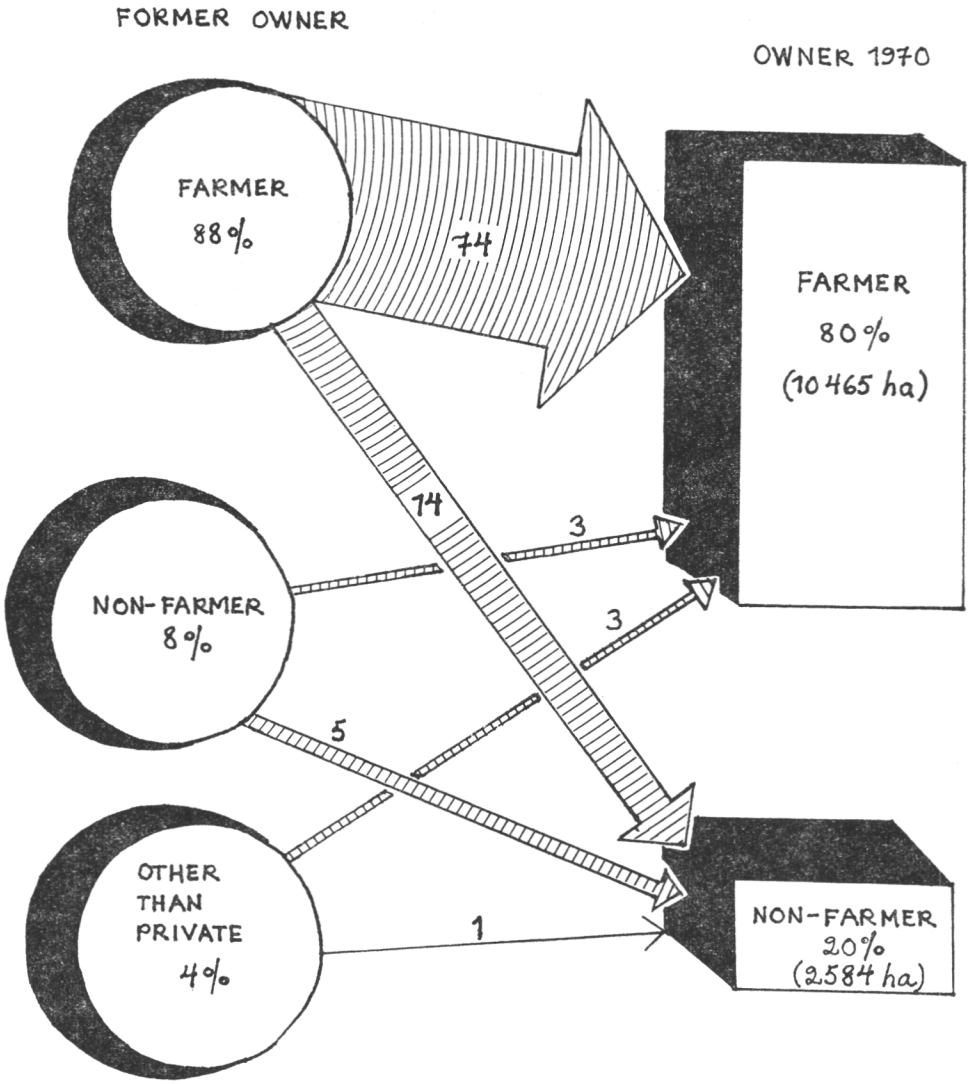


Figure 3.3. Transfer of forest ownership from former owner to present (1970) owner in Keski-Suomi.

Change of occupation means a situation, where a farmer decides to leave farming and go to earn his living from another occupation, and maintains the ownership of his forest holding. In such case the ownership of forest holding does not change, the same person owns continuously the forest, but the forest ownership structure changes.

These changes can be described by transfers of ownership from the former owner to the present owner. This is done in Figure 3.3., which is based on Table 3.6. Arrows' broadness reflects the amount of transfers of ownership.

Table 3.6. Transfer of forest ownership from former owner to present (1970) owner in Keski-Suomi according to the sample.

Present owner acquired the forest by	Former owner	Present (1970) owner			
		Farmer		Non-farmer	
		Hectares	% [1]	Hectares	% [1]
Inheritance or purchase from parents or relatives	Farmer	8 145	62.4	1 089	8.3
	Non-farmer	230	1.8	424	3.3
Purchase from the market	Farmer	1 529	11.7	367	2.8
	Non-farmer	106	0.8	257	2.0
Settlement activities	Other than private	457	3.5	101	0.8
Change of occupation	Farmer	—	—	346	2.6
	Total	10 467	80.2	2 584	19.8

[1]) The percentages are calculated from the total private forest area of the sample 13 051 ha.

In the Figure the present (1970) distribution of private forest ownership is shown by rectangles for farmers (80 %) and non-farmers (20 %). Former owners are marked by circles. The broadest arrow (74 %, percentage is calculated from the total private forest area in the sample) goes from farmers to farmers, and when we also take into account changes from non-farmers to non-farmers (5 %), it can be concluded that *four-fifths of ownership changes have not changed ownership structure.*

Arrows crossing each other show the change occurred in ownership structure. Non-farmers have received additional forests from farmers (14 %), but on the other hand part of their forests (3 %) has moved to farmer ownership. Through settlement activities farmers (3 %) and also non-farmers (1 %) have got some additional forests.

From Table 3.6. the main channels of change in private forest ownership structure can be calculated. The *increase* of forest land area of non-farmers originated as follows:

	hectares	%
— inheritance or purchase from parent or relative, who was a farmer	1 089	57
— purchase on the free market from a farmer	367	20
— farmer's change of occupation	346	18
— settlement activities	101	5
Total	1 903	100

This shows that inheritance has been the main channel for changing private forest ownership structure. Remembering (Table 3.4., p. 27) that farmers had obtained four-fifths of their forests from relatives, the original reason for the effect of farmers' occupation change to forest ownership structure thus lies mainly in inheritance, and we come to the conclusion that *inheritance has been the mechanism for 75 % of the increase of non-farmers' forest land area.* The rest is explained by free market purchases and settlement activities.

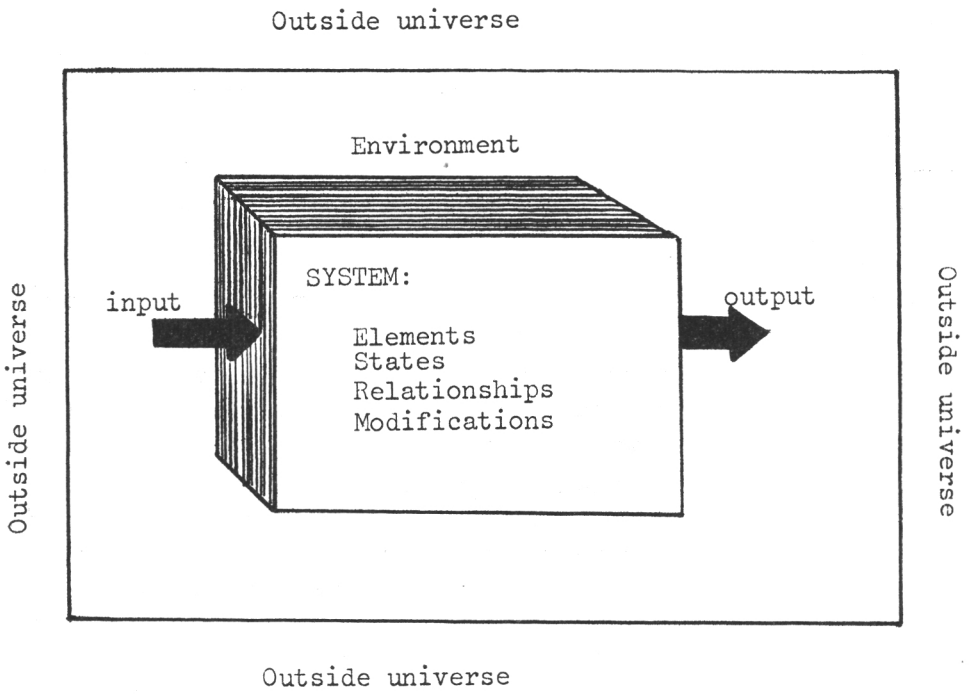


Figure 3.4. The concept of the system. Source: P a l o 1971, p. 12.

333. Private forest ownership change as an open system

A changing phenomenon can be described as a system. There are several definitions of system, for the purpose of this study a *system is defined as a set of elements together with relationships between the elements and between their states* (A r o s a l o 1968, p. 30, O z b e k h a n 1969, p. 53, P a l o 1971, p. 10). A system is *closed*, if there is no flow of energy or material or information between it and its environment. If such a flow exists, the system is *open*. An open system can be viewed as follows:

Input → | System | → Output

Input is defined as any event occurring in the environment that alters the system. Output is defined as any change caused in the environment by the system. (A h m a v a a r a 1969, p. 93—96, O z b e k h a n 1969, p. 109). According to P a l o (1971, p. 12) a system viewed as a machine can be illustrated as in Figure 3.4.

All human social systems are open systems interacting with their environment (O z b e k h a n 1969, p. 107). Thus private forest ownership can be

described as an open system receiving inputs from the environment and giving outputs to the environment. What, then, is the inner structure of private forest ownership system and what is the environment in this case?

According to Fig. 3.4. the inner structure of a system consists of elements, states, relationships and modifications. In the *private forest ownership system* these properties can be given the following interpretation:

— *elements* = private forest holdings.

— *states* = forest ownership groups (farmers and non-farmers), thus the elements have only two possible states.

— *relationships* = channels through which forest ownership can change from one state to another. Inheritance, purchase and change of occupation have been the principal channels.

— *modifications* = changes of the properties of states or relationships in time. Modification is a typical feature of dynamic, for example cybernetic, systems (P a l o 1971, p. 11). Concerning the private forest ownership system one might imagine, for example, new channels, or restrictions to the old channels (restrictions to inheritance or purchase) that might appear in the future.

In order to get an image of the relevant *environment* of the private forest ownership system, we can imagine a particular change in the state of the system. Let us consider a case where a non-farmer has inherited a forest holding from a farmer. This was the most usual change of state that occurred in the sample of forest holdings in Keski-Suomi. Prerequisites for this change of state are the following:

— a farmer exists who owns a forest holding,

— the farmer has a relative or relatives,

— this relative is non-farmer,

— the farmer dies (he may also voluntarily give his property as inheritance before his death),

— an inheritance system exists which decides that the relative has the right to inherit the forest holding.

The existence of farmers, non-farmers and an *inheritance system* are special characteristics of society. During this century, and also during the study period 1945—1970, farmers have owned the majority of private forests, and a stable inheritance system has existed. A change has occurred in the distribution of farmers' heirs: an increasing number of heirs have been non-farmers thus following the rapid change of the structure of the Finnish

society. The *urbanization process* can be considered in the case of inheritance as an *input* from the environment to the private forest ownership system.

Urbanization is also found to be the input in the case of *purchases* of forest holdings and *occupation changes of farmers*. When the right for private persons to buy forests has existed, increase in the number of urban population has reflected in the increasing number of their purchases of forest holdings.

Part of the decrease of the rural population has occurred when farmers' heirs have moved from rural to urban areas, but also a large number of farmers have ceased farming and changed to urban professions. Thus a conclusion can be made that *urbanization has been the main input causing change in the private forest ownership system.*

When urbanization is a typical feature of a changing, industrializing society, the name of *society* can be given to the environment in question.

The *output* of the private forest ownership system to society was already dealt with in Chapter 2, although systems language was not used. The importance of output can be presented in the following way: with a certain private forest ownership structure the output of the system is a certain combination of forest owners' silvicultural and timber-selling behaviour. When society gives inputs to the system, the balance between the two states of the system is changed (the number and share of non-farmers increases), as a result the system's output changes, and in this case in a manner that has been considered harmful for society.

It was seen in section 332, that the balance between the states of the system may also change in the opposite way: farmers may get forests from non-farmers. This is, however, expected to be rather small as long as the urbanization process continues. When the process reaches an end, inputs from the environment to the private forest ownership system cease (supposing that right to inheritance and right to forest ownership is maintained stable), and the two states of the system will achieve a balance.

Processes within a system or between a system and its environment can be dominant or dominable. A *dominant process* is such that cannot be altered by an agent observing the process. A *dominable process*, on the contrary, can be influenced. A process can be dominant for one agent but dominable for another acting on the next hierachial level. For example inflation is a process that is dominant to authorities on communal level, whereas on national level it is (at least partly) dominable. de J o u v e n e l (1972, p. 144) stresses that some social phenomena, like world population growth, are mainly of dominant character.

Division of processes to dominant and dominable seems useful and interesting for the private forest ownership system. *Processes inside the system*,

which are based on the relationships mentioned (inheritance, purchase, change of occupation), can be considered as dominant for forest policy and dominable for general societal policy. *Input process* from environment to the system (urbanization) is also dominant for forest policy and dominable for general societal policy. *Output process*, silvicultural and timber-selling behaviour of private forest owners, is the only part of the system that can be considered as dominable both for forest policy and general societal policy.

4. FUTURE PRIVATE FOREST OWNERSHIP STRUCTURE

41. How to get information about the future

411. General remarks

The third task of the study was defined as »to find out information about the future private forest ownership structure relevant to forest policy decisions» (p. 21). Two questions immediately arise: how can we generally get *information concerning the future*, and what kind of information can be considered as *relevant to forest policy*. The first one of these questions is treated in this section.

In historical times man was considered only as a faithful transcriber of gods, the future was seen as *deterministic*. It was only because of lack of man's knowledge that all future events could not be foreseen exactly. Towards the end of the Renaissance attitudes changed, and now man began to see himself as *creator* of the future. A long period of optimism commenced. New inventions and continuous development of technology made people trust in the coming of a golden age for mankind. (P o l a k 1961 I, p. 33, G a b o r 1964, p. 13). It was, however, not until after World War II that wide interest in forecasting developed. Many trials had been made earlier concerning the development of population and technology, for example, but forecasting techniques and methods have mainly been developed in the 1950s and 1960s (J a n t s c h 1967, p. 322—371).

One reason for the rapid growth of interest in forecasting (and in other approaches of considering the future) was the increasing number of disturbances in the development of societies. In order to be able to avoid these disturbances and even dangers, extensive forecasting activities were necessary (G a b o r 1964, p. 20, B e r g e r 1967, p. 10, de J o u v e n e l 1972, p. 338). In the 1960s it became evident that these disturbances — like the too fast population growth, environmental deterioration, crisis of social systems, alienation and so on — were world wide and in a complicated relationship with each other, and that their free development threatened the existence of mankind (B e r g e r 1967, p. 79, O z b e k h a n 1969, p. 104, P e c c e i 1970, T o f f l e r 1972, M e a d o w s et al. 1972, p. 11). It was

stated that mankind had arrived at a turning point, at a deadlock unique in history, where old experience, old ethics and present value systems have lost their guiding power (Polak 1961 II, p. 99, Ozbekhan 1968, p. 209, Peccei 1970, Drucker 1970, p. 13—20, Meadows et al. 1972, p. 11—12). Thus man, who had believed in his ability to create his own future, was suddenly in a situation, where he seemed to lose his vision of the future. His creative power had turned against him, he had become a prisoner of his own progress (Polak 1961 II, p. 288, Peccei 1970).

This world-wide change, a turning point in the history of mankind, is presented here because it seems that if it is real — and there are strong reasons to believe that it is — it has an effect on all efforts made to acquire information about the future. A turning point in history means that trends and tendencies of the past can no longer be used as guidelines to the future — or their use is at least strictly limited. It means that efforts to get information about the future can no longer be based on old, traditional methodology only. A new element in our attitude towards the future is needed. This new element is reflected in expressions such as *futures-creation*, *willed future*, *anticipation* (Ozbekhan 1969, p. 87, 90, 130), *inventing the future* (Gabor 1964) and *futuribles* (de Jouvenel 1972, p. 33). The main content of these expressions is that man now, in one way or another, has to find himself a new future in order to avoid the dangers threatening mankind.

Although this study is limited to private forest ownership structure in Finland, it is worthy of note that it has direct connections with the social system. When the possibilities to get information about the future society — environment in the open system model in section 333 — change radically as has happened, the possibilities to get information about the structure of the system within the society change as well.

412. Forecasting

A *forecast* was earlier (p. 20) defined as a »quantitative estimate of some specified future condition or event». There are a large number of methods by which such an estimate can be obtained. Maybe the most commonly used method is that mentioned by Brown (1963, p. 4): »Forecast is an estimate of what future observations will be if the underlying process continues as it has in the recent past». By studying the past development some kind of trend or tendency may be found and forecast is then achieved by extension of this tendency. Extension may be done by mere *extrapolation;* time-series may be interpreted and some hypothesis may be constructed concerning future developments, then we talk about *projection;* probabilities may be

calculated from past developments, then the forecast in question is a *probabilistic forecast.*

Generally three parts can be distinguished in a forecast: a *deterministic* part, amenable to exact calculation by the inductive method, a *probabilistic* part, revealed by the deductive method of observing the process for a long time to determine its probabilistic properties, and a purely *random* part, which principally cannot be predicted (I v a k h n e n k o and L a p a 1967, p. XIV). It depends on the phenomenon concerned in what amounts these three parts relate to each other. No general *theory of forecasting* exists to distinguish the roles these three parts play in a given situation or to assist choosing the »best» forecasting method. In this sense forecasting can be considered as an art and not as a science (de J o u v e n e l 1972, p. 32).

In the field of forestry and forest industries a good example of forecast of a dominant phenomenon has been the *European Timber Trends Studies* (FAO 1953, 1964), where consumption of wood-based products was forecast on the basis of economic growth and relative prices of wood. The authors stress that »estimates made were not prophecies of what will actually happen — the conclusions simply assert what is likely to happen if the assumptions prove correct» (FAO 1964, p. 221). In the first Timber Trends Study (for the period 1950—1960) the assumptions proved to be quite close to the correct ones in that the agreement between estimated and actual trend was very close, the difference between estimated and actual total consumption of industrial wood was only 2 %. The main importance of this study was not, according to the authors, the accuracy of the forecast but the capable set of statistics that was gathered, and that basic underlying trends in consumption were detected and qualified with a considerable degree of accuracy (FAO 1964, p. 226).

The first Timber Trends Study was successful because the underlying process was correctly estimated, and because investments to forest industries increased considerably after the Study was published. If the demand for wood-based products had been considerably smaller than estimated, a great number of misinvestments may have occurred. Happily enough the trend was correct in this case. It can be supposed, also, that the Timber Trends forecast had some properties of a self-fulfilling forecast, because the authority of the maker of the forecast, FAO. was widely trusted. There are, however, many examples of other forecasts where the estimate of the underlying process has been false, and in consequence even disastrous decisions have been made (de J o u v e n e l 1972, p. 164—167). An important observation concerning this study is that at present *estimation of underlying social processes is much more difficult than before, because the complexity of social systems has increased, and the future process may even be impossible to appraise, because the present processes just cannot continue.*

413. Planning

When defining the third task of the study (p. 20) it was mentioned that besides forecasting two other approaches exist to deal with the problems of future and policy-making, namely planning and prospect. *Planning* can be generally defined as a future directed process, where actions are designed in order to change the object in the manner that has been previously defined. (O z b e k h a n 1969, p. 54, 151). The relationship between planning and decision-making is not clear, but usually planning is considered to deal essentially with the *long range*, and decision-making with the *short range* (J a n t s c h 1969 a, p. 29). Planning concerns mainly phenomena that can be called as *dominable*, as can be derived from the expression »to change the object». However, in most decision-making situations phenomena concerned are only partially dominable, decisions have to be made with certain limits. When planning occurs on several levels of decision-making (for example communal — provincial — State levels), the planner on the lowest level can consider a relatively small number of phenomena as dominable.

Planning and forecasting are closely connected. In the *orthodox* mode of planning the existence of a trend or underlying process is first examined, a forecast is made, the decision-maker chooses the objective, and the planner is supposed to find the best means to reach this objective. This manner of planning concentrates on the problems of *»how to get there»* (O z b e k h a n 1969, p. 119—120). At present, which can be described as the beginning of a major crisis, developing in years and decades rather than over the centuries, *orthodox planning has lost its effectiveness*. The main drawback is the gap between the decision-maker and the planner: the planner needs a decision of the »best», but the decision-maker is not able to make one (J a n t s c h 1969 b, p. 472, O z b e k h a n 1969, p. 139).

This difficulty can be clearly seen in a study by E r v a s t i et al. (1970), which concerned the development of forestry and forest industries in Finland in 1970—2015. Four different forestry programmes were suggested, estimates of profitability of programmes were evaluated, and based on this information it was expected that decision-makers (in this case State authorities) could make the decision of the objective. Although the study was thorough and detailed, no clear political decision has so far (1974) been made concerning the choice of the forestry programme. Why has the decision-maker not acted? A detailed answer is not possible, but it is probably not far from truth to say that nobody has been able to estimate the value of these programmes to the Finnish society as a whole. When new objectives, still undefined under the title of »quality of life» have appeared to compete with traditional objectives and in this case with that of economic growth (see for example Talousneuvosto 1972), the decision-maker has not, in the

confusion been able to make any clear decisions. Without the decision of the input programme of forestry rational long-term planning cannot be effected for either forestry or the forest industry (E r v a s t i et al. 1970, p. 7). Thus *in the complex social situation programmes carefully prepared have not succeeded to improve rationality of decision-making in a manner intended.*

Attempts to remove the gap between the planner and the decision-maker have been made, but no unique solution can be presented. Planning capable to deal with the grave and complex problems of to-day does not yet exist. Still, agreement does seem to exist regarding the direction in which planning should be developed. This direction is characterized in a way that *consideration on values and norms is somehow taken into the planning process itself.* Thus a decision-maker who separately, from the outside of the planning process, gives objectives to the planner will exist no more, but the required values and norms are found or created in a process where *the planner and the decision-maker are in close cooperation.* Before describing some features of this »new» planning, the contents of values and norms must be defined.

Values are dominant, historically evolved commitments of a culture or society. Values define the way of life, as well as the quality of life in such cultures or societies. There are individual values and social values. Social values are more stable and more formal, they are commitments of a whole culture, from which a large part of individual values can be abstracted. Individual values, from their part, affect to the slow changement of social values.

Norms are rules or value standards which permit us, in relation to specific values, to determine the legitimate value content of alternative value statements (O z b e k h a n 1969, p. 80—81). According to O z b e k h a n (1969, p. 144) western humanity at the present time decides and acts mainly with reference to values that rest on three traditional norms: love as the social norm, objectivity as the scientific norm and utility as the technological norm. When these norms only cease to guide mankind, new norms have to be created.

It remains a problem in which manner values and norms should be taken into the planning process, and who could be able to define the needed new norms. It is evident that planners themselves cannot do this (R o o s 1973, p. 275), but what would the needed cooperation of planners and decision-makers be like where new norms could be established? J a n t s c h (1969 b, p. 473) states that the new *normative planning system* should be *adaptive* (or cybernetic) — continuously modifying objectives and preferences—, *democratic* (based on principle of decentralized initiative and centralized synthesis) and *not responsible for decision-making* (but providing a richer information base for decision-making). What these properties really mean and how they could be brought into practice, is still an open question.

Still another aspect of new planning is that it should be *»futures-creative»*, it should draw several possible images of the future and thus give us the possibility of seeking new norms as free of the old norms that are on the base of the »logical» future, the extended present. From this viewpoint suggestions for special *»look-out» institutions* have been made (J a n t s c h 1967, p. 92, 291, O z b e k h a n 1969, p. 87). What do these properties of normative planning mean in practice? Unfortunately experience of normative planning is so little yet that we have no clear example of what concepts of »norm-seeking», »adaptive», »democratic» and »futures-creative» would mean together, and it is only together that they form the idea that is called normative planning. One interesting way to try to get an idea of what might be understood with this normative aspect has been to consider society as a *cybernetic, self-regulating system*, which acts like a living organism. It gets information from the environment, based on this information it acts, tries to adapt itself to the changing situation or tries to change the environment or both of them. There is a continuous and iterative information-feedback system so that the cybernetic system is all the time prepared to act to changing environment. New norms can be considered as new rules of behaviour that the system adapts in order to maintain or improve its position in the environment. According to this cybernetic model planning is a continuous process, which is in contrast to the »five-year plans» nowadays widely used, even when these are recast annually (A h m a v a a r a 1969, B e e r 1969, p. 398, 422).

Concerning planning we come to the same conclusion as with forecasting: *it is no longer useful to plan in the old, orthodox manner.* However, *with the development of planning towards a normative approach by taking values and norms into the planning process, there seems to be promising possibilities for getting a new and stronger system of planning.*

414. Prospective approach

When in planning the problem of finding new norms lead researchers to the suggestion of a »futures-creative» approach, a similar approach has developed also from another origin. In countries with the system of five-year-plans, for example in France and in the Soviet Union, it was realized that applicable and efficient plans were difficult to achieve, if the horizon of the plan was not mapped at all. To be able to fix the objectives of the plan, some information on a longer perspective was needed. The *prospective approach* has been developed to fulfill this need. The task of a prospect is to draw an *image of the horizon of the plan*, describe the tendencies but also the possibilities to show, where it is necessary, desirable, useless or disastrous to proceed (M a s s é 1967, p. 117, B a r e l 1971, p. 19). How a prospect is

actually achieved depends on the special situation and information available, and prospect has the same weakness as normative planning: there exists no well-developed theory. However, the amount of prospective efforts have increased rapidly in the past ten years (Prospective . . . 1972, p. 20—30) and it is considered as a necessary addition to the planning process.

Three steps can be distinguished in making a prospect (D e c o u f l é 1972, p. 36, Prospective . . . 1972, p. 38): *first*, available information of the past is gathered and analyzed, *second*, projections are made on the basis of known determinisms or heavy tendencies, and *third*, the projections are compared to one or several clearly expressed value systems. The term *»heavy tendency»* (»tendance lourd» in French) is used in the meaning of a dominant process (de J o u v e n e l 1972, p. 146). As was mentioned earlier (p. 35), dominant process for one decision-maker may be dominable for another.

The notion of value comparison originates from the fact that objectives have to be set for the plan, and decision-makers alone are incapable to decide operational objectives. Thus consideration of objectives, values and norms have to be taken into a prospect in a manner that the decision-maker has a better ability to make rational decisions.

A prospect draws the image of several possible worlds, it starts from an exploration of the future (the horizon) to be able to find the desired future (B e r g e r 1967, p. 26, D e c o u f l é 1972, p. 28). In the search for the desired an iterative process is necessary where these images of the future are compared to the present, and reasoning is made on how these images fit to the present value system. Expressions like »look at the future from the present and at the present from the future» (D e c o u f l é 1972, p. 5), »a mutation in our attitude towards the future» (M a s s é 1967, p. 337), and »the purpose of a prospect is not to answer questions posed a priori but to formulate precise questions the answers to which are open to several interpretations» (Prospective . . . 1972, p. 15) show these general properties of a prospect.

Eearlier it was mentioned that such characteristics as *adaptive, democratic, not responsible for decision-making and »futures-creative»* are essential features of normative planning. All these features are also properties of prospects, and when we still take into account that no well-developed theory of prospects exists (Prospective . . . 1972, p. 15), as there exists no general theory of planning, a conclusion can be made that *prospects and normative planning are names for fairly similar approaches in order to achieve relevant information about the future.* A difference can be seen in institutional frame: in normative planning it is suggested that this »futures-creative» activity can be taken within the same organisation as the planning process itself, whereas prospects are thought mainly to be made in a different organisation than planning.

42. Choice of method

After this general background of the ways of getting information about the future the next question can be raised: in which manner can information relevant to forest policy be obtained? Is the most suitable approach in this case that of forecasting, planning or prospect? The system model of private forest ownership, presented in section 333, can be taken as basis for considerations. The principal input from the environment (society) to the system was defined as urbanization. Within the system this input was channelled by three relationships: inheritance, purchase and change of occupation. As a consequence of urbanization and the existence of these three channels the private forest ownership structure has changed in the past, the number of non-farmer forest owners has increased. Forest policy is concerned with the consequences of structural change, the output of the system. The unfavourable change in the behaviour of forest owners has been the output.

The main part of the system is *dominant* for forest policy. The input to the system or the relationships inside the system cannot be altered with forest policy measures. It is only on the output, forest owners' behaviour, that forest policy may have influence.

Because forest owners' behaviour can be considered as a *dominable* phenomenon for forest policy, the first suggestion might then be that the decision-makers of forest policy should take a *planning* approach towards the solution of the problem. What supports this suggestion is that in this case the objective is quite well determined (see p. 18): private forest owners should practice intensive forestry and they should sell the timber evenly without periodic fluctuations. Thus the methods of orthodox planning could be used without difficulty, the objective is determined, the task of planning is just to find suitable means to achieve this objective. In a more detailed consideration, however, a difficulty arises: to be able to draw an efficient plan to affect forest owners' behaviour, it is necessary to have some information about the amounts in which behaviour is expected to vary in the future (see p. 19). The behaviour of farmers and non-farmers was seen to be different, thus *some information about the future number of farmers and non-farmers is needed.*

The future number of farmers and non-farmers is a result of inputs and inner structure of the private forest ownership system, and, as already stated, these parts of the system are *dominant* for forest policy. Thus the approach to appraise the number of non-farmers (and farmers) cannot, from the viewpoint of forest policy, be that of planning, but it might be that of *forecasting.*

The idea behind forecasting is simple. When the process of private forest ownership change is known to depend on the change of society, the task is

just to forecast the change of society, and then the forest ownership structure can be simply deduced. An important question therefore is whether social change can be forecast. Returning to section 412. (p. 39) it seems evident that forecasting, i.e. finding out underlying social processes, is at present very complicated and may even be impossible when some present processes just cannot continue. What can be said about urbanization? Is it a process that can continue according to past trends, or are there some factors possibly changing the rate of urbanization? The task of this study is not to try to give a correct answer to this question, but to bring up one point: at the present time, when whole mankind seems to be at a turning point in its history, *the validity of all long range social forecasts must be questioned.* This notion stresses that the result of deducing forest ownership structure from a forecast of urbanization can be completely misleading, or useless, if a forecast of social change is just taken as given. In Finland there are a large number of forecasts of urbanization and of a closely related phenomenon, the development of population according to different industries (primary, secondary and tertiary industries) (for example Suomi 2000, 1970, Muistio . . . 1974). One solution to the problem of this study might consist of a certain social forecast made, the deduction of the corresponding forest ownership structure, and a final statement that the forecast is made on the *condition* that this population development occurs.

The objection towards this kind of forecasting is, in this case, that a forest policy decision-maker, who needs the forecast of forest ownership structure, would have no criteria to appraise the reality of the forecast, if he has no idea of the reality of the underlying population forecast. Thus, in spite of taking a certain population development as given, the *underlying assumptions must be treated when drawing the secondary, private forest ownership structure forecast.*

Normally, in population, urbanization and other forecasts the assumptions are, of course, stated on which the forecasts are based. These assumptions have the weakness that they are based on the present (and past) value system, and therefore the needed change of social values and inventing new norms does not normally come into consideration. It was just because of this shortcoming that the new concepts of normative planning and prospect were developed.

It is, of course, not the task of a limited study like this to begin to make prospects of urbanization and population development in order to finally get the secondary forecast. When theories of planning and prospects are still lacking, this kind of exploration is really an immense task and outside the scope of this study. However, *it seems important to keep this idea of changing values and changing norms in mind even in a secondary forecast.* This is, it is hoped, a way to avoid consideration of the secondary forecast as a prophecy,

and it is also hoped that this is the way a forecast can better serve decision-making.

In section 411. (p. 38) it was stated that a new element in acquiring information about the future is needed. This new element has been developing in the forms of normative planning and prospect. Forecasting is generally understood as continuing the underlying processes, planning means above all activity concerned with a dominable phenomenon. This study concerns a dominant phenomenon (from the viewpoint of forest policy), and the image of continuing underlying processes seems misleading, therefore the term used in the following will be *prospect.*

The prospect drawn will be carried out in the following way. Instead of measuring urbanization, measurements are made on the inverse process, the *decrease of the number of farmers,* which more accurately reflects to the change of private forest ownership structure. This decision bases on the idea that farmers have traditionally owned the majority of Finnish private forests, therefore the future development of the private forest ownership structure is mainly dependent on how farmers' forest area developes. In section 431. a *prospect for farmers' forest ownership* is made. When the result of this prospect was considerable decrease in farmers' forest area from 1970 to 2000, the next prospect was made to consider the possible new owners of forest lands left over by farmers. This *prospect,* in sections 432. and 433. *deals, not only with non-farmer forest owners, but also with other owner groups* (State, forest industry companies) that may be interested and capable of acquiring these left-over forests.

Values and *norms* will be taken into the prospects in the manner that, when considering social processes and forecasts (and plans) made about them, the underlying assumptions and values and norms connected to these assumptions are stated as clearly as possible. This kind of presentation does not have firm theoretical background, and therefore it may quite easily be criticized. The opinion of the author is, however, that when the traditional way of getting relevant future information has shown to be wanting, a new kind of approach is worth trying.

Figure 4.1. clarifies the prospective approach chosen in this study. Social change is dominable for societal policy, thus a prospect of social change could be drawn along the three steps mentioned (gather information, make projections, compare projections to value systems), and the societal policy decision-maker could use the prospect for directing social change towards a desired end. In question of forest policy and the private forest ownership structure this kind of approach is not, however, directly applicable, because a forest policy decision-maker cannot decide the values and norms which affect the forest ownership structure. The role of forest policy is mainly that of adapting to the changing forest ownership structure. The *contents of prospective ap-*

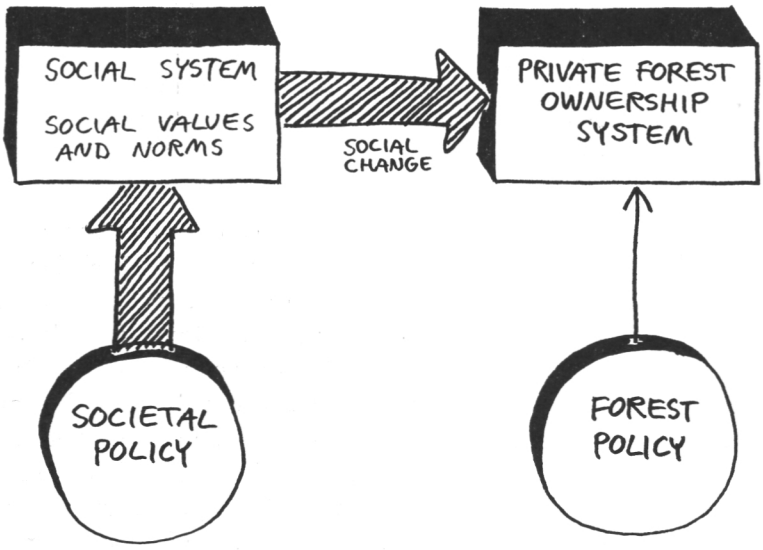


Figure 4.1. Relations of societal policy, social system, private forest ownership system and forest policy.

proach is in this case that values and norms connected to social change are expressed as clearly as possible in order to improve forest policy decision-maker's possibilities to adapt to the changes possibly occurring in the future.

The years 1970—2000 were chosen as the period for the prospects. The main criterion for this choice was availability of plans and forecasts of change of the social structure (Suomi 2000, 1970, Growth . . . 1972, H o n k a n e n et al. 1973). Prospects are presented for years 1980 and 2000, the former was chosen in order to get an intermediate image and thus a better view for the whole period of 1970—2000.

43. Prospect for private forest ownership change in 1970—2000

431. Forest ownership of farmers

4311. H e a v y t e n d e n c i e s i n a g r i c u l t u r e

In this section some information of the past development of agriculture in Finland is first given in order to get a general background on which to base the prospect. According to the Agricultural Censuses (SVT 45.3 1954; III : 55, 1962, III : 66, 1971) the forest land area (productive and poorly productive, see p. 10) on farms with forest developed, between 1929—1969, as follows:

Year	Million hectares
1929	10.5
1950	10.8
1959	10.8
1969	9.8

Figures of 1929 and 1950 are not directly comparable because Finland lost remarkable land areas in the World War II; this deficiency is not, however, important, because main interest in this study lies in the observation that since 1959 farmers' forest land area has tended to decrease. According to the national forest inventories (K u u s e l a 1972, p. 16) the total private forest land area (productive only) has developed differently from that of farmers' (Table 4.1.). A slight decrease from the 1920s to the 1950s is explained by land relinquishments after the World War II, after the 1950s a remarkable increase has occurred. Figures from the Agricultural Censuses and the forest inventories are not comparable (see p. 26) but the trends can be compared: whereas the *total private forest land area has increased since the 1950s, the forest land area of farmers' has decreased.*

The decrease of farmers' forests is one sign of the general change in the Finnish population structure (Table 4.2.). In 1950 economically active population in agriculture was 795 000, in 1970 it had decreased to less than half. The same occurred with the whole rural population. The number of farms with at least 3 hectares of arable land decreased in 1959—1969, however, only 4 %, and the corresponding area of arable land even increased by 5 % (H o n k a n e n et al. 1973, p. 2,4). This shows that the reduction in the number of economically active population in agriculture occurred mainly in the groups of paid labour and farmers' assisting family members.

In the same period the average age of farmers grew: in 1959 35 % of farmers were over 50 years, in 1969 the respective percentage was 43 % (Maatilatalouden . . . 1973, p. 22). Problems of agricultural overproduction were typical in the 1960s. Productivity in agriculture increased rapidly in 1961—1970: production of corn per hectare rose about 30 %, production of milk per cow rose 25 % (H o n k a n e n et al. 1973, p. 101—103). It has

Table 4.1. Forest land ownership in Finland in 1920s to 1960s based on the results of the national forest inventories. Source: K u u s e l a 1972, p. 16.

Year	Total, million hectares	Private owners	
		per cent of total	million hectares
1921—24	20.1	54.9	11.1
1951—53	17.3	62.3	10.8
1964—70	18.7	65.3	12.2

Table 4.2. Economically active population in primary industries, 31 December, 1950, 1960 and 1970 according to population census. Source: Suomen tilastollinen ... 1973, p. 40.

Year	Economically active population, 1 000 persons	
	Agriculture	Agriculture and Forestry
1950	795	909
1960	609	721
1970	364	429

been estimated that in 1970 the domestic consumption of agricultural products could have been met with arable land of 400 000 hectares less than the existing area (Growth ... 1972, p. 83).

Projections for the development of agriculture can be made in several ways. H o n k a n e n et al. (1973) made a projection for 1970—1980 based on the structure of the agricultural population and interviews of farmers. They estimated the decrease of active farmers by using death rates, disability rates and farmers' opinions. The estimate of new farmers entering into profession was based also on interviews.

There are large number of uncertainties in this kind of approach. Death and disability rates are based on previous conditions for living and working, and these conditions are slowly changing all the time. It is, also, very difficult to estimate how well farmers can make an appraisal on the length of their remaining duration in farming, when they do not know future economic and social conditions. Similar difficulties arise when considering the possible or probable number of new farmers on the base of interviews.

Realizing these uncertainties the researchers never-the-less made an estimate that the *number of active farmers, with at least 3 hectares of arable land, will decrease from 235 000 in 1969 to 157 000 in 1980*, and *the respective decrease in the area of arable land will be 731 000 hectares*. This appraisal becomes reality only if the death and disability rates used are true, if farmers' ideas of the future economic and social development are true and if researchers have interpreted farmers' ideas correctly.

Another approach is to base the appraisal on the principle of *self-sufficiency* of agricultural products. The major policy objectives in agriculture in Finland are (Growth ... 1972, p. 81):

— output corresponds the level of domestic consumption,
— production should be rationalized,
— agreement should be achieved on the most appropriate regional pattern of production, and
— income level of farming population should raise in step with that of other groups.

Having these objectives as given the Economic Planning Centre calculated the area of arable land and the number of active population needed in 1980 (Growth . . . 1972). Several forecasts were needed to form the base for the calculations:

— size of the future population,
— consumption habits of the population, and
— development of productivity in agriculture.

All these forecasts contain a number of problems. It is stressed (Growth . . . 1972, p. 30) that forecasting population growth in the 1970s in Finland is particularly difficult because of recent changes in birth rate and because of uncertainty about emigration. For example, in 1970 a forecast was made that the Finnish population in 1980 would amount to 5.0 millions (Suomi 2000, 1970). Some years later in a new forecast it had diminished to 4.7 millions (Muistio . . . 1974, p. 2). Forecasts on consumption habits of the population and agricultural productivity were made on the ground of trends in 1960s. If these trends continue, the *number of economically active population in agriculture and forestry will decrease from 429 000 persons in 1970 to 211 000 in 1980, and the area of arable land will decrease by some 600 000—700 000 hectares.*

It is to be stressed that although these two predictions came quite close to each other, they are closely tied to the problems of objectives and values of society. They make us ask questions like the following:

— Will the *principle of self-sufficiency* and the resulting diminution of arable land hold in the world, where the majority of people are suffering of hunger? This is a problem of developed and developing countries, a problem of the future of the whole world, which may cause the abolishment of the self-sufficiency principle. This abolishment would change all future images of agricultural production and population.

— Will the *change of rural structure*, caused by the considerable decrease of rural population and farms, be accepted in society? The decrease of 700 000 hectares of arable land and 30 % of the number of farms would mean a remarkable weakening of the rural structure (H o n k a n e n et al. 1973, p. 110). There are signs of values contradictory to the value of economic effectiveness, which has so far been the leading idea behind social change. Instead of the level of earnings we have begun to speak of level of living and, in the late 1960s, of quality of living (for example Talousneuvosto 1972).

These questions show how social projections are necessarily tied to consideration of values and norms. Questions could, for example, also be made on desirable population growth, desirable consumption habits and desirable productivity. In this study the task is not to try to answer such questions but just to bring them up to show more clearly the contents of the projections above.

Heavy tendency has been defined (p. 43) to mean a dominant process. Can it be judged, in this case, whether a heavy tendency exists in the development of agriculture and agricultural population? The first forecast by Honkanen et al. (1973) seems to suggest the existence of such a tendency, because the forecast was based largely on past development of the population. The second approach, that of the Economic Planning Centre (Growth ... 1972), was planning rather than forecasting, as it began by defining the objectives for agriculture first. It may be considered a coincidence that these two approaches came so close to each other, but it may, also, be regarded as an expression of an existing heavy tendency. The latter view is adopted in this study, and thus the *decrease of the number of farmers in 1970—1980 by 30 % is considered as a result of an underlying heavy tendency.*

4312. Prospect for decrease of farmers' forest land area

When a farmer ceases farming, it has immediate impact to forest ownership structure: forest land area owned by farmers diminishes. The effect of this change depends on who will be the next owner of the forest holding. Ownership change may not happen if a farmer merely changes occupation and maintains the ownership himself. If this is not the case, then new possible owners are other farmers, non-farmers, the State or forest industry companies. There are also other possible owner groups (see p. 10) but their importance is so small that they can be ignored. In this section only the first change, the immediate decrease in the amount of farmers' forests is dealt with, and the task in the next two sections will be to consider the new owners.

Farms that cease the production, are mainly small (Honkanen et al. 1973, p. 91). These small farms have, on the average, less forest than larger farms. According to the 1969 Agricultural Census (SVT III: 68, 1971) private agricultural holdings, with less than 5 hectares of arable land, comprised of 30 % of the total number (260 000) of private agricultural holdings. In this case only those holdings with at least 2 hectares of forest land were taken into the calculations. Of the respective forest land area (productive and poorly productive), 9.5 million hectares, 22 % belonged to farms with less than 5 hectares of arable land.

With the assumption that the 30 % decrease in the number of farms occurs only in the group of small farms with less than 5 hectares of arable land, in other words production ceases on all these farms, then the resulting decrease in forest land area would be 22 %. Actually all farms with less than 5 hectares of arable land will not cease farming, and a number of farms with more arable land will cease; the decrease of forest land area of farmers will therefore be slightly larger than 22 %. When it is known, in question of small farms, that their forest area is smaller than the average, then a decrease of 30 % in the number of farms means a slightly smaller decrease in forest land area. Thus an appraisal is made for the purpose of this study that *in 1970—1980 the forest land area of farmers will decrease by 25 %.*

According to the national forest inventory the total private forest land area was in 1965 12.2 million hectares (p. 10). In Keski-Suomi the share of farmers of private forest land area was 80 % in 1970 (p. 25) and according to Järveläinen (1974) it was the same in the whole country. Thus in 1970, supposing that the forest inventory result was representative also then, farmers owned 9.8 million hectares of forest land. *The resulting prospect for the decrease of farmers' forest land area up to 1980 is 2.5 million hectares.*

Projections on the number of farmers presented in section 4311. ended to year 1980. To be able to make a prospect up to year 2000 some other information is needed. Information consists of the following: Projections made on the development of the number of farmers from 1970 to 1980 resulted to 700 000 hectares decrease of arable land. The remaining area of arable land in Finland, 1.8 million hectares, is considered to be sufficient for domestic consumption (Honkanen et al. 1970, p. 96). When one of the objectives of agriculture is a balance between domestic production and consumption (p. 49), this would imply that after 1980 there is no longer a need to decrease the area of arable land or the number of farms. The heavy tendency that existed in the 1960s and 1970s would cease.

Another viewpoint is the continuous development of technology. It may be unrealistic to suppose that no improvements in agricultural production techniques occur after 1980. When technology improves, the area needed for self-sufficiency and the number of farms needed for production decrease. According to two different projections (presented in Suomi 2000, 1970) economically active population in agriculture would decrease in 1980—2000 by 50 %, from 330—340 000 persons to 160—170 000 persons. Evidently, a part of this decrease consists of farmers. The projection for the number of farmers in 1980 by Honkanen et al. (1973) was 157 000, thus quite near to half of the economically active population in agriculture (330—340 000 persons). When the decrease occurs after 1980 it does not consist of the whole group of farmers or the others (paid labour and family members working in the farm), but a certain amount of them both. The farmer group has not decreased

as rapidly as the group of others in the past. For making the prospect it is supposed that 25 % of the decrease (of 160—170 000 persons) consists of farmers and the rest of others. The decrease in the number of farmers after 1980 amounts approximately to 40 000, that is 25 % of the number of farmers in 1980. Making again the assumption that farms are quite small, a prospect is obtained that *in 1980—2000 the forest land area of farmers decreases by 20 %*. The amount of this decrease in hectares cannot be calculated before the amount of farmers' forest holding purchases in 1970—1980 has been appraised. It will be appraised in section 433.

432. Prospect for increase of State and forest industry company forests

Forest industry companies have always been interested in buying forest holdings. They bought almost all of their present forests (7 % of the forest land area) at the end of the last century before a Decree restricting their right to buy was passed in 1915. According to this Decree they are able to buy forest holdings but only with the permission of State authorities and only such forest holdings that cannot be used as additional lands for existing farms. Since 1915 forest land area owned by forest industry companies has decreased as a consequence of settlement activities. Since 1960, companies' purchases have exeeded their losses. In the period 1965—1969 companies bought 64 000 hectares of forest land and in 1970— 1972 123 000 hectares (K u p a r i n e n 1973).

Forest industry companies' purchases have been concentrated mainly near to their previous forests, and they have comprised of all kinds of forests, even clear-cut areas. Variations in their annual amounts of purchases are largely explained by private forest owners' willingness to sell. The years 1970—1972 are generally considered as a peak of sales, which resulted from several coincidences (a general deterioration of living conditions in rural areas, a couple of new agricultural laws) (R e u n a l a 1974).

The policy of forest industry companies is to try to increase their forest area (K u p a r i n e n 1973). It is a question of social values, what amount they will be allowed to buy in the future. K u u s e l a (1974, p. 135) thinks that in the coming years the amount of forests coming to the free market is so considerable that the State cannot buy all of it, thus companies should be given right to buy the rest, because they are known as »good» forest owners, practicing intensive silviculture. There are, however, strong opinions also against forest ownership by companies, both in political circles and in the rural areas (R e u n a l a 1974).

The State has been a net loser of forests up to the end of 1960s. Settlement activities in the beginning of this century and after the World War II have taken large areas of the State forests. In 1921—24 the State owned

35 % of forest lands, in 1964—70 its share was 24 % (K u u s e l a 1972, p. 16). In 1969, when it became evident that landowners were beginning to sell increasing numbers of forest holdings, the State changed its policy and came in as one buyer. In 1969—1973 the State bought a total of 69 000 hectares of forests, which were mainly in rather poor condition and in distant regions (R e u n a l a 1974).

The role of buyers of forest holdings in the future depends on *who has the money to buy and who has the right to buy*. So far no definite decisions have been made concerning the most suited owner group from the societal viewpoint. All ownergroups have been able to buy, so, for the purpose of prospect, it is supposed that they will continue to be able to buy also in the future. There are several suggestions of limiting forest holding purchases (for example Komiteanmietintö 1966: B 98, Maanhankinnan . . . 1974) but they are restricted mainly to forest holdings that can be used as additional lands for agriculture and thus their importance for the totality of forest holding purchases is not very remarkable.

The State's purchases in 1969—1973, 69 000 hectares, showed continuous annual increase during these first five years of its active participation in forest holding markets. K u u s e l a (1974, p. 136) suggests that the amounts of the State's purchases should be increased because of benefits (economical, environmental, societal) that can be achieved. An appraisal of a slightly augmented level of purchases is taken as the basis for the prospect, resulting to purchases of 100 000 hectares in five years and thus to *200 000 hectares from 1970 to 1980.*

Forest industry companies bought about 15 000 hectares/year in 1965—1969 and 40 000 hectares/year in 1970—1972. An appraisal of their future purchases will be taken between these two figures, 30 000 hectares/year. As a result *prospect for the period 1970—1980 will be 300 000 hectares.*

Because the decrease of the number of farmers was expected to slow down after 1980, it would be unrealistic to suppose continuing equal amounts of State and forest industry company purchases. Another approach is therefore taken in order to get the prospect for State and company purchases from 1980 to 2000.

Instead of the equal level of purchases, equal *proportion* of State and company purchases of the total decrease of farmers' forest area is taken as principle. From 1970 to 1980 the prospect for the decrease of farmers' forest land area was 2.5 million hectares. The prospect for State and forest industry purchases for that period is 0.5 million hectares, equal to 20 %. A study was made on purchases of forest land in the period 1967—1972 in four communes of Finnish Lapland (Lapin . . . 1973). Its result cannot be considered as representative for the whole of Finland, but anyhow, one result is worth mentioning: of the forest land area entering into the free market 44 % were

bought by farmers, 36 % by non-farmers, 7 % by the State and 13 % by forest industry companies. Thus the share of the State and companies was of about the same magnitude as estimated in the prospect for whole Finland for the period 1970—1980.

It is supposed that this same relation continues during the period 1980—2000, so that the *share of purchases of the State and forest industry companies stays, until 2000, on the level of 20 % of the decrease of farmers' forests.* What this 20 % means in hectares cannot yet be calculated, because the decrease of farmers' forests in the period 1980—2000 has not been expressed in areal terms. These calculations will be made in section 434, after a prospect for farmers' purchases of forests has been made in the next section.

433. Prospect for increase of non-farmers' forest land area

This section begins with the consideration on private forest owners' motives for forest ownership. So far, both farmers and non-farmers have been eager to own forests. Will this willingness continue in the future?

The main function of a forest holding for a private owner is *economic.* Besides selling timber, farmers have got income by working in their own forest (see p. 14). Farmers themselves consider forests as a necessary part of their livelihood, without which they cannot manage (for example Reunala 1974). Besides continuous incomes, forest owners appreciate the economic safety that forests provide for them (Järveläinen 1974). The group of non-farmers is more heterogenous than that of farmers. According to Järveläinen (1974) half of non-farmers in 1971 were workers, the other half belonged to the middle-class or were in leading posts. In addition to economic factors many non-farmers consider forests often also as a source for *recreation* (see for example Hahtola et al. 1973). Hämäläinen (1971, p. 419) compared various investments and came to the conclusion that investments to forestry have generally been more profitable than investments to bank accounts or State obligations. His study period consisted of years 1950—1970, and he supposed that the same relations would continue. As a conclusion it can be stated that there are no major observations to suggest that the importance of forests for a private owner would decrease. Both *farmers and non-farmers seem to have continuously a number of motives to own forest.*

The second inevitable question is that even if farmers and non-farmers are willing to own forests, are they *allowed* to acquire forests to their ownership? In rural areas and especially within the agricultural population a strong opinion exists that forest ownership of non-farmers is unfavourable and should be restricted (Reunala 1974). In connection with the prospect for State and forest company forests in the preceding section an opinion was taken and the same opinion is taken here concerning private persons that

participants in the forest holding market will be allowed to buy forest holdings in the same manner as before.

Besides purchases, inheritance has been as a channel for forest ownership changes, and the main channel for the increase of non-farmers' forests. In Keski-Suomi inheritance (including purchase arranged in the purpose of inheritance and farmers' change of occupation, see p. 32) had been the channel for 75 % of the increase of non-farmers' forest land area. Can it be supposed that the role of inheritance stays as prominent in the structural change of private forest ownership as it has done in the past? Several suggestions have been made in order to avoid consequences of forest ownership change that are considered as unfavourable (for example Komiteanmietintö 1966: B 98, Maanhankinnan . . . 1974, Reunala 1974), but no generally accepted suggestions have been presented concerning inheritance. Inheritance has in this century, except in abnormal conditions such as after the World War II, been a rule, a social value, which has its base in the Finnish Constitution, where (Suomen Asetuskokoelma 1917 no. 94, 6 §) the right to private ownership is declared. The supposition is made that *inheritance will maintain its position in the prospect period.*

In section 4312. it was appraised that in 1970—1980 a total of 2.5 million hectares of forest land will be the decrease of farmers' forest area. In the following section (432.) the amount bought by the State and forest industry companies was appraised to be 0.5 million hectares. Thus an area of 2.0 million hectares was left to be transferred to the ownership of non-farmers by inheritance and purchase and to the ownership of farmers by purchase. But what will be relations between these different transfers of ownership?

In Table 3.4 (p. 27) it can be found that in Keski-Suomi non-farmers had obtained 25 % of their forests by purchase on the market, and the rest by inheritance. On the study of all forest purchases in Lapland (Lapin . . . 1973, see p. 54) in four communes it was found that purchases of farmers consisted of 44 % and purchases of non-farmers of 36 % of all purchases made. A small number of farmers' purchases were made between relatives, but this number could not be estimated. However, it may not be far from correct to say that in this case groups of farmers and non-farmers bought about equal amounts of forest land.

There are certainly a large number of uncertainties in generalizing the results above to cover the whole of Finland, but because better information is not available, an estimate is made that forest land areas obtained by non-farmers through inheritance, by non-farmers through purchase and by farmers through purchase will relate to each other in relation of 3 : 1 : 1.

The following prospect is obtained: *in 1970—1980 the forest land area of non-farmers will increase by 1.6 million hectares (1.2 million hectares by inheritance and 0.4 million by purchase) and that of farmers by 0.4 million hectares by purchase.*

Table 4.3. Prospect for private forest ownership structure in 1980 and 2000 in Finland.

Year	Non-farmers				Farmers				Private forest land, total	
	Increase by		Total forest land		Decrease	Increase	Total forest land			
	inheritance	purchase							million hectares	%
	million hectares			%	million hectares			%		
1970	—	—	2.4	20	—	—	9.8	80	12.2	100
1980	+1.2	+0.4	4.0	34	—2.5	+0.4	7.7	66	11.7	100
2000	+0.8	+0.2	5.0	44	—1.5	+0.2	6.4	56	11.4	100

434. Prospect for private forest ownership structure in 1980 and 2000

All different prospects made in sections 431—433, are drawn together in this section. Table 4.3 shows the result. According to the prospect *forest land area of non-farmers almost doubles in 1970—1980 from 2.4 million hectares to 4.0 million hectares. In the same period forest area of farmers decreases from 9.8 to 7.7 million hectares.* Non-farmers' share of the total private forest land area would thus grow *from 20 % to 34 %* during the period, the share of farmers will consequently decrease.

Prospect for the year 2000 has been calculated on the basis of change rates mentioned in the previous sections and keeping year 1980 as basis. Prospect for the decrease of farmers' forest area during the period 1980—2000 was 20 % from the 1980 level, it makes 1.5 million hectares. The State and forest industry companies were appraised to buy 20 % of this, 0.3 million hectares. The remaining 1.2 million hectares was supposed to be divided by non-farmers' inheritance, purchase and farmers' purchase in relation of 3 : 1 : 1, thus respective forest land areas of 0.75, 0.25, 0.25 million hectares are obtained (in Table 4.3 these last figures are rounded).

According to the prospect the structural change of private forest ownership continues after 1980 but at a slower rate than in 1970—1980. Estimated *forest land area of non-farmers for the year 2000 is 5.0 million hectares (44 % of total private forest land area) and that of farmers is 6.4 million hectares (56 % of total).*

It is also worth noting that the total private forest land area, according to the prospect, decreases during the period 1970—2000 by 0.8 million hectares, which is about 7 % of the forest land area in 1970.

The reader may feel rather confused after this prospect, when the numerical result obtained looks like that of a quantitative forecast. These quantitative results might as well have been obtained by a »normal» forecasting method. What is actually the difference between forecast and prospect, and can this result obtained be considered more useful for forest policy than that of a forecast? In the next Chapter some remarks are made to these questions.

5. DISCUSSION

This Chapter deals with three questions raised by this study. First the choice of aim is discussed, then some comments are made concerning the methodological approach employed, and last the possibility of using a dynamic system model for making a prospect of the private forest ownership structure is discussed.

The aim (defined in Chapter 2) was to acquire relevant information for forest policy concerning private forest ownership structure. The choice of the aim resulted from the fact that structural change of private forest ownership was observed to cause some new difficulties regarding achievement of the forestry objectives. Achievement of these objectives, which never can be total, was supposed to be improved, if information concerning the past forest ownership structure and also some information about the future structure would be available for forest policy making. In section 333. it was found that the private forest ownership system is mostly dominant for forest policy, only the output of the system can be regarded to be partly dominable. The role of forest policy is thus mainly to try to adapt to the structural change.

It is evident that information concerning the past and future forest ownership structure is necessary for the best possible choice of forest policy measures, but another approach might have been to handle the problem on the next hierarchical level, where the whole system is dominable. The aim of the study would then have taken the following form: *what is the best possible private forest ownership structure for society*. This aim would have lead the study to the approach of *normative planning* (p. 41): defining the norms for a »good» forest owner, considering the possibilities of changing the present ownership structure towards the »better» one, and finally making a plan for a preferred possibility. The problem of this approach lies in the definition of »good» forest owners or the »best» forest ownership structure. As already stated, no generally accepted theory exist in which manner this »good» should be defined. From the viewpoint of efficient timber production the task might be quite simple, already S a a r i (1928, p. 14—16) stated that forest ownership by the State and forest industry companies was

to be regarded as the most suitable, and K u u s e l a (1974, p. 135) considers forest ownership by forest industry companies, as a part of an integrated system of forestry and forest industry, the most favourable type of ownership. Forest ownership has, however, other consequences for society, and all these consequences should be taken into consideration. Only one example is needed to show the difficulties that might arise when trying to define the »good»: right to private ownership is mentioned in the Finnish Constitution as one of the basic rights of all Finnish citizens; in which manner it is possible to compare values connected with intensive timber production and values connected with right to private ownership? The »best» forest ownership structure from the viewpoint of timber production is different from the »best» structure from the viewpoint of right to private ownership. How, in such a case, can an average of »best» be achieved?

The picture becomes even more complicated, when all the other values connected to forest ownership are considered. Forest ownership structure is, for example, considered an important factor for the rural communes, and local ownership is regarded as best for the development of the communes. Thus the normative planning approach has a large number of difficulties to overcome in order to become effective. Concerning normative planning of ownership in particular, it can be added that it is an essential political issue where strong contradictionary opinions exist.

Besides this difficulty of normative planning — the same difficulty of considering values and norms exists in the prospective approach — another problem also arises: from the viewpoint of societal policy the consequences of private forest ownership change (change of forest owners' silvicultural and timber-selling behaviour) might be considered of so little importance that efforts towards a planning approach might be regarded as worthless; it is just in case of a problem growing to grave proportions that a planning approach is worth while. At the beginning of this study it was quite difficult to estimate the possible gravity of the consequences of the increase of non-farmers' forest land area, thus the prospective approach taken seems justified. Later, after the prospect has been made, it is possible to continue to the process of normative planning if it seems useful.

Methodologically the three tasks of this study (p. 20) caused different problems. The two first tasks (to obtain information about private forest ownership structure in 1970, about the past ownership structure and the change mechanism) did not cause many difficulties. *Interview procedure seemed well suited for the exact definition of the present (1970) owner and also for the mapping of the former owners of the holding in 1945—1970.*

Another observation also suggests the relatively high reliability of these measurements: when non-farmers' share of the private forest land area was, according to this study, 20 % in Keski-Suomi in 1970, it was 21 %

for holdings of over 5 hectares throughout the whole country in 1971 in the sample of Järveläinen (1974).

The third task was to find out information about future private forest ownership structure relevant to forest policy decisions. What kind of information concerning the future can be considered *relevant?* Remembering that the private forest ownership system is mainly dominant for forest policy, the first suggestion might be to take some social changes like urbanization as given, deduce the resulting forest ownership structure, and state that on the basis of this urbanization process the forest ownership structure will be as follows . . . For policy-making this kind of situation would be ideal, if the primary forecast of urbanization is correct. By correct, in this case, is meant that primary forecast comes very close to the true rate of urbanization.

However, it is quite seldom that forecasts of social phenomena become true. Of course sometimes they can hit the trend with surprising accuracy (for example FAO 1964), but frequently forecasted and true values are far from each other. Thus a *forest policy decision-maker cannot take the primary forecast as a »given» future.* The unlikely existence of a »given» future is even more stressed by the complicated nature of the present social changes and also by the impossibility of the continuing of some past trends. So, when a »given» future does not exist, a rough image of the future must be strived for.

Typical to normative planning and prospects is that *several images of the future* are presented and the choice of the best is thus expected to be facilitated for the decision-maker. In this study several projections might have been made in the following way: first several projections of the development of the agricultural population would have been made, then two or three projections of the possible development of the right to ownership would have been drawn, and, as a combination of all projections, some four or six different images of the future forest ownership structure would have been obtained. Two of these images would have been as *minimum* and *maximum* projections for non-farmers' share of the forest land area.

This kind of methodological solution, which at first sight may look tempting, was not, however, chosen for this study. This decision was based on the opinion that available projections of the agricultural population did not offer any real and useful choices. Various suppositions of the development of the agricultural population would, of course, have been made in this study, but their rationality would have remained open. It was thought that choices like these would not give any additional information to the forest policy decision-maker.

There is also another point that led the study to the choice of one numerical outcome only, and it was the fact that some information about the minimum and maximum values for non-farmers' share was already available. The

private forest ownership change was explained to be an expression of a heavy tendency, thus the figure of 20 % for non-farmers' share of private forest lands can be considered as a minimum. On the other hand, it is evident that some amount of forests will continuously belong to farmers although the number of farmers is decreasing rapidly. This maximum figure for non-farmers' share depends not only on the number of farmers but also on the question who will get the ownership of the forests left over by farmers during the prospect period. So, in this study the range of the prospect was not expressed by numerical values of several possibilities, but with the consideration of possible or probable value changes. Each value change in the primary prospect results in a more or less large change in the secondary prospect. So, although the prospect for private forest ownership change was given certain numerical values in section 434, these figures are by no means accurate but around each figure there is a region of uncertainty which cannot be accurately estimated, and which depends on the primary prospects and on the values and norms connected with them.

If the region of uncertainty around the appraisals of non-farmers' share of private forest land area (34 % in 1980, 44 % in 2000) cannot be accurately estimated, how is a forest policy decision-maker expected to use the prospect? The answer to this question comes from the cybernetic property of the prospective approach: A decision-maker judges the prospect and its applicability himself and tries to estimate the region of uncertainty. If he feels incapable of making a decision on the basis of the prospect made, then a feedback system is necessary by which he turns again to the prospect-maker asking for new details; this can, in fact, be considered as a normal activity of a decision-maker. Bringing prospects to this activity means one addition to the normal: consideration of values and norms is not left only to the decision-maker, but it is already one part of the prospective approach, aiming at facilitating the decision-making.

One remark can still be made concerning the prospect made in this study. Although the appraisal of the importance of possible value changes is normally the duty of the decision-maker, some conclusions can sometimes be drawn directly from the prospect, and this occurs when the prospect can be largely regarded as the result of a heavy tendency. In section 4311. (p. 51) the conclusion was drawn that during the period 1970—1980 a 30 % decrease in the number of farmers can be considered a result of a heavy tendency. According to this tendency private forest ownership structure will keep changing in the 1970s so that the non-farmers' share of private forests will continuously increase. It seems probable that after 1980 the same tendency will continue but with less strength than before. This kind of statement concerning continuous change in a certain direction can be of immediate use for forest policy, even if the speed of the change cannot be defined.

The system model was used in this study in quite a rough and simplified manner: only one input (decrease of the number of farmers) and one stable inner structure of the system were supposed, and as a result a certain change in the system was obtained. The result was, however, considered to be useful for a forest policy decision-maker because of the continuous stress of the values and norms on which the change is based. The use of two or several sets of inputs or inner structure were rejected because several sensible projections were not at hand.

During the research process, however, an idea of a more effective use of the system model frequently appeared into mind. Although a trial has not been made with the present problem and data, it seems that a *dynamic* system model like the World Model of Meadows et al. (1972) could give more detailed results and information more useful for a decision-maker than the method used. With a dynamic model several possible futures can be appraised in a rational way, with which the complicated relations of several interconnected phenomena can be taken into the calculations of the model with the aid of computer. With simple projections these complicated relationships cannot be brought into the view, and thus a possible turning of the tendency as a result of changes in all interconnected phenomena cannot be observed. Thus, as the next step in searching for relevant information to forest policy, a dynamic system model seems worth trying.

REFERENCES

Ahmavaara, Yrjö. 1969. Yhteiskuntatieteen kyberneettinen metodologia. Helsinki.

Arosalo, Uolevi. 1968. Muutoksen tutkimuksen menetelmiä. Tampereen yliopiston sosiaalipsykologian laitoksen monistesarja n:o 49. Mimeographed. Tampere.

Asutustoiminnan aikakauskirja. Eri vuosilta. Asutushallitus. Helsinki.

Barel, Yves. 1971. Prospective et analyse des systèmes. Travaux et Recherches de Prospective n:o 14. Documentation française. Paris.

Beer, Stafford. 1969. The aborting corporate plan. A cybernetic account of the interface between planning and action. In: Jantsch, Erich (ed.). Perspectives of planning. OECD. Paris.

Berger, Gaston. 1967. Étapes de la prospective. Paris.

Brown, Robert G. 1963. Smoothing, Forecasting and Prediction of Discrete Time Series. Prentice-Hall Inc. Englewood Cliffs, N. J.

Cochran, William G. 1963. Sampling Techniques. Second edition. New York —London—Sydney.

Decouflé, André-Clément. 1972. La Prospective. Presses Universitaires. de France. Paris.

Drucker, Peter F. 1970. Muuttumisen aika. Helsinki.

Ervasti, Seppo, Heikinheimo, Lauri, Kuusela, Kullervo & Mäkinen, Veikko 1970. Forestry and forest industry alternatives in Finland 1970—2015. Folia Forestalia n:o 88. Helsinki.

FAO. 1953. European Timber Trends and Prospects. Food and Agriculture Organisation, United Nations. Geneva.

—»— 1964. European Timber Trends and Prospects. A new appraisal 1950—1975. Food and Agriculture Organisation, United Nations. New York.

Gabor, Dennis. 1964. Inventing the Future. Penguin Books. Middlesex, England.

Growth prospects for the Finnish economy up to 1980. 1972. Economic Planning Centre. Helsinki.

Hahtola, Kauko. 1967 a. Hankintahakkuut ja maatilakokonaisuus. Summary: Delivery cuts of timber in farm management. Acta Forestalia Fennica Vol. 84. Helsinki.

—»— 1967 b. Maatilametsätalouden yhteys taloudelliseen ja sosiaaliseen ympäristöön. Summary: Farm forestry and its socio-economic environment. Acta Forestalia Fennica Vol. 84. Helsinki.

Hahtola Kauko. 1971 a. Alueelliset näkökohdat maatilametsätalouden edistämisessä. Kansantaloudellinen aikakauskirja n:o 2. Helsinki.

—»— 1971 b. Forest owner's decision making and theories of the firm. Seloste: Metsänomistajan päätöksenteko ja yrityksen teoriat. Työtehoseuran julkaisuja n:o 158. Helsinki.

—»— Järveläinen, Veli-Pekka & Reunala, Aarne. 1973. Metsänomistajien puunmyyntikäyttäytyminen. Summary: The timber-sales behaviour of private forest owners. Silva Fennica Vol. 7, n:o 3. Helsinki.

Heikinheimo, Lauri & Palo, Matti. 1972. Increasing Investments in Finnish Forestry. In: Forest harvest with environmental awareness. Loggers Handbook Vol. XXXII 1972. Portland, Oregon, USA.

Heikkerö, Topi E. 1970. Hupenevat puureservit ja ylikysyntä. Helsingin Sanomat 23. 2. 1970.

Helander, A. Benj. 1949. Suomen metsätalouden historia. Porvoo—Helsinki.

Helsingin Sanomat. 13. 2. 1970. Metsänomistaja ei myy puuta. Yli-ikäisiä metsiä lahoaa Etelä-Suomessa.

—»— 6. 6. 1970. Puunjalostukselle povataan vaikeuksia. Olli Sarantolan haastattelu.

Holopainen, Viljo. 1971. Keinottelu metsämaalla pitäisi voida estää. Helsingin Sanomat 7. 2. 1971.

Honkanen, Seppo, Komonen, Aimo & Vainio-Mattila, Ilkka. 1973. Suomen maatalous 1960—1980. Laskelmia maatalouden ja maataloustuotannon rakenteellisesta kehityksestä. Pellervo-Seuran Markkinatutkimuslaitoksen julkaisuja n:o 14. Helsinki.

Huttunen, Terho. 1974. Suomen puunkäyttö, poistuma ja metsätase vuosina 1971—73. Summary: Wood consumption, total drain and forest balance in Finland in 1971—73. Folia Forestalia n:o 205. Helsinki.

Hämäläinen, Jouko. 1971. Pankkitalletukset ja valtion obligaatiot metsänomistajan sijoitusvaihtoehtoina. Summary: Bank Deposits and Government Bonds as Investment Alternatives for a Forest Owner. Liiketaloudellinen Aikakauskirja n:o IV. Helsinki.

Ihamuotila, Risto. 1968. Viljelijöiden työtulojen taso kirjanpitotiloilla 1956—1965. Summary: Labour income level of farmers on Finnish book-keeping farms in 1956—1965. Maatalouden taloudellisen tutkimuslaitoksen julkaisuja n:o 10. Helsinki.

Ilvessalo, Mikko. 1959. Suomen maan- ja metsänomistussuhteet 1920—1950-luvuilla. Referat: Land- und Waldbesitzverhältnisse in Finnland in 1920—1950ern Jahren. Metsäntutkimuslaitoksen julkaisuja n:o 51.6. Helsinki

Ilvessalo, Yrjö. 1957. Suomen metsät metsänhoitolautakuntien toiminta-alueittain. Valtakunnan metsien inventoinnin tuloksia. Summary: The forests of Finland by forestry board districts. Metsäntutkimuslaitoksen julkaisuja n:o 47.3. Helsinki.

IUFRO, Section 31, Working Group 4. 1971. Forecasting in forestry and timber economy. Folia Forestalia n:o 101. Helsinki.

Ivakhnenko, A. G. & Lapa, V. G. 1967. Cybernetics and forecasting techniques. American Elsevier Publishing Company Inc. New York.

Jantsch, Erich. 1967. Technological Forecasting in perspective. OECD. Paris.

—»— 1969 a. Synopsis of papers and discussions. In: Jantsch, Erich (ed.). Perspectives of planning. OECD. Paris.

—»— 1969 b. Adaptive institutions for shaping the future. In: Jantsch, Erich (ed.). Perspectives of planning. OECD. Paris.

de Jouvenel, Bertrand. 1972. L'art de la conjecture. 2e édition. S.E.D.E.I.S. Paris.

Jutikkala, Eino. 1968. Suomen teollistuminen. Teoksessa Jutikkala, Eino (toim.). Suomen talous- ja sosiaalihistorian kehityslinjoja. Porvoo—Helsinki.

Järveläinen, Veli-Pekka. 1971. Factors influencing silvicultural activity. A study of the influence of attitudes, individual farm background and regional conditions on the silvicultural activity of forest owners in Karstula and Jämsä, Finland. Seloste: Metsänhoidolliseen toimintaan vaikuttavat tekijät. Metsäntutkimuslaitoksen julkaisuja n:o 73.2. Helsinki.

—»— 1974. Yksityismetsänomistajien metsätaloudellinen käyttäytyminen. Summary: Forestry behaviour of private forest owners in Finland. Folia Forestalia n:o 222. Helsinki.

Komiteanmietintö 1966: B 98. Yksityismaakomitean osamietintö II. Komitean selvitykset ja päätelmät. Mimeographed. Helsinki.

Kulha, Keijo K. 1963. Asutustoiminta Keski-Suomessa 1945—1960 vuoden 1945 maanhankintalain nojalla. Keski-Suomen Maakuntaliitto r.y. Jyväskylä.

Kuparinen, Paavo. 1973. Metsäteollisuusyhtiöiden maanhankinta. Muistio. Suomen Metsäteollisuuden Keskusliitto.

Kuusela, Kullervo. 1972. Suomen metsävarat ja metsien omistus 1964—70 sekä niiden kehittyminen 1920—70. Summary: Forest resources and ownership in Finland 1964—70 and their development 1920—70. Metsäntutkimuslaitoksen julkaisuja n:o 76.5. Helsinki.

—»— 1974. Metsätalous teollistuvassa Suomessa. SITRA, sarja B n:o 12. Helsinki.

Kähönen, Urho. 1970. Rakennerationalisointimaata runsaasti keinoittelijain käsiin. Asutushallituksen ostomenettely liian hidas. Maaseudun Tulevaisuus 19. 9. 1970.

Lapin maatilatalouden kehittämistoimikunta. 1973. Maakaupat Inarin, Pellon, Posion ja Sallan kunnissa vv. 1967—1972. Mimeographed. Rovaniemi.

Lento, Reino. 1951. Maassamuutto ja siihen vaikuttaneet tekijät Suomessa vuosina 1878—1939. Summary: Internal migration and factors affecting it in Finland in 1878—1939. Väestöpoliittisen tutkimuslaitoksen julkaisuja, sarja A : 5. Helsinki.

Lönnstedt, Lars. 1974. En förklaringsmodell till privatskogsägarnas beteende. Institutionen för skogsekonomi. Skogshögskolan. Mimeographed. Stockholm.

Maanhankinnan rajoittamistyöryhmän I mietintö. Annettu maa- ja metsätalousministeriölle 19. 9. 1974. Mimeographed. Helsinki.

Maatilatalouden työryhmän mietintö. 1973. Kehitysalueiden neuvottelukunta, Elinkeinopoliittinen jaosto. Mimeographed. Helsinki.

Makkonen, Olli. 1974. Forst-sanan alkuperä. Summary: On the origin of the word forst (forest). Silva Fennica Vol. 8, n:o 1. Helsinki.

Massé, Pierre. 1967. Prévision et prospective. Dans Berger, Gaston. Etapes de la prospective. Paris.

Meadows, Donella H., Meadows, Dennis L., Randers, Jørgens & Behrens, William W. III. 1972. The Limits to growth. A report for the Club of Rome's project on the predicament of mankind. London.

Muistio alueittaisesta työpaikka- ja väestökehityksestä vuoteen 1980. 14. 1. 1974. Valtioneuvoston kanslia. Mimeographed. Helsinki.

Osara, N. A. 1935. Suomen pienmetsätalous. Referat: Die Kleinwaldwirtschaft in Finnland. Metsäntutkimuslaitoksen julkaisuja n:o 21.1. Helsinki.

Ozbekhan, Hasan. 1968. The triumph of technology: »can» implies »ought». In: Anderson, Stanford (ed.). Planning for diversity and choice. Cambridge, Massachusetts.

—»— 1969. Toward a general theory of planning. In: Jantsch, Erich (ed.) Perspectives of planning. OECD. Paris.

Palo, Matti. 1971. A systems-oriented frame model for planning research projects in forestry. Seloste: Metsällisen tutkimusprojektin suunnittelun systeemiteoreettinen kehysmalli. Metsäntutkimuslaitoksen julkaisuja n:o 72.4. Helsinki.

—»— 1974. Goal-setting for Finnish forest research policy of the 1970's. Seloste: Suomen metsäntutkimuspolitiikan suuntaviivat 1970-luvulla. Acta Forestalia Fennica Vol. 142. Helsinki.

Peccei, Aurelio. 1970. Where are we? Where are we going? »SUCCESSO» no. 2, February 1970.

Polak, Fred L. 1961. The image of the future. I and II. Leyden A. W. Sythoff, New York Oceana publications.

Prospective et société. 1972. Travaux et Recherches de Prospective. Documentation française. Paris.

Raivio, Arvi. 1960. Suomen väestön elinkeinoryhmitys vuosina 1820—1870. Väestöntutkimuksen vuosikirja VI-1960. Helsinki.

Reunala, Aarne. 1972. Yksityismetsänomistuksen rakennemuutos Keski-Suomessa 1945—1970. Kansantaloudellisen metsäekonomian lisensiaattitutkimus, Helsingin yliopiston maatalous-metsätieteellinen tiedekunta. Mimeographed. Helsinki.

—»— 1974. Metsänomistuksen muutokset ja aluepolitiikka. Summary: Forest ownership changes and regional policy. Manuscript. Forest Research Institute. Helsinki.

—»— & Tikkanen, Ilpo. 1972. Metsätilanomistajat metsätalouden edistämistoiminnan kohteena Keski-Suomessa. Summary: Non-farmer forest owners and promotion of private forestry. Folia Forestalia n:o 134. Helsinki.

Riihinen, Päiviö. 1963. Metsänhoidon tason vaihtelu Suomen maatilametsälöillä. Tutkimus metsänhoitolautakunnittaisten erojen taloudellisista ja sosiaalisista eroista. Summary: Variations in the Level of Silviculture on the Finnish Farm Woodlots. A Study of Economic and Social Factors Affecting the Regional Level of Silviculture. Acta Forestalia Fennica Vol. 75. Helsinki.

Roos, J. P. 1973. Suunnittelun teorioista. Sosiologia n:o 6/1973. Helsinki.

Rubin, Theodore J. 1969. Toward information systems for environmental forecasting. In: Jantsch, Erich (ed.). Perspectives of planning. OECD. Paris.

Saari, Eino. 1928. Metsätalouden taloudelliset erikoisuudet ja perusteet. Maa ja metsä IV. Metsätalous I. Porvoo.

Seppälä, Risto. 1974. Yksityismetsänomistajien hakkuukäyttäytyminen Suomen itäosissa. Summary: Cutting behaviour of private forest owners in eastern Finland. Folia Forestalia n:o 189. Helsinki.

Suomen Asetuskokoelma 1917 n:o 94. Suomen hallitusmuoto.

—»— 1958 n:o 353. Maankäyttölaki.

—»— 1966 n:o 465. Laki metsähallinnosta.

—»— 1967 n:o 412. Yksityismetsälaki.

Suomen kansantalouden kehitysmahdollisuudet vuoteen 1980. 1972. Taloudellinen suunnittelukeskus. Helsinki.

Suomi 2000. 1970. Seutusuunnittelun keskusliitto. Helsinki.

SVT (Suomen Virallinen Tilasto) 45.3. 1954. Yleinen maatalouslaskenta 1950. Osa III, metsälötilasto. Helsinki.

—»— III : 55. 1962. Yleinen maatalouslaskenta 1959. Osa III, metsälötilasto. Helsinki.

—»— XXX. 1967. Asutustilastoa. Asutustoiminta 1959—1965. Helsinki.

—»— XVII A : 1. 1969. Metsätilastollinen vuosikirja 1968. Folia Forestalia n:o 70. Helsinki.

—»— III : 66. 1971. Yleinen maatalouslaskenta 1969. I nide. Yleinen osa. Helsinki.

—»— III : 68. 1971. Yleinen maatalouslaskenta 1969. III nide, metsälötilasto. Helsinki.

—»— XVII A : 5. 1974. Metsätilastollinen vuosikirja 1972. Folia Forestalia n:o 195. Helsinki.

Suomen tilastollinen vuosikirja vuonna 1972. 1973. Tilastokeskus. Helsinki.

Talousneuvosto. 1972. Elämisen laatu, tavoitteet ja mittaaminen. Yhteiskuntapolitiikan tavoitteet ja niiden mittaamista tutkiva jaosto. Mimeographed. Helsinki.

Toffler, Alvin. 1972. Hätkähdyttävä tulevaisuus. Keuruu.

Törnqvist, Leo. 1974. Aikasarjojen analyysi ja ennustaminen. Jyväskylä.

Uusvaara, Arno. 1969. Maan ja metsän omistus Suomessa v. 1965 alussa ja sen kehitys v. 1957—65. Summary: Land and forest ownerships in Finland 1965 and their development during 1957—65. Folia Forestalia n:o 63. Helsinki.

Waris, Heikki. 1968. Muuttuva suomalainen yhteiskunta. Porvoo.

Vasama, Pyry-Matti & Vartia, Yrjö. 1972. Johdatus tilastotieteeseen. Osa 2. Helsinki.

Vennamo, Veikko. 1968. Siirtoväen asuttaminen. Teoksessa Jutikkala, Eino (toim.). Suomen talous- ja sosiaalihistorian kehityslinjoja. Porvoo—Helsinki.

Virkkunen, Paavo. 1973. Virasto- ja laitoskohtainen suunnittelu. Valtiovarainministeriö, suunnittelusihteeristö. Helsinki.

Virta, Jouko. 1971. Yksityismetsänomistajien puunmyyntialttius Länsi-Suomessa vuonna 1970. Summary: Timber-sales propensity of private forest owners in western Finland in 1970. Folia Forestalia n:o 114. Helsinki.

YKSITYISMETSÄNOMISTUKSEN RAKENNEMUUTOS

Seloste

Yksityismetsänomistajat (yksityishenkilöt, perikunnat ja yksityiset toiminimet) omistivat Suomessa vuonna 1965 12.2 milj. hehtaaria metsämaata eli 65 % koko metsämaan pinta-alasta. Puuston kuutiomäärästä yksityismetsien osuus oli 71 % ja vuotuisesta kasvusta 78 %. Vähintään 2 hehtaarin kokoisten yksityismetsälöiden lukumäärä oli vuonna 1969 noin 350 000.

Puuntuotannon tehostaminen on 1960-luvun alusta lähtien ollut eräänä keskeisenä kansantaloudellisena päämääränä metsätaloudessa. Yksityismetsätaloudessa tämän päämäärän tavoitteleminen on ongelmallista, koska siellä on yli 300 000 päätöksentekijää, joiden tavoitteet vaihtelevat eivätkä suinkaan aina osu yksiin kansantaloudellisten päämäärien kanssa. Lakien ja yksityismetsätalouden edistämisorganisaation avulla, ja 1960-luvulla kuvaan tulivat vielä mukaan useat metsätalouden tehostamisohjelmat, kehitystä on Suomessa pystytty ohjaamaan vähitellen kansantaloudellisten päämäärien suuntaan. 1960-luvun loppupuolella alkoi näkyä ensimmäisiä merkkejä eräästä uudesta ilmiöstä, joka näytti tuovan vaikeuksia päämäärien tavoitteluun: yksityismetsien, jotka perinteellisesti ovat olleet viljelijäväestön omistuksessa, huomattiin lisääntyvässä määrin siirtyvän muiden, erityisesti kaupunkilaisten omistukseen. Tässä tutkimuksessa käytetään nimeä *metsätilanomistaja* sellaisista yksityismetsänomistajista, jotka saavat pääasiallisen toimeentulonsa muusta kuin omasta maa- ja metsätaloudesta. Huolta aiheutti erityisesti se, että näiden metsätilanomistajien arveltiin olevan vähemmän kiinnostuneita tehokkaasta puun tuotannosta kuin maanviljelijöiden. Tutkimuksissa (esimerkiksi H a h t o l a ym. 1973) onkin sittemmin voitu todeta, että metsätilanomistajien joukossa on sellaisia jotka eivät ole kovin kiinnostuneita puun tuotannon tehostamisesta tai tasaisista puun myynneistä.

Tällaisen uuden metsänomistajaryhmän ilmaantuminen aiheuttaa uusia pulmia metsäpolitiikassa. Metsäpolitiikan päätöksentekijöiden olisi tunnettava tällaisen ryhmän koko, sen tavoitteet ja käyttäytyminen, jotta tuloksellinen metsäpolitiikka olisi mahdollista. Tämän *tutkimuksen tarkoituksena* oli hankkia sellaista yksityismetsänomistuksen rakennetta koskevaa tietoa, joka on hyödyllistä metsäpolitiikan päätöksentekijöille. Hyödyllisen tiedon saamiseksi tälle tutkimukselle asetettiin kolme tehtävää:

— hankkia tietoa metsätilanomistajien lukumäärästä ja heidän omistamastaan metsäpinta-alasta
— kuvata yksityismetsänomistusrakenteessa tapahtuneita muutoksia ja analysoida niiden mekanismeja, ja
— hankkia metsäpolitiikan kannalta hyödyllistä tietoa tulevaisuudessa mahdollisista metsänomistusrakenteen muutoksista.

Kahta ensimmäistä tehtävää varten hankittiin tietoa haastattelemalla yksityismetsänomistajia Keski-Suomessa. Näyte käsitti 510 yli 10 hehtaarin kokoista metsälöä, joiden omistajat haastateltiin lokakuussa 1970 — tammikuussa 1971. Näytteen mukaan metsätilanomistajat omistivat vuonna 1970 24 % yksityismetsälöiden luku-

määrästä ja 20 % niiden metsämaan alasta. Käyttäen hyväksi muista tutkimuksista saatavissa olevaa tietoa 10 hehtaaria pienemmistä metsälöistä, saatiin *metsätilanomistajien osuudeksi kaikkien Keski-Suomen yksityismetsälöiden lukumäärästä 30 % ja niiden metsämaan alasta 20 %.*

Vuodesta 1945 vuoteen 1970 metsätilanomistajien osuus yksityismetsien pinta-alasta kasvoi 8 %:sta 20 %:iin. Tästä 57 % tapahtui perintömekanismin ja vanhemmilta tai sukulaisilta oston välityksellä, 20 % vapailla markkinoilla tehdyillä kaupoilla, 18 % maanviljelijöiden vaihtaessa ammattia, ja loput 5 % asutustoiminnan yhteydessä. Kun ammattia vaihtaneet maanviljelijät olivat useimmissa tapauksissa saaneet tilan haltuunsa perimällä, voitiin todeta, että *kolme neljäsosaa metsätilanomistajien metsäpinta-alan lisäyksestä tapahtui perintömekanismin välityksellä.*

Yksityismetsänomistusta ja siinä tapahtuvia muutoksia voidaan kuvata systeemin avulla. Perintö on eräs välittävä mekanismi, jonka kautta systeemin tiloissa tapahtuu muutoksia. Muutos ei kuitenkaan johdu välittävistä mekanismeista sinänsä vaan systeemin ympäristöstä tulevista ärsykkeistä. Ärsykkeinä (input) ovat tässä tapauksessa yhteiskunnan rakenteessa tapahtuvat muutokset, joita voi kuvata nimellä elinkeinorakenteen muuttuminen tai kaupungistuminen. Systeemi puolestaan lähettää ärsykkeitä ympäristöön (output), tässä tapauksessa metsänomistajien muuttuvina tavoitteina ja käyttäytymisenä. Metsäpolitiikan kannalta tarkasteltuna ainoastaan systeemistä ympäristöön lähtevä ärsyke, metsänomistajien käyttäytyminen, on vaikutettavissa oleva tekijä, muut osat systeemistä ovat rajoituksia, sellaisia, joihin ei voi vaikuttaa metsäpoliittisin toimenpitein. Yleisellä yhteiskuntapolitiikalla sen sijaan voidaan vaikuttaa koko metsänomistusrakennesysteemiin.

Kahdessa ensimmäisessä tämän tutkimuksen tehtävistä ongelmat liittyivät pääasiassa mittaukseen ja kuvaukseen, kolmannen tehtävän ongelmat olivat sen sijaan suurimmaksi osaksi metodisia. Tulevaisuutta voidaan tutkimuksessa tarkastella kolmella toisistaan jonkin verran poikkeavalla tavalla: ennustamalla, suunnittelemalla, ja lähestymistavalla, jonka englanninkielinen nimi on »prospect». Koska termillä »prospect» ei ole suomenkielistä vastiketta, käytän siitä nimitystä normatiivinen ennustaminen. *Ennustamisella* ymmärretään tavallisesti vallitsevan prosessin (trendin) jatkamista tulevaisuuteen. *Suunnittelu* on ennen kaikkea tekemisissä vaikutettavissa olevien ilmiöiden kanssa. *Normatiivisella ennustamisella (prospect)* tarkoitetaan ilmiön vaihtoehtoisten tulevaisuuksien kartoittamista ja arviointia suunnittelun ja päätöksenteon avuksi.

Teoreettisesti mainitut kolme lähestymistapaa ovat puutteellisia, selviä rajoja ennustamisen, suunnittelun ja normatiivisen ennustamisen välille ei ole kyetty määrittelemään. Normatiivisen ennustamisen menetelmä valittiin tämän tutkimuksen lähestymistavaksi seuraavista syistä: ensiksikin näin toivottiin vältettävän mielikuva tietyn trendin jatkamisesta, joka liittyy perinteelliseen ennustamisen käsitteeseen. Toiseksi käsitettä suunnittelu ei pidetty sopivana, koska se kohdistuu vaikutettavissa oleviin ilmiöihin, ja kuten aiemmin todettiin, metsänomistusrakennesysteemiin ei voi metsäpolitiikalla vaikuttaa kuin vähäiseltä osin.

Normatiivisen ennustamisen (ja myös normatiivisen suunnittelun) oleellinen osa on arvojen ja normien pohdinta ennusteprosessin yhteydessä. Tällä tavalla päätöksentekijälle pyritään antamaan selkeämpi kuva siitä, mikä tulevaisuuden vaihtoehto on tavoiteltava ja mikä mahdollisesti haitallinen jne. On kuitenkin ratkaisematon ongelma, miten tällainen arvojen ja normien punninta pitäisi tehdä ja minkälaisen tulisi olla ennustajan (tai suunnittelijan) ja päätöksentekijän yhteistyö. Oma ongelmansa on se, miten arvot ja normit pitäisi ottaa huomioon, kun tarkasteltava ilmiö ei ole päätöksentekijän vaikutettavissa, kuten tässä tutkimuksessa on laita. Silloin päätöksentekijä ei tietenkään voi ryhtyä ratkomaan korkeamman hierarkiatason arvoja ja normeja.

Tässä tutkimuksessa meneteltiin seuraavasti: Käytettävissä olleet ennusteet yhteiskunnan muutosprosessista (väestön määrä, elinkeinojakauma ym.), otettiin sekundaarisen metsänomistusrakenne-ennusteen pohjaksi, mutta ei suinkaan annettuina, vaan niiden tarkastelun yhteydessä pyrittiin korostamaan niiden riippuvuutta arvoista ja normeista. Tällä tavalla menetellen toivottiin metsäpolitiikan päätöksentekijöiden saavan selkeämmän kuvan tulevan yhteiskuntakehityksen mahdollisuuksista ja vaihtoehdoista päätöstensä perusteiksi.

Näiltä perusteilta lähtien laadittiin normatiivinen ennuste yksityismetsänomistusrakenteesta vuosille 1980 ja 2000 siten, että ensin arvioitiin maatilataloudesta tehtyjen ennusteiden perusteella se osa maanviljelijöiden omistuksessa vuonna 1970 olleita metsiä, joka siirtyy (ainakin hetkellisesti) pois viljelijäväestön omistuksesta kun maanviljelyksen harjoittaminen tilalla lakkaa. Tämän jälkeen tehtiin arvio siitä, miten suuri osa näistä metsistä tulee siirtymään metsähallituksen ja metsäteollisuusyhtiöiden omistukseen. Lopuksi arvioitiin jäljelle jääneen metsäalan siirtyminen perimällä tai ostamalla metsätilanomistajille, ja ostamalla maanviljelijöille. Tämän normatiivisen ennusteen mukaan saatiin *metsätilanomistajien osuudeksi yksityismetsien pinta-alasta 34 % vuonna 1980 ja 44 % vuonna 2000.*

Laadittu normatiivinen ennuste ei ole profetia siitä, mitä todella tulee tapahtumaan. Ennusteen numerollinen arvio perustuu esimerkiksi siihen, että maatilatalouden ja maatalousväestön kehitys noudattaa tiettyä trendiä, vaikka tällaisen trendin toteutuminen riippuu muun muassa siitä, säilyykö maataloustuotannon omavaraisuusperiaate vallitsevana arvona, ja miten suhtaudutaan maatalousväestön vähenemisen seurauksena olevaan maaseudun toiminnallisen rakenteen heikkenemiseen. Keskeisinä ennusteen kannalta ovat myös metsän omistamiseen ja perimiseen liittyvät arvot; saavatko metsätilanomistajat, metsäteollisuusyhtiöt ja valtio edelleen ostaa ja omistaa metsiä niinkuin tähänkin asti.

Tutkimuksen ongelmaa olisi ollut mahdollista lähestyä toisestakin näkökulmasta, tarkastelemalla metsänomistusta yhteiskunnallisena ilmiönä, jota voidaan yhteiskuntapolitiikalla ohjata haluttuun suuntaan. Voidaan kuvitella, että »paras» metsänomistusrakenne voitaisiin sopivilla kriteereillä määrittää, jonka jälkeen yhteiskuntapolitiikan keinoin pyrittäisiin kohti tätä »parasta» olotilaa. Tätä lähestymistapaa ei kuitenkaan tutkimuksessa valittu, ja tämä johtui siitä, että »parhaan» määrittäminen on kerrassaan mutkikas ja laaja, ehkäpä ratkaisematon ongelma, ja sen lisäksi tuntuu siltä, että metsänomistuksen merkitys on sen verran vähäinen yhteiskuntapolitiikan kokonaiskentässä, että siihen ei toistaiseksi, ainakaan erillisenä ilmiönä, ole aihetta puuttua ratkaisevasti yhteiskuntapolitiikan keinoin.

Laadittu metsänomistusrakenteen normatiivinen ennuste tuntuu hyödylliseltä kahdelta kannalta: ensiksikin näyttää siltä, että ainakin 1970-luvulla aikaisempi kehityssuunta jatkuu voimakkaana, ja vuoden 1980 jälkeenkin kehitys jatkuu samansuuntaisena, joskin hidastuneella nopeudella. Nopeudesta on hyvin vaikea tehdä arvioita, mutta jo sekin toteamus, että muutos on jatkuvaa ja tapahtuu entiseen suuntaan, voi olla hyödyllinen metsäpolitiikan kannalta. Toiseksi, on luultavaa, että arvojen ja normien esille tuominen normatiivisen ennusteen laatimisen yhteydessä antaa metsäpolitiikan päätöksentekijälle paremman käsityksen metsänomistusrakenteessa odotettavissa olevista muutoksista kuin jos näitä arvoja tai normeja ei ollenkaan käsiteltäisi. Koska metsäpolitiikan päätöksenteko on jatkuvaa toimintaa ja seurantaa, niin kuvaa metsänomistusrakenteen mahdollisesta kehityksestä tarvitaan myös jatkuvasti. Kun päätöksentekijä tietää, mihin arvoihin metsänomistusrakenteen muuttuminen perustuu, on hänen mahdollista jatkuvasti, tarkkailemalla arvoissa tapahtuvia muutoksia, täsmentää metsänomistusrakenteesta hahmottamaansa tulevaisuudenkuvaa.

Appendix

Structural change of
private forest ownership 1970
Forest Research Institute

INTERVIEW OF FOREST OWNERS

A study concerning structural change in private forest ownership has began in the Forest Research Institute. Structural change means change of forest ownership from farmers to persons, who earn their living from other professions. — This interview is one part of the study. All information gathered is confidential and it will be used only for scientific purposes.

1. Forest owner n:o _____

   Name _____

   If a deceased's estate or family company, then the name of the responsible

   Other partners of the deceased's estate or family company _____

   _____

   Personal information and opinions are asked from the person who has responsibility of the deceased's estate or family company

2. Date of birth _____

3. Profession _____

   if retired then the former profession and the date of retiring

   Post address _____

4. Do you live permanently
   1. In the countryside
   2. In town

5. Ownership of house or apartment, where you live permanently
   1. Own
   2. Rented apartment
   3. Rented room

6. What domestic services do you have?

   Central heating
   Running water
   Drainage
   WC
   Electricity

   Total _____ items

7. What domestic effects do you own?

Refrigerator
Telephone
Television
Freezer
Car Total _____ items

To be asked from those living in the countryside (8—12)

8—12. How far is it from your home to the nearest

8. Shop, where food is usually bought _____ km _____ m
9. Post office _____ km _____ m
10. Communal Office _____ km _____ m
11. Elementary School _____ km _____ m
12. Neighbour _____ km _____ m

Name of the holding _____

Register numbers _____

Village (official name) _____

13. Commune _____

14. Forest land area of the sample forest holding

which comprise Reg. n:o _____ ha _____ Reg. n:o _____ ha _____
in the following way Reg. n:o _____ ha _____ Reg. n:o _____ ha _____

15. Other forests of the owner, ha _____
Total forests of the owner, ha _____

16. Arable land, ha _____

cultivated personally ha _____
manager cultivates ha _____
rented to others ha _____
reserved ha _____

17. Do you live permanently on your farm? 1. Yes
2. No

18. Marital status
1. Married
2. Unmarried
3. Widow
4. Divorced

19. Number of children _____

20. Number of children of over 15 years _____

21. Which schools have you attended _____

_____

22. For how many years has the forest holding or the largest part of it been in your or your family's ownership?

1. 0— 10 years
2. 11— 25 years
3. 26— 50 years
4. 50—100 years
5. over 100 years

To be filled later on the basis of APPENDIX 1. (23—24)

23. How many years has the owner owned the forest holding (largest part of it) _____

24. In which manner the owner obtained the forest holding (or the largest part of it).

To be asked from non-farmers (25—34)

25. Have you, between 1945—1970, ever had farming as your main profession?

1. Yes 2. No → to question 26.

When, years _____

What did you do with your arable land when you ceased farming _____

→ to question 27

26. You didn't ever choose to be a farmer. What was the main reason for that?

1. Parents did not give the farm in time
2. Another of the children planned to be farmer
3. Education led to another profession
4. Holding would not have offered good enough living possibilities
5. Other reason, what _____

27—34. In the next questions you are asked to compare your present profession to the profession of farmer. In which — in your present profession or in farming . .

	In present profession			in farming	
	considerably	somewhat	do not know	somewhat	considerably
27. Earnings are better	5	4	3	2	1
28. Working conditions are more comfortable	5	4	3	2	1
29. Work is more variable	5	4	3	2	1
30. Work is better esteemed	5	4	3	2	1
31. Work is lighter	5	4	3	2	1
32. Work is more free	5	4	3	2	1
33. Work is more responsible	5	4	3	2	1
34. Career possibilities are better	5	4	3	2	1

To be asked from farmers (27—34)

In the next questions you are asked to compare your own profession of farmer to ordinary town professions. In which one —in farming or in town professions . . . questions 27—34

35. How satisfied you are with your profession?

1. Very satisfied
2. Satisfied
3. Do not know
4. Dissatisfied
5. Very dissatisfied

To be asked from those not living on the farm (36)

36. Have you during 1945—1970 sometimes lived permanently in your farm?

1. Yes 2. No

When, years _____

37. A number of professions are mentioned in the following list. How people generally regard these professions, which is the most highly esteemed, the next highly and so on. (Highest gets value 1, the next 2 . . . the lowest 7)

_____ Driver
_____ Teacher in elementary school
_____ Farmer, 10 ha of arable land
_____ Metal industry worker
_____ Forest worker
_____ Police
_____ Office worker

38—44. In the following questions you are asked to compare life in town and in the countryside. In which — in town or in the countryside — life generally speaking is . . .

	in town			in the countryside	
	considerably	somewhat	do not know	somewhat	considerably
38. More peaceful	5	4	3	2	1
39. More variable	5	4	3	2	1
40. Freer	5	4	3	2	1
41. More comfortable	5	4	3	2	1
42. Safer	5	4	3	2	1
43. Easier	5	4	3	2	1
44. People are more kind	5	4	3	2	1

45. What do you estimate to be the monthly rent of a 50 m² two-room flat in Jyväskylä?

mk _____

46. And how much do you estimate that a family of four members (2 adults, 2 children) in Jyväskylä spends on food per month?

mk _____

47. In the next question there is the picture of a ladder. If on the highest step there is a forest owner who makes his living from forest incomes only, and on the lowest step one who makes his living completely from other than forest incomes, on which step you would put yourself considering the relative importance of forest incomes?

48. There is another question about the same ladder. If on the highest step there is a forest owner whose forest is of very good quality, and on the lowest step one whose forest is of poor quality, then on which step you would put yourself?

To be asked only from farmers (49)

49. And still one question about the ladder: if on the highest step, there is a successful farmer, and on the lowest an unsuccessful, then on which step you would put yourself?

50—55. Now I shall read to you some properties connected to forest ownership. How important do you consider them for you and your family? You can choose the following answers

5. Very important
4. Quite important
(3. Do not know)
2. Not so important
1. Not important at all

50. Forests offer regular income

51. Forests offer many opportunities for recreation

52. Forests give security for old age

53. Forests help to meet exceptional needs for money

54. Forests increase possibilities to get a loan

55. Forests give security for future generations

56. Which one of the mentioned properties you personally consider the most important? n:o _____

Have you ever bought forest?

1. Yes → to question 57 2. No → to question 65

To be asked only from those who have bought a forest holding (57—63)

57—63. Now I shall read to you some properties that are connected to the purchase of forest holding. How important did you consider them when buying forest? You can choose the following answers:

5. Very important
4. Quite important
(3. Do not know)
2. Not so important
1. Not important at all

57. Forests are more profitable as an investment than a bank deposit

58. It is possible to get back the money invested in a forest rather quickly

59. Forest ownership increases the social esteem of the owner

60. Purchase improved the structure of the holding

61. Forest is an insurance towards possible future difficulties

62. Purchase gave the possibility to carry out farming

63. What was the most important reason for your decision to buy forest? _____

---

64. How did you finance the purchase?

1. Completely with own money
2. With own money and loan from bank
3. With state loan, in addition to own and bank money
4. Other way, how _____

65. How large a share of your total income comes from the forest?

1. 0—10 %, 2. 11—20 %, 3. 21—30 %, 4. 31—40 %, 5. 41—50 %,
6. 51—60 %, 7. 61—70 %, 8. 71—80 %, 9. 81— %

66. If it were possible for you to change your profession, would you do it?

1. Yes, certainly
2. Yes, probably
3. Do not know
4. Probably not
5. Certainly not

Into which profession _____

_____

To be asked only from those living in the countryside (67)

67. If you could move to town, would you do it?

1. Yes, certainly
2. Yes, probably
3. Do not know
4. Probably not
5. Certainly not

68. Do you think that you will live on your farm in 1980?

1. Yes
2. Do not know
3. No

69. Do you think that you will buy or get more forest before 1980?

1. Yes
2. Do not know
3. No

In which manner _____

70. Have you planned to give the ownership of our holding to any family member or relative before 1980?

1. Yes → to question 71
2. Do not know } → to question 72
3. No }

71. Do you think that your family member or relative will begin to cultivate the holding?

1. Yes → to question 73
2. Do not know
3. No

72. Have you planned to give up your holding in any other way before 1980?

1. Yes → How _____
   When _____
   Why _____
2. Do not know
3. No

73. Have you planned to sell part of your forest holding before 1980?

1. Yes → How many hectares of forest land? _____ ha
2. Do not know
3. No

74. Do you think that your heirs will continue to maintain the possession of the holding?

1. Yes
2. Do not know
3. No

INTERVIEWERS REMARKS:

75. Interviewees attitude:

1. Strongly against
2. Against
3. Neutral
4. Positive
5. Enthusiastic

76. Interview situation

1. Others present, disturbance
2. Others present, no disturbance
3. Others not present

Remarks _____

_____

The interview lasted _____ minutes

Date _____

Interviewer _____

Appendix 1.

OWNERS OF HOLDING 1945—1970. *REGISTER N:o* _____

PARCEL [1]	YEARS marked as whole years	OWNER [2]	PROFESSION	OBTAINED THE HOLDING BY				
				Inheritance or gift from parents or relatives	Purchase	Purchase from the free market	Purchase according to land acquisition law	Other way
				1	2	3	4	5

[1]) Parcels need to be marked separetely only if they have had different owners in the same time.
[2]) All information is marked concerning the present owner even if he had obtained the forest holding before 1945.

Explanations, comments _____

_____

ÜBER DIE IN DEN MÄNNLICHEN BLÜTENKÄTZCHEN DER RAUH- UND MOORBIRKE VORKOMMENDEN *ARGYRESTHIA*-ARTEN (LEPIDOPTERA: ARGYRESTHIIDAE)

PAAVO JUUTINEN

SELOSTE

RAUDUS- JA HIESKOIVUN HEDENORKOISSA ESIINTYVISTÄ *ARGYRESTHIA*-LAJEISTA (LEPIDOPTERA: ARGYRESTHIIDAE)

HELSINKI 1974

ISBN 951-40-0116-8

Helsinki 1974. Valtion painatuskeskus

VORWORT

Die Anregung zu der vorliegenden Untersuchung über *Argyresthia goedartella* L. und *A. brockeella* Hb. erhielt ich schon vor Jahren von Herrn Prof. Risto Sarvas, der bei seinen Forschungen über das Blühen und den Samenertrag unserer Waldbäume auch den in den männlichen Blütenkätzchen der Rauhbirke (*Betula verrucosa* Ehrh.) und der Moorbirke (*B. pubescens* Ehrh.) vorkommenden Kleinschmetterlingsraupen und den von ihnen verursachten Schäden Interesse zugewandt hatte. Besonders da das Ausmass der Kätzchenschäden ähnlich wie die Samen- und Zapfenschäden der Nadelhölzer in verschiedenen Jahren stark zu schwanken schien, lag der Gedanke nahe, die Erforschung der Biologie und des Vorkommens der in den männlichen Birkenkätzchen lebenden Schmetterlingsarten könne auch Hinweise auf die Faktoren geben, die den Massenwechsel der wirtschaftlich bedeutsamen Zapfen- und Samenschädlinge der Fichte beeinflussen.

Im Lauf der Untersuchung stellte sich jedoch heraus, dass die Erforschung des Massenwechsels der in den männlichen Birkenkätzchen lebenden Kleinschmetterlingsarten methodisch offenbar noch schwieriger ist als die Klärung der Ursachen für die Bestandesschwankungen der Samen- und Zapfenschädlinge der Nadelhölzer. Ausserdem konnte festgestellt werden, dass im Lebenszyklus dieser beiden Schädlingsgruppen derartige Unterschiede bestehen, dass man sie biologisch nicht koordinieren kann. Weil aber die Kleinschmetterlingsraupen auf jeden Fall in gewissen Jahren im südlichsten Finnland sehr viele Schäden anrichten, die sicherlich den Samenertrag wenigstens der Rauhbirke beeinträchtigen, schien es doch gerechtfertigt, dass die Untersuchung in engerem Rahmen zu Ende geführt wurde.

Das Untersuchungsmaterial wurde aus verschiedenen Gründen im Lauf einer ziemlich langen Zeit gesammelt, hauptsächlich aber doch in den Jahren 1968—71. Kätzchenproben wurden in verschiedenen Gegenden Finnlands in zahlreichen Ortschaften genommen. Die Untersuchungen über die Biologie der Arten sind jedoch fast ganz in Tuusula im Versuchsgebiet Ruotsinkylä der Forstlichen Forschungsanstalt sowie in Tapiola, Espoo, (Abb. 2, Punkt 6 und 4) durchgeführt worden.

Im Lauf meiner Arbeit durfte ich mit Prof. Sarvas oftmals über mit dem Thema verknüpfte Fragen diskutieren, und ausserdem hat er mir

freundlicherweise seine Untersuchungsergebnisse über das Blühen der Birke zur Verfügung gestellt. Auch Prof. Esko Kangas und Dr. Erkki Annila haben das Manuskript durchgesehen. Viele Personen sind mir beim Einsammeln und Prüfen der Kätzchenproben behilflich gewesen. Für alle mir geleistete Unterstützung möchte ich hier meinen besten Dank aussprechen.

Helsinki, den 15. Oktober 1973

Paavo Juutinen

INHALTSVERZEICHNIS

Seite

Mengenverhältnisse der *Argyresthia*-Arten und anderer in männlichen Blütenkätzchen lebender Insektenarten 7
Die Wirtspflanzen der *Argyresthia*-Arten 9
Biologie 11
Vorkommen 20
Zusammenfassung 27
Literaturverzeichnis 29
Suomenkielinen seloste 31

MENGENVERHÄLTNISSE DER *ARGYRESTHIA*-ARTEN UND ANDERER IN MÄNNLICHEN BLÜTENKÄTZCHEN LEBENDER INSEKTENARTEN

Für die vorliegende Untersuchung sind viele in verschiedenen Teilen unseres Landes und zu verschiedenen Jahreszeiten gesammelte männliche Birkenkätzchen geprüft worden. Der Hauptteil des Materials (über 36 000 Kätzchen) stammt aus den Jahren 1968—71. Besonders in der Wintersaison 1970—71, d.h. von etwa Mitte Oktober 1970 bis Anfang Mai des nächsten Jahres, haben wir uns bemüht, Proben aus möglichst vielen Gegenden zusammenzubringen. Dieses Material, das die Situation eines Jahres — also des Frühjahrs 1971 — veranschaulicht und insgesamt 13 560 an Rauh- und Moorbirken in 39 Kirchspielen gesammelte Kätzchen umfasst, ist in Tab. 3 (S. 22) zusammengestellt und nach Ortschaften und Holzarten geordnet.

Aus der Tabelle geht hervor, dass auf 100 männliche Kätzchen der Rauhbirke in dem Material durchschnittlich 29.1 *Argyresthia*-Raupen kamen und nur 1.5 Raupen anderer Kleinschmetterlinge. Bei der Moorbirke waren die entsprechenden Zahlen 12.5 und 1.8. Im ganzen machte der Anteil der *Argyresthia*-Raupen 92.3 % von allen determinierten Raupen aus; diese Arten waren also deutlich häufiger als alle anderen in den Kätzchen vorkommenden Kleinschmetterlingsarten. Dies gilt besonders für den südlichsten Teil Finnlands, wo die Schmetterlingsraupen die allerschwersten Schäden angerichtet hatten. Das Material vom Frühjahr 1970 blieb aus gewissen Gründen sehr mangelhaft, besonders was Südfinnland betrifft. Im Frühjahr 1969 wurden Kätzchen aus 9 Ortschaften in verschiedenen Gegenden untersucht. Weil sich in diesem Material sehr viele in den ersten Entwicklungsstadien abgestorbene Raupen befanden, deren Bestimmung schwierig oder, besonders noch wenn die Raupen beschädigt sind, geradezu unmöglich ist, wurde dieses Material nicht im ganzen behandelt. Von den determinierten Individuen machten die *Argyresthia*-Raupen 89.4 % aus, also etwa den gleichen Prozentsatz wie im Frühjahr 1971.

Von den anderen in den männlichen Birkenkätzchen lebenden Kleinschmetterlingsarten kamen *Epinotia bilunana* (Haworth) und *E. ramella* (L.) am häufigsten vor. Die Biologie dieser Arten wird in der vorliegenden Unter-

suchung nicht behandelt. Erwähnt sei aber doch, dass *E. bilunana* in den Kätzchen als ziemlich grosse Raupen überwintert. Bei meinen sowohl im Freien wie im Labor durchgeführten Zuchten schlüpften die Imagines der Art durchschnittlich deutlich früher als die *Argyresthia*-Imagines. *E. ramella* dagegen überwintert als kleine Raupen. Meinen spärlichen Beobachtungen gemäss beginnt die Flugzeit der Art auch in den südlichsten Teilen Finnlands erst Ende Juli, also später als bei den anderen in männlichen Birkenkätzchen lebenden Kleinschmetterlingsarten. Das Mengenverhältnis zwischen den obengenannten Arten wurde aufgrund des gesammelten Raupenmaterials nicht zu bestimmen versucht. Bei den Zuchten wurde *E. bilunana* erheblich mehr erhalten als *E. ramella*. Dies dürfte jedoch grossenteils durch das spätere Schlüpfen der Imago bei der letztgenannten bedingt sein, weil bis dahin die leicht vertrocknenden und verschimmelnden Kätzchen in den Zuchten gewöhnlich schon verdorben sind.

Die dritte *Epinotia*-Art, *E. demarniana* (F. R.), die laut der Literatur (Schütze 1911, Benander 1950, Schultz 1953, van Deurs 1956, Swatschek 1958) ebenfalls als Raupe in den männlichen Birkenkätzchen lebt, ist in dem für die vorliegende Untersuchung gesammelten Material nicht mit Sicherheit angetroffen worden. Dies kann eventuell damit zusammenhängen, dass die Raupen vielleicht auch bei uns schon im Herbst auf den Boden gehen (vgl. Schultz op.c.). In manchem im Herbst und Winter untersuchtem Kätzchenmaterial sind denn auch einige teilweise miteinander versponnene, grösstenteils ausgehöhlte Kätzchenpaare gefunden worden, in denen keine Raupen waren. In diesen Fällen handelte es sich möglicherweise um *E. demarniana*. In einigen Kätzchenpartien, die in Ruotsinkylä im August oder Anfang September gesammelt worden waren, wurden auch 4 Wicklerraupen gefunden, die ich nicht bestimmen konnte. Swatscheks (op.c.) Beschreibung der Raupe von *E. demarniana* passt m.E. nicht auf diese Raupen.

Nach Swatschek (op.c.) lebt auch *Epinotia tenerana* (Den. & Schiff.) (*E. penkleriana* F. R.) in den Kätzchen und Knospen nicht nur der *Alnus*- sondern auch der *Betula*-Arten. Disqué (1904) teilt mit, die Raupe lebe ausschliesslich in den Knospen von Erle und Birke. In Birkenkätzchen oder Birkenknospen habe ich die Art indessen nicht gefunden, während sie dagegen in den männlichen Kätzchen sowohl der Grau- als auch besonders der Schwarzerle häufig ist und offenbar auch an der Hasel vorkommt (vgl. Benander 1950). Nach den Untersuchungen von Silvestri (Escherich 1931) lebt die Art in Südeuropa zahlreich in den Knospen und weiblichen Blütenkätzchen der Hasel und richtet gelegentlich beträchtliche Schäden an (vgl. auch Gäbler 1958). Hinsichtlich ihrer Lebensweise weicht die Art von den anderen oben erwähnten Wicklerarten insofern ab, als die Eier meistens am Ansatz der Kätzchen sogar in richtigen Haufen liegen (in

einem Kätzchen können 10—15 Eier sein), aus welchem Grunde man im gleichen Kätzchen gewöhnlich mehrere Raupen findet.

Was sonstige Insektenarten betrifft, so kommen in den männlichen Birkenkätzchen ziemlich häufig längliche, meistens etwa in der Mitte des Kätzchens in kleinen Grüppchen liegende Eier vor. Die Eier sind ganz im Innern des Kätzchens, aber die Stelle der Eiablage ist auch von aussen deutlich zu sehen. Es handelt sich offenbar um eine Wanzenart, die bis jetzt noch nicht bestimmt werden konnte. Derartige Eier sind auch in den aus Nord-Finnland stammenden Proben angetroffen worden (nördlichster Fundort Kittilä). In dem ganzen geprüften Material wurden bei der Moorbirke 4.7 Eier und bei der Rauhbirke 0.6 Eier pro 100 Kätzchen gefunden, es besteht also zwischen den Birkenarten ein klarer Unterschied. Wanzeneier sind auch in den Kätzchen von Grau- und Schwarzerle, Haselstrauch und Zwergbirke festgestellt worden. Meistens vertrocknet das Kätzchen nur in einem kleinen Bereich rings um die Eier. Die Eiablage hindert das Kätzchen meistens auch nicht am Aufbrechen, so dass der Schaden kaum Bedeutung hat.

DIE WIRTSPFLANZEN DER *ARGYRESTHIA*-ARTEN

Als Wirtspflanzen von *Argyresthia goedartella* werden in der Literatur fast ausnahmslos die *Betula*- und *Alnus*-Arten genannt. Bezüglich *A. brockeella* sind die Angaben in den älteren Untersuchungen strittig (vgl. Übersicht bei Schultz 1953), aber gewöhnlich wird als Wirtspflanze doch entweder »*Alnus*» oder »*Betula*» angeführt. In der spärlichen neueren Literatur, die mir in die Hände gefallen ist, habe ich nur wenige Hinweise gefunden: Im Handbuch von Gusev und Rimski-Korsakov (1951) wird *A. brockeella* als Schädling von Grau- und Schwarzerle erwähnt, Gäbler (1958) berichtet, die Art aus männlichen Birkenkätzchen gezogen zu haben, nach Friese (1969) leben die Raupen in den Knospen von Erlen- und Birkenarten, und Rudnew, Semkowa und Iwanowa (1970) nennen die Art in ihrem Verzeichnis der zu verschiedenen Gruppen zählenden Insektenarten, welche die männlichen Birkenkätzchen schwer schädigen.

Die morphologischen Unterschiede zwischen den Raupen der hier in Frage stehenden *Argyresthia*-Arten dürften noch ungeklärt sein. In Werners (1958) Werk über die Raupensystematik gewisser Kleinschmetterlingsfamilien ist nur *A. goedartella* besprochen, nicht aber *A. brockeella*. Die älteren Beschreibungen von der Raupe der letztgenannten Art — die früheste soweit bekannt schon vom Jahre 1846 — sind offenbar alle mehr oder weniger ungefähr (vgl. Schultz 1953). Auch anhand des für die vorliegende Untersuchung gesammelten Raupenmaterials habe ich keine sicheren Unterschiede zwischen den Arten herausfinden können. Die ältesten Raupen lassen

Tabelle 1. Vorkommen von *Argyresthia goedartella* und *A. brockeella* in den Kätzchen von Rauh- und Moorbirke bei den Zuchten 1970—71. (Bei der Aufzucht erhaltene Individuenzahlen.)

Ortschaft	Jahr	Rauhbirke		Moorbirke	
		A. goedartella	*A. brockeella*	*A. goedartella*	*A. brockeella*
Espoo	1971	537	2	169	115
Tuusula	1970	83	3	73	79
Tuusula	1971	86	1	96	69
Liljendal	1970	12	1	—	—
Lapinjärvi	1970	16	0	0	16
Punkaharju	1970	79	1	2	0
Punkaharju	1971	—	—	12	0
Laihia	1970	2	0	—	—
Zusammen		815	8	352	279

sich eventuell mit einiger Sicherheit aufgrund der Farbe voneinander unterscheiden (vgl. S. 13), aber das ist natürlich kein zuverlässiges Merkmal für die Artbestimmung. Der einzige sichere Weg zur Lösung der Wirtspflanzenfrage war es demnach, die in den von verschiedenen Holzarten gesammelten Kätzchen lebenden Raupen zu Imagines zu ziehen.

Die Zuchten wurden nach einigen Vorversuchen hauptsächlich in den Jahren 1970—71 durchgeführt, und zwar sowohl im Labor wie auch im Freien. Das Hauptgewicht wurde auf die Rauh- und die Moorbirke gelegt. Im Labor wurden die im März—April oder in den ersten Maitagen gesammelten Kätzchen bei Zimmertemperatur in Kunststoffbeuteln aufbewahrt, die vier- bis fünfmal pro Woche für eine Zeitlang aufgemacht wurden, um zu verhindern, dass die Kätzchen verschimmelten. Die für die Aufzucht im Freiland bestimmten Kätzchen wurden möglichst spät gesammelt, aber doch ehe die Birkenblüte eingesetzt hatte, und die Raupen anfingen, sich zur Erde herabzulassen. Die Kätzchen wurden entweder an schattigen Stellen in Gazebeuteln aufgehängt oder auf dem Boden in Holzkästen mit Drahtnetzdeckeln verwahrt. Die allerbesten Resultate wurden bei den Freilandzuchten erzielt, weil die Kätzchen im Zimmer leicht vertrockneten oder verschimmelten. Für diesen Versuch wurden in verschiedenen Ortschaften insgesamt 20 Partien Kätzchen von Rauhbirke und 15 von Moorbirke gesammelt. Manche Partien enthielten Kätzchen von verschiedenen Baumindividuen. Die Ergebnisse sind in Tabelle 1 zusammengestellt.

Von anderen Birkenarten wurden keine Aufzuchten gemacht. In zwei ziemlich grossen, im Herbst 1971 in Lemi und Kangasniemi gesammelten Kätzchenproben von Zwergbirke (*Betula nana* L.) wurde keine einzige Schmetterlingsraupe gefunden. (Die Kätzchen der Zwergbirke sind ausgesprochen im Herbst sehr klein.) Im Frühjahr 1969 und 1970 wurden in Vantaa Kätzchenproben von einigen Dutzend Stück von *Betula alleghaniensis*

Brit. und *B. papyrifera* Marsh. genommen. In beiden wurden Kleinschmetterlingsraupen gefunden, *Argyresthia*-Raupen aber nur in der letzteren. Höchstwahrscheinlich handelte es sich um *A. brockeella*. Von Grau- und Schwarzerle wurden Imagines aus Material gezogen, das im Frühjahr 1971 und 1972 in Espoo gesammelt worden war. Aus den Schwarzerlenkätzchen wurden insgesamt 241 Exx. und den Grauerlenkätzchen 73 Exx. *A. goedartella*, aber kein einziges Exemplar von *A. brockeella* gewonnen. In den in Espoo und Tuusula 1968—70 gesammelten und geprüften Haselkätzchen wurden keine Raupen von *Argyresthia*-Arten gefunden.

Die oben besprochenen Aufzuchten ergaben also im ganzen 1768 *Argyresthia*-Imagines. Ausgesprochen hinsichtlich Rauh- und Moorbirke kann das Material wohl für ausreichend gelten. Aus den Resultaten geht etwas überraschend hervor, dass die Wirtspflanze von *A. brockeella* praktisch ausschliesslich die Moorbirke ist, obwohl *A. goedartella* bei uns an den einheimischen Holzarten ausser an Rauh- und Moorbirke auch noch an Grau- und Schwarzerle vorkommt.

BIOLOGIE

Das E i. Über das Eistadium der hier in Frage stehenden *Argyresthia*-Arten habe ich in der Literatur nur sehr spärliche Angaben gefunden. W e r n e r (1958) sagt in seiner Beschreibung der Lebensweise der Raupe von *A. goedartella:* »Überwinterung unter Eipaketen an den Zweigen». Das Ei wird jedoch nicht genauer beschrieben. Nach F r i e s e (1969) dagegen sind Ei und Eiablage von *A. goedartella* und *A. brockeella* unbekannt. Nach einigen erfolglosen Versuchen fand ich zum erstenmal im Herbst 1970 an im August und September in Ruotsinkylä gesammelten Kätzchen mehrere Eier, die einen so weit entwickelten Embryo enthielten, dass er aufgrund des Nackenschildes und der Punktaugen ohne Schwierigkeit als zur Gattung *Argyresthia* gehörig bestimmt werden konnte.

Die im folgenden dargelegten Beobachtungen über das Eistadium fussen auf zwei Probenserien, die im Sommer und Herbst 1970 und 1971 in Ruotsinkylä in einem kleineren Bestand von Rauh- und Moorbirken gesammelt worden waren. In dem erstgenannten Jahr wurden, von geringen Ausnahmen abgesehen, die Proben, die jeweils 100 Rauhbirken- und 100 Moorbirkenkätzchen umfassten, in der Zeit vom 13. VII—29. IX genommen, gewöhnlich im Abstand von einer bis anderthalb Wochen. Im folgenden Sommer wurde mit dem Probensammeln schon am 1. VII angefangen. Dann wurden allwöchentlich bis zum 3. IX Proben genommen, wonach später im Herbst nochmals zwei Partien gesammelt wurden (21. IX und 15. X). Die Kätzchen wurden an zwei Rauh- und zwei Moorbirken im mittleren und unteren Teil der Krone gesammelt. Von jedem Baumindividuum wurden jeweils 50

Kätzchen genommen. (Die eine Rauhbirke war leider insofern schlecht gewählt, als die Kätzchen nicht bis zum Schluss ausreichten.) Die zwei zuletzt im Herbst 1971 genommenen Kätzchenpartien wurden vor der Untersuchung unbehandelt bei —20°C verwahrt, alle anderen in Alkohol.

Die Eier sind länglich, durchschnittlich etwa 0.4 × 0.5 mm gross und sehr hell. Hinsichtlich ihrer Form unterscheiden sie sich deutlich von den in den Kätzchen befindlichen, linsenförmig platten Wicklereiern. Meistens sitzen die Eier am Ansatz der Kätzchen, entweder unter den basalen Schuppen der Kätzchengruppe oder zwischen den Kätzchen, manchmal auch im Ansatz einer neben dem Kätzchen befindlichen Knospe oder sogar in von Insekten genagten Löchern an der Oberfläche der Kätzchen. In dem oben besprochenen Material wurden im ganzen 423 gefunden. In je einer Kätzchengruppe, die meistens zwei Kätzchen umfasste, waren 1—6 Eier. Kätzchengruppen mit höchstens zwei Eiern waren im Jahr 1970 99.4 % und 1971 91.0 %. Da eine Gruppe u.U. drei und sogar vier Kätzchen umfassen kann, kam also auf ein Kätzchen selten mehr als 1 Ei.

Der Beginn der Eiablage konnte im Sommer 1970 nicht festgestellt werden, weil schon in den ersten, d.h. am 13. VII genommenen Proben Eier waren. 1971 wurden die ersten Eier am 8. VII gefunden. Da aber auch dann in 200 geprüften Kätzchen insgesamt nur 3 Stück angetroffen wurden, musste die Eiablage ganz kürzlich angefangen haben. Noch am 15. VII betrug die Gesamtanzahl der gefundenen Eier nur 10 Stück, aber danach nahmen sie rasch zu, und am 12. VIII kamen sowohl an der Rauh- wie an der Moorbirke 42 Stück auf 100 Kätzchen. Weiterhin konnte dann der Fortgang der Eiablage nicht mehr verfolgt werden. Überhaupt waren die relativ kleinen Eier garnicht so leicht aufzufinden, und wenn dann die Raupen schlüpfen, ist die Suche nach den leeren Eiern besonders an dem in Alkohol konservierten Material noch schwieriger und das Finden fast zufallsbedingt.

Ein Teil der Eier war von einer bislang nicht bestimmten Schmarotzerwespe verdorben. Die parasitierten Eier sind in der Regel rauchfarben oder noch dunkler. 1971 wurden an den in der Zeit vom 12. VIII bis 21. IX genommenen Proben Puppen von Parasiten gefunden. Die parasitierten Eier machten in dem am 12. VIII und danach gesammelten Material — an dem die Parasiten schon mit ziemlicher Sicherheit erkannt werden konnten — etwa 15 % aus. Weil aber zu dieser Zeit nicht mehr alle Eier aufgefunden werden konnten — wenigstens ein Teil der Raupen war ja schon geschlüpft — war der Prozentsatz der Parasiten in Wirklichkeit ziemlich gering.

Da bei den oben besprochenen Untersuchungen keine wesentlichen Unterschiede zwischen Rauh- und Moorbirke beobachtet wurden, kann man aufgrund dessen, was früher über die Wirtspflanzen der hier in Frage stehenden *Argyresthia*-Arten gesagt worden ist, den Schluss ziehen, dass die obigen Feststellungen wenigstens für *A. goedartella* gelten. Nicht sicher ist es

dagegen, ob sie auch auf *A. brockeella* zutreffen. Wahrscheinlich legt aber auch diese Art ihre Eier in die Kätzchen oder deren unmittelbare Umgebung. Nicht ausgeschlossen ist es natürlich, dass beide Arten auch weiter entfernt im Geäst Eier legen, aber das lässt sich sehr schwer nachweisen.

R a u p e und P u p p e. Die ersten Raupenstadien von *A. goedartella* sind gelblichweiss, die grösseren Raupen dagegen häufiger gelblichrot, manchmal grünlich. Die grossen Raupen haben rings um die Borstenansatzstellen meistens sehr deutlich abgehobene (manchmal allerdings ganz kleine) gelblichweisse Flecken, weshalb die Raupen einen auffällig bunten Eindruck machen. In den Birkenkätzchen kommen jedoch auch solche Raupen vor, die keine solche hellen Flecken haben, und die nicht selten vorwiegend grün oder teilweise eher karmin- als gelblichrot getönt sind. Im Frühjahr 1970 zog ich im Labor mehrere Dutzend *Argyresthia*-Raupen an einzeln in kleinen Glasröhrchen verwahrten Kätzchen. Vor Beginn der Zucht wurden die Kätzchen soweit aufgemacht, dass die darin befindlichen Raupen geprüft werden konnten. Leider war in diesen Kätzchenproben wenig *A. brockeella*. Auf jeden Fall liess sich aufgrund der Imagines sagen, dass alle Raupen, die selbst noch so kleine helle Flecken um die Borsten hatten, *A. goedartella* waren, ganz unabhängig von der sonstigen Färbung, während die Raupen ohne Höfe *A. brockeella* repräsentierten.

Um die Zahl der Raupenstadien zu ermitteln, wurde (mit dem Okularmikrometer) bei 716 Raupen von zu verschiedenen Jahreszeiten an Rauhbirken gepflückten Proben die Breite der Kopfkapsel gemessen. Obwohl die Zahl der kleinsten Raupen gering war — vor allem weil ihre Aufbewahrung ziemlich schwierig ist — dürfte sich aufgrund der Ergebnisse doch der Schluss ziehen lassen, dass zumindest *A. goedartella* fünf Raupenstadien hat, deren Kopfkapseln durchschnittlich 0.14, 0.23, 0.33, 0.45 und 0.65 mm breit sind. E i d m a n n (1960) hat festgestellt, dass *A. laevigatella* 4 oder 5 Raupenstadien hat; die Kopfkapselbreite des ersten und letzten Stadiums betrug durchschnittlich 0.14 und 0.59 mm.

Die ersten Raupen wurden in den Kätzchen in Ruotsinkylä im Sommer 1969 am 18. VIII (an Moorbirke) gefunden, 1970 an beiden Birkenarten am 17. VIII, aber 1971 an Moorbirke schon am 5. VIII und an Rauhbirke am 12. VIII. Da die Proben in relativ langen Abständen genommen wurden, lässt sich nicht sagen, ob zwischen den Baumarten selbst im letztgenannten Jahr ein nennenswerter Unterschied bestand. In den zu verschiedenen Zeiten gesammelten Proben wurde auch die Länge der Kätzchen gemessen. Es ergab sich, dass zu der Zeit, wo die Raupen zahlreicher erschienen, das Längenwachstum des ersten Jahres im grossen ganzen schon ganz oder beinahe aufgehört hatte.

Nach S c h u l t z (1952, 1953) verhalten sich die Raupen der *Argyresthia*-Arten insofern verschieden, als die Raupen von *A. brockeella* sich in das

Tabelle 2. Auftreten der verschiedenen Raupenstadien in zu verschiedenen Jahreszeiten von Rauhbirke genommenen Proben

Datum	Ortschaft	Raupen St.	Raupenstadium				
			L_1	L_2	L_3	L_4	L_5
			%				
19.VIII. 71	Ruotsinkylä	10	80	20	—	—	—
26.VIII. 71	»	23	57	43	—	—	—
3. IX. 71	»	13	—	77	15	8	—
21. IX. 71	»	37	—	11	86	3	—
15. X. 71	»	39	—	3	56	41	—
26. X. 70	Hamina	51	—	—	—	100	—
27. X. 70	Heinola	75	—	—	3	97	—
27. X. 70	Mäntyharju	75	—	—	1	99	—
30. XI. 70	Ruotsinkylä	50	—	—	18	82	—
17. III. 70	Punkaharju	58	—	—	—	71	29
15. IV. 69	Kalanti	86	—	—	—	64	36
4. V. 68	Punkaharju	174	—	—	—	20	80
14. V. 69	Ruotsinkylä	25	—	—	—	—	100

Kätzchen von der Spitze her einbohren, die Raupen von *A. goedartella* von der Seite her. Den Beobachtungen gemäss, die an dem oben erwähnten Kätzchenmaterial vom Jahr 1970 gemacht wurden, hatten sich von den in Rauhbirkenkätzchen angetroffenen Raupen nur 14 % entweder ganz an der Spitze oder jedenfalls im Spitzenteil eingebohrt, von den Raupen an Moorbirke dagegen 57 % (insgesamt 252 Beobachtungen). Zwischen den Arten scheint in dieser Beziehung also tatsächlich ein Unterschied zu bestehen. Wenn die Raupe von der Spitze her in das Kätzchen eindringt, geht die Spitze schon im Spätsommer ein und wird schwarz, bohrt die Raupe sich aber von der Seite her ein, so ist die Spur nicht so deutlich zu sehen. Aus diesem Grunde machen die Schäden an den Moorbirken im Herbst einen ärgeren Eindruck als die an den Rauhbirken, obwohl es sich in Wirklichkeit meistens umgekehrt verhält.

Eine gewisse Auffassung von der Entwicklungsgeschwindigkeit der Raupen vermittelt Tabelle 2, worin das für die Messung der Kopfkapseln benutzte Material der Jahreszeit gemäss chronologisch geordnet dargelegt ist. Aus dieser Tabelle geht hervor, dass der Anteil des 2. Raupenstadiums Anfang September am grössten war; 2—3 Wochen später waren die meisten Raupen im 3. Stadium, und bis Ende Oktober war weitaus der grösste Teil schon im 4. Stadium. Bemerkenswert ist es, dass Raupen des 5. Stadiums erst im Frühjahr vorkamen.

In den in der Tabelle vorgelegten Materialien, die ausgesprochen hinsichtlich der kleinsten Raupen freilich recht gering sind, wurde das 1. Raupenstadium im September überhaupt nicht angetroffen. Im Zusammenhang mit manchen anderen Prüfungen sind sowohl an Rauh- wie an Moorbirke am

7. IX. 70 Eier gefunden worden, die einen lebenden Embryo enthielten. Es liegt somit auf der Hand, dass ein Teil der Raupen erst Anfang September schlüpft, so dass also zwischen dem Schlüpfen der frühesten und der letzten Raupen eine Zeitspanne von mehreren Wochen liegt. Der Umstand, dass fast alle Raupen beim Einbruch des Winters trotzdem im gleichen Entwicklungsstadium stehen, dürfte mit der im 4. Raupenstadium auftretenden Diapause zusammenhängen, infolgederen die Entwicklung von da an erst nach dem Überwintern fortschreiten kann.

Sarvas (1972) hat festgestellt, dass die Differenz zwischen der in der Freiluft und der im Innern der Kiefernknospe herrschenden Temperatur an sonnigen Tagen im März bis zu fast 15°C betragen kann. Wahrscheinlich ist die Temperatur auch in den an den Zweigspitzen sitzenden, dunklen Kätzchen im Sonnenschein im September und noch im Oktober wenigstens um die Mittagszeit verhältnismässig hoch. Die Verhältnisse im Innern der Kätzchen sind demgemäss im Herbst für die Entwicklung der Raupen offenbar wenigstens etwas günstiger, als man aufgrund der üblichen Messungen der Lufttemperatur schliessen könnte, obschon es im Herbst gewöhnlich viel weniger klare Tage gibt als im Frühjahr.

Die Länge der zum Eliminieren der Diapause erforderlichen Zeit wurde nicht genauer gemessen. Erwähnt sei, dass in einer schon am 18. XII. 70 ins Labor genommenen Kätzchenprobe mehrere Dutzend *A. goedartella* -Imagines schlüpften. Bis zum Schlüpfen der ersten vergingen 54 Tage; in zwei am 20. und 23. III. 71 ins Labor genommenen Proben war die entsprechende Zeit durchschnittlich nur 9.5 Tage kürzer.

Wie vorn schon gesagt wurde, kommen Raupen von *A. goedartella* nicht nur in Rauh- und Moorbirkenkätzchen, sondern auch in den Kätzchen von Grau- und Schwarzerle vor. Weil die Erlen viel früher blühen als die Birken, kann man sich fragen, ob auch in der Entwicklungsgeschwindigkeit der Raupen irgendein Unterschied zwischen diesen Holzarten besteht. Am 21.—22. IV. 71 wurden in Tapiola kleine Kätzchenproben von einer Rauhbirke, einer Grau- und einer Schwarzerle genommen, die an hinsichtlich der Beleuchtungsverhältnisse ganz gleichartigen Stellen wuchsen, und die in den Kätzchen befindlichen Raupen wurden in Verwahrung genommen. Den Messungen der Kopfkapsel gemäss standen von den Raupen an beiden Erlenarten 100 % im 5. Stadium, an der Birke hingegen nur 62 % (die restlichen im 4. Stadium). Bezüglich der Birke handelt es sich wohl kaum um eine exzeptionelle Beobachtung, denn das Resultat stimmt gut mit den in Tabelle 2 aufgeführten Werten überein. Sowohl an der Grau- wie an der Schwarzerle waren die Raupen also etwas weiter entwickelt als an der Rauhbirke. Die Beschleunigung der Entwicklung kann mit den höheren Tagestemperaturen im Innern der Kätzchen oder der Beschaffenheit der Nahrung zu tun haben (vgl. z.B. Schwerdtfeger 1963: 345).

Die Raupen wachsen aber doch nicht aus, ehe die Erlen blühen, weshalb sie aus den männlichen Kätzchen in die weiblichen und in die Knospen übersiedeln. Dies kann — insbesondere wenn die Raupen zahlreich sind — schon vor dem Aufbrechen der männlichen Kätzchen geschehen. Besonders aus den weiblichen Kätzchen bohren die Raupen sich in den Trieb und höhlen ihn auf einer Länge von mehreren Zentimetern aus. (Erwähnt sei, dass ich in mehreren hundert von mir geprüften Birkenknospen nur in zwei ein von der Raupe genagtes Loch gefunden habe.) Im Frühjahr 1969 wurden in Ruotsinkylä an Schwarzerlentrieben noch am 9. V *Argyresthia* -Raupen gefunden; die später, sogar noch Anfang Juni an den gleichen Erlen angetroffenen Raupen waren *Epinotia tenerana*, die im letzten Stadium ihrer Raupenentwicklung offenbar auch junge Blätter fressen. Im ganzen genommen dürfte also in der Länge der Raupenzeit doch kein wesentlicher Unterschied zwischen den Holzarten bestehen (vgl. auch S. 19).

Die ausgewachsenen *A. goedartella* -Raupen lassen sich an den Zweigen und am Stamm entlang entweder zum Wurzelende des Stamms oder auf den Boden herab und verpuppen sich. Insbesondere der Stamm grosser, alleinstehender Rauhbirken ist Ende Mai oftmals fast ganz von einem seidig glänzenden Gespinst überzogen. Für die Verpuppung gehen die Raupen unter abgelöste Rinde, Rindenschuppen oder am Stamm wachsende Flechten, oder an der Rauhbirke, deren Rinde am Wurzelende meistens sehr eng festsitzt, in die aufgesprungene, harte Borke. Nachdem die Raupen sich in die Rinde eingebohrt haben, sieht man am Wurzelende dickrindiger Rauhbirken hunderte von rotbraunen Bohrmehlhäufchen. Ausgesprochen an den Moorbirken findet man gelegentlich unter passend losgelösten Rindenstückchen dutzendweise eng nebeneinander sich verpuppende Raupen. Manche Raupen bohren sich in die Erde ein, aber der grösste Teil auch von diesen verpuppt sich offenbar in der Rinde der Wurzeln und nur der kleinere Teil in der Erde. Bei den Zuchtversuchen verpuppten die Raupen sich auch in den Falten und Zipfeln der Gaze- und Kunststoffbeutel, besonders gern oben, wo die Beutel zugeschnürt waren. Mit besonderer Vorliebe scheinen sie sich in die zu diesem Zweck in die Beutel gelegten Polystyrenstücke einzubohren, in denen sie sich dann leicht transportieren und ziehen lassen.

Unter der Rinde der Birken habe ich keine *A. brockeella* -Raupen gefunden; auch in allen aus solchen Materialien vorgenommenen Zuchten habe ich nur *A. goedartella* -Imagines erhalten. Um herauszufinden, ob sich die *A. brockeella* -Raupen auf den Boden herablassen, wurde in Ruotsinkylä im Frühjahr 1972 am Stamm zweier Moorbirken ein breiter Leimring gestrichen, und oberhalb davon wurden Polystyrenstücke befestigt. Zwischen dem Polystyren und insbesondere zwischen diesem und der Rinde verpuppten sich etwa zweihundert *Argyresthia*-Individuen, von denen 115 zu Imagines gezogen werden konnten; unter diesen befand sich keine einzige *A. brockeella*.

Gleichzeitig wurden Kätzchen von Moorbirke in zerlöcherte Gazebeutel getan, die in einem 30 cm hohen, bis zur Oberfläche des Mineralbodens in die Erde versenkten, oben mit Gaze verschlossenen Kunststoffzylinder aufgehängt wurden. Aus den in den Beuteln befindlichen Kätzchen konnten 10 und vom Boden 2 *A. brockeella* -Individuen gezogen werden. (*A. goedartella* entsprechend 31 und 12 Stück). Da auch in den zu Boden gefallenen Kätzchen keine Puppen gefunden wurden, lässt sich aus den für die vorliegende Untersuchung gemachten Beobachtungen nichts darüber schliessen, wo die Raupen von *A. brockeella* sich verpuppen.

Die Raupen dürften sich in der Regel nachts aus den Kätzchen herablassen. Im Frühjahr 1971 wurden in Tapiola die ersten Gespinste an Birkenstämmen am 8. V festgestellt, und vom 9. V an kamen die in Freilufttemperatur in Gazebeuteln gewesenen Raupen in grosser Zahl aus den Kätzchen heraus. Zu dieser Zeit waren die Kätzchen der Rauhbirken mindestens an sonnigen Stellen grösstenteils schon aufgebrochen.

Die Verpuppung der Raupen wurde 1970 und 1971 in Tapiola verfolgt, indem im Mai—Juni Proben von mehreren Birken genommen wurden, deren unteres Stammende nicht der direkten Sonnenbestrahlung ausgesetzt war. Im Frühjahr 1970 wurde festgestellt, dass am 17., 23. und 31. V alle geprüften Individuen im Raupenstadium waren, am 6. VI waren 84 % verpuppt und am 21. VI 100 %. (Im ganzen wurden 465 Individuen untersucht.) Die allermeisten hatten sich also im Lauf von ein paar Tagen Anfang Juni verpuppt. Im nächsten Frühjahr waren die Proben spärlicher. Erwähnt sei immerhin, dass am 20. V nur Raupen gefunden wurden, am 26. V waren 14 % Puppen und am 30. V 35 %. In Ruotsinkylä waren am 2. VI schätzungsweise schon etwa 75—90 % verpuppt.

I m a g o. Die Zeichnung der Vorderflügel von *A. goedartella* variiert beträchtlich. Nach F r i e s e (1969) sind in der Literatur sieben Aberrationen beschrieben worden. Am deutlichsten unterscheidet sich von der Hauptform vielleicht ab. *splendida* Reutti, die auf den Vorderflügeln überhaupt keine weissen, sondern nur heller und dunkler goldgelbe Zeichnungen hat. Diese Form ist auch in Finnland keine Seltenheit. *A. brockeella* ist eine viel einheitlichere Art. In den für die vorliegende Untersuchung gesammelten Materialien habe ich keine von den bei F r i e s e (op.c.) beschriebenen Aberrationen gefunden.

Für die Beobachtung des Schlüpfens der Imagines sammelten wir in Ruotsinkylä im Frühjahr 1970 und 1971 an Rauh- und Moorbirke eine grössere Partie Kätzchen, ehe diese aufgeblüht waren. Die Proben wurden, jede Holzart für sich, in auf der Seite liegende Sperrholzkistchen (30 × 30 × 60 cm) getan, die mit Fliegendraht bespannte Deckel hatten. Die Kästen standen im Halbschatten (auf dem Boden) und wurden durchschnittlich zweimal pro Woche kontrolliert. Im Frühjahr 1971 wurde ausserdem noch

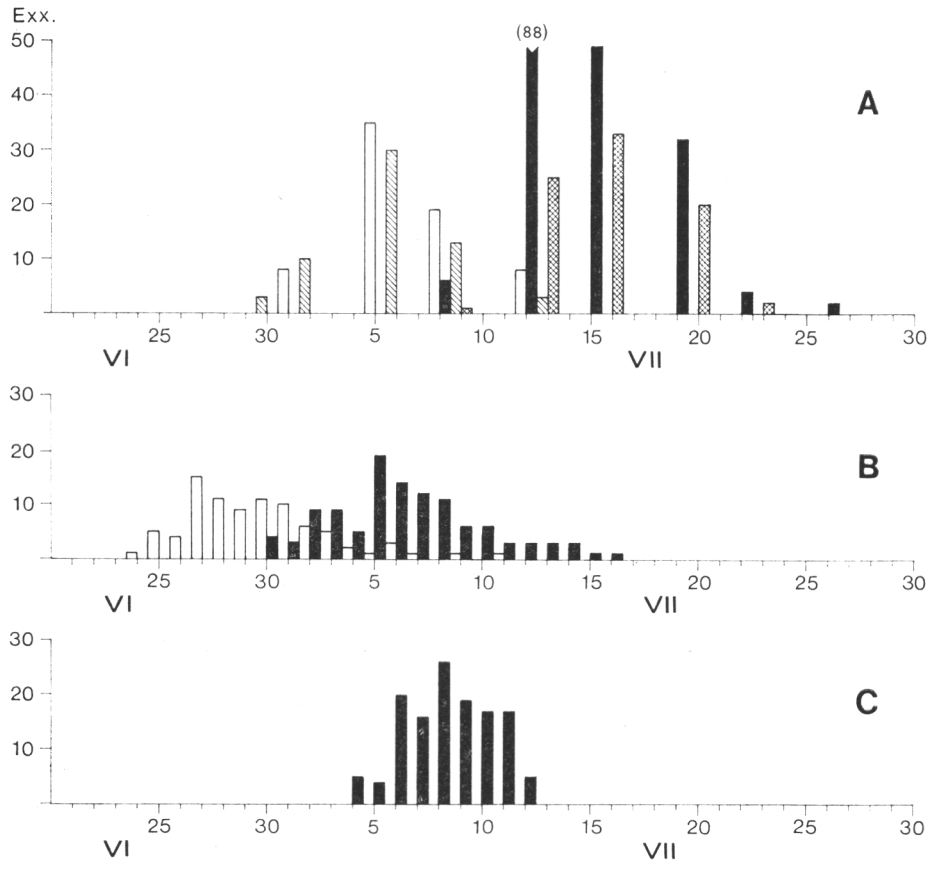


Abb. 1. Das Schlüpfen der *Argyresthia*-Imagines in manchen im Freien durchgeführten Zuchten. A. Ruotsinkylä, Sperrholzkistchen 1970 und 1971. B. Tapiola, im Halbschatten gehaltene Gazebeutel 1971, Moorbirke. C. Desgleichen, Rauhbirke. Säulen: schraffiert = *A. brockeella* 1970, kreuzschraffiert = *A. goedartella* 1970, weiss = *A. brockeella* 1971, schwarz = *A. goedartella* 1971.

Anfang Mai in Tapiola eine grössere Menge Kätzchen gesammelt und in Gazebeuteln bei Aussentemperatur im Halbschatten aufbewahrt. Die Beutel wurden im allgemeinen jeden Tag kontrolliert. Die Resultate dieser Zuchten sind in Abb. 1 dargestellt.

Aus der Abbildung ist ersichtlich, dass in allen drei Zuchten, in denen beide Arten erhalten wurden, *A. brockeella* deutlich früher schlüpfte als *A. goedartella*. Zwischen dem Beginn und dem Gipfel des Schlüpfens lag zwischen den Arten ein Unterschied von etwa einer Woche. Zwischen dem Schlüpfen des ersten und des letzten Individuums vergingen in der gleichen Zucht bei *A. goedartella* 8—18 Tage und bei *A. brockeella* 11—17 Tage, m.a.W. das Schlüpfen ging im Lauf einer ziemlich kurzen Zeit vor sich. Namentlich

aufgrund der bei den Laborzuchten gemachten Beobachtungen lässt sich der Schluss ziehen, dass die Imagines ihre Verpuppungsstätten fast ausschliesslich in der Dämmerung oder im Dunkeln verlassen.

Am 21. IV. 71 wurden in Tapiola an Grau- und Schwarzerle Kätzchen gesammelt und dann in Gazebeuteln zuerst draussen im Halbschatten, später in einem ungeheizten Schuppen verwahrt. Es zeigte sich, dass *A. goedartella*-Individuen seit etwa dem 29. VI schlüpften. Noch am 17. VII waren in dem einen Beutel ein und in dem anderen zwei lebende Imagines.

Angaben über die Flugzeit habe ich auch von Lic.d.Forstw. B. L å n g s t r ö m erhalten, der im Sommer 1971 bei seinem Lichtfang in Süd-Finnland auf meine Bitte auch die *Argyresthia*-Arten aufbewahrt hatte. Dieses Material ist unten zusammengestellt.

Ortschaft	Datum	*A. goedartella* Exx.	*A. brockeella* Exx.
Bromarv	18. VII	3	0
»	23. VII	34	0
»	26. VII	172	1
»	30. VII	95	0
Punkaharju	12.VIII	62	0

Von den Literaturangaben sei erwähnt, dass nach F r i e s e (1969) *A. brockeella* in Deutschland von Anfang Juni bis Mitte Juli fliegt. Manche wurden aber auch noch im August und sogar Anfang September erbeutet. Weil späte Stücke nur in witterungsmässig günstigen Sommern angetroffen worden sind, könnte es sich nach F r i e s e um eine zweite Generation handeln; man weiss bloss nicht, wo sie sich entwickeln könnte. Die Flugzeit von *A. goedartella* dauert nach der gleichen Quelle von Ende Mai bis Mitte September (Hauptflugzeit von Mai bis Anfang August). Es gibt keine Beweise dafür, dass es sich um zwei Generationen handeln könnte.

Aus den oben besprochenen einheimischen Beobachtungen dürfte man den Schluss ziehen können, dass die Flugzeit von *A. goedartella* auch in den südlichsten Teilen Finnlands gewöhnlich erst Anfang Juli einsetzt, gelegentlich auch in den letzten Junitagen, und mindestens bis Mitte August dauert. Von den Faktoren, die auf die Dauer der Flugzeit Einfluss haben, dürfte die unterschiedliche Beschaffenheit der Verpuppungsstätten (am Stamm, an den Wurzeln, auf dem Boden in verschiedenen Expositionen) im Vordergrund stehen, infolgederen die Verpuppung und das Schlüpfen der Imago auch im gleichen Waldbestand offenbar im Lauf bedeutend längerer Zeit stattfinden kann als in den oben besprochenen Zuchten, die jeweils nur in gleichartigen Verhältnissen durchgeführt wurden. Über die Flugzeit von *A. brockeella* dagegen lässt sich aufgrund der dargelegten Beobachtungen nicht viel sagen. In den gleichen Zuchtverhältnissen schlüpfte die Art früher als *A. goedartella*. Die Flugzeit ist wahrscheinlich kürzer als bei *A. goedartella*.

VORKOMMEN

Vorn ist schon das Vorkommen der hier in Frage stehenden *Argyresthia*-Arten an verschiedenen Holzarten behandelt worden. Die eventuellen Unterschiede in der Dichte der Raupen in verschiedenen Beständen, an Bäumen verschiedenen Alters und in den verschiedenen Teilen der Krone wurden nicht genauer geklärt. An manchen Birken wurden Proben zwar sowohl vom Wipfel wie von den untersten Zweigen genommen, aber derartiges Material hatten wir so wenig, dass aufgrund dessen keine Schlüsse gezogen werden konnten. Weil die Birken lichtbedürftige Holzarten sind, und weil sich an den beschatteten Zweigen auch keine Kätzchen entwickeln, dürften die durchschnittlichen Unterschiede zwischen den verschiedenen Partien der Krone recht geringfügig sein.

Etwas mehr Beobachtungen liegen über die Unterschiede zwischen den einzelnen Baumindividuen vor. Das in Süd-Finnland 1969—71 gesammelte Material ist aus der folgenden Zusammenstellung ersichtlich. In dieser Zusammenstellung sind die Fälle enthalten, wo im gleichen Bestand an zwei in gleichartigen Verhältnissen gewachsenen und ungefähr gleichaltrigen Baumindividuen je mindestens 100 Kätzchen gesammelt worden sind; die Kätzchen wurden dann auch bei der Untersuchung getrennt gehalten. Von den meisten Bäumen wurden mindestens 200 Kätzchen geprüft, von manchen sogar 500—600 Stück. (In den angeführten Zahlen sind sowohl die *Argyresthia*- wie die *Epinotia*-Raupen enthalten.)

Ortschaft	Datum	Holzart	Raupen Stück/100 Kätzchen
Ruotsinkylä	8. V. 69	Moorbirke	13.8; 21.2
»	8. V. 69	»	15.7; 30.1
Kalanti	3. V. 71	»	28.0; 61.0
»	3. V. 71	Rauhbirke	55.0; 79.0
Heinola	28.XII. 70	Moorbirke	18.0; 38.5
Mikkeli	27. X. 70	»	6.0; 12.0
Punkaharju	14.XII. 70	»	7.0; 9.0
»	14.XII. 70	Rauhbirke	40.0; 61.5

Von den acht angeführten Fällen ist der Unterschied in fünf statistisch signifikant. Auch bei manchen anderen Schadinsekten der Blüten und Samen von Forstgehölzen sind Frequenzunterschiede zwischen den einzelnen Bäumen beobachtet worden (vgl. z.B. Annila 1966, Rudnew, Semkowa & Iwanowa 1970).

Um ein Gesamtbild vom Vorkommen der in den männlichen Birkenkätzchen lebenden Kleinschmetterlingsraupen in den verschiedenen Teilen Finnlands zu gewinnen, haben wir uns bemüht, vom Herbst 1970 bis zum Frühjahr 1971 Proben von Rauh- und Moorbirke aus möglichst vielen Ge-

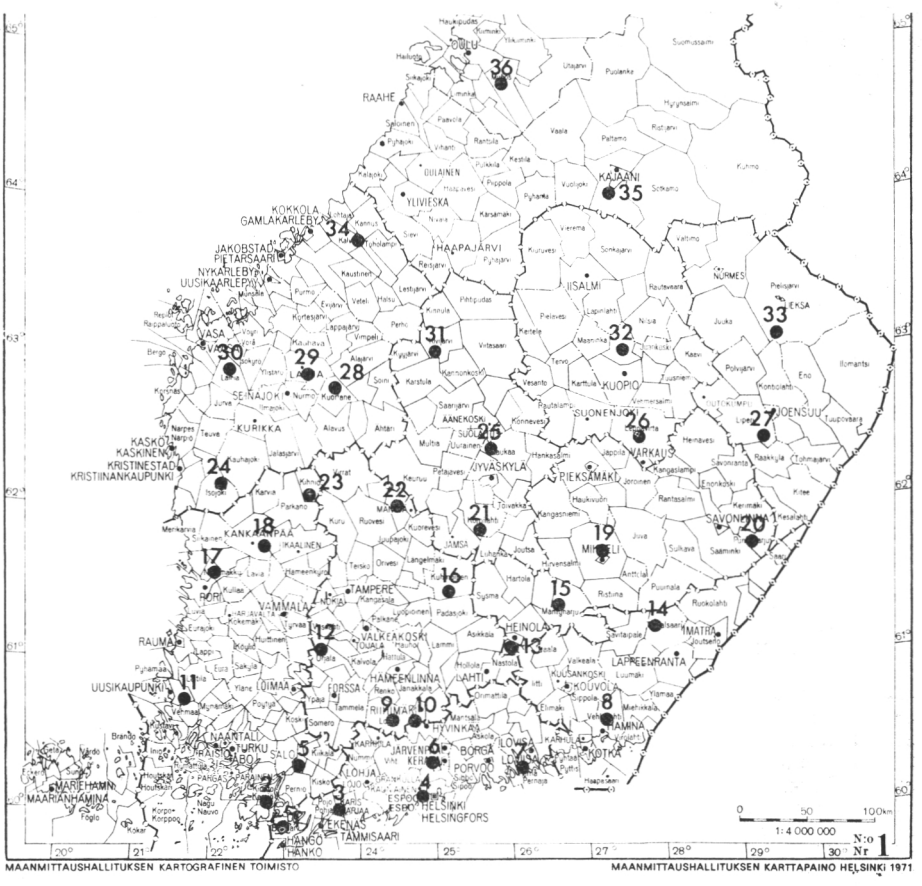


Abb. 2. Sammelstätten der vom Herbst 1970 bis zum Frühjahr 1971 geprüften Kätzchenproben. Die Nummern verweisen auf Tab. 3. Ausserdem wurden noch in folgenden nordfinnischen Ortschaften Proben gesammelt: Landgemeinde Rovaniemi, Versuchsgebiet Kivalo (37), Kittilä, Sätkänänvaara (38) und Inari, Versuchsgebiet Laanila (39).

genden besonders in Süd-Finnland zu bekommen. Die Proben wurden in verschiedenem Zusammenhang gesammelt, und schon deswegen repräsentieren sie Birken von verschiedenerlei Standorten und aus verschiedenartigen Beständen; die Regel war aber doch, dass sie nicht von alleinstehenden oder auf Blössen wachsenden Bäumen genommen wurden. 90 % von den Kätzchenproben wurden in der Zeit vom 12. X. 70 bis 3. V. 71 gesammelt; Ausnahmen waren nur folgende Ortschaften: Inari (Laanila) (27. VIII), Riihimäki (20. IX), Leppävirta (18. V), Liperi (31. V) und Kajaani (4. VI). Die Ortschaften, wo die Proben genommen wurden, sind aus Abb. 2 ersichtlich, und die Resultate nach Ortschaften und Holzarten geordnet aus Tab. 3.

Tabelle 3. Anzahl der Raupen von *Argyresthia* und anderen Kleinschmetterlingen in je 100 Kätzchen in den vom Herbst 1970 bis zum Frühjahr 1971 in verschiedenen Ortschaften gesammelten Proben. In den Zahlen sind auch die toten Raupen enthalten

Nr	Ortschaft	Rauhbirke		Moorbirke	
		Argyr.	Andere	*Argyr.*	Andere
1.	Bromarv	111.0	3.0	—	—
2.	Kemiö	—	—	63.3	12.2
3.	Karjaa	54.5	1.0	—	—
4.	Espoo	138.0	1.0	71.0	0
5.	Salo	80.7	0	44.7	4.7
6.	Tuusula	44.0	1.3	34.0	2.0
7.	Pernaja	13.8	0	22.5	3.5
8.	Hamina	67.5	5.5	33.5	2.5
9.	Loppi	—	—	20.7	1.3
10.	Riihimäki	—	—	6.7	0
11.	Kalanti	61.5	5.5	38.5	6.0
12.	Urjala	66.8	0.5	16.3	0
13.	Heinola	72.0	5.5	21.3	4.3
14.	Taipalsaari	41.5	5.5	6.5	4.0
15.	Mäntyharju	57.5	3.0	7.5	1.0
16.	Kuhmoinen	39.0	0.5	21.5	1.0
17.	Noormarkku	21.2	0	11.0	0
18.	Kankaanpää	2.0	0	—	—
19.	Mikkeli	2.0	1.0	5.0	4.0
20.	Punkaharju	48.3	2.5	6.3	1.8
21.	Korpilahti	6.5	2.0	1.0	0.5
22.	Vilppula	0.5	0.5	0.5	0.5
23.	Kihniö	3.0	1.0	4.0	3.5
24.	Isojoki	6.5	1.5	1.0	1.0
25.	Laukaa	1.5	0.5	1.5	0
26.	Leppävirta	0	1.8	1.7	1.2
27.	Liperi	—	—	(0)	(2.0)
28.	Kuortane	3.0	0	1.5	0
29.	Lapua	—	—	1.5	1.0
30.	Laihia	14.5	0.5	4.5	0
31.	Kivijärvi	0	0	0	0
32.	Siilinjärvi	0	2.8	0	2.8
33.	Pielisjärvi	1.0	0.5	1.0	1.5
34.	Kälviä	2.5	0.5	1.5	0
35.	Kajaani	(0)	(0)	(0)	(0)
36.	Muhos	1.0	3.0	0	2.1
37.	Rovaniemi	0	0	0	0
38.	Kittilä	0	0	0	0
39.	Inari	—	—	0	0
	Durchschnittlich	29.1	1.5	12.5	1.8

In den Proben aus Liperi und Kajaani waren die Kätzchen, als sie untersucht wurden, schon am Aufbrechen oder aufgebrochen, weshalb die diesbezüglichen, etwas unsicheren Werte in der Tabelle eingeklammert sind.

Wie die Tabelle zeigt, wurden an den Rauhbirken durchschnittlich erheblich mehr *Argyresthia*-Raupen angetroffen als an den Moorbirken; im Vorkommen der anderen, d.h. der *Epinotia*-Arten dagegen bestand zwischen den Baumarten kein wesentlicher Unterschied. Aus der Tabelle geht weiter

hervor, dass das zahlreiche Vorkommen der *Argyresthia*-Arten auf die südlichsten Teile des Landes konzentriert war. Die nördlichsten Ortschaften, wo mindestens 20 Raupen auf 100 Kätzchen kamen, waren bezüglich der Rauhbirke Punkaharju und Noormarkku, bezüglich der Moorbirke Kuhmoinen und Heinola. Berechnet man die Mittelwerte beiderseits des 62. Breitengrads, so erhält man in den Rauhbirkenproben für den südlichen Teil 48.9 und für den nördlichen nur 2.4 Raupen, und in den Moorbirkenproben entsprechend 22.7 und 1.1 Raupen. Die nördlichsten Fundorte von *Argyresthia*-Raupen waren bei der vorliegenden Untersuchung Muhos (1971) und Rantsila (1969).

Auch *Epinotia*-Raupen wurden in den südlichen Landesteilen durchschnittlich etwas häufiger gefunden als in den nördlichen, aber der Unterschied war längst nicht so gross wie bei den *Argyresthia*-Arten. An und für sich können die Raupen relativ zahlreich auch noch ziemlich weit nördlich auftreten. In der am 26. V. 70 in Muhos genommenen Moorbirkenprobe kamen 9.6 *Epinotia*-Raupen auf 100 Kätzchen. Der nördlichste sichere Fundort ist die Landgemeinde Rovaniemi (Versuchsgebiet Kivalo der Forstlichen Forschungsanstalt). In den 1968—71 in Rovaniemi genommenen Moorbirkenkätzchen wurden in allen anderen Jahren ausser 1971 Raupen gefunden, am zahlreichsten 1968 (9 Stück in 297 Kätzchen), in den Rauhbirkenkätzchen dagegen überhaupt nie. Mindestens eine von diesen Arten kommt offenbar noch weiter nördlich vor. Dem Prüfungsprotokoll gemäss wurde nämlich in einer Probe aus Kittilä vom 21. V. 68 eine tote Raupe gefunden. Sie wurde leider nicht aufbewahrt und konnte daher nicht bestimmt werden.

Im Frühjahr 1969 wurden Kätzchenproben nur aus 9 und im folgenden Jahr aus 10 Ortschaften geprüft. Die Proben vom Jahr 1969 repräsentierten verschiedene Partien des Landes, aber 1970 kam der Hauptteil des Materials aus gewissen Gründen aus Mittel- und Nord-Finnland. In beiden Jahren wich das erhaltene Bild nicht wesentlich von dem oben besprochenen ab.

Um die jährlichen Massenschwankungen in den gleichen Beständen aufklären zu können, wurden einige Probeserien in Ruotsinkylä, Punkaharju, Vilppula und Rovaniemi genommen. Weil in den zwei letztgenannten Ortschaften in allen Jahren sehr wenig Raupen gefunden wurden (höchstens 3 Stück/100 Kätzchen), werden im folgenden nur zwei Serien besprochen, von denen die eine in den Jahren 1965—71 in Ruotsinkylä von Moorbirke genommen wurde und die andere 1968—71 in Punkaharju von Rauhbirke.

Das Material von Ruotsinkylä wurde 1965—68 derart gesammelt, dass etwas vor der Birkenblüte von mehreren Bäumen Zweige genommen und dann im Labor bei Zimmertemperatur in grosse Wasserkübel gestellt wurden. Die Kätzchen wurden ziemlich spät kontrolliert, wobei festgestellt wurde, ein wie grosser Teil von ihnen entweder ganz oder teilweise oder überhaupt nicht aufgegangen war. Auch die Raupen wurden gezählt, weil aber damals schon

ein beträchtlicher Teil die Kätzchen verlassen hatte, waren die Zahlen nicht brauchbar. In den Jahren 1969—71 wurden die Proben Ende April (1971) oder Anfang Mai genommen, und geprüft, ehe die Kätzchen ganz aufgegangen waren. Beim Untersuchen wurde ausser der Zahl der Raupen auch diejenige der geschädigten Kätzchen festgestellt, so dass sich diese Resultate im grossen ganzen mit den früheren vergleichen lassen (am schlechtesten betreffs 1971).

Die Ausdeutung der Resultate wird durch den Umstand erschwert, dass es wegen der grossen Menge und der hohen Vernichtungsrate der Kätzchen sowie wegen der Form der Birkenkrone (unregelmässiges Geäst) praktisch geradezu unmöglich ist, die ursprüngliche Gesamtzahl der männlichen Kätzchen (im Herbst) z.B. pro eine bestimmte Flächeneinheit in irgendeinem Bestand zu bestimmen, Aus diesem Grunde ist es auch sehr schwierig, die absolute Grösse der Schädlingspopulation in den verschiedenen Jahren zu ermitteln, was für die Klärung des wirklichen Massenwechsels unbedingt notwendig wäre (vgl. z.B. H e d l i n 1964).

Die hier in Frage stehenden Birkenbestände wurden jedoch deswegen zum Untersuchungsobjekt genommen, weil an ihnen schon seit langem für verschiedene Untersuchungen von Prof. R. S a r v a s jedes Jahr mit Hilfe von bestimmten Sammeltrichtern laufend auch die Reste der abgefallenen männlichen Kätzchen mengenmässig bestimmt worden waren (Trockengewicht g/m²). Obschon das so bestimmte Gewicht der Kätzchenmasse teilweise eben vom Ausmass der Insektenschäden abhängig ist, geben diese Resultate doch einen gewissen Vergleichspunkt ab. Die Menge der Reste der männlichen Kätzchen und die erzielten Resultate gehen aus der folgenden Zusammenstellung hervor. Zu bemerken ist, dass die jährliche Probe allermindestens 200 Kätzchen umfasste — in der Regel allerdings mehr — und dass in den Zahlen auch die *Epinotia*-Raupen und die von ihnen verursachten Schäden enthalten sind, die jedoch in allen Jahren nur wenig Bedeutung hatten.

Punkaharju (Rauhbirke)	1967	1968	1969	1970	1971
Reste männlicher Kätzchen g/m²	8.93	8.30	18.85	11.77	27.33
Raupen St./100 Kätzchen	—	47.2	34.6	42.8	50.8
Lebende Raupen St./100 Kätzchen ..	—	28.4	1.8	33.2	50.0

Ruotsinkylä (Moorbirke)	1964	1965	1966	1967	1968
Reste männlicher Kätzchen g/m²	17.85	0.58	3.17	7.55	1.22
Geschädigte Kätzchen %	—	98.6	20.8	18.3	72.8

	1969	1970	1971
Reste männlicher Kätzchen g/m²	8.88	3.27	12.64
Geschädigte Kätzchen %	21.3	19.2	42.5

Betrachtet man die in Punkaharju erzielten Resultate, so sieht man, dass 1971 über dreimal so viel Kätzchenreste erhalten wurden als 1968. Die Menge der männlichen Kätzchen wies also ganz beträchtliche Schwankung auf, aber trotzdem war sie in allen fraglichen Jahren mindestens ziemlich reichlich. In dem Moorbirkenbestand von Ruotsinkylä war die Schwankung viel grösser. Besonders im Frühjahr 1965 gab es wirklich wenig Kätzchen; dies zeigt sich auch darin, dass an den von insgesamt 11 Bäumen genommenen Zweigen nur 494 Kätzchen untersucht werden konnten. 1971 war auch hier ein ertragreiches Jahr. Aus der Zusammenstellung ist auch ersichtlich, dass von den im Frühjahr 1969 in der Probe von Punkaharju gefundenen Raupen die meisten vernichtet waren. Auch in Ruotsinkylä war der Anteil der toten Raupen in diesem Jahr auffallend gross (46.8 %).

Vergleicht man die Frequenz der Raupen und der geschädigten Kätzchen mit der Gesamtmenge der männlichen Kätzchen, so stellt sich heraus, dass im allgemeinen die Schäden relativ umso grösser waren, je weniger Kätzchen es gab. Es verhielt sich aber nicht immer so. Eine deutliche Ausnahme ist vor allem das Jahr 1971. Obwohl es damals sehr reichlich Kätzchen gab, war die relative Menge der Raupen in Punkaharju grösser als in den anderen Jahren, und der Anteil der geschädigten Kätzchen war auch in Ruotsinkylä recht hoch. Ohne Zweifel war die absolute Menge der Raupen pro Flächeneinheit in beiden Waldbeständen 1971 grösser als in den anderen in Frage stehenden Jahren. Bemerkenswert ist auch, dass, obwohl in Punkaharju die Raupen grösstenteils in Herbst und Winter 1968—69 zugrunde gingen, ihre relative Menge schon im nächsten Jahr wieder recht gross war.

H e d l i n (1964) hat in Kanada im Lauf von sechs Jahren in Douglastannen-Beständen ausser dem Zapfenertrag auch die Individuendichte mancher Zapfen- und Samenschädlinge pro Acre bestimmt. Die Ergebnisse der Untersuchung zeigen u.a., dass in schlechten Zapfenjahren die Schäden relativ am grössten sind, die Individuenzahlen der Schädlinge pro Acre aber wegen der geringen Zapfenzahl trotzdem niedrig bleiben. Wenn auf ein schwaches Zapfenjahr ein wenigstens mittelmässiges folgt, kann die Insektenpopulation sogar über das Hundertfache im Vergleich zum Vorjahr ansteigen. Beim Erörtern der Ursachen für den Massenwechsel wurde festgestellt, dass die Schwankung ausser vom Ausmass des Zapfenertrags auch vom Überliegen der Insekten herrührte, das in manchen Jahren sehr häufig war.

Da die Resultate aus den in Punkaharju und Ruotsinkylä gesammelten Materialien in mancher Hinsicht denen von H e d l i n ähnlich sind, erhebt sich die Frage, ob das Überliegen auch auf den Massenwechsel der hier in Frage stehenden *Argyresthia*-Arten Einfluss hat.

In vielen Untersuchungen über die Biologie von Insektenschädlingen der Nadelholzzapfen ist nachgewiesen worden, dass diese Arten entweder als ausgewachsene Raupen oder im Puppenstadium überliegen (z.B. H e d l i n

1960, 1967; B a k k e 1963). Vorn (S. 15) ist schon die Rede davon gewesen, dass mindestens bei *Argyresthia goedartella* die Diapause wahrscheinlich im vierten Raupenstadium eintritt, m.a.W. in einem Entwicklungsstadium, nach welchem die Raupe noch Nahrung braucht. Da die männlichen Kätzchen nach der Blüte abfallen und im nächsten Frühjahr sicherlich nicht mehr als Nahrung für die Raupen taugen, ist es klar, dass das Überliegen nicht in diesem Stadium stattfinden kann.

Bei den zahlreichen Prüfungen, die ich in verschiedenen Jahren im Spätsommer, Herbst und zeitig im Frühjahr durchgeführt habe, habe ich auch an den Verpuppungsstätten keine lebenden Raupen oder Puppen finden können, wohl aber Puppen, aus denen im Frühjahr Schmarotzerwespen schlüpften. Um die Wirkung relativ niedriger Temperaturen aufzuklären, wurden in Ruotsinkylä im Frühjahr 1973 Birkenkätzchen gesammelt und in Gazebeuteln Mitte Mai in den Zuchtschrank getan, wo eine Temperatur von 10°C herrschte, was erheblich niedriger ist als die Temperatur der Erde im Hochsommer in Süd-Finnland in der Tiefe, wo ein Teil der *Argyresthia*-Raupen sich verpuppt (vgl. z.B. Kuukausikatsaus Suomen ilmastoon 1972). Dessenungeachtet schlüpften aus den Kätzchen im Lauf des September 18 Imagines von *A. goedartella* und 2 von *A. brockeella*. Als die Zucht am 9. X. 73 beendigt wurde, waren in den Beuteln noch ein paar tote Raupen sowie 10 tote und nur 1 lebende Puppe, die bei der Untersuchung leider verdarb.

Aufgrund des obigen ist es wahrscheinlich, dass der Massenwechsel der *Argyresthia*-Arten — mindestens was *A. goedartella* betrifft — nicht mit dem Überliegen zusammenhängt, sondern — ausser noch manchen anderen Faktoren — eher von der Menge der Nahrung.

Bei den im Frühjahr durchgeführten Untersuchungen ist beobachtet worden, dass pro eine *Argyresthia*-Raupe gewöhnlich 1—1.5 männliche Birkenkätzchen zugrunde gehen. Da in den im Frühjahr 1971 geprüften Kätzchenproben stellenweise sogar mehr als 1 Raupe auf ein Kätzchen kam (Tabelle 3), kann wahrscheinlich in manchen Jahren im südlichsten Finnlands ein Teil der Population geradezu aus Nahrungsmangel zugrunde gehen. Im Mai 1971 habe ich denn auch in Tapiola feststellen können, dass von einer Birke, deren Kätzchen fast gänzlich vernichtet waren, sich nur ein paar wenige Raupen zur Verpuppung zum Fuss des Baumes oder auf den Boden herabgelassen hatten.

Die Bedeutung der Parasiten konnte im Rahmen der vorliegenden Untersuchung nicht aufgeklärt werden. Was sonstige Begrenzungsfaktoren der Vermehrung betrifft, so wurden — wie vorn schon in anderem Zusammenhang erwähnt worden ist — in manchen Jahren im Lauf des Herbstes und Winters zahlreiche aus vorwiegend unbekannten Gründen zugrunde gegangene Raupen angetroffen. Von den in Rauh- und Moorbirkenproben gefundenen Raupen waren in den Jahren 1969, 1970 und 1971 insgesamt

57.1, 23.0 und 1.3 % eingegangen. Da sowohl *A. goedartella* wie auch *A. brockeella* Arten mit relativ südlicher Verbreitung sind, wäre es denkbar, dass die Vernichtung mit der Witterung zu tun haben könnte. Aufgrund des hier dargelegten Materials lässt sich jedoch nichts dergleichen nachweisen.

Was nun die forstwirtschaftliche Bedeutung der die männlichen Birkenkätzchen schädigenden Kleinschmetterlinge anbelangt, so liegt es auf der Hand, dass sie in dieser Hinsicht nicht mit den Schadinsekten der Samen vieler Holzarten zu vergleichen sind. In seiner Untersuchung über die Blüte und den Samenertrag der Birke hat S a r v a s (1952) jedoch nachgewiesen, dass der Prozentsatz der keimfähigen Samen von der relativen Menge der Bestäubung abhängig ist. Man darf daher annehmen, dass auch die von den *Argyresthia*-Raupen verursachten Schäden in gewissen Jahren im südlichsten Finnland die Qualität des Samenertrags besonders der Rauhbirke beeinträchtigen.

ZUSAMMENFASSUNG

In der vorliegenden Untersuchung werden die Biologie und das Vorkommen zweier *Argyresthia*-Arten — *A. goedartella* L. und *A. brockeella* Hb. —, die als Raupen in den männlichen Blütenkätzchen der Rauh- und Moorbirke leben, in Finnland behandelt. Auch gewisse Beobachtungen über manche *Epinotia*-Arten, die ebenfalls männliche Kätzchen schädigen, werden besprochen. Das Material der Untersuchung ist im Lauf ziemlich langer Zeit in verschiedenen Gegenden Finnlands gesammelt worden, der Hauptteil jedoch in den Jahren 1968—71. Die Untersuchungen über die Biologie der Arten wurden fast gänzlich in der Umgebung von Helsinki gemacht.

Aufgrund von Zuchten konnte festgestellt werden, dass *A. goedartella* an einheimischen Holzarten ausser Rauh- und Moorbirke auch noch an Grau- und Schwarzerle vorkommt, *A. brockeella* dagegen fast ausschliesslich an Moorbirke. An Zwergbirke und Haselstrauch wurden keine Raupen der beiden Arten angetroffen.

Die Eiablage geschieht mindestens hauptsächlich an der Basis junger männlicher Kätzchen und beginnt im südlichsten Finnland Anfang oder Mitte Juli. Die ersten Raupen schlüpfen etwa einen Monat später im August, die letzten erst Anfang September. Die Arten haben fünf Raupenstadien. Im Herbst bleibt die Entwicklung (wenigstens bei *A. goedartella*) wegen der Diapause auf dem vierten Stadium stehen. Raupen des fünften Stadiums wurden erst nach dem Überwintern angetroffen.

Die ausgewachsenen Raupen von *A. goedartella* lassen sich zur Verpuppung zum Fuss oder zum Wurzelwerk der Bäume oder auf den Boden herab. Die Verpuppungsstätte von *A. brockeella* war nicht herauszufinden. In der Gegend von Helsinki geht die Verpuppung um die Monatswende Mai—Juni

vor sich. Die Flugzeit von *A. goedartella* setzt auch in den allersüdlichsten Landesteilen gewöhnlich erst Anfang Juli ein und dauert mindestens bis Mitte August. *A. brockeella* hat vermutlich kürzere Flugzeit.

Die nördlichsten Fundorte von *Argyresthia*-Raupen waren Muhos und Rantsila in Nord-Pohjanmaa. Schlimmere Schäden kommen aber im allgemeinen nur in den südlichsten Teilen Finnlands, etwa südlich vom 62. Breitengrad vor. Meistens sind die Schäden, deren Ausmass an den verschiedenen Baumindividuen auch des gleichen Bestandes weitgehend wechseln kann, an den Rauhbirken durchschnittlich viel schwerer als an den Moorbirken.

Um das Ausmass der jährlichen Massenschwankungen zu ermitteln, wurden in manchen Beständen mehrjährige Untersuchungen gemacht, die ergaben, dass die relative Menge der Raupen und der geschädigten Kätzchen meistens umso grösser war, je weniger Kätzchen es gab. Die absolute Menge der Raupen pro Flächeneinheit war dessenungeachtet aber in reichen Kätzchenjahren ganz offenbar grösser als in schlechten Kätzchenjahren.

Überliegen von einem oder mehreren Jahren konnte wenigstens bei *A. goedartella* in keinem Entwicklungsstadium festgestellt werden. Das Überliegen scheint im Massenwechsel der hier besprochenen *Argyresthia*-Arten also nicht die das Nahrungsangebot synchronisierende Wirkung zu haben, die bei manchen Insektenschädlingen der Zapfen und Samen von Nadelhölzern nachgewiesen worden ist.

LITERATURVERZEICHNIS

Annila, E. 1966. On the occurrence of *Plemeliella abietina* Seitn. (Dipt., Cecidomyidae) and *Megastigmus strobilobius* Ratz. (Hym., Chalcididae) in Finland. Ann. Ent. Fenn. 32.1: 3—11.

Bakke, A. 1963. Studies on the spruce-cone insects *Laspeyresia strobilella* (L.) (Lepidoptera: Tortricidae), *Kaltenbachiola strobi* (Winn.) (Diptera: Itonidae) and their parasites (Hymenoptera) in Norway. Biology, distribution and diapause. Medd. Norske Skogforsøksvesen 19: 1—151.

Benander, P. 1950. Vecklarefjärilar. Tortricina. Svensk insektfauna 10, II. Stockholm.

Deurs, W. van 1956. Sommerfugle VIII. Viklere. Danmarks Fauna 61. København.

Disqué, H. 1904. Die Tortriciden-Raupen der Pfalz. Deutsche Ent. Zeitschr. Iris 17: 209—256.

Eidmann, H. 1960. On lärkskottmalen (*Argyresthia laevigatella* H. S.) i Sverige. Medd. Stat. Skogsforskn.inst. 49.3: 1—22.

Escherich, K. 1931. Die Forstinsekten Mitteleuropas III. Berlin.

Friese, G. 1969. Beiträge zur Insekten-Fauna der DDR: Lepidoptera — Argyresthiidae. Beitr. Ent. 19: 693—752.

Gusev, V. I. & Rimski-Korsakov, M. N. 1951.
Гусев, В. И. и Римский-Корсаков, М. Н. Определитель повреждений лесных и декоративных деревьев и кустарников европейской части СССР. Москва-Ленинград.

Gäbler, H. 1958. Beiträge zur Kenntnis der Schadinsekten der Blüten und Samen von Forstgehölzen. Archiv f. Forstwesen 7, 10—11: 786—827.

Hedlin, A. F. 1960. On the life history of the Douglas-fir cone moth, *Barbara colfaxiana* (Kft.) (Lepidoptera: Olethreutidae), and one of its parasites, *Glypta evetriae* Cush. (Hymenoptera: Ichneumonidae). Can. Ent. 92: 826—834.

—»— 1964. A six-year plot study on Douglas-fir cone insect population fluctuations. Forest Science 10.1: 124—128.

—»— 1967. The pine seedworm, *Laspeyresia piperana* (Lepidoptera: Olethreutidae), in cones of ponderosa pine. Can. Ent. 99: 264—267.

Kuukausikatsaus Suomen ilmastoon (Monatsübersicht des Klimas in Finnland) 1972. Ilmatieteen laitos. Helsinki.

Rudnew, D. F., Semkowa, R. I. & Iwanowa, R. M. 1970. Samenschädlinge der Laubhölzer in der zentralen Ukraine und einige Faktoren, welche ihre Widerstandsfähigkeit gegen Schadinsekten bestimmen. Anz. f. Schädlingskunde 42: 129—132.

Sarvas, R. 1952. On the flowering of birch and the quality of seed crop. Comm. Inst. For. Fenn. 40.7: 1—38.

—»— 1972. Investigations on the annual cycle of development of forest trees. Active period. Comm. Inst. For. Fenn. 76.3: 1—110.

Schultz, V. G. M. 1952. Neue Beiträge zur Schmetterlingskunde, Nr. 25. Natur und Heimat 12: 81—85.

—»— 1953. Neue Beiträge zur Schmetterlingskunde, Nr. 29, 30. Ibid. 13: 42—51, 90—98.

Schütze. 1911. Mitteilungen über Kleinschmetterlinge. Deutsche Ent. Zeitschr. Iris 25: 80—90.

Schwerdtfeger, F. 1963. Ökologie der Tiere. Autökologie. Hamburg u. Berlin.

Swatschek, B. 1958. Die Larvalsystematik der Wickler (Tortricidae und Carposinidae). Abhandl. z. Larvalsystematik der Insekten Nr. 3. Berlin.

Werner, K. 1958. Die Larvalsystematik einiger Kleinschmetterlingsfamilien (Hyponomeutidae, Orthotelidae, Acrolepidae, Tineidae, Incurvaridae und Adelidae). Ibid. Nr. 2.

SELOSTE

Raudus- ja hieskoivun hedenorkoissa esiintyvistä Argyresthia-lajeista (Lepidoptera: Argyresthiidae)

Tässä tutkimuksessa käsitellään toukkina raudus- ja hieskoivun hedenorkoissa elävien koiperhoslajien *Argyresthia goedartella* L. ja *A. brockeella* Hb. biologiaa sekä esiintymistä Suomessa. Joitakin havaintoja on esitetty myös eräistä hedenorkkoja vioittavista *Epinotia*-lajeista. Tutkimuksen aineisto on koottu pitkähkön ajan kuluessa eri puolilta maata, pääosa kuitenkin vuosina 1968—71. Lajien biologiaa koskevat tutkimukset on suoritettu lähes kokonaisuudessaan Helsingin ympäristössä.

Suoritettujen kasvatusten perusteella todettiin *A. goedartellan* esiintyvän kotimaisista puulajeista paitsi raudus- ja hieskoivussa myös sekä harmaa- että tervalepässä, *A. brockeellan* sen sijaan lähes yksinomaan hieskoivussa. Kummankaan lajin toukkia ei tavattu vaivaiskoivusta eikä pähkinäpensaasta.

Muninta tapahtuu ainakin pääasiassa nuorten hedenorkkojen tyviin ja alkaa eteläisimmässä osassa maata heinäkuun alkupuolella tai puolivälissä. Ensimmäiset toukat kuoriutuvat noin kuukautta myöhemmin elokuussa, viimeiset vasta syyskuun alkupuolella. Toukka-asteita on viisi. Syksyllä kehitys pysähtyy (ainakin *A. goedartellalla*) diapausin takia neljännelle asteelle. Viidennen asteen toukkia tavattiin vasta talvehtimisen jälkeen.

A. goedartellan täysikasvuiset toukat laskeutuvat koteloitumaan joko puiden tyviosiin tai juuristoon tahi maahan, *A. brockeellan* koteloitumispaikkaa ei saatu selville. Koteloituminen tapahtuu Helsingin seudulla touko—kesäkuun vaihteessa. *A. goedartellan* lentoaika alkaa maan eteläisimmissäkin osissa tavallisesti vasta heinäkuun alussa ja kestää ainakin elokuun puoliväliin saakka. *A. brockeellan* lentoaika on luultavasti lyhyempi.

Pohjoisimmat *Argyresthia*-toukkien löytöpaikat olivat Muhos ja Rantsila Pohjois-Pohjanmaalla. Voimakkaita tuhoja esiintyy kuitenkin yleensä vain maan eteläisimmissä osissa n. 62. leveysasteen eteläpuolella. Tavallisesti tuhot, joiden määrä vaihtelee samankin metsikön eri puuyksilöissä, ovat rauduskoivussa keskimäärin selvästi yleisempiä kuin hieskoivussa.

Vuotuisten kannanvaihteluiden suuruuden selvittämiseksi suoritettiin eräissä metsiköissä useampivuotisia tutkimuksia, jotka osoittivat toukkien ja vioitettujen norkkojen suhteellisen määrän olleen useimmiten sitä suuremman mitä vähemmän norkkoja oli ollut. Toukkien absoluuttinen määrä pinta-alayksikköä kohti oli tästä huolimatta kuitenkin aivan ilmeisesti suurempi runsaina kuin niukkoina norkkovuosina.

Yhden tai useamman vuoden kestävää jättäytymistä ei ainakaan *A. goedartellalla* voitu todeta missään kehitysvaiheessa. Jättäytymisilmiöllä ei tässä käsiteltyjen *Argyresthia*-lajien kannanvaihtelussa näin ollen liene sellaista ravinnon runsauteen synkronoivaa vaikutusta kuin eräillä havupuiden käpyjä ja siemeniä tuhoavilla hyönteislajeilla on osoitettu olevan.

AFFORESTATION OF FIELDS IN FINLAND: AGRICULTURAL BACKGROUND AND RECENT ACHIEVEMENTS

ASHLEY SELBY

SELOSTE

PELTOJEN METSITYS SUOMESSA

HELSINKI 1975

ISBN 951-40-0140-0

Helsinki 1975. Valtion painatuskeskus

PREFACE

This report presents the first results of an ongoing project examining the afforestation of agricultural land in Finland. These initial results are on the national level and examine field afforestation against the background of agricultural change resultant upon governmental legislation aimed at confirming new agricultural policies and objectives which run counter to traditional ones. The afforestation of fields through two specific Acts is examined in detail and compared with afforestation achievements as a whole. Field afforestation is discussed in the context of future trends and developments in agriculture and forestry.

This study has necessitated close co-operation with both forestry and agricultural authorities in Finland, and particularly the Central Board of Forestry Tapio (Keskusmetsälautakunta Tapio), district forestry boards (piirimetsälautakunnat), the National Board of Agriculture (Maatilahallitus) and the Farmers' Retirement Pension Institute (Maatalousyrittäjien Eläkelaitos), as well as internally within the Finnish Forest Research Institute (Metsäntutkimuslaitos). Special acknowledgements must go to Professors Viljo Holopainen, director of the Finnish Forest Research Institute, and Lauri Heikinheimo, head of the Institute's Forest Economics Department for their encouragement and advice at all times. These, and Professor Jouko Hämäläinen reviewed the manuscript for publication. Mrs. Aune Väisänen, head of the National Board of Agriculture's Statistics Office, has been a willing and cheerful source of information concerning many aspects of Finnish agriculture. Mr. Esko Jaatinen has been my unfortunate colleague and has had to suffer frequent interruptions to untangle me from difficulties with the Finnish language!

Ashley Selby

Helsinki, December 1974

CONTENTS

Page

Preface 3

Summary 5

1. Introduction 7
   1.1. Background to the study 7
   1.2. Sources of data 9
      1.2.1. Agricultural data 9
      1.2.2. Forestry data 12

2. Recent agricultural changes 13
   2.1. Changes in farm-size structure and farmed area 1959—1969 13
   2.2. Abandonment of agricultural holdings 18
      2.2.1. Previous studies 18
      2.2.2. General synopsis 19
      2.2.3. Reasons for abandonment 22
   2.3. The field reservation programme 24
      2.3.1. Previous studies 24
      2.3.2. Field reservation activity 1969—1973 25

3. Afforestation of fields 28
   3.1. Developments in forestry and agricultural land-use policies and legislation affecting field afforestation 28
      3.1.1. Land-use policies and legislation affecting the afforestation of fields 28
   3.2. Recent afforestation and afforestation of fields 30
      3.2.1. General synopsis 30
      3.2.2. Afforestation of fields through legislation and State funds, ... 34
      3.2.3. The need for legislation 39

4. Discussion 40

Bibliography 47

Seloste 50

Appendix 52

SUMMARY

This paper examines recent achievements in the afforestation of fields in Finland against the background of agricultural changes in the decade 1959 to 1969, recent legislation affecting agricultural and forestry land-use and the economic growth and social objectives outlined for the 1970s.

Agricultural policies in Finland are aimed at reducing production of dairy products and bread grains to the level of self sufficiency by the end of the 1970s. The rationalization of agriculture and the improvement of farm-size and farmers' age structure are also important goals. To achieve these objectives at least 600 000 hectares of arable land need to be withdrawn from cultivation by 1980 and the number of farms reduced by 33 %.

Forest productivity needs to be increased to meet the growing demand for wood-based products. Increased forest productivity is to be achieved by massive silvicultural investments, but total production can also be improved by increasing the forest area through afforestation. The afforestation of fields will assist the achievement of both agricultural and forestry goals.

Farm-size structure has improved during the 1960s. In 1969 32 % of all farms with more than two hectares of arable land were larger than 10 arable hectares compared with 25 % in 1959; the figures for similar farms in northern Finland being 22 % and 17 % respectively.

The abandonment of farms during the 1960s led to some 12 600 hectares of farm land being in state of abandonment in 1969. The mean size of abandoned holdings has increased two-fold during the 1960s. The abandonment process has moved northwards during this period.

The Field Reservation Act (1969) has led to the withdrawal of 229 000 hectares of arable land from cultivation between 1969 and 1973, of which 40 % was in southern and western Finland, 27 % in central and eastern Finland and 33 % in northern Finland. 37 % of all reservation contracts were made during the first year of the Act.

Afforestation activities have increased nation-wide since 1969, but particularly in eastern and northern Finland. In central and eastern Finland field afforestation has accounted for most of the afforestation activity. Afforestation activities are largely confined to the private sector of forest ownership. Since 1969 there has been a large increase in the planting of birch in all regions of Finland except the extreme north. The planting of spruce has proportionately declined.

Afforestation has been encouraged through the Forest Improvement Act (1967) and the afforestation of fields has been encouraged through the Field Reservation Act (1969) and an ammendment to the Forest Improvement Act (1969). Afforestation of fields has also been achieved independently.

The Forest Improvement Act (1967 & 1969) together with the Field Reservation Act (1969) led to 44 900 ha of afforestation between 1969 and 1973 of which 36 500

ha (81 %) was field afforestation. Afforestation of fields has been increasingly important in its contribution to the total afforestation achieved through State grants via the FIA, increasing from 50 % in 1969 to 88 % in 1972, decreasing slightly to 85 % in 1973. This contribution is almost wholely attributable to the FRA which created incentives for land-use change. Between 1969 and 1973 permission to afforest 32 500 ha of reserved fields was granted, being 14 % of the total area of fields reserved during that period.

Comparison of the area of private afforestation achieved through the legislation in question and that achieved independently (private sector) reveals the value of legislation in promoting afforestation and especially afforestation of fields. Between 1969 and 1973 only 5 000 ha of afforestation was achieved independently of State funds whereas 44 500 ha of afforestation was achieved via the FIA, a ratio of 1: 9. The figures for field afforestation during the same period being 2 100 ha and 36 500 ha respectively, a ratio of 1: 17.

The achievements in field afforestation are modest compared with other silvicultural achievements. This can be partly attributed to farmer's difficulties in accepting the rapid changes in agricultural policies and objectives during the late 1960s. Old values have been destroyed and new ones have yet to be accepted.

Future developments in both agriculture and forestry may affect afforestation activities. Larger farms, younger farmers, increased productivity and reduced arable area may release farm land for other economic uses, especially forestry. Conversely, a fundamental rejection of the deep-going changes in rural society, the increasing world food shortage and other factors could halt the withdrawal of farmland from cultivation and could even reverse the trend.

Developments in forestry, especially increased profitability brought about by the increase demand for forest-industry products, may make the use of land for forestry more profitable than its use for agriculture. The successful adoption of short-rotation forestry in Finland may well alter the whole farm-forestry structure as it is known today, with strong implications for the afforestation of fields.

1. INTRODUCTION

1.1 Background to the study

Finnish agricultural production during the 1960s was characterized by the over-production of certain products, especially bread grain and dairy products. This surplus led to the need to export at a time when the international trade prices for agricultural products was relatively low — lower, in fact, than the cost of production — and also lower than domestic prices in most trading countries (»Growth prospects for the Finnish economy up to 1980» pages 84 & 85).

In consequence of this trading situation, and also because of the need to rationalize Finnish agriculture, a number of policy objectives have been suggested for the 1970s (Growth . . .» p. 81):

- — agricultural output should be brought to a level corresponding to domestic consumption;
- — production should be rationalized;
- — an appropriate regional pattern of production should be agreed upon;
- — the income level of the farm population should be raised, and kept in step with that of other economic groups.

Figures for the output of certain agricultural products in 1970 and the consumption estimates for the years 1970, 1975 and 1980 have been prepared by the Ministry of Agriculture and are shown in table 1.1.

Table 1.1. Output and consumption estimates for certain agricultural products, 1970, 1975 and 1980

Taulukko 1.1. Eräiden maataloustuotteiden arvioitu tuotanto ja kulutus 1970, 1975 ja 1980

Product *Tuote*	Output 1970 *Tuotanto 1970* (mill. kg)	Consumption — *Kulutus* 1970	1975 (mill. kg)	1980
Wheat — *Vehnä*	409	300	260	220
Rye — *Ruis*	131	113	102	90
Butter — *Voi*	86[1]	66	65	60
Cheese — *Juusto*	41[1]	21	25	30
Pork — *Sianliha*	94	91	100	110
Beef and veal — *Naudan- ja vasikanliha*	106	100	115	130

[1] Dairy output only — *Vain meijerituotteet*

Source: »Growth . . .» page 84. — *Lähde: »Suomen kansantalouden kehitysmahdollisuudet 1980», (Englannin kielinen versio)*

Self-sufficiency targets set for agricultural production are 105 % for livestock and 100 % for bread grain and these should be achieved by the late 1970s. On the basis of present estimates, therefore, a drastic reduction in the output of grain and dairy produce is required whilst the production of pork and beef must increase. In terms of the present state of agricultural productivity some 400 000 hectares of arable land are surplus to self-sufficiency requirements (»Growth . . .» page 83). Productivity is rising faster than consumption, however, and it is estimated that a total of 60 000 ha of arable land should be withdrawn annually from agricultural production (»Growth . . .» page 83). During the period 1969—1973 some 230 000 ha of arable land were removed, albeit temporarily, from production through the Field Reservation Programme, but this falls short of the 60 000 ha per annum target. Clearly, the need exists for a greater movement of people away from agriculture with the consequence abandonment of arable land, although this must involve many social and regional development considerations.

An extensive expansion of Finland's forest industry has also taken place during the 1960s. In fact, the expansion has been such that the long-term balance of Finnish forests has been threatened, especially north of a line running from Savonlinna to Kokkola via Mikkeli and Tampere. In this northern zone fellings have regularly exceeded both increment and allowable cut. In consequence of this, the main objective in forestry are to increase the allowable cut in order to meet the increasing demands of industry my means of massive investment programmes designed to intensify silviculture and promote productivity. Such programmes include the MERA III Programme [1] which is discussed with other programmes by Ervasti, et. al. (1970). At present none of the programmes has legistative backing.

Another factor affecting forest production is the changing structure of private forest ownership. Studies by Järveläinen (1971 & 1974) and Reunala (1971 & 1974), for example, indicate a movement of forest ownership away from the farmer. This, they say, is likely to adversely affect the supply of commercial timber in the future as non-farmer forest owners cut and sell timber less frequently than farmers, saving their forest for recreation or for other purposes. Thus, saving forests and obtaining income from timber sales have become opposite and alternative forestry goals.

A dichtomy therefore exists between agriculture and forestry, and also within forestry itself. Agriculture requires extensive contraction and rationalization, whilst forestry requires expansion and intensification. The latter is somewhat threatened by recent ownership trends in the private forestry sector. Honkanen, et. al. (1973), on the basis of interview studies concerning

[1] Metsätalouden rahoitusohjelma (Forestry Financing Programme) III, Helsinki 1969.

farmers' future, estimate that the number of active farmers with holdings of three hectares of arable land or more will decrease from 235 000 in 1969 to 157 000 in 1980, and the respective decrease in arable land will be 730 000 hectares (which exceeds the 600 000 hectares the Economic Planning Centre predicted needed to be withdraw from production, see »Growth . . .» page 83). It would seem, therefore, that the necessary changes in agriculture can be achieved although their is little evidence of this happening at present. The 600 000 to 700 000 ha of arable land to be withdrawn from agriculture must therefore be considered for some other economic purpose. One alternative is to abandon it to natural regeneration by forests. Another consideration would be the deliberate afforestation [1] of these fields [2] with selected species. It is the latter alternative which is the primary topic of this paper, and on which the author is now conducting research. This paper describes agricultural changes between 1959 and 1969 as a background to discussing recent legislation affected land-use change and examining recent achievements in the afforestation of arable land.

1.2 Sources of data

1.2.1. Agricultural data

The descripition of changes in Finnish agriculture between 1959 and 1969, see Section 2, were primarily based on the Agricultural Censuses of those years (SVT III: 54 and SVT III: 67 respectively). Whilst the method of investigation was the same for both censuses, a different farmsize classification was used in the 1969 Census which necessitated an adjustment to the 1959 figures to make them compatible with those for 1969. The minimum farm-size included in the 1969 census was 1 hectare of arable land compared with 0.25 ha of arable land in 1959. It was not possible to make a similar adjustment for the areal changes in land-use categories and so these figures contain an error of about + 1 %.

Data on abandoned farms were provided by the Board of Agriculture and are based on the agricultural censuses and separate studies. An attempt to obtain information on the number of farms abandoned in Mikkeli Agricultural District since 1969 by sending a questionnaire to local agricultural societies proved fruitless with only five replies from the 28 communes involved.

[1] Afforestation is defined as the establishment of a forest by seeding or planting on land, such as arable land, pasture land and open peat land, which has not been under forest in recent history.

[2] The Finnish word »pelto» can be translated as »arable land» in the strictest interpretation or »field» in a general interpretation; the two terms are interchangeable for the purpose of this paper.

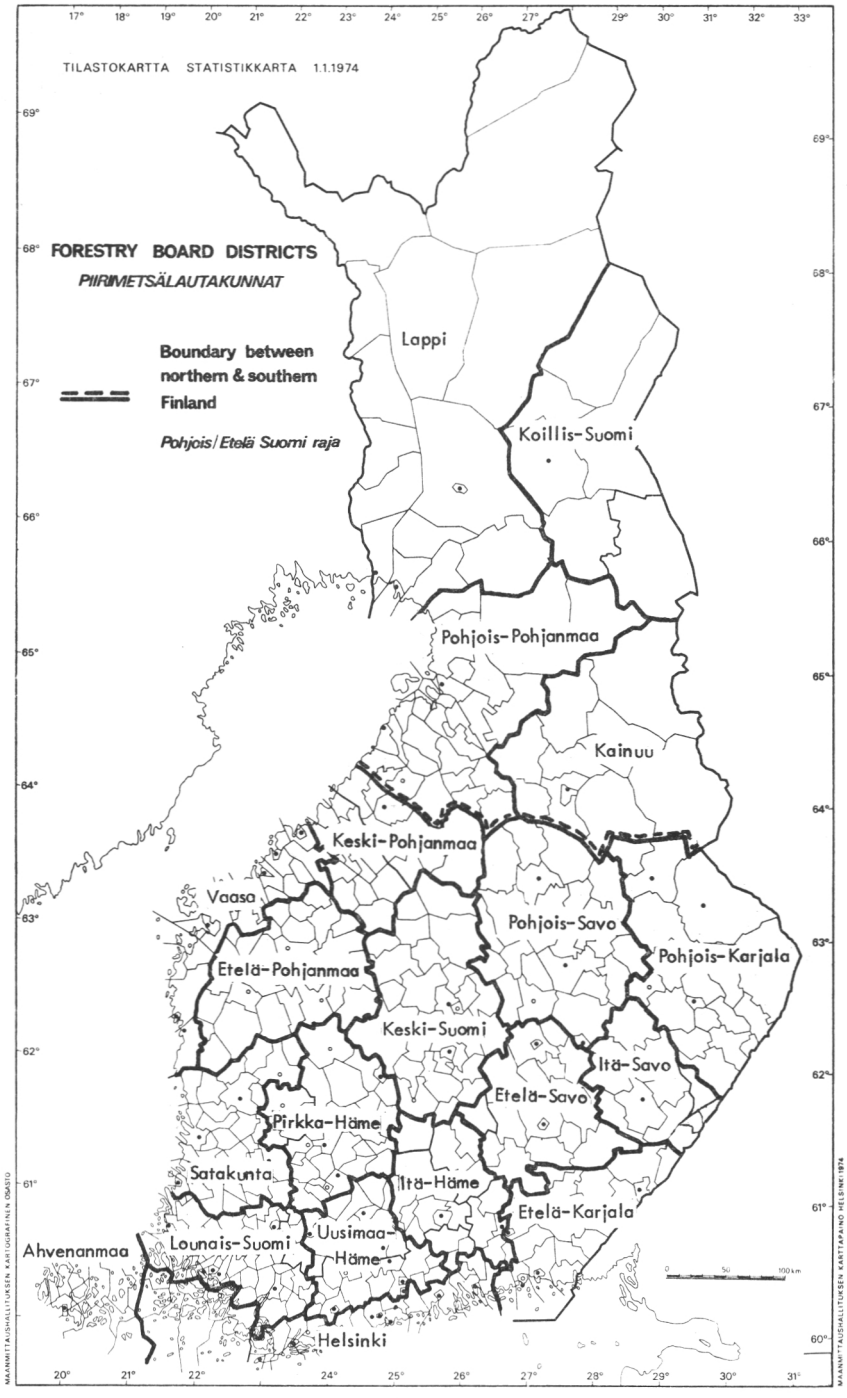


Figure 1.1 Location of forestry board districts
Kuva 1.1 Piirimetsälautakunnat

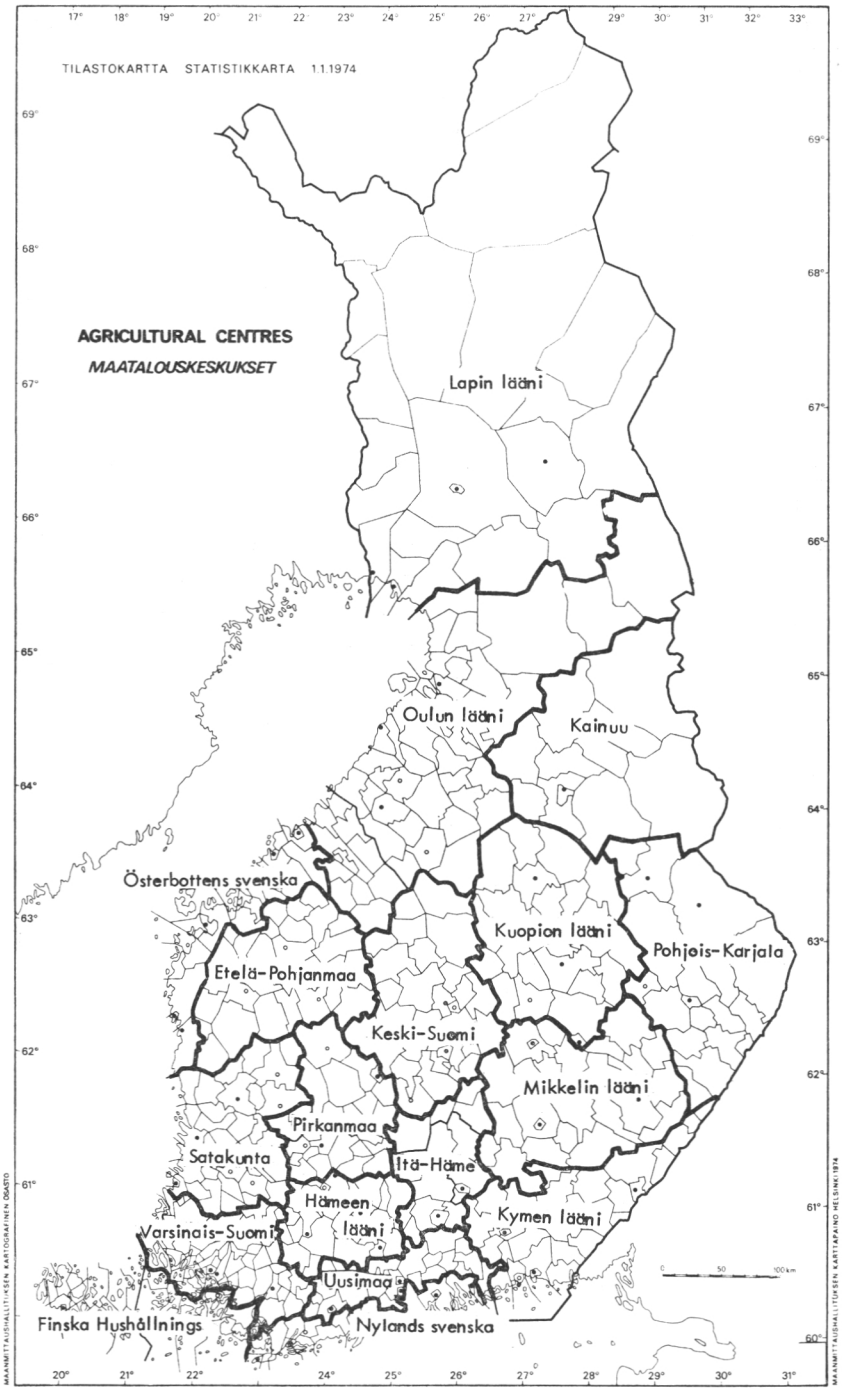


Figure 1.2 Location of agricultural centres
Kuva 1.2 Maatalouskeskukset

All data on the Field Reservation Programme, Section 2.3., were provided by the Board of Agriculture. The main problem here, as with all the agricultural data, was that the data on afforestation were arranged by agricultural districts were as all other forestry data used in this study were arranged by forestry board districts. The task of regrouping the field reservation afforestation data into forestry board districts would have been time consuming and figure 3.5. is therefore by agricultural districts. The writer wonders how long it will be before all official statistics in Finland are published by one definitive regional classification so as to bring about optimum comparability.

1.2.2. Forestry data

Data on afforestation were provided by the Mathematical Department of the Finnish Forest Research Institute, but as afforestation has only recently entered official policies, data collection is only of recent origin and are only available for afforestation of arable land [1] from 1969, and afforestation in general from 1970. Data concerning the Forest Improvement Ast were provided by the Central Forestry Board Tapio.

Data concerning the afforestation of fields through the Field Reservation Act were provided by the Board of Agriculture.

Data on the species content of afforestation activity came from the Central Board of Forestry Tapio.

Agricultural and forestry administrative divisions are similar, but not indentical, and are presented in figures 1.1. and 1.2. Statistical maps and diagrams contained in this paper will not necessarily recapitulate on these administrative divisions' names or their locations, and the reader is encouraged to refer to these two index figures.

[1] Figures for the afforestation of land other than arable, e.g. meadow land and pasture, are not given separately.

2. RECENT AGRICULTURAL CHANGES

2.1 Changes in farm-size structure and farmed area 1959—1969

Figure 2.1. reveals the continuation of a recognized and understood pattern in Finnish agricultural development. Throughout the early 1960s the expansion of agricultural activity was still being actively encouraged, especially in northern Finland, partly in consequence of post-war resettlement activities. The 1958 Land Use Act has continued to provide grants for land purchases, including purchases from State forests, for clearing fields, pasture and land improvement, construction works, and so on. Table 2.1. shows the distribution of the grants given under the 1958 Act between 1960 and 1972. It can be seen that certain activities, notably clearance activities, have decreased through the 1960s, whilst payments for land improvement and the purchase of land have increased. This reflects the most recent trends in Finnish agricultural policy which has been working towards rationalization, and a reduction of the production of certain commodities such as milk and grains.

Table 2.1. Loans granted under the Land Use Act

Taulukko 2.1. Maankäyttölain puitteissa myönnetyt lainat

	1960	1965	1967	1968	1969	1970	1971	1972
Total ('000 Fmk.) — *Yhteensä (1 000:sia mk)*	77 650	93 000	52 000	68 550	72 451	75 256	97 063	113 716
Percentage distribution — *Prosentuaalinen jakautuma*	25.4	30.7	37.3	36.4	38.2	37.3	41.3	39.6
Purchase of land — *Lisämaan ostamiseen*	14.9	19.2	23.7	20.3	20.8	21.2	17.5	16.2
Prevention of farm partition by legacies — *Sisarosuuksien maksamiseen*	51.8	42.0	31.5	36.6	35.5	35.5	33.8	34.7
Building construction — *Rakennuksiin*	2.3	1.3	0.8	0.5	0.2	0.0	0.0	0.0
Clearing of fields — *Pellon raivauksiin*	2.4	0.9	0.8	1.8	0.5	0.3	0.3	0.2
Purchase of chattels — *Kaluston hankintoihin*	—	0.2	—	—	—	—	—	—
Pasture improvement — *Laidunten parantamiseen*	0.4	0.4	0.9	1.1	0.7	1.2	3.1	4.3
Land improvement — *Maaparannustoimintaan*	2.8	5.0	4.7	3.1	3.9	3.7	3.4	4.4
Electrification — *Sähköistämiseen*								
Water supply — *Veden saantiin*	—	—	—	—	—	0.5	0.4	0.4
Road construction — *Teiden rakennukseen*	—	0.3	0.3	0.2	0.2	0.3	0.2	0.2

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

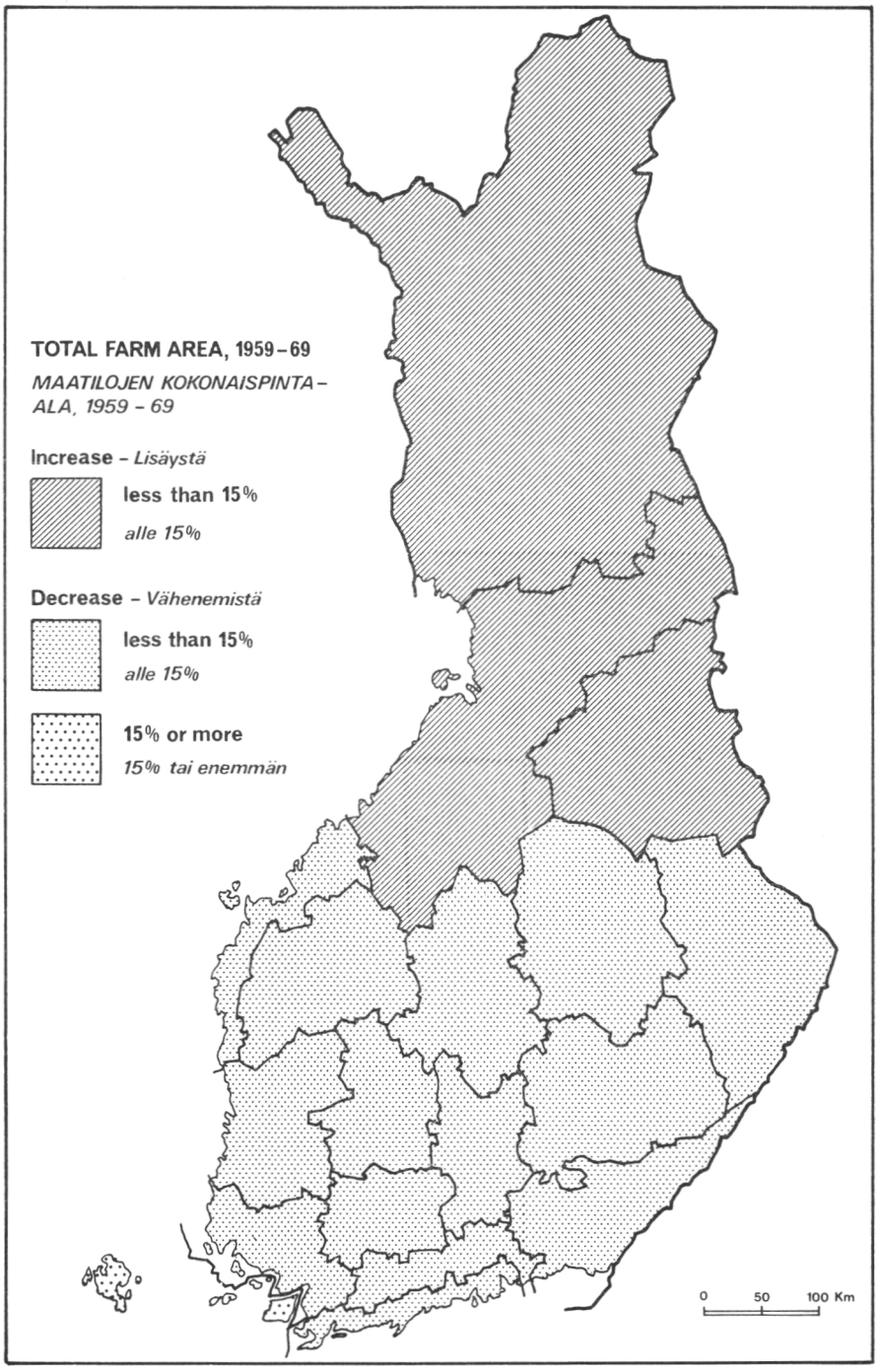


Figure 2.1 Percentage change in the total area of farms 1959—69, by agricultural centres
Kuva 2.1 Maatilojen kokonaispinta-alan prosentuaalinen muutos maatalouskeskuksittain 1959—69

The rationalization process in Finnish agriculture has led to a 10.3 % decrease in the number of agricultural holdings, and an improvement in the farm-size structure. Figure 2.2. shows how this change in size structure has been distributed, with a decrease in the very small holdings and an increase in the medium-sized holdings. The decrease in the number of small holdings is particularly marked in northern Finland. By 1969 68 % of farms in southern Finland owned less than 9.9 ha of arable land, compared with a figure of 75 % in 1959. In northern Finland the figures for the same size-class were 78 % in 1969 compared with 83 % in 1959. The decrease in the number of farms with less than 10 ha of arable land is, perhaps, one of the most significant developments in Finnish agriculture during the 1960s.

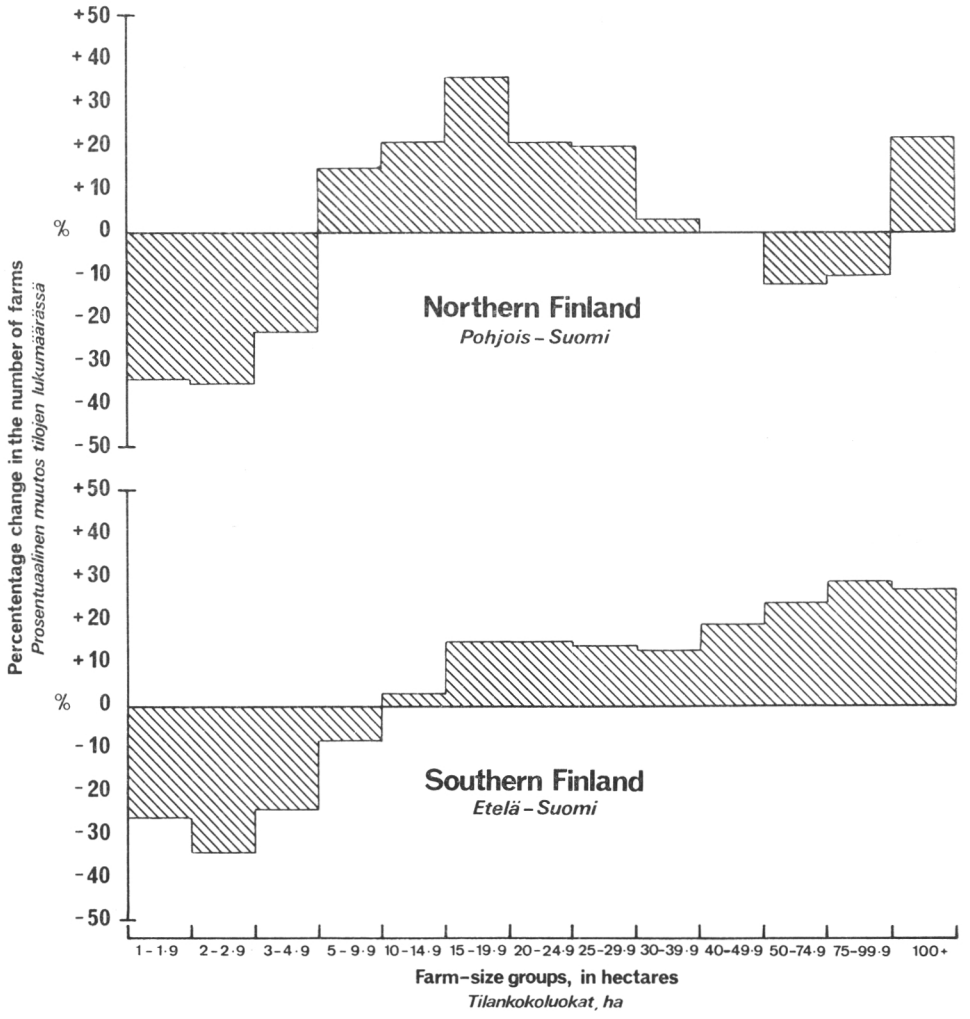


Figure 2.2 Change in the farm-size structure 1959—69
Kuvat 2.2 Maatilojen kokorakenteen muutokset 1959—69

The process of rural change in Finland compares fairly closely with events in Sweden, although in the case of the latter the process began much earlier. The first legislative measures to rationalize and intensify agriculture were introduced in 1947. Since then the Swedish government has continuously encouraged the abandonment of agricultural holdings to facilitate rationalization as well as the afforestation of fields. The Swedish goal is to achieve 80 % self-sufficiency in food production whilst maintaining farm incomes at an industrial parity. In consequence of these measures, the number of farms in Sweden has fallen from 232 900 in 1961 to 162 200 in 1969, a reduction of 30.4 %. In Finland, during a slightly longer period — 1959 to 1969 — the number of farms fell from 331 300 to 297 300, or by only 10.3 %, see table 2.2. Since 1969, the decrease in the number of farms has continued in both countries, 3.5 % per annum in Sweden and 2.3 % per annum in Finland. Because of rationalization the area of arable land in Sweden has not fallen so markedly, being only 8 % from 1961 to 1969. In Finland, between 1959 and 1969, the arable land actually increased by 1.4 %, but this was the result of a 12.4 % increase in northern Finland consequent upon land settlement activities and the enlargement of »cold farms», see figure 2.3.

Table 2.2. Change in the number of farms, 1959—1969, by agricultural centres
Taulukko 2.2. Muutos tilojen lukumäärässä, 1959—1969, maatalouskeskuksittain

Agricultural Centre *Maatalouskeskus*	Number of farms > 1 ha arable *Tilojen lukumäärä > 1 ha peltoa*			Arable area *Peltopinta-ala* 1959—69
	1959	1969	Percentage change *Prosentuaalinen muutos*	Percentage change *Prosentuaalinen muutos*
Uusimaa	12 040	10 662	—11.5	0.0
Nylands svenska	7 603	6 265	—17.7	— 4.1
Varsinais-Suomi	22 699	19 942	—12.2	— 0.1
Finska hushållningssällskapet	4 347	3 631	—16.5	— 3.6
Satakunta	27 450	24 665	—10.2	— 0.5
Pirkanmaa	13 840	12 387	—10.5	— 1.8
Hämeen lääni	15 149	13 283	—12.3	+ 0.3
Itä-Häme	9 379	8 222	—12.3	— 1.9
Kymen lääni	19 683	17 561	—10.8	— 0.5
Mikkelin lääni	19 868	17 991	— 9.5	— 1.2
Kuopion lääni	25 576	22 968	—10.2	+ 4.6
Pohjois-Karjala	22 400	20 224	— 9.7	+ 6.8
Keski-Suomi	18 622	16 882	— 9.3	+ 2.4
Etelä-Pohjanmaa	33 216	30 036	— 9.6	+ 0.3
Österbottens svenska	15 536	13 130	—15.5	— 3.8
Oulun lääni	37 010	33 429	— 9.7	+ 4.4
Kainuu	10 719	10 058	— 6.2	+17.6
Lapin lääni	16 126	15 921	— 1.3	+15.7
Whole Country — *Koko maa*	331 263	297 257	—10.3	+ 1.4

Source: SVT III: 54 and SVT III: 67. — *Lähde: SVT III: 54 ja SVT III: 67.*

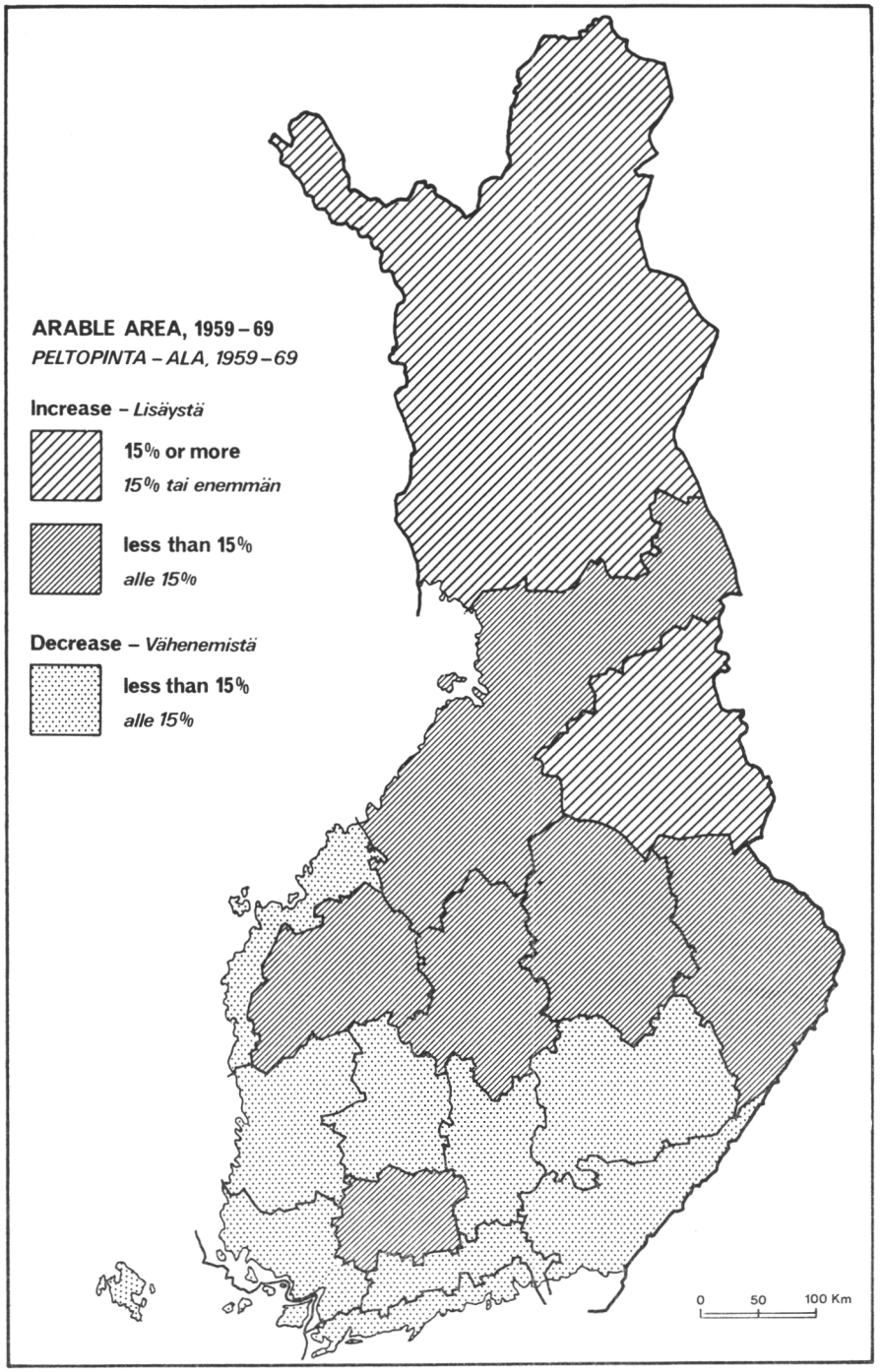


Figure 2.3 Percentage change in arable area 1959—69, by agricultural centres
Kuva 2.3 Peltopinta-alan prosentuaalinen muutos maatalouskeskuksittain 1959—69

One consequence of rationalization is increased efficiency and increased output per hectare. This has to be taken into consideration when future reductions in arable area are planned. This was noted by the Finnish Economic Planning Centre (»Growth . . .» 1973, page 83), and by Enequist (1968) who, discussing Swedish rationalization, states:

> »There are, however, agricultural experts who are of the opinion that the decrease in the total harvests will never drop to the 80 % limit since each field will now considerably increase its yield».

Further changes in the size and number of Finnish farms are therefore necessary, and plans have been made to this effect.[1] The number of farms with one or more hectares of arable land will be reduced from 297 300 in 1969 to about 120 000 in 1985, whilst the average size of farm-holdings will be increased from 9.9 ha of arable land (1969) to 15 ha of arable land (1985). It is also proposed that the median age of farmers will be reduced from 51.9 years (1969) to around 48 years (1985). All this having been achieved, the structure of Finnish agriculture will be markedly improved.

2.2 Abandonment of agricultural holdings

2.2.1. Previous studies

Despite post-war clearance activities, the 1950s and 1960s have been characterized by a degree of agricultural abandonment. The phenomenon has not been studied in detail, and much still needs to be learned about the social and economic factors which lead to abandonment. No systematic records have been kept on abandoned farms by regional agricultural centres or by local agricultural societies. The Board of Agriculture has statistics for 1955, 1959 and 1969 and has produced the only one detailed report [2] on the problem of abandonment.

The Board of Agriculture defines abandoned farms [3] as agricultural holdings the fields of which are no longer cultivated and the *dwellings of which are no longer permanently occupied.* If the owner uses the dwelling of an abandoned farm for holidays, etc. for more than two weeks in a year then the farm is not considered abandoned for statistical purposes. Farms holding less than 2 hectares of field are excluded from the definition.

The writer considers this to be an inappropriate definition from the point of view of land-use studies as most emphasis is placed on the farm dwelling. This makes the precise identification and registering of abandoned agricultural land almost impossible. It is probable that much abandoned

[1] »Growth prospects for the Finnish economy up to 1980», Helsinki 1972.
Öller, L.-E. 1973. (preliminary draft).
Honkanen, S., et al. 1973.

[2] Maatilahallitus 1960: »Selvitys autiotilatilanteesta 15. 6. 1959». Mimeo.

[3] Maatilahallitus: Maatalouden peruslaskenta 1969. Lomake N:o 2.

farm land remains so simply because the farm buildings are occasionally used for recreational purposes. It is to be hoped that the planned Farm Act will revise the working definition of abandoned farms so as to place more emphasis on *land* in order to ensure the collection of a meaningful set of statistics for both land-use planning and for studying land-use policies.

For the purpose of this study a more meaningful definition would be the following: abandoned farms are farms with a minimum of 2 hectares of fields on which all agricultural production has ceased irrespective of whether the farm buildings are occupied for parts of the year or not. Farms which have sold or let their fields are excluded from the definition, as are those farms which have entered their fields into field reservation contracts.

As the Board of Agriculture is the source of the data used in this section of this paper, and as these data cannot be converted to fit the writer's definition, the Board's definition has to be accepted.

2.2.2. General synopsis

The distribution of abandoned farms in 1955, 1959, 1965 and 1969 according to Board of Agriculture reports [1] are shown in table 2.3. The

Table 2.3. Distribution of abandoned farms holding 2 hectares of fields or more in 1955, 1959, 1965 and 1969, by agricultural centres

Taulukko 2.3. Peltopinta-alaltaan 2 ha ja sitä suurempien autiotilojen jakauma v. 1955, 1959, 1965 ja 1969 maatalouskeskuksittain

Agricultural Centre *Maatalouskeskus*	Total number of abandoned farms *Autiotiloja yhteensä*			
	1955	1959	1965	1969
Uusimaa	46	19	43	8
Nylands svenska	2	5	6	17
Varsinais-Suomi	70	94	31	29
Finska hushållningssällskapet	90	98	28	8
Satakunta	95	129	79	44
Pirkanmaa	60	63	55	28
Hämeen lääni	29	45	32	12
Itä-Häme	73	91	75	46
Kymen lääni	50	90	33	37
Mikkelin lääni	106	154	158	152
Kuopion lääni	101	164	170	147
Pohjois-Karjala	119	179	164	196
Keski-Suomi	111	107	132	116
Etelä-Pohjanmaa	180	188	140	52
Österbottens svenska	111	117	83	21
Oulun lääni	420	432	338	425
Kainuu	114	120	196	177
Lapin lääni	128	122	260	255
Whole country — *Koko maa*	1 955	2 217	2 023	1 770

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

[1] Maatilahallitus 1960. Selvitys autiotilatilanteesta 15. 6. 1959.
» 1966. Yksityismaakomitean osamietintö II. Komiteanmietintö 166: B 98.
» 1969. Agricultural Census returns.

figures are drawn from various sources but the method of collecting the data is the same in each case and according to the same definition, see above. The figures are therefore comparable.

Table 2.3. shows that the late 1950s and early 1960s was the peak period in the post-war era for agricultural abandonment, although the area of abandoned agricultural land was the same in 1969 as it was in 1959, see table 2.4.

Table 2.4. Mean size of abandoned farms and their main land-use categories, 1955, 1959 and 1969

Taulukko 2.4. Autiotilojen keskimääräinen koko ja maankäyttöluokkajakauma 1955, 1959 ja 1968

	1955		1959		1969	
	Total *Yhteensä*	Mean *Keskim.*	Total *Yhteensä*	Mean *Keskim.*	Total *Yhteensä*	Mean *Keskim.*
Number of farms — *Tilojen lukumäärä, kpl*	1 955		2 217		1 770	
Forest area, in hectares — *Metsäpinta-ala, ha*	43 695	22.4	78 336	35.3	70 573	39.9
Arable area, in hectares — *Peltopinta-ala, ha*	6 675	3.4	12 111	5.5	8 270	4.7
Other land, in hectares — *Muu maa, ha*	13 154	6.7	22 610	10.2	34 347	19.4
Total area, in hectares — *Kokonaispinta-ala, ha*	63 524	32.5	113 057	51.0	113 190	64.0

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

For the study of land-use policies, and for land-use planning perhaps as important as the number and area of abandoned farms is the duration of abandonment. This provides some indication as to how many of these farms are sold, or re-allocated in other ways, and how many remain as neglected or waste land. According to the Board of Agriculture [1] of the 2 217 farms in a state of abandonment in 1959, nearly 18 % had been abandoned before 1950, and 54 % before 1955. This indicates a slow turn-over of abandoned farms and thus a weak trend in consolidation and rationalization activities.

The mean size of abandoned farms doubled during the period 1955 to 1969, see table 2.4. Similarly, the mean-size of the main land-use categories on these farms has increased, although the increase in the mean arable area on abandoned farms has increased only 38 %. The mean area of forest on abandoned farms has increased 78 % during the same period.

The geographical distribution of abandoned farmland in 1969 is shown in figure 2.4. The figure shows the area of abandoned farms in relation to the total agricultural area in 1969. The distribution has a strong south-west

[1] Maatilahallitus 1960 (op. cit.), liite N:o 7.

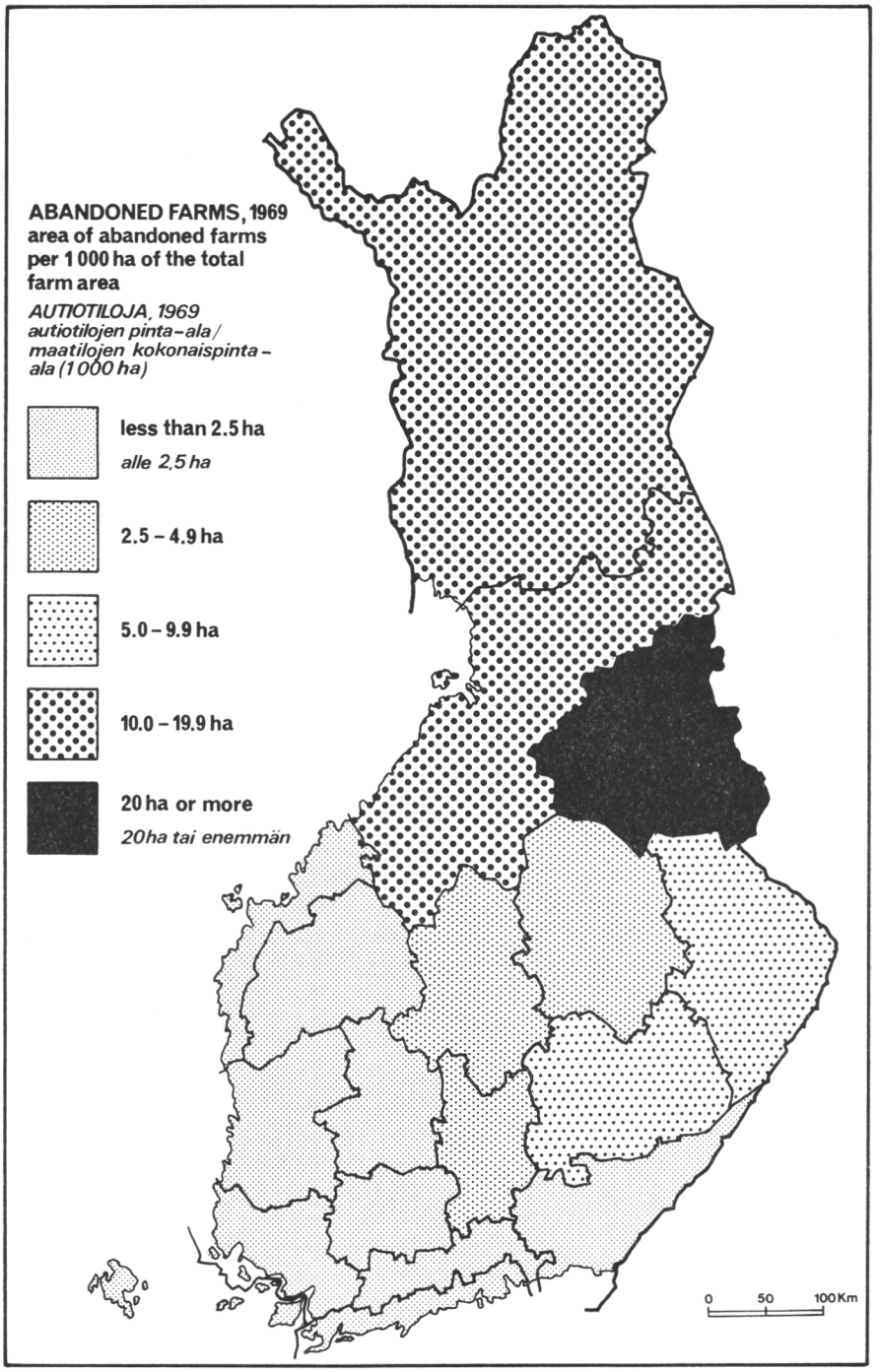


Figure 2.4 The distribution of abandoned farms in 1969, by agricultural centres
Kuva 2.4 Autiotilojen jakautuminen maatalouskeskuksittain v. 1969

to north-east trend, with Varsinais-Suomi, Nyland, Etelä-Pohjanmaa and Hämeen lääni agricultural districts having less than 1 hectare of abandoned agricultural land per thousand hectares of farmland, whilst in the north-east, Kainuu and Lappi agricultural districts had 21 hectares and 17.5 hectares abandoned farmland per thousand hectares of agricultural land respectively. This distribution is very similar to that of the number of abandoned holdings in 1969 (see table 2.3.) as can be expected. The correlation between the two distributions is 0.97.

The change in the regional distribution of abandoned farms with time, and the proportional change in land-use categories there-on, is shown on table 2.5. The eastward and northward movement of abandonment activity since 1955 can be clearly seen. In 1955, 44 % of all abandoned farms were situated in western Finland,[1] but by 1969 this proportion had fallen to 21.5 %. In eastern Finland during the same period the share of abandoned farms rose from 19 % to 30 %, and in northern Finland the regional proportion rose from 36 % to 48 %.

This trend in the number of abandoned farms is reflected in the figures and proportions for land-use categories and the total area of abandoned farms.

2.2.3. Reasons for abandonment

The reasons for abandonment are many and varied, and certainly have complex inter-relationships. Neither the reasons nor their relationships have been fully examined. The Board of Agriculture's study on abandoned farms (see section 2.2.1.) does not present a wholely satisfactory account in this respect. Their results are often subjective in nature, for example: the principle reasons for abandonment are given in three versions, based on the farmers' own replies, the interviewers' interpretation of the farmers' replies, and the views of the administrators of the survey. The results in each case were often widely different.[2] Of considerable significance, however, is the fact that 50 % of owners replied that they did not know the reason they had abandoned agriculture. This indicates either a lack of co-operation on the part of the farmer, or perhaps a lethargy brought about by lack of faith in the future, as noted by Jaatinen and Nygård (1970) in may farmers who had entered their land into field reservation contracts.

A change of occupation, and age and illness were the most clearly defined reasons for abandonment. The former reasons is not wholely satisfactory in isolation, however, as it needs further analysis to determine why the

[1] See footnote to table 2.5. for definition of regions.
[2] Maatilahallitus 1960: (op. cit) page 9.

Table 2.5. Regional distribution of abandoned farms and their land-use categories, in 1955, 1959 and 1969

Taulukko 2.5. Autiotilojen alueellinen jakauma maankäyttöluokittain v. 1955, 1959 ja 1969

Region *Alue*	Number of farms *Tilojen lukumäärä (kpl)*	%	Arable *Pelto-pinta-ala* (ha)	%	Forest *Metsämaan pinta-ala* (ha)	%	Other land *Muu maa* (ha)	%	Total area *Kokonais-pinta-ala* (ha)	%
1955:										
Western Finland [1] — *Länsi-Suomi*	867	44.4	3 258	48.8	12 298	28.1	2 193	16.7	17 749	27.9
Eastern Finland [2] — *Itä-Suomi* ..	376	19.2	685	10.3	5 449	12.5	254	1.9	6 388	10.1
Northern Finland [3] - *Pohjois-Suomi*	712	36.4	2 732	40.9	25 948	59.4	10 707	81.4	39 387	62.0
Whole country — *Koko maa*	1 955	100.0	6 675	100.0	43 695	100.0	13 154	100.0	63 524	100.0
1959:										
Western Finland	956	43.1	5 763	47.6	24 468	31.2	6 478	28.6	36 709	32.5
Eastern Finland	587	26.5	2 587	21.4	19 777	25.3	2 160	9.6	24 524	21.7
Northern Finland	674	30.4	3 761	31.0	34 091	43.5	13 972	61.8	51 824	45.8
Whole country	2 217	100.0	12 111	100.0	78 336	100.0	22 610	100.0	113 057	100.0
1969:										
Western Finland	381	21.5	1 688	20.4	6 859	9.7	2 056	6.0	10 603	9.4
Eastern Finland	532	30.1	2 210	26.7	14 831	21.0	2 640	7.7	19 681	17.4
Northern Finland	857	48.4	4 372	52.9	48 883	69.3	29 651	86.3	82 906	73.2
Whole country	1 700	100.0	8 270	100.0	70 573	100.0	34 347	100.0	113 190	100.0

Source: Board of Agriculture — *Lähde: Maatilahallitus.*

[1] Varsinais-Suomi, Finska Hushållningssällskapet, Nyland, Uusimaa, Itä-Häme, Hämeen lääni, Satakunta, Pirkanmaa, Keski-Suomi, Etelä-Pohjanmaa and Österbotten agricultural centres. — *Varsinais-Suomen, Uudenmaan, Itä-Hämeen, Hämeen läänin, Satakunnan, Pirkanmaan, Keski-Suomen ja Etelä-Pohjanmaan Maatalouskeskukset, Nylands svenska, Finska Hushållningssällskapet ja Österbottens svenska Lantbrukscentral.*

[2] Kymen lääni, Mikkelin lääni, Pohjois-Karjala and Kuopion lääni agricultural centres. — *Kymen läänin, Mikkelin läänin, Pohjois-Karjalan ja Kuopion läänin maatalouskeskukset.*

[3] Oulun lääni, Kainuu and Lapin lääni agricultural centres. — *Oulun läänin, Kainuun ja Lapin läänin maatalouskeskukset.*

change in occupation was considered necessary. Never-the-less, the report is useful despite the fact that it is now out-of-date, as it throws some light on the problems underlying the abandonment process. Its general conclusions regarding the reasons for abandonment are summarized in table 2.6.

Table 2.6. Generalized reasons for abandoning agricultural holdings, 1955 and 1959
Taulukko 2.6. Syyt maanviljelyksestä luopumiseen; yleistetyssä muodossa v:lle 1955 ja 1959, prosentteina

Reason *Syy*	1955 %	1959 %
Economic — *Taloudellinen*	52.7	43.7
Personal — *Henkilökohtainen*	32.0	29.1
Other — *Muu*	15.3	27.2
All reasons — *Yhteensä*	100.0	100.0

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

2.3 The field reservation programme

2.3.1. Previous studies

Much has been written about the Field Reservation programme,[1] and a number of detailed studies have been made of its consequences since its

[1] Alho, P. 1969. Nykyinen maankäyttöpolitiikka ja peltojemme metsittäminen. Kaleva 29. 6. 1969.

Hintikka, N. 1971. Maataloustuotannon tasapainoittamistoimenpiteistä vuosina 1969—1971. Summary: About the balancing measures of Finnish agricultural production 1969—1971. Maataloushallinnon Aikakauskirja, 1 1971 N:o 2.

Jaatinen, S. and U. Kärkkäinen. 1970. Pellonvaraustoiminta Suomessa 1969 ja sen tulokset. Summary: The reserving of fields in Finland in 1969 and its results. A preliminary survey. Asutustoiminnan Aikakauskirja, 23, 1970 N:o 1.

Jaatinen, S. and U. Kärkkäinen. 1971. Vuoden 1969 pellonvaraustoiminta. Summary: The field reservation programme of Finland in 1969. Helsingin Yliopiston maantieteen laitoksen julkaisuja, Sarja B, 7.

Jaatinen, S. and M. Nygård. 1972. Vuosien 1970—71 pellonvaraustoiminta ja vuoden 1970 »Teurastuspalkkiolaki». Summary: The field reservation programme and »the slaughter subsidy Act» in Finland, 1970—71. Helsingin Yliopiston maantieteen laitoksen julkaisuja, Sarja B, 12.

Kangas, E. 1972. Pellonvaraustoiminnasta. Maataloushallinnon Aikakauskirja, 2 1972 N:o 1.

Kähönen, U. 1969. Pellonvarausjärjestelmä ja siitä saadut kokemukset. Summary: The system of reserving fields in Finland. Asutustoiminnan Aikakauskirja, 22, 1969 N:o 3.

Mannola, E. 1969. Pellonvarausjärjestelmä. Summary: The general agricultural policy and the system of compensating for the reserve of fields. Asutustoiminnan Aikakauskirja, 22, 1969 N:o 1—2.

Numminen, J. 1970. Pellonvaraussopimusten alaisten peltojen metsitys. Silva Fennica 4.4.

Saarinen, O. 1969. Pellonvarausjärjestelmän tehostamista tarkoittavista lainmuutoksista. Asutustoiminnan Aikakauskirja, 22, 1969 N:o 4.

introduction in 1969 (Law 216/1969). In particular, Jaatinen and Kärkkäinen (1970 & 1971) and Jaatinen and Nygård (1972) deal extensively with the agricultural adjustment brought about by the Act and its subsequent ammendments. Jaatinen and Nygård (op. cit) also examine the reasons why farmers entered fields into reservation contracts. These reasons were found to be (i) on the personal level — primarily old age, illness or disability, but also distance from work; (ii) on the aggregate level — social factors became important, notably general trading conditions and the changing structure of society, the diffusion of innovations (in relation to the field reservation programme), the amount of the field reservation subsidy, the agricultural tax reform (which increased the tax burden of small farms), migration and emigration caused by economic factors in-society, the decrease in farmers' supplementary earnings caused by the mechanization of forest work, and the perception of a negative attitude to agriculture in mass media and a growing pessimism in farmers.

2.3.2. Field reservation activity 1969—1973

Tables 2.7. and 2.8. summarize the developments in field reservation activity during the period 1969 to 1973, whilst section 3.2.2. examines the affect of the field reservation programme on afforestation activity. Table 2.7. shows that throughout Finland reservation activity has declined since its introduction in 1969 both in terms of the number of contracts made, and the field area involved. The decline in reservation activity is not evenly distributed, however, as in eastern Finland 17 % of all contracts made during the period 1969—1973 were made in 1973 compared with 13.5 % in western Finland and 11.4 % in northern Finland. The 1973 figure for the whole country being 13.5 %. A similar pattern applies to the area of reserved fields. There was also a slight increase in reservation activity throughout the whole country during 1973. Table 2.8. further emphasises the significance of reservation activity in eastern Finland showing a relative increase in the contracts made yearly compared with relative declines in western and northern Finland.

Between 1969 and 1973 some 35 237 contracts were made. The area of reserved fields was 229 058 hectares. This represents about 11 % of the arable area recorded in Finland in 1969.[1]

The Field Reservation Act is soon due to expire,[2] and this is generally considered a good thing, as not only has the field reservation programme caused instability in certain areas of agricultural production, in meat and

[1] S.V.T. III: 67.
[2] No new contracts will be made after May 1975.

Table 2.7. Chronological variations in field reservation activity, by regions
Taulukko 2.7. Ajassa tapahtunutta vaihtelua pellonvaraustoiminnassa, alueittain

Year *Vuosi*	Western Finland [1] *Länsi-Suomi* [1]				Eastern Finland *Itä-Suomi*			
	Contracts *Sopimuksia*		Area of reserved fields *Sopimusten alainen pelto-pinta-ala*		Contracts *Sopimuksia*		Area of reserved fields *Sopimusten alainen pelto-pinta-ala*	
	Number *Lukumäärä*	%	hectares *ha*	%	Number *Lukumäärä*	%	hectares *ha*	%
1969	5 996	40.9	36 955	40.4	2 989	29.5	18 042	28.9
1970	3 324	22.7	19 643	21.5	2 034	20.0	12 989	20.8
1971	1 871	12.8	12 681	13.9	1 709	16.9	10 678	17.1
1972	1 626	11.1	10 571	11.6	1 664	16.4	10 266	16.4
1973	1 838	12.5	11 481	12.6	1 744	17.2	10 528	16.8
Total — *Yhteensä*	14 655	100.0	91 331	100.0	10 140	100.0	62 503	100.0

	Northern Finland *Pohjois-Suomi*				Whole country *Koko maa*			
1969	4 509	43.2	30 656	40.7	13 494	38.3	85 653	37.4
1970	2 328	22.3	17 271	23.0	7 686	21.8	49 903	21.8
1971	1 282	12.3	9 772	13.0	4 862	13.8	33 131	14.5
1972	1 133	10.8	8 514	11.3	4 423	12.6	29 351	12.8
1973	1 190	11.4	9 011	12.0	4 772	13.5	31 020	13.5
Total — *Yhteensä*	10 442	100.0	75 224	100.0	35 237	100.0	229 058	100.0

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

milk products for example, but its general affect on agricultural production can be regarded as transient, and has contributed little towards achieving the long-term agricultural goals outlined in »Growth . . .». At the same time, the programme has created frustations and a loss of confidence in the farming community. However, it has been important in bringing about field afforestation in conjunction with an ammendment to the Forest Improvement Act (425/1969). This is discussed further in sections 3.1., 3.2.2. and 3.2.3.

Steps are now being taken restore confidence in agriculture. The proposed Farm Act, together with the 1974 Farm closure Pension Act (Law 16/1974) — both discussed further in section 3.2.1. — could well be used to introduce positive measures to encourage a return of confidence. Farm consolidation and rationalization are still necessary, but this must be achieved through positive policies.

[1] See footnote to table 2.5. for definition of regions. — *Alueet: ks. taulukon 2.5. alahuomautukset.*

Table 2.8. Regional distribution of Field Reservation Contracts, 1969—1973
Taulukko 2.8. Pellonvaraustoiminnan alueellinen jakauma, 1969—1973

Field reservation contracts *Pellonvaraussopimukset*	Western Finland [1] *Länsi-Suomi* [1]	Eastern Finland *Itä-Suomi*	Northern Finland *Pohjois-Suomi*	Whole country *Koko maa*
1969:				
Number of contracts — *Sopimuksen lukumäärä*	5 996	2 989	4 509	13 494
%	44.4	22.2	33.4	100.0
Area of reserved fields (ha) — *Sopimusten alainen peltopinta-ala (ha)*	36 955	18 042	30 656	85 653
%	43.1	21.2	35.7	100.0
1970:				
Number of contracts	3 324	2 034	2 328	7 686
%	43.2	26.4	30.2	100.0
Area of reserved fields (ha)	19 643	12 989	17 271	49 903
%	39.4	26.0	34.6	100.0
1971:				
Number of contracts	1 871	1 709	1 282	4 862
%	38.5	35.1	26.4	100.0
Area of reserved fields (ha)	12 681	10 678	9 772	33 131
%	38.3	32.2	29.5	100.0
1972:				
Number of contracts	1 626	1 664	1 133	4 423
%	36.8	37.6	25.6	100.0
Area of reserved fields (ha)	10 571	10 266	8 514	29 351
%	36.0	35.0	29.0	100.0
1973:				
Number of contracts	1 838	1 744	1 190	4 772
%	38.5	36.6	24.9	100.0
Area of reserved fields (ha)	11 481	10 528	9 011	31 020
%	37.0	33.9	29.1	100.0
1969—1973:				
Number of contracts	14 655	10 140	10 442	35 237
%	41.6	28.8	29.6	100.0
Area of reserved fields (ha)	91 331	62 503	75 224	229 058
%	39.9	27.3	32.8	100.0

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

[1] See footnote to table 2.5. for definition of regions. — *Alueet: ks. taulukon 2.5. alahuomautukset.*

3. AFFORESTATION OF FIELDS

3.1 Developments in forestry and agricultural land-use policies and legislation affecting field afforestation

3.1.1. Land-use policies and legislation affecting the afforestation of fields

Afforestation of fields has long been a part of forestry and agricultural practice in Finland — Cajander (1933) lists a large number of afforestation projects on arable land and meadows in connexion with the development of spruce stands in southern Finland. It is only recently that the specific use of agricultural land for afforestation has entered into forestry and land-use policy. For example, Ervasti, et. al. (1965) »The development of Finland's forests in 1964—2000», Silvia Fennica 117/2 (page 30) refer to the afforestation of arable land only in passing and no account is taken of afforestation in the development of the growing stock during the period 1962—2010, whereas by 1970, Ervasti, et al. »Forestry and forest industry production alternatives in Finland, 1970—2015» Folia Forestalia 88/1970 (page 12), include afforestation of agricultural land as a separate and definite factor in the development of increment and allowable cut from 1969, with benefits being obtained from the mid-1980s onwards.

In 1969, the Field Reservation Act (Law 216/1969) was introduced to reduce certain areas of agricultural over-production. Its aim was to subsidice suspension of cultivation whilst no allowing the fields to suffer from neglect. The Act was ammended later (Law 19/1970) to remove the upper size limit and to include company owned farms. The subsidy is subjected to review, and has been, since 1970, 250 Fmks per hectare for the first 14 hectares, 200 Fmks/ha. for the next 7 hectares, and 150 Fmks/ha. for all subsequent hectares. Another ammendment to the Act was the Slaughter Subsidy Act (Law 189/1970) which gave greater incentives to reduce the size of their dairy herds. This Act led to the slaughter of 45 000 head of cattle before it was repealed. The Slaughter Subsidy Act has been criticised and has led to regional imbalance in the supply of dairy products. The workings of the FRA and the Slaughter Subsidy Act are described in detail by Jaatinen and Kärkkäinen (1970 and 1971) and by Jaatinen and Nygård

(1972). The FRA also provides for the afforestation of reserved fields, the subsidy then applies for 15 years, and as well as the subsidy receives free seedlings and labour under the terms of the Forest Improwement Act. Afforestation of fields was not the central target of field reservation legislation however, it was merely a subsidiary means of reducing the arable area.

The 1969 ammendment (Law 425/1969) to paragraph 6 of the Forest Improvement Act (Law 417/1967) enables State funds to be used for the afforestation of fields or parts of fields, providing these are not in a state neglect. The ammendment also requires that the future enlargement of the farm be considered when making afforestation plans. This Act adds an incentive by providing for the replacement of those parts of seedlings stands damaged or destroyed by natural elements within six years of the final inspection of the afforested area. The Act has been extended by a further three years and will expire in June 1975.

The exclusion of neglected land from the Act is surprising, however, as it is just this land which should be brought under afforestation. As it is, neglected fields remain at the discretion of the 1958 Land-Use Act which gives the Board of Agriculture acquisition rights. Also, natural forest regeneration may take effect.

No legislation yet exists preventing forest land from being converted to other forms of land use. Grants and subsidies have always been available to the farmer to enable him to clear his forests and so extend his arable area.

The 1958 Land-Use Act (Law 353/1958) has been discussed in Section 2.1. Its aim has been to improve the economic and social structure of farms, partly by providing loans for the acquisition of land, the clearing of fields (including the removal of forests), preventing fragmentation of holdings due to inheritance laws, and other wide ranging improvement activities, see table 2.1. By 1973, over 40 % of the loans given under the terms of the Act had been for land purchases, followed closely by loans for building and for the prevention of fragmentation. Further credit was made available under the Basic Credit Act (Law 156/1965) which provided loans for basic improvements in agriculture at favourable interest rates. It must be appreciated that the small size of Finnish farms makes it particularly difficult for farmers to raise credit. However, these Acts have contributed nothing to afforestation activity as they have been designed solely for agricultural development.

The 1958 Land-Use Act did bring about the transfer of 850 000 ha. of forest land from State to private ownership between 1959 and 1969 in order to improve the structure of certain farms despite the growing trend in rural depopulation, see Holopainen (1971). The afforestation of fields was not considered at this time.

The afforestation of fields is mentioned in one of the most recent pieces of agricultural legislation, the Farm-Closure Pension Act (Law 16/1974). This legislation is aimed at agricultural rationalization by acquiring farm land for redistribution. Farmers over 55 years of age (well over 40 % of all farmers in 1974 according to Board of Agriculture estimates) are qualified to apply for the pension, which will carry them over to the age of 65 when they begin to receive the normal State pension, provided that they sell their arable land to the Board of Agriculture, or to a neighbouring farm. The farm buildings may remain the property of the retiring farmer. The Law makes vague reference to the possibility of afforesting certain fields, but does not go into details. Certainly afforestation is not related to any specific goals in either forestry or agriculture.

The Farm Legislation Committee has proposed a new Farm Act for 1975 which will recommend more far reaching measures for rationalization and land-use change than are embodied in the 1958 Land-Use Act which it will replace. Local authorities will be given land purchasing rights, whilst the Board of Agriculture will no longer be required to sell its acquired land, and will thus form a »land bank» with strong implications for future land-use planning.

3.2 Recent afforestation and afforestation of fields

3.2.1. General synopsis

It has been noted that the afforestation of fields as a direct policy measure is of recent origin. It has also been noted that the afforestation of fields is not new. However, it was not until 1969 that forestry statistics began to cover the afforestation of fields, and not until 1970 that all afforestation activities were included — prior to this, afforestation figures were included in figures for all planting and seeding.

Figure 3.1. presents the pattern of afforestation activity in forestry board districts for the period covered by the statistics. The northern and eastern districts show pronounced increases in afforestation activity including that of fields. Afforestation of fields plays a less important role in the north however; during the period 1970—72 only 12 % of all afforestation in Lappi forestry board district was of fields. In the Savo region of central eastern Finland, however, the highest rates of afforestation of fields can be found. During the period 1970—72, afforestation of fields accounted for 78 % of all afforestation in Pohjois-Savo forestry board district, 77 % in Etelä-Savo Forestry Board district, and 62 % in Itä-Savo forestry board district. The proportion of afforestation of fields in Itä-Häme forestry board district was also high, being 74 %. The minor role

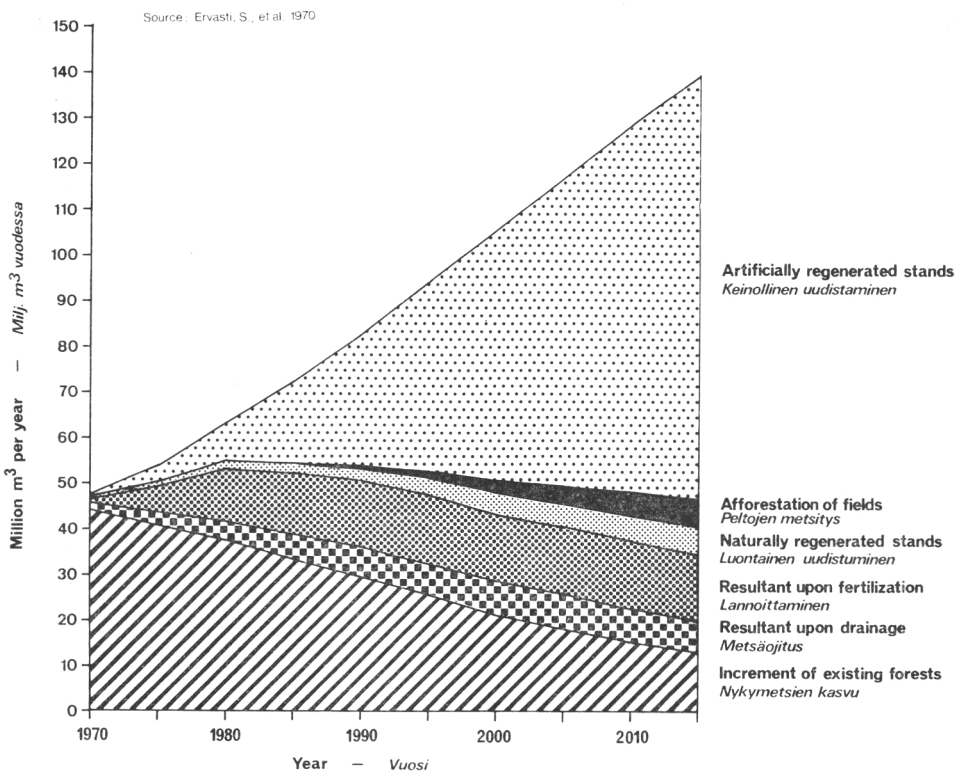


Figure 3.2 The role of field afforestation in the development of total increment — maximum programme. (After Ervasti, et al. 1970)

Kuva 3.2 Peltojenmetsitystoiminnan merkitys maksimiohjelman mukaisen vuotuisen kasvun kehityksessä (Lähde: Ervasti, et al. 1970)

played by field afforestation in the north in understandable as forest increment is low and farmers may be disinclined to afforest fields in view of the long wait before benefits can be enjoyed. A further reason may well be that farmers are reluctant to afforest fields that all too frequently have been cleared from wasteland and forest by the hard manual labour of the past one or two generations. In perspective, however, afforestation is but a small part of all silvicultural activity. According to Ervasti, et al. (1970) the afforestation of fields will have contributed only 4 % to the total increment by 2 015 even if the so called »Maximum programme» is followed, figure 3.2.

Figure 3.3. shows the regional variations in the afforestation of arable land and other land by owner groups. The regional division is based on that of Huttunen (1974) and is one which divides the country into fairly homogenous forestry regions. With the exceptions of region VII which

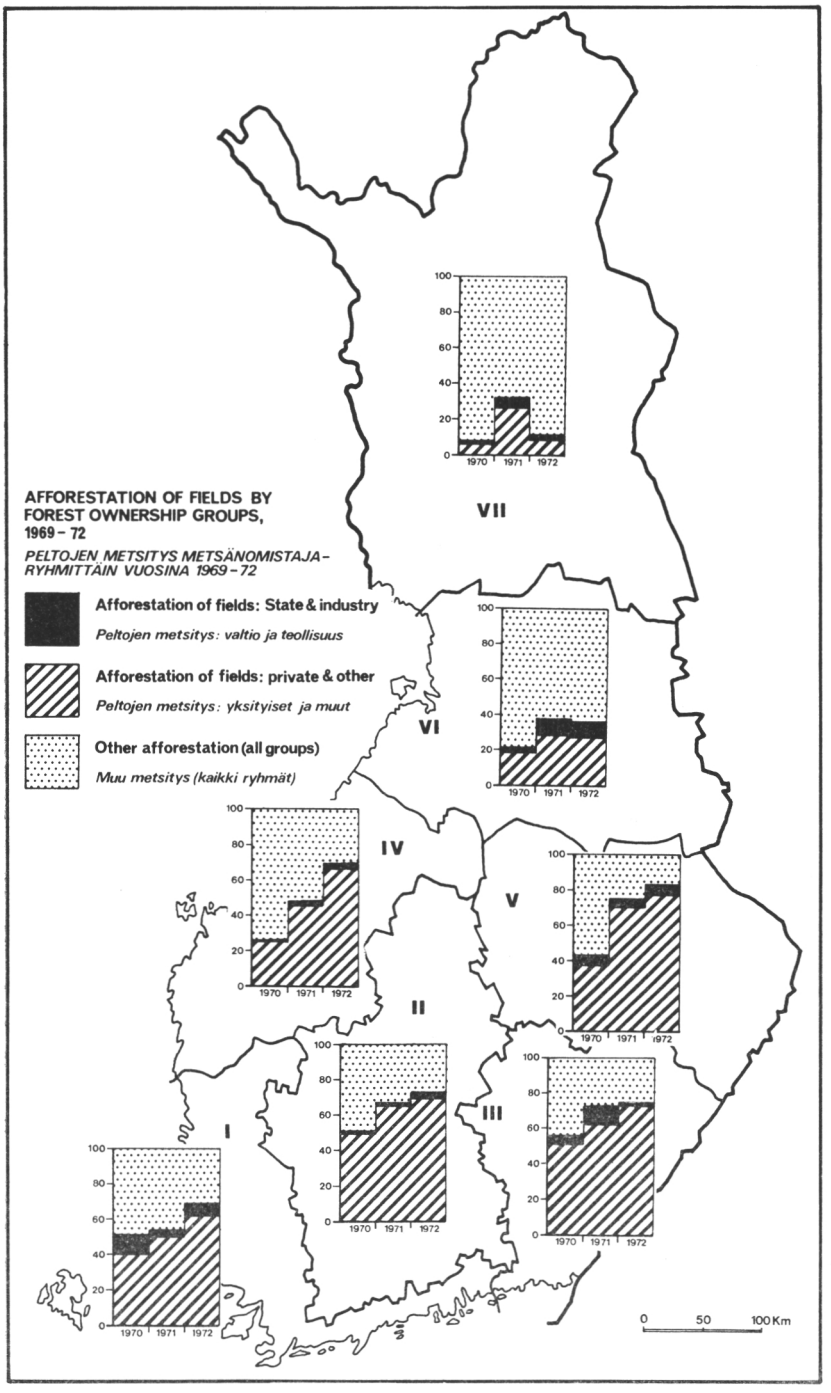


Figure 3.3 Afforestation of fields by ownership groups in relation to total afforestation activity, in percents, 1970—72, by forestry board districts

Kuva 3.3 Peltojenmetsityksen prosentuaalinen osuus kokonaismetsitystoiminnasta omistajaryhmittäin ja piirimetsälautakunnittain 1970—72

exhibits an erratic behaviour for the short duration of the statistics, and region VI which shows stability after an initial increase, all other regions show large increases in the afforestation of fields, with the largest increases being in regions IV and V. Most of the afforestation activity is in the private sector, but this is to be expected due to the landownership structure in Finand.[1]

The species structure of afforestation of fields is shown in figure 3.4. The data for this figure being those used for figures 3.1. and 3.3. The most interesting aspect of figure 3.4. is the marked increase in birch plantings. This has been at the expense of spruce, particularly in central, eastern and southern districts, with Itä-Häme, Pohjois-Savo, Pohjois-Karjala and Etelä-Karjala forestry board districts worth special mention. Further, in Keski-Pohjanmaa forestry board district the development of birch plantings has been such that the planting of spruce has decline from 42 % of all plantings in 1969 to 2 % in 1972, whilst birch has risen from insignificance in 1969 to 42 % in 1972. The increase in birch plantings in the forestry board districts of Vaasa, Satakunta, Helsinki and Pirkka-Häme has largely been at the expense of pine. Pine plantings have otherwise remained fairly constant, with large increases confined to Lappi and Koillis-Suomi forestry board districts.

Birch has been heavily depleted during the 20th Century and has been generally considered a waste wood because of its poor quality. It has been primarily used for fuel. Recent developments in the wood-working industry have led to an increased demand for birch veneer as well as for birch pulpwood, and the increasing shortage of this timber is reflected in its value, and therefore in increased incentives for planting. The improvement in the position of birch can be seen from table 3.1. The stumpage prices of birch fuelwood and pulpwood increased 9-fold between felling years 1959/60 and 1971/72, and 3-fold between 1968/69 and 1971/72 alone. The stumpage price for birch veneer logs increased 3-fold between 1959/60 and 1971/72, and 2-fold between 1968/69 and 1971/72. By comparison, the stumpage price for spruce pulpwood increased only 2-fold between 1959/60 and 1971/72, and by only 50 % during the period 1968/69—1971/72.

The aesthetic value of birch is also being appreciated by landscape architects and planners. The destruction of birch stands in the past and their replacement by uniform stands of conifers has brought criticism. Many communes now require new stands of conifers, as well as new roads and buildings, to be screened by stands of birch. The increase in birch plantings is therefore based to some extent on environmental grounds.

[1] See Kuusela (1972).

Table 3.1. Development of stumpage prices for birch timber assortments and spruce pulpwood in private forests during the cutting seasons 1959/60 to 1971/72

Taulukko 3.1. Kantohintojen kehitys koivupuutavaralajeille ja kuusipaperipuulle yksityismetsissä hakkuukausina 1959/60 ... 1971/72

Cutting season *Hakkuukausi*	Birch fuelwood *Koivuhalko*		Birch veneer-logs *Vanerikoivu*		Birch pulpwood *Koivupaperipuu*		Spruce pulpwood *Kuusipaperipuu*	
	Fmk/ piled m³ with bark *Mk/p-m³, K:lista*	Index *Indeksi* 1959/60 = 100	Fmk/ft³ *Mk/j³*	Index *Indeksi* 1959/60 = 100	Fmk/ piled m³ with bark *Mk/p-m³, K:lista*	Index *Indeksi* 1959/60 = 100	Fmk/ piled m³ with bark *Mk/p-m³, K:lista*	Index *Indeksi* 1959/60 = 100
1959/60	1.16	100	0.52	100	1.01	100	8.10	100
1960/61	1.86	160	0.57	109	1.62	160	12.34	152
1961/62	2.47	212	0.62	119	2.15	212	13.75	169
1962/63	3.01	259	0.61	117	2.62	259	11.37	140
1963/64	3.63	312	0.62	119	3.16	312	14.36	177
1964/65	3.66	315	0.72	138	3.18	314	16.31	201
1965/66	3.38	291	0.82	157	2.77	274	15.48	191
1966/67	3.25	280	0.82	157	2.83	280	13.04	161
1967/68	3.31	285	0.79	151	2.70	267	11.00	135
1968/69	3.50	301	0.86	165	3.20	316	12.81	158
1969/70	6.29	542	1.18	226	5.35	529	14.98	184
1970/71	11.05	952	1.88	361	8.84	875	18.66	230
1971/72	11.14	960	1.64	315	9.46	936	19.57	241

Source: Yearbook of forest statistics 1971. SVT XVII A: 4. — *Lähde: Metsätilastollinen vuosikirja 1971. SVT XVII A: 4.*

3.2.2. Afforestation of fields through legislation and State funds, 1969 to 1973

The 1969 ammendment (425/1969) to the Forest Improvement Act (413/1967) and the Field Reservation Act both legislated for the afforestation of fields. Figures from the Central Board of Forestry concerning forest improvement work carried out under the terms of the FIA and administered through the district forestry boards, forest management associations and forest improvement districts between 1969 and 1973 show that of 44 876 hectares of afforestation, 36 492 hectares (81 %) consisted of afforestation of fields, see table 3.2.

Very noticeable is the massive increase in afforestation activity through the FIA since 1969, table 3.2. There was an 4-fold increase in afforestation between 1969 and 1972, and a 7-fold increase in the afforestation of fields during the same period. Through the FIA, afforestation of fields has increased year by year, with most forestry board districts achieving maximum afforestation of fields in absolute or relative terms in 1972, when 10 845 hectares (88 %) of the 12 279 hectares afforested was of fields. Afforestation could not begin simultaneously with the introduction of the legislation as farmers and the administrative machinery had to adjust to the new circumstances and applications to be made and considered, etc. Further, and of major significance, their was a temporary shortage of seedlings,

Table 3.2. Afforestation and afforestation of fields carried out through the Forest Improvement Act and supervised by district forestry boards, forest management associations and forest improvement districts, 1969 to 1973

Taulukko 3.2. Metsänparannuslain alainen piirimetsäkuntien, metsänhoitoyhdistysten ja metsänparannuspiirien valvoma metsitys ja peltojen metsitys vuosina 1969—1973

Year *Vuosi*	Total afforestation *Metsitetty kaikkiaan* ha	of which: Afforestation of fields *josta Peltojen metsitystä* ha	Field afforestation as percentage of total afforestation *Peltojen metsitys prosentteina koko metsitetystä alasta*	Chronological distribution of field afforestation *Peltojen metsityksen jakautuma* (%)
1969.....	3 019	1 521	50.4	4.2
1970.....	7 060	4 952	70.1	13.6
1971.....	10 750	9 104	84.7	24.9
1972.....	12 279	10 845	88.3	29.7
1973.....	11 768	10 070	85.6	27.6
Total — *Yhteensä*.....	44 876	36 492	81.3	100.0

Source: Central Board of Forestry Tapio. — *Lähde: Keskusmetsälautakunta Tapio.*

and a delay therefore existed — and still exists — between the making of afforestation plans, the application for permission and for funds and the actual planting of trees. This is clearly seen in table 3.3. which reveals an apparant disparity between the area of afforestation permission granted through the Field Reservation Act and the actual afforestation completed through the Forest Improvement Act. The columns showing the cumulative totals for area with afforestation permission and actual field afforestation achieved do not come in balance until 1973.

Table 3.3. Afforestation and field afforestation through the Forest Improvement Act and the Field Reservation Act, 1969—1973

Taulukko 3.3. Metsänparannuslain ja pellonvarauslain kautta suoritettu metsitys vuosina 1969—1973

Year *Vuosi*	Total FIA afforestation *Metsitetty kaikkiaan MPL:n kautta* ha	of which: field afforestation *josta: peltojen metsitystä* ha		Afforestation permission granted through the Field Reservation Act *Pellonvarauslain kautta myönnetyt metsitysluvat* ha	
		by year *vuosittain*	cumulative total *kumulatiivinen summa*	by year *vuosittain*	cumulative total *kumulatiivinen summa*
1969.....	3 019	1 521	*1 521*	14 350	*14 350*
1970.....	7 060	4 952	*6 473*	7 400	*21 750*
1971.....	10 750	9 104	*15 577*	5 105	*26 855*
1972.....	12 279	10 845	*26 422*	3 076	*29 931*
1973.....	11 768	10 070	*36 492*	2 567	*32 498*
Total — *Yhteensä*.....	44 876	36 492	*36 492*	32 498	*32 498*

Source: Central Board of Forestry Tapio and Board of Agriculture. — *Lähde: Keskusmetsälautakunta Tapio ja Maatilahallitus.*

Most of the field afforestation achieved during the period 1969—73 has been due to the effect of the Field Reservation Act. This is clearly shown in table 3.3. Further details of the results of this Act are presented in table 3.4. Particularly noteworthy is the apparant change of attitude towards afforestation of fields. In 1969 only 20 % of all field afforestation applications were made at the time the reservation contract was made, 80 % of

Table 3.4. Area of reserved fields and area with afforestation permission granted, in hectares, and proportion of reservation and afforestation activity, under the Field Reservation Programme, 1969—1973

Taulukko 3.4. Pellonvaraussopimusten alaisten peltojen pinta-ala ja metsistetty pinta-ala (ha) sekä pellonvaraus- ja metsitystoiminnan välinen suhde 1969—1973

Year of contract *Sopimusvuosi*	Reserved fields *Sopimusten alainen pelto*		of which: afforestation permission granted *josta: metsistyslupa myönnetty* ha						
			at time of reservation contract *pellonvaraus-sopimuksessa*		after making reservation contract *pellonvaraus-sopimuksen teon jälkeen*		Total area *Koko-naisala* ha	per 1 000 ha of reserved fields *per 1 000 ha peltoa*	Chrono-logical dis-tribution *Kronolo-ginen suhde* %
	Area in hectares *Ala (ha)*	Pro-portion *Suhde* %	Area *Ala* ha	per-centage of total area % *koko-nais-alasta*	Area *Ala* ha	per-centage of total area % *koko-nais-alasta*			
1969	85 653	57.2	2 900	20.2	11 450	79.8	14 350	167.5	44.1
1970	49 903	21.7	2 651	35.8	4 749	64.2	7 400	148.3	22.8
1971	33 131	14.4	1 612	31.6	3 493	68.4	5 105	154.1	15.7
1972	29 351	13.1	1 419	46.1	1 657	53.9	3 076	104.8	9.5
1973	31 020	13.6	1 584	61.7	983	38.3	2 567	82.8	7.9
Total — *Yhteensä*	229 058	100.0	10 166	31.3	22 332	68.7	32 498	141.9	100.0

Source: Board of Agriculture. — *Lähde: Maatilahallitus.*

the afforestation contracts for that year were made later. Slowly, as attitudes improved, the number of afforestation applications made at the time of making the reservation contract increased, and by 1973 62 % of the field afforestation applications were made at the time of making the reservation contracts. However, for the whole period, twice as many field afforestation applications were made after making the reservation contract than were made at the time of making the contract. The legislation has therefore had an increasing affect on field afforestation, presumably due to the slow acceptance of the farming community to field afforestation. By 1973, of the 229 000 ha of agricultural land, reserved, for a variety of social and

economic reasons,[1] 32 500 ha (14 %) had been afforested or had granted afforestation permission.

Figure 3.5. shows the regional distribution of afforestation through the FRA for the period 1969—1973. The northern districts have least afforestation activity, whilst the central and eastern districts have the greatest afforestation activity, with Mikkeli agricultural district achieving 281 hectares of afforestation per 1 000 hectares of reserved fields. Figure 3.6. shows the areal distribution of afforestation and afforestation of fields through the FIA. The pattern closely resembles that for total afforestation, see figure 3.1., but the greater importance of field afforestation can be seen, due to the influence of the FRA. Afforestation of fields is less extensive in the north of the country where social attitudes, the recent agricultural history, the size of farms and the environment are all factors working against the ready acceptance of afforestation. Also, the State and industrial companies own large tracts of forest in the north.

Table 3.5. Field afforestation through the Forest Improvement Act, by species, 1969—1973

Taulukko 3.5. Metsänparannuslain alainen peltojen metsitys puulajeittain vuosina 1969—1973

	Pine *Mänty* ha	Spruce *Kuusi* ha	Birch *Koivu* ha	Other *Muu* ha	Total *Yhteensä* ha	Species ratio *Lajien suhde* Pine: *Mänty*	Spruce: *Kuusi:*	Birch: *Koivu*
1969.....	460	932	127	2	1 521	3 :	6 :	1
1970.....	1 696	2 425	1 805	26	4 952	3 :	5 :	2
1971.....	3 582	2 803	2 641	78	9 104	4 :	3 :	3
1972.....	4 483	2 485	3 985	92	10 845	4 :	2 :	4
1973.....	3 853	1 627	4 538	52	10 070	4 :	1.5 :	4.5
Total — *Yhteensä*.....	13 874	10 272	12 096	250	36 492	4 :	3 :	3

Source: Central Board of Forestry Tapio. — *Lähde: Keskusmetsälautakunta Tapio.*

The species content of afforestation of fields through the FIA follows the general trend observed in section 3.2.1. Table 3.5. reveals that the planting of birch has increased four-fold in relative terms between 1969 and 1973, and whilst the planting of pine has increased slightly, spruce has undergone a marked decline in terms of its proportion of the total plantings.

[1] See Jaatinen & Kärkkäinen 1970 & 1971, and Jaatinen & Nygård 1972.

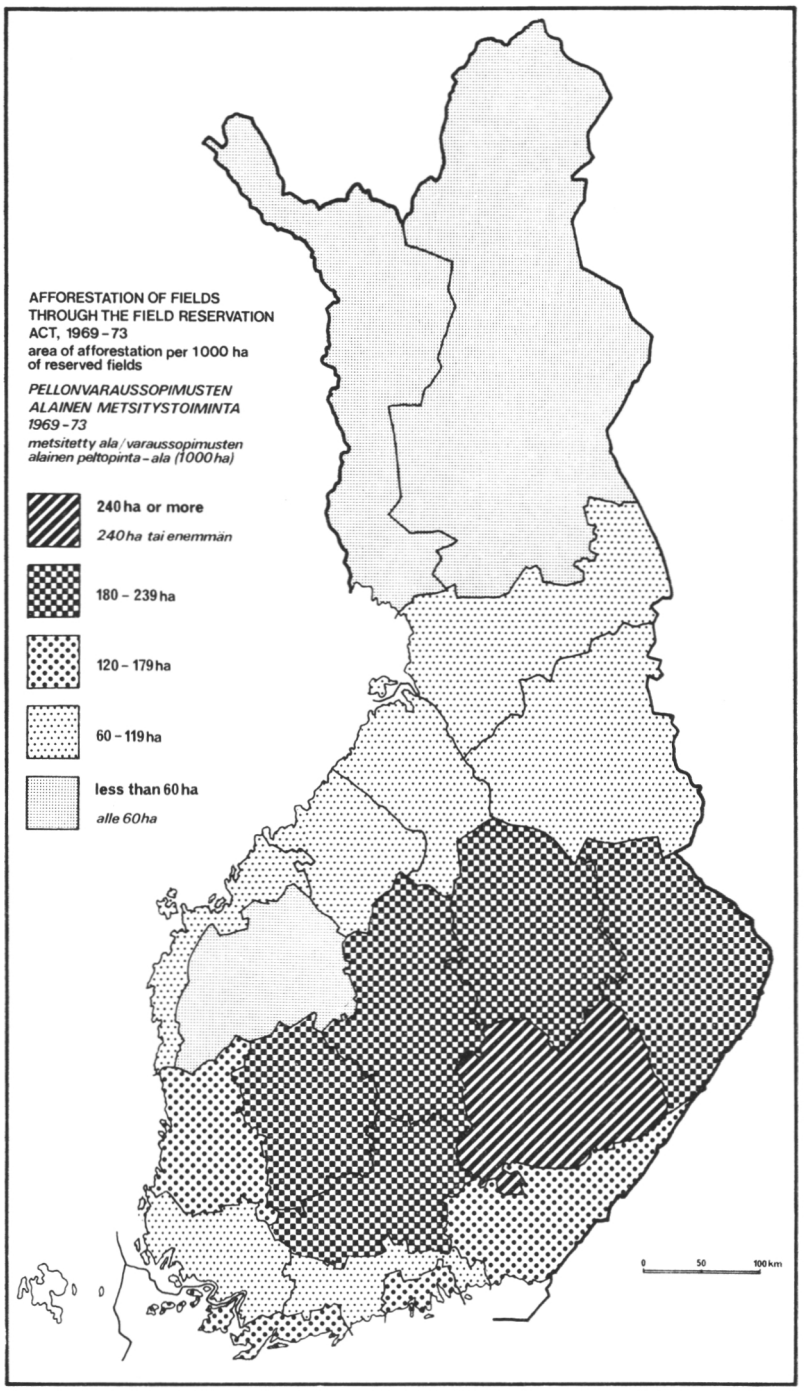


Figure 3.5 Regional variation of field afforestation through the Field Reservation Act, 1969—73, by agricultural districts

Kuva 3.5 Pellonvarauslain perusteella tapahtuneen metsitystoiminnan alueittainen vaihtelu maatalouspiireittäin 1969—73

3.2.3. The need for legislation

The Field Reservation Programme is to be phased out as from May 1975, after which no new contracts will be made; further, the duration of the subsidies will be reduced from 15 to 9 years.

A month later, the 1969 ammendment to the Forest Improvement Act expires. Thus, after June 1975 there will be no legislation directly promoting field afforestation unless such measures are contained in the forthcoming Farm Act. The main body of the Forest Improvement Act (413/1967) will still hold force.

Table 3.6. Afforestation and afforestation of fields achieved independently and through State funds via the Forest Improvement Act, 1969—73

Taulukko 3.6. Metsänparannuslain kautta valtion varoilla itsenäisesti suoritettu metsitys ja peltojen metsitys vuosina 1969—73

Year *Vuosi*	Total afforestation *Metsitetty kaikkiaan* ha			of which: Field afforestation *josta: Peltojen metsitystä* ha		
	achieved independently *itsenäisesti*	achieved via the FIA *MPL:n kautta*	Ratio *Suhde*	achieved independently *itsenäisesti*	achieved via the FIA *MPL:n kautta*	Ratio *Suhde*
1969.....	1 082	3 019	1: 3	335	1 521	1: 5
1970.....	1 037	7 060	1: 7	314	4 952	1: 16
1971.....	1 041	10 750	1: 10	519	9 104	1: 18
1972.....	982	12 279	1: 13	494	10 845	1: 22
1973.....	906	11 768	1: 13	434	10 070	1: 23
Total — *Yhteensä*	5 048	44 876	1: 9	2 096	36 492	1: 17

Source: Central Board of Forestry Tapio. — *Lähde: Keskusmetsälautakunta Tapio.*

Table 3.6. shows the relationship between afforestation and field afforestation achieved through legislation and State funds — the Forest Improvement Act and its ammendment — and that achieved by private forest owners independently, at their own cost. During the period 1969—73 afforestation achieved via the Forest Improvement Act exceeded independent afforestation by a factor of nine, and in the case of field afforestation by a factor of 17. Much of the latter can be attributed to the effects of the Field Reservation Act which created a situation favourable to field afforestation. The increased effectiveness of the legislation throught the period is largely due to the administrative (and biological) delays discussed above.

The importance of legislation in promoting afforestation and especially field afforestation is therefore beyond doubt, and it would appear that the achievement of the forestry and agricultural objectives discussed in section 1.1. may depend to a large extent on the effectiveness of supporting legislation. The measures which will supersede the Field Reservation Act and the 1969 ammendment to the Forest Improvement are therefore awaited with great interest.

4. DISCUSSION: WHAT FOR THE FUTURE?

At the present time a dichotomy exists between agricultural and forestry in Finland. There exists an urgent need to reduce the arable area of Finnish farms by as much as 700 000 hectares by 1980 in order to balance production with domestic consumption. Simultaneously, the need exists to intensify and expand Finland's forest resources in order to cope with the growing demands of the Finnish (and world) wood-based industries.

A number of measures have been tried or are being tried to reduce both the arable area and the number of farms. The 1958 Land-Use Act concentrated on improving farm-structure improvements and the control of land-use by making funds available for drainage works, building and buildings repairs, and land acquisition to prevent undue fragmentation of holdings. Towards the end of the 1960s, however, the magnitude of Finland's agricultural over-production in dairy products and bread grains was such that measures for limiting the production of these commodities had to be introduced. Concern was also being expressed at this time about the worsening structure of Finnish agriculture, with its high proportion of small, often marginal farms and the increasingly higher mean age of farmers. This was accompanied by large-scale rural depopulation, especially of the fertile age group (17—34 years). Emmigration continued to be a feature of Finnish population movements adding to the problem.

Agricultural legislation during the late 1960s was specifically designed to reduce output, but it also created uncertainty in agriculture, certainly in terms of the small-holding. The 1967 Agricultural Tax Reform descriminated against farms with 10 arable hectares or less, drastically increasing the 1968 tax dues of these farms whilst reducing the tax burden of larger farms. This was followed by the 1969 Field Reservation Act which subsidized the withdrawal of arable land from cultivation and also permitted the afforestation of fields. Between 1969 and 1973 some 230 000 hectares of arable land were reserved under the terms of this Act.

Agriculture has always held presedence in Finland, and forest policy has therefore remained subordinate to agricultural policy. Until the 1969 Field Reservation Act, the clearing of forests for fields was encouraged and subsidized. Neither the 1967 Private Forest Act (Law 412/1967) nor

the Forest Improvement Act of the same year (Law 413/1967) altered this fact. The 1969 Field Reservation Act (Law 216/1969) and the Ammendment to the Forest Improvement Act (Law 425/1969) legislated for the afforestation of fields for the first time. Both the 1969 Acts are, however, of temporary duration. The ammendment to the Forest Improvement Act was initially to run for three years, but has been extended until June 1975.

Despite these Acts, the long-term strategy for removing up to 70 000 hectares of arable land per year from cultivation between 1970 and 1980 does not seem to be clear in form or principle. The Field Reservation Act has resulted in an average of 46 000 ha per year being withdrawn from cultivation, although the area has fallen steadily each year since the first year of the programme, see table 2.3. Furthermore this measure is only temporary. Numminen (1970) reported that two-thirds of the arable land reserved at that time would be returned to cultivation at the expiry of the contract period. Figures from the Board of Agriculture indicate that the reduction of arable land area is not in line with policy objectives. If the target of 700 000 hectares less arable by 1980 is to be achieved, then further measures are needed to encourage the withdrawal of this land.

Despite the apparent lack of success so far, consideration must be given to the alternative economic uses of arable land withdrawn from cultivation consistent with the agricultural and forestry objectives. Forestry is the obvious alternative to arable as the conversion of land from arable to forest usage would assist in achieving both objectives. Concerning the economic use of land, Pihkala (1965, page 53) writes:

> »At present there are no strictly comparative data permitting determination of the relative advantageousness of land use for agriculture or forestry purposes on different soil-types and under varying marketing conditions. However, the economic results of the book-keeping farms, for example, indicate to some extent that in certain regions of Finland the use of land for agriculture is no longer more advantageous than its use for forestry.»

If this was true in 1965 then at the present time it must be even more so. Studies concerning precisely which land is most suitable for agriculture or forestry would now be beneficial in order to formulate positive, long-term policies for both productive agriculture and the afforestation of fields. Such a policy would be seen as a rational guide and might contribute to a return of faith in agriculture.

As things stand, however, the agricultural laws of the late 1960s, and especially the Field Reservation Act and its consequences presented a change of policy for which the farming community as a whole was not prepared. The rigid administrative machinery of this Act was a further

barrier of its general acceptance. Economic and social considerations were involved, in that arable land had often been hard-won by previous generations and had considerable sentimental value — as well as a higher monetary value than forest land. The move to suspend cultivation and to even afforest fields was therefore seen as a heresy. Afforestation also requires faith in the future as it is a long-term investment, and so the high average age of the Finnish farmer, the frequent lack of an heir, as well as the reversal of policy initially led to a less than enthusiastic adoption of the afforestation measures.

Numminen (1970) found that 58 % of the farmers interviewed in connexion with adoption of the Field Reservation Act's proposals were not prepared to afforest fields. Positive attitudes towards forestry were associated with those farmers who had a positive attitude to forestry in general. Table 4.1. summarizes the reasons for reserved fields being afforested or not, whilst table 4.2. presents farmers' opinions concerning related topics; both tables are adapted from Numminen (1970).

Table 4.1. Farmers' main reason for afforesting reserved fields or not
Taulukko 4.1. Maanviljelijäin pellonvarauslain alaisten peltojen metsitysten tai metsittämättä jättämisen peruste

Reasons against afforestation *Metsittämättä jättämisen peruste*	Reasons for afforestation *Metsityksen peruste*
Fields too good — *Hyvät pellot*	Distant fields — *Syrjäiset pellot*
Fields will probably or definitely be cultivated in the future — *Pellot tullaan todennäköisesti tai varmasti viljelemään tulevaisuudessa*	Cessation of agricultural cultivation — *Ei aio viljellä*
Sale of fields considered — *Mahdollinen myynti*	(Reserved) fields must be productive — *Maa ei saa olla tuottamattomana*
No personal benefits from afforestation — *Metsittämisestä ei koidu itselle hyötyä*	Poor quality fields — *Heikot pellot*
Fields surrounded by others — *Pellot sijaitsevat toisten peltojen keskellä*	

Source: Numminen (1970, page 255). — *Lähde: Numminen (1970, sivu 255).*

According to these figures, 43 % of the farmers concerned proved to be negative regarding afforestation of fields due to the effort requiring in pioneering them. In contrast, 69 % agreed that forestry should be considered as an alternative to arable when such land is withdrawn from cultivation. Only 7 % proved totally against artificial seeding and planting in principle. In a study of forest owners, Järveläinen (1974) found that 41 % (including non-farmers) considered field afforestation a mistake,

Table 4.2. Farmers' opinions concerning selected topics. Qualified answers omitted
Taulukko 4.2. Eräitä maanviljelijäin mielipiteitä. Vähänkin epävarmat vastaukset on jätetty huomioon ottamatta

Topic *Väittämä*	Agree *Täysin samaa mieltä* %	Disagree *Täysin eri mieltä* %
a) Fields should not be afforested because of the hard labour involved in their creation — *Peltoja ei pitäisi metsittää, koska ne aikoinaan on suurella työllä raivattu*	43	10
b) A field should produce a marketable product, and the production of timber must be considered in the event of agricultural overproduction — *Maa on pantava tuottamaan sellaista tuotetta, joka menee kaupaksi. Kun maataloudessa on ylituotantoa, jota ei saada markkinoiduksi, on parempi saattaa pelto puuntuotantoon kuin jättää se heitteille*	69	3
c) Artificial regeneration is too much in favour these days — *Metsänviljelyä suositaan nykyään liikaa*	7	30
d) Forestry is now more profitable than agriculture in Finland — *Metsähoito kannattaa Suomessa paremmin kuin maanviljelys*	11	14
e) The creation of new pasture land should stop — *Uudisraivausta ei enää tulisi suorittaa*	73	1
f) Agricultural subsidies should be increased — *Maatalouden tukemista tulisi lisätä*	14	7

Source: Numminen (1970, page 257). — *Lähde: Numminen (1970, sivu 257).*

whilst 22 % of forest owners were unfavourably disposed to artificial regeneration.

The results of five years of FRA and FIA activity were presented in sections 3.2.2. and 3.2.3. of this paper. Field afforestation through these Acts was shown to have accounted for 81 % of all state-financed afforestation in the private forestry sector. The legislation has been shown to have been particularly successful in achieving afforestation and especially field afforestation when compared with independently achieved afforestation in the private sector; and further, these Acts have seemingly led to an improved attitude towards field afforestation as indicated by the large number of post-contract afforestation applications made, particularly during the first two years of the FRA.

Whilst recent legislation concerning afforestation has resulted in a substantial increase in this activity, especially in relation to the afforestation of fields, a number of questions remain concerning future developments.

Improvement in farm size structure and productivity per hectare, achieved through the objectives discussed in section 1 of this paper, should lead to more profitable and prosperous farms. This has implications for the future of farm-forestry, and by implication for afforestation. Järveläinen (1971, page 69) found that good productive and economic resources increased a forest owners use of expert assistance and the absolute extent of silvi-

cultural measures. Further, the relative extent of silvicultural activity and readiness to act depended almost equally on the forest-owner's silvicultural attitude and his individual farm background conditions (op. cit, page 69—70) in that good productive and economic resources increase the relative extent of silvicultural activity and readiness to act. However, Reunala (1974) concludes that farmers, who at present own 79 % of the forest area, will lose about 9 million hectares of forest land between 1970 and 1980, predominantly due to inheritance laws, whilst non-farmer forest owners will increase their share of private forests from 20 % to 34 % during the same period. Järveläinen (1974) also notes that at present half of the non-farmer forest owners are from professional classes and many live far from their forest holdings, and he notes that this trend is increasing. Hämäläinen (1971, page 428) had already confirmed that forest holdings compared favourably with Government Bonds and bank deposits as a means of investment.[1] These developments in forest ownership structure are likely to reduce the role of farm-forestry. These developments are also contrary to the forestry objectives outlined in »Growth ... 1980» as it is less likely that non-farmer forest owners will manage their forests in such a way that a constant supply of timber to industry will be maintained. Järveläinen (1971) found that distant location and the abandonment of agricultural husbandry among major factors causing the reduction of silvicultural activity and also found (1974) that 52 % of farmers sold timber at least every three years compared with only 26 % of non-farmer forest owners. Similarly, farmers were more likely to undertake silvicultural activities than non-farmers. 65 % of all forest owners considered securing a constant potential cut a main goal of forestry, although 32 % of these considered this goal in terms of security for »bad times ahead». Further, 62 % of forest owners considered too much timber was now being felled.

These are some of the factors which need careful consideration at this time regarding the dichotomy between the socio-economic structure and objectives of agriculture and forestry. Given the right land-use policies, the withdrawal of agricultural land from cultivation could lead to extensive field afforestation, as in Sweden (see Ahlbäck 1969). Forest would then remain an essential part of the farm structure which should, according to Järveläinen and others,[2] lead to increased silvicultural activity and would be more likely to secure a regular supply of timber.

Many questions remain to be solved concerning the development of both agriculture and forestry in Finland during the next decade, and also to the end of the century. On the negative side are the questions concerning forest

[1] See also Hahtola, K., et al. (1973).

[2] The silvicultural behaviour of forest owners is discussed in detail by Järveläinen (1971 & 1974), Hahtola (1967 a, 1967 b, 1971 a & 1971 b), Riihinen (1963 & 1970), Seppälä (1974) and Virta(1971).

ownership structure and the supply of timber, discussed above, but also the acceptability of the massive social and economic changes to which the Finnish countryside will be subjected in order to fulfill the objectives recommended. The withdrawal of 700 000 hectares of arable land, a reduction in the number of farms by one third as well as a halving of the economically active population in agriculture and forestry may so weaken rural society that these changes become unacceptable (see Honkanen, et al. 1973, page 110). Further the agricultural self-sufficiency objective may be difficult to achieve because of increased productivity consequent upon rationalization. It may also be abolished if the increasing world food shortage leads to a re-appraisal of such an objective. Deteriorating climatic conditions [1] may also lead to reduced harvests thus making it necessary to once more increase the arable area to offset lower yields.

Further developments in forestry may also have a direct bearing on the role played by farm-forests and particularly the afforestation of fields. A major argument against afforestation reported by Numminen (1970) was »no personal benefit», which is certainly the case at present with the majority of farmers being over 50 years of age; economic benefits from afforested fields being available after only 20 to 30 years in southern Finland (and up to 80 years in northern Finland) when commercial thinnings are taken from the forests. Järveläinen (1974) found a similar attitude to silvicultural activity in 38 % on the forest owners interviewed in his study.

It is for just this reason that the growing interest in short-rotation forestry is to be welcomed. Research into this aspect of forestry has reached advanced stages in the U.S.A.[2] In Finland research into short rotation forestry is only in its second year but the project is receiving massive financial support from the State SITRA fund.[3] The Finnish Forest Research Institute's Department of Forest Genetics and the State Tree Breeding Foundation are currently experimenting with species of birch, alder, poplar and willow as potential short rotation stock, pine and larch are also being considered for some applications. Many questions remain open at this point in time due to the recent origin of the project and the consequent paucity of data; for example — the rotation period could vary from ten years or less in southern Finland and on the best soils to well over 30 years in northern Finland; the mode of cultivation, i.e. standards

[1] Calder, N. »The Weather Machine» BBC Publications 1974.
Calder, N. »The Snow Blitz» The Guardian, 20. 11. 1974.
Crawford, M. »The Economics of the New Ice-Age» The Sunday Times, 3. 11. 1974.
Schneider, 1974. Ambio 1974/3 and 4.

[2] See J. H. Rike. »A review of short rotation forestry with comments on the prospect of meeting future demands for forest products». Life Sciences and Agricultural Experimental Station, University of Maine at Orono, 1974.

[3] See P. Hakkila. »Kokopuun Käyttö Yhdysvalloissa vuoden 1973 päättyessä sekä sen sovellutusmahdollisuudet Suomessa. SITRA Sarja B No. 13. Helsinki 1974.

or coppice, remains undecided and could well depend on the types of harvester eventually adopted. In fact, the success of the whole short rotation programme could well depend on the development of a suitable harvesting machine. Research on the latter is being carried out privately and by Forest Technology Department of the Finnish Forest Research Institute. The pulp and board industry has also to develop techniques for handling green wood chips. The goal, however, is simple — the maximum dry weight production per hectare per year.

The successful adoption of short rotation forestry will be a major development in Finnish forestry; moreover, it could well transform the farm-forest structure as it is known today. The ability of farmers to afforest fields knowing that they can expect a good economic return in, say, ten to twenty years should lead to an improved attitude towards forestry and afforestation. Also, the ability to afforest fields knowing that the fields can be reclaimed for agriculture in one or two decades (assuming a »complete tree» method of harvesting is available, i.e. the removal of stem, branches *and roots)* could further encourage farm forestry. Yet another incentive would be that the adoption of the coppice method would remove the need for post-harvest artificial regeneration.

In conclusion it can be said that whilst achievements concerning the afforestation of fields have so far been modest, it has been shown that agricultural land can be made available for afforestation. Technological and silvicultural developments may further encourage a more positive attitude towards the afforestation of fields and farm-forestry in general. Various timber-trends studies forecast a growing demand for forest products and we have already seen a substantial increase in stumpage and wood product prices. There is reason to suppose that private forestry in Finland will become increasingly profitable in line with these trends. Further, as a result of factors applicable only at the national level, such as the relationship between taxation and subsidies, the broader time-horizon, the reduced effects of »less than total use of production factors», multiplier effects of forestry production and the need for sustained yield, afforestation and artificial regeneration are (even) more profitable in terms of the national economy than they are in the private sector.[1]

[1] Report of the Committee on the cost of forest planting and seeding, Folia Forestalia 109, Helsinki 1971, page 24.

BIBLIOGRAPHY

Ahlbäck, A. 1969. Om neskogning av nedlagd jordbruksmark. Summary: Afforestation of abandoned arable and pasture lands. Sveriges Skogsvårdsförbunds Tidskrift, Vol. 67/7. Stockholm.

—»— 1970. Mer skog på nedlagd åker. Skogsägaren, Vol. 46/2. Stockholm.

Cajander, E. K. 1933. Tutkimuksia Etelä Suomen viljelyskuusikoiden kehityksestä. Communicationes Instituti Forestalis Fenniae 19.3. Helsinki.

Calder, N. 1974. The Weather Machine. BBC Publications. London.

—»— 1974. The Snow Blitz. The Guardian 20. 11. 1974. London.

Crawford, M. 1974. The economics of the new Ice-age. The Sunday Times 3. 11. 1974. London.

Enequist, G. 1968. Agricultural holdings in Sweden 1951—1966 and 1980. Acta Geographica 20.7. Helsinki.

Ervasti S., L. Heikinheimo, V. Holopainen, K. Kuusela and G. Siren. 1965. The development of Finland's forests in 1964—2000. Silvia Fennica 117.2. Helsinki.

—»— L. Heikinheimo, K. Kuusela and V. O. Mäkinen. 1970. Forestry and forest industry production alternatives in Finland, 1970—2015. Folia Forestalia 88. Helsinki.

Growth Prospects for the Finnish Economy up to 1980. 1972. Economic Planning Centre. Helsinki.

Hahtola, K. 1967 a. Hankintahakkuut ja maatilakokonaisuus. Summary: Delivery cuts of timber in farm management. Acta Forestalia Fennica 84. Helsinki.

—»— 1967 b. Maatilametsätalouden yhteys taloudelliseen ja sosiaaliseen ympäristöön. Summary: Farm forestry and its socio-economic environment. Acta Forestalia Fennica 84. Helsinki.

—»— 1971 a. Alueelliset näkökohdat maat;ilametsätalouden edistämisessä. Kansantaloudellinen aikakauskirja, No. 2. Helsinki.

—»— 1971 b. Forest owner's decision making and theories of the firm. Työtehoseuran julkaisuja, No. 158. Helsinki.

—»— V.-P. Järveläinen and A. Reunala. 1973. Metsänomistajien puunmyyntikäyttäytyminen. Summary: The timber-sales behaviour of private forest owners. Silva Fennica 7.3. Helsinki.

Hakkila, P., S. Karsila, K. Oittinen, J. Ranki and A. Reinikainen. 1973. Esitutkimus metsän lyhytkiertoviljelystä. SITRA Sarja B, No. 13. Helsinki.

Heikinheimo, L. and M. Palo. 1972. Increasing investments in Finnish forestry. Logger's Handbook, Vol. XXXII. Oregon.

Holopainen, V. 1957. Metsätalouden edistämistoiminta Suomessa. Tapio 1907—1957. Summary: Promotion of private forestry in Finland. Tapio 1907—1957. Silva Fennica 94. Helsinki.

—»— 1971. Keinottelu metsämaalla pitäisi voida estää. Helsingin Sanomat 7. 2. 1971. Helsinki.

Honkanen, S., A. Komonen and I. Vainio-Mattila. 1973. Suomen maatalous 1960—1980. Laskelmia maatalouden ja maataloustuotannon rakenteellisesta kehityksestä. Pellervo-Seuran Markkinatutkimuslaitoksen Julkaisuja, No. 14. Helsinki.

Huttunen, T. 1974. Wood consumption, total drain and forest balance in Finland, in 1971—1973. Folia Forestalia 205. Helsinki.

Hämäläinen, J. 1971. Pankkitalletukset ja valtion obligaatiot metsänomistajan sijoitusvaihtoehtoina. Summary: Bank deposits and government bonds as investment alternatives for a private forest owner. Liiketaloudellinen Aikakauskirja, No. IV/1971. Helsinki.

Jaatinen, S. and U. Kärkkäinen. 1970. Pellonvaraustoiminta Suomessa 1969 ja sen tulokset. Asutustoiminnan Aikakauskirja 23.1. Vammala.

—»— 1971. Vuoden 1969 Pellonvaraustoiminta. Helsingin Yliopiston Maantieteen Laitoksen Julkaisuja 8.7. Helsinki.

Jaatinen, S. and M. Nygård. 1972. Vuosien 1970—1971 Pellonvaraustoiminta ja vuoden 1970 »Teurastuspalkkiolaki». Helsingin Yliopiston Maantieteen Laitoksen Julkaisuja 8.12. Helsinki.

Janhunen, J. 1974. The FAO study and analysis of the influence of social security schemes on structural changes in agriculture in selected European countries — report from Finland. Central Pension Security Institute, Helsinki.

Järveläinen, V.-P. 1971. Factors influencing silvicultural activity. Communicationes Instituti Forestalis Fenniae 73.2. Helsinki.

—»— 1974. Yksityismetsänomistajien metsätaloudellinen käyttäytyminen. Summary: Forestry behaviour of private forest owners in Finland. Folio Forestalia 222. Helsinki.

Kärkkäinen, U. 1968. Changes in farm-size structure in Finland, 1959—1964. Acta Geographica 20.15. Helsinki.

Kuusela, K. 1972. Suomen metsävarat ja metsien omistus 1964—1970 sekä niiden kehittyminen 1920—1970. Summary: Forest resources and ownership 1964—1970 and their development 1920—1970. Communicationes Instituti Forestalis Fenniae 76.5. Helsinki.

Nummminen, J. 1970. Pellonvaraussopimusten alaisten peltojen metsitys. Summary: Afforestation of agricultural land under soil bank contracts. Silva Fennica 4.4. Helsinki.

Maatilahallitus. 1960. Selvitys autiotilatilanteesta 15. 6. 1959. Mineographed. Helsinki.

—»— 1966. Yksityismaakomitean osamietintö II. Komiteanmietintö 1966: 898. Mimeographed. Helsinki.

Pihkala, K. U., 1965. Possibilities of comparing land use for farming and forestry. Acta Agriculturae Scandinavica, Supp. 14. Stockholm.

Report of the Committee on the cost of forest seeding and planting, 1971. Folia Forestalia 109. Helsinki.

Reunala, A. 1972. Yksityismetsänomistuksen rakennemuutos Keski-Suomessa 1945—1970. Kansantaloudellisen metsäekonomian lisensiaattitutkimus, Helsingin Yliopiston maatalous-metsätieteellinen tiedekunta. Mimeographed. Helsinki.

—»— 1974. Structural change of private forest ownership in Finland. Communicationes Instituti Forestalis Fenniae 82.2. Helsinki.

Riihinen, P. 1963. Metsänhoidon tason vaihtelu Suomen maatilametsälöillä. Tutkimus metsänhoitolautakunnittaisten erojen taloudellisista ja sosiaalisista eroista. Summary: Variations in the level of silviculture on the Finnish farm woodlots. A study of economic and social factors affecting the regional level of silviculture. Acta Forestalia Fennica 75. Helsinki.

—»— 1970. The forest owner and his attitudes towards forestry promotion; a study based on forest owners in Ostrobothnia, Finland. Acta Forestalia Fennica 109. Helsinki.

Rike, J. H. 1974. A review of short rotation forestry with comments on the prospect of meeting future demands for forest products. University of Maine. Orono.

Schneider, S. H. 1974. The Population explosion: Can it shake the climate? Ambio 1974 No. 3/4. Stockholm.

SVT (Suomen Virallinen Tilasto) III: 54. Census of Agriculture, Volume II, 1959. Helsinki 1960.

—»— III: 67. Census of Agriculture, Volume II, 1969. Helsinki 1970.

—»— XVII A: 4 Year Book of Forest Statistics 1971. Helsinki 1972.

Virta, J. 1971. Yksityismentsänomistajien puunmyyntialttius Länsi-Suomessa vuonna 1970. Summary: Timber-sales propensity of private forest owners in western Finland in 1970. Folia Forestalia 114. Helsinki.

Öller, L.-E. 1973. Factors and aspects of long-term economic growth in Finland. Senior economic advisers to ECE governments. Seminar on factors and conditions influencing long-term growth. Stockholm, 3—8 December 1973. *Seen in preliminary draft.*

SELOSTE

Tutkimuksessa analysoidaan peltojen metsityksen viimeaikaista kehitystä Suomessa. Tarkastelun taustan muodostavat maataloudessa vuosina 1959—1969 tapahtuneet muutokset, äskettäin uusittu maa- ja metsätalouden maankäyttöä koskeva lainsäädäntö sekä taloudelliselle kosvulle ja muulle yhteiskuntapolitiikalle hahmotellut 1970-luvun päämäärät.

Suomen maatalouspolitiikassa pyritään maitotaloustuotteiden ja leipäviljan tuotosten vähentämiseen omavaraisuuden tasolle 1970-luvun loppuun mennessä. Maatalouden rationalisointi sekä maatilojen koon ja maanviljelijöiden ikärakenteen parantaminen ovat myös tärkeitä päämääriä. Niiden toteuttaminen edellyttää ainakin 600 000 peltohehtaarin ottamista pois viljelyn piiristä ja maanviljelijöiden lukumäärän vähentämistä kolmanneksella vuoteen 1980 mennessä.

Metsäteollisuustuotteiden kasvavan kysynnän tyydyttäminen edellyttää metsien puuntuotantokyvyn kohottamista. Siihen pyritään ensi sijassa laajamittaisilla metsäinvestoinneilla jo olemassaolevalla metsämaalla, mutta puuntuotosta voidaan myös kohottaa lisäämällä metsämaan pinta-alaa perusmetsityksin (lähinnä avosoiden ja peltojen metsitystä). Peltojen metsityksen voidaankin katsoa edistävän sekä maatalous- että metsäpolitiikan päämäärien saavuttamista.

Maatilojen kokorakenne on parantunut 1960-luvulla. Vuonna 1969 oli koko maassa 32 prosentilla kaikista yli kahden peltohehtaarin tiloista enemmän kuin 10 hehtaaria peltoa kun vastaava luku vuonna 1959 oli 25 %. Kehitys Pohjois-Suomessa näytti samansuuntaiselta vastaavien suhdelukujen ollessa 22 % ja 17 %.

Maatilojen autioituminen jatkui 1960-luvulla. Niinpä vuonna 1969 oli 8 300 peltohehtaaria autiotiloilla. Autiotilojen keskikoko kaksinkertaistui viime vuosikymmenellä. Maatilojen autioitumisprosessi on samanaikaisesti siirtynyt pohjoista kohden.

Vuoden 1969 pellonvarauslaki (lait pellon käytön rajoittamisesta: 216 & 217/1969 ja 19/1970) on johtanut vuosina 1969—1973 229 100 peltohehtaarin siirtämiseen pois viljelyksen piiristä. 40 % tästä määrästä oli Etelä- ja Länsi-Suomessa, 27 % Keski- ja Itä-Suomessa ja 33 % Pohjois-Suomessa. Runsas kolmannes (37 %) kaikista pellonvaraussopimuksista tehtiin ensimmäisenä lain voimassaolovuonna, jonka jälkeen innostus on vähentynyt.

Perusmetsitystä on rohkaistu metsänparannuslaeilla ja nimenomaan peltojen metsitystä vuoden 1969 pellonvarauslailla sekä samana vuonna annetulla metsänparannuslain muutoksella. Peltojen metsitystä on myös tapahtunut näistä laeista riippumatta.

Perusmetsitys on lisääntynyt vuodesta 1969 lähtien koko maassa, mutta erityisesti Itä- ja Pohjois-Suomessa. Keski- ja Itä-Suomessa peltojen metsitys on muodostanut metsitystoiminnan pääosan. Perusmetsitystoiminta on rajoittunut pääosiltaan yksityismetsiin. Vuodesta 1969 lähtien on tapahtunut koivun istutuksen voimakas laajentuminen muissa osissa maata paitsi Pohjois-Suomessa. Kuusen istuttamisen suhteellinen osuus on vähentynyt.

Metsäparannuslain (1967 ja 1969) ja pellonvarauslain (1969) perusteella metsitettiin vuosina 1969—1973 yhteensä 44 900 ha, josta 36 500 ha (81 %) oli peltojen metsitystä. Peltojen metsityksen suhteellinen osuus metsänparannuslain kautta valtion varoilla suoritetusta kokonaismetsitystoiminnasta lisääntyi tutkimusajanjaksona 50 %:sta (1969) 88 %:iin (1972) ja tämän jälkeen väheni 85 %:iin vuonna 1973. Tämä peltojen metsityksen osuuden kasvu johtuu melkein yksinomaan pellonvarauslain luomista metsitykselle suotuisista olosuhteista. Vuosina 1969—1973 myönnettiin metsityslupa 32 500 pellonvarauslain alaiselle peltohehtaarille. Metsitysluvan saanut peltoala oli 14 % ko. ajanjaksona pellonvarauslain piirissä olevasta kokonaispeltoalasta.

Valtion varoilla suoritetun yksityisomistuksessa olevan maan metsityksen pinta-alaosuuden vertaaminen muulla tavoin rahoitetun metsityksen pinta-alaosuuteen osoittaa selvästi ko. lainsäädännön arvon metsityksen ja erityisesti peltojen metsityksen edistämistä. Metsänparannuslain kautta valtion varoilla metsitettiin vuosina 1969—1973 44 500 ha kun taas muuta tietä metsitettiin ainoastaan 5 000 ha (metsitysten suhde 9 :1). Peltojen metsityksestä suoritettiin samana ajanjaksona valtion varoilla 36 500 ha ja muuta tietä vain 2 100 ha (suhde 17: 1).

Toteutunut peltojen metsitys on melko vaatimatonta luokkaa verrattuna muiden metsänhoitotoimenpiteiden toteutumismääriin. Osittain tähän on voinut vaikuttaa se, että maanviljelijöiden on ollut vaikea hyväksyä maatalouspolitiikan ja sen päämäärien nopeita muutoksia 1960-luvun lopulla. Vanhoja arvoja on hävitetty ja uusien arvojen hyväksyminen tapahtuu hitaasti.

Sekä maatalous- että metsätalouspolitiikan tuleva kehitys vaikuttaa perusmetsitystoimenpiteiden muotoutumiseen. Kookkaammat maatilat, nuoremmat maanviljelijät ja tuottavuuden kasvu saattavat vapauttaa peltoja maatalouden ulkopuoliseen taloudelliseen ja etenkin metsätalouden käyttöön. Toisaalta maaseutuyhteiskunnan syvällisten muutosten jyrkkä vastustaminen, maailman elintarvikepula ja muut tekijät voivat pysähdyttää peltojen siirtämisen pois maataloudesta ja voivat jopa kääntää kehityssuunnan vastakkaiseksi.

Metsätalouden kehitys, etenkin metsäteollisuustuotteiden kysynnän kasvun aiheuttama kannattavuuden nousu, saattaa vaikuttaa siten, että maan käyttö metsätalouteen tulee kannattavammaksi kuin sen käyttö maatalouteen. Puiden lyhytkiertoviljelyn onnistunut sovellutus Suomeen saattaa hyvinkin muuttaa koko nykyisen maatilametsätalouden rakenteen ja vaikuttaa olennaisesti peltojen metsitykseen.

APPENDIX

At the time of going to press, data concerning afforestation and afforestation of fields in 1973 became available. These have been incorporated into the text, but for practical reasons are not able to be added to the figures. The reader may wish to complete these diagrams physically or mentally and so the relevent data are presented here in tabular form.

Table I. Afforestation and afforestation of fields in 1973, by forestry board districts
Taulukko I. Metsitys ja peltojen metsitys piirimetsälautakunnittain v. 1973

Forestry board district *Piirimetsälautakunta*	Total afforestation *Metsitetty kaikkiaan* ha	of which: Field afforestation *josta: peltojen metsitystä* ha	Field afforestation as percentage of total afforestation *Peltojen metsitys prosentteina koko metsitetystä alasta*
Helsinki	444	288	64.9
Lounais-Suomi	341	216	63.3
Satakunta	566	413	73.0
Uusimaa-Häme	636	466	73.3
Pirkka-Häme	1 021	859	84.1
Itä-Häme	693	554	79.9
Etelä-Savo	1 251	1 058	84.6
Etelä-Karjala	881	744	84.4
Itä-Savo	911	761	83.5
Pohjois-Karjala	1 815	1 564	86.2
Pohjois-Savo	1 925	1 678	87.2
Keski-Suomi	1 868	1 157	61.9
Etelä-Pohjanmaa	940	593	63.1
Vaasa	635	563	88.7
Keski-Pohjanmaa	635	325	51.2
Kainuu	656	438	66.8
Pohjois-Pohjanmaa	1 306	605	46.3
Koillis-Suomi	250	161	64.4
Lappi	687	413	60.1
Whole County — *Koko maa*	17 461	12 856	73.6

Source: Finnish Forest Research Institute. — *Lähde: Metsäntutkimuslaitos.*

Table II. Afforestation and Afforestation of fields carried out through the Forest Improvement Act, 1973, by forestry board districts

Taulukko II. Metsänparannuslain alainen metsitys ja peltojen metsitys v. 1973 piirimetsälautakunnittain

Forestry board district *Piirimetsälautakunta*	Total afforestation *Metsitetty kaikkiaan* ha	of which: Afforestation of fields *josta: peltojen metsitystä* ha	Field afforestation as percentage of total afforestation *Peltojen metsitys prosentteina koko metsitetystä alasta*
Lounais-Suomi	220	149	67.7
Satakunta	438	343	78.3
Uusi-Häme	432	373	86.3
Pirkka-Häme	883	793	89.8
Itä-Häme	578	483	83.6
Etelä-Savo	1 091	1 015	93.0
Etelä-Karjala	775	684	88.3
Itä-Savo	855	734	85.8
Pohjois-Karjala	1 441	1 360	94.4
Pohjois-Savo	1 509	1 209	80.1
Keski-Suomi	1 205	1 011	83.9
Etelä-Pohjanmaa	778	554	71.2
Keski-Pohjanmaa	290	247	85.2
Kainuu	285	264	92.6
Pohjois-Pohjanmaa	552	495	89.7
Koillis-Suomi	106	106	100.0
Lappi	322	258	80.1
Total — *Yhteensä*	11 768	10 070	85.6

Source: Tapio's Yearbook 1973. — *Lähde: Tapion Vuosikirja 1973.*

WASTE PAPER RECYCLING: ECONOMIC AND ECOLOGICAL PROSPECTS

MATTI PALO & OLLI NISSILÄ

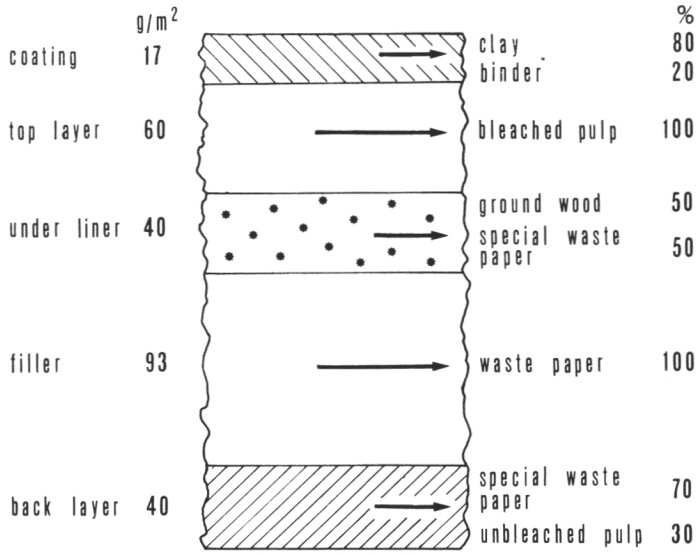
KERÄYSPAPERIN KÄYTÖN EKONOMISET JA EKOLOGISET PERUSTEET JA MAHDOLLISUUDET

HELSINKI 1975

ISBN - 951 - 40 - 0138 - 9

Helsinki 1975. Valtion painatuskeskus

Structure of this board sample page:



This page: Coated Tam-Duplex 250 g/m², contains 55 % waste paper. Oy Tampella Ab, Ingerois Board Mill.

PREFACE

The idea for this study was raised by Matti Palo in 1971. He presented the tentative theoretical framework of this subject in the ECE/FAO symposium in Helsinki in the spring of 1972. Because of other duties there was over a year's interruption in this study since then.

The manuscript or parts of it were read and useful comments were made by James P. Cunningham, Jouko Hämäläinen, Esko Jaatinen, Martti Kangas, Kullervo Kuusela, Risto Seppälä and Hannu Väliaho. Mr. Cunningham also checked the English language. Matti Helander and Maija Kuusijärvi drew the figures. Nora Sepulveda and Brita Sjöstrand took care of the majority of typing. Valuable information tempered by practical experience were provided by Veikko Mäkelä and Unto O. Silventoinen from Paperinkeräys Oy, Anssi Kärnä from Oy Tampella Ab and Jali Ruuskanen from Sitra. Several other persons and organizations have also aided in completing this study. The authors wish to express their sincere gratitude to all of them. The participation of the authors was divided as follows: Chapters 1—3 were designed and executed by Palo and the other chapters are joint efforts of the authors.

Helsinki, December 1974

Matti Palo *Olli Nissilä*

CONTENTS

0. Summary 7

1. Introduction 11
   1.1. Environmental economics 11
   1.2. Deterioration caused by production and consumption of pulp and paper 12
   1.3. Paper recycling and its terminology 16
   1.4. Outline of the study 18

2. Study problem 20

3. Theoretical frame of reference 23
   3.1. Economic theory and linear technology 23
   3.2. Objectives of national society 25
      3.2.1. Level of living 25
      3.2.2. Economic growth 26
      3.2.3. Environmental quality 29
         3.2.3.1. Ecosystem concept 29
         3.2.3.2. Functioning of ecosystems 31
         3.2.3.3. State of environmental quality 34
      3.2.4. Economic growth vs. environmental quality 35
   3.3. Circular technology 37

4. State of paper recycling — empirical analyses 43
   4.1. Global situation 43
      4.1.1. Regional variations 43
      4.1.2. Regression models of 16 OECD countries 47
         4.1.2.1. Amount of recovery 47
         4.1.2.2. Recovery rate 52
         4.1.2.3. Utilization rate 58
      4.1.3. International trade 60
   4.2. Finland — a case of scarce timber supply 62
      4.2.1. Waste paper market 62
      4.2.2. Explanatory models 68
         4.2.2.1. Amount of recovery 68
         4.2.2.2. Recovery rate 70
      4.2.3. Forecasting models 71
         4.2.3.1. Trials of function forms 71
         4.2.3.2. Alternative forecasts 72
   4.3. U.S.A. — a case of environmental pressure 77
      4.3.1. Past development 77
      4.3.2. Future trends 81

5. Feasibility of increased recycling 84
5.1. Technological aspects 84
5.2. Economic aspects 88
5.3. Ecological aspects 93
6. Discussion 95
6.1. Reservations 95
6.2. Actions to increase recycling 97
References 99
Seloste 104
Appendices 107

LIST OF TABLES

Table 1. Expected ranges in the composition of mixed municipal refuse in the U.S.A. 15
Table 2. Consumption of waste paper and total fiber in paper and board production 1962—1967 43
Table 3. FAO estimates for waste paper recovery rates by regions 44
Table 4. Waste paper recovery rates in the 16 OECD countries 1961—1973 46
Table 5. International trade of waste paper in some OECD countries 60
Table 6. Waste paper recovery and consumption of paper and board in Finland, 1950—1973 64
Table 7. The correlation coefficients of logarithmic indices of the 13 variables in analyses of waste paper recovery in Finland, 1950—1970 69
Table 8. Consumption and recovery of paper and board in Finland, 1950—1973 and forecasts up to 1985 75
Table 9. Four alternative normative forecasts of waste paper recovery in Finland 77
Table 10. Consumption of fibrous materials and paper and board in the U.S.A., 1929—1972 78
Table 11. Three alternative projections for consumption of fibrous materials and paper and board in the U.S.A. up to 2000 81

LIST OF FIGURES

Fig. 1. Water use and main effluent generation in pulp and paper manufacturing 13
Fig. 2. Study problem within a country 21
Fig. 3. A theoretical linear-technology model for a paper production and consumption system 24
Fig. 4. An ecosystem model depicting linear energy flows and cyclical nutrient and water flows 30
Fig. 5. The interplay of major information systems 35
Fig. 6. Indifference curves describing levels of living as a function of gross national product (GNP) per capita and environmental quality 36
Fig. 7. A theoretical circular-technology model for a paper production and consumption system 40
Fig. 8. Recovered and consumed waste paper in the 16 OECD countries in 1969 48
Fig. 9. Major factor groups affecting waste paper recovery 48
Fig. 10. Hypothetical factors affecting waste paper recovery 49
Fig. 11. Recovery rates of waste paper in the 16 OECD countries in 1969 and 1971 53
Fig. 12. Recovery and utilization rates of waste paper in the 16 OECD countries in 1969 54
Fig. 13. Hypothetical factors affecting consumption of paper and board 55
Fig. 14. Utilization rates of waste paper in the 16 OECD countries in 1969 and 1971 59
Fig. 15. Amount of waste paper recovery, output of board and consumption of paper and board (indices, 1950 = 100, log scale) in Finland, 1950—1972 63
Fig. 16. Waste paper recovery rates in the Netherlands, Austria, Finland and Norway, 1961—1971 67
Fig. 17. Three alternative forecasts for consumption of paper and board per capita in Finland 74
Fig. 18. Consumption and recovery of paper and board in Finland, 1950—1972 and forecasts up to 1985 76
Fig. 19. The U.S. consumption of fibrous materials per ton of paper and board produced 1919—1972, with projections up to 2000 82

Photos: on sample page, p. 38, 65 and 86 provided by Paperinkeräys Oy; p. 15 Kuvapalvelu U. A. Saarinen.

0. SUMMARY

Water and air pollution caused by the pulp and paper industry have already been long and widely studied and discussed. Solid wastes form the third category of environmental deterioration due to the production-consumption system of pulp and paper. Waste paper, which is not recycled nor incinerated, is a major component of these solid wastes.

Waste paper recycling has been practiced on a small scale for centuries, but globally the recovery rate has never risen very high. The total world consumption of paper and paperboard was 127 million metric tons in 1970. About 23 % of this amount has been recovered for manufacturing of new paper and paperboard.

The bulk of waste paper until today has been negatively valued as solid waste. *The purpose of this study was to reveal the economic and ecological prospects of waste paper recycling.* This was carried out by attempting to identify factors favoring and limiting increased industrial reuse of waste paper.

Both in manufacturing pulp and paper and in consuming the products, wastes were for a long time dumped into water, the air and onto land without any reflection of the costs of resulting environmental deterioration in the prices of products. This linear technology worked satisfactorily in the early stages of industrialization.

Quite recently environmental quality has been widely approved as an essential goal for national societies. Therefore, efforts have been made to promote the transformation of the traditional linear technology towards a circular tehnology, in which production and consumption are organized in harmony with the proper functioning of the ecosystems. *The circular technology* of the pulp and paper production-consumption system requires a strong increase in waste paper recycling.

In recent years waste paper has comprised almost a quarter of all fibrous raw materials consumed in the world's production of paper and paperboard. The United States of America clearly had the highest tonnages of waste paper recovery followed by Japan, the Federal Republic of Germany and the United Kingdom. On the other hand the lowest amounts of recovery among the chosen 16 OECD countries were observed in Norway, Denmark, Finland and Austria.

The most significant factors causing such a great variation in the amounts of waste paper recovery (from 11.3 to 0.1 million tons in 1969) were explored by correlation and linear regression methods with cross-sectional data of the 16 OECD countries from the year 1969. The variation in the amounts of recovered waste paper was caused mainly by consumption of paper and paperboard, recovery costs and the structure of the paper and board industry.

The recovery rate of waste paper is defined as a ratio of the amount of recovered waste paper to total paper and board consumption, expressed in per cent. Recovery rate describes the country's ability to transform »consumed» and discarded paper and paperboard from a waste deteriorating the human environment into a useful resource. Among the 16 OECD countries studied the Netherlands had the highest recovery rate of 39 % in 1969. It was followed by Japan, Switzerland and Austria. Recovery rates under 20 % were observed in Norway, Denmark and Canada. This variation in waste paper recovery rate was best explained by costs of recovery, prices of paper and paperboard, level of wages and scarcity in the supply of virgin fibers.

The ratio of consumed waste paper to total paper and paperboard output is referred to here as utilization rate (%). It thus describes the relative importance of waste paper among the fibrous raw materials available for paper and paperboard production in each country. Lately, the Federal Republic of Germany has had the highest utilization rate of 46 %. The next highest utilization rates were found in the United Kingdom, Japan and the Netherlands. On the other hand, Finland, Canada, Sweden and Norway formed a clearly distinct group in this respect. Each of them had a utilization rate of 7 % at most. These countries have relatively small domestic consumption of paper and paperboard compared to their overall production capacities as they all are rather heavy exporters of these commodities. In addition, utilization rate seemed to be affected by the scarcity in the supply of virgin fibers, recovery costs, structure of paper and paperboard industry and prices of paper and paperboard.

Finland, as a case of a country having scarce timber supply, was studied in more detail based on time series of 1950—1970. During this period the amount of recovered waste paper had varied from 14 000 to 140 000 tons. In accordance with the cross-sectional analysis of the 16 OECD countries the consumption of paper and paperboard was also the strongest explanator of the variation of recovered waste paper in Finland. In addition, prices of paper and board appeared to have explanation power.

During the period 1950—1970 the recovery rate varied annually in Finland from 8 to 27 per cent. This variation was explained by the time factor, prices of paper and paperboard and scarcity of timber supply. The last two explanators were also found effective in the analysis of the 16 OECD coun-

tries. Time is often considered to include changes in technological know-how and in level of other knowledge.

Alternative *forecasts of waste paper recovery in Finland* up to 1985 were also developed by simple linear regression models. This forecasting was carried out in two steps. First, the consumption of paper and paperboard was forecast by using two growth predictions of gross domestic product. Second, the forecasts of waste paper recovery were produced using consumption forecasts as input data. According to this trend forecasting procedure the recovery rate in Finland will be about 26 % in 1985 and the amount of waste paper recovery 275 000—342 000 tons.

As a second approach alternative normative forecasts of waste paper recovery in Finland were made by applying four different recovery rates and the above low forecast of the consumption of paper and paperboard. The *increase in waste paper recovery from 1973 to 1985* would be 121 000—308 000 tons according to these varying recovery rate assumptions. The minimum rate (25 %) represents approximately the recovery rate forecast above and the highest rate (42.5 %) is assumed to represent the maximum realizable recovery rate. Forecasts of this kind are thought to be useful in planning and goal-setting for future waste-paper recovery activities in Finland. The normative forecast based on the recovery rate of 35 % showed for 1980 waste paper recovery of 308 000 tons or 0.8—1.7 million m^3 in pulpwood equivalents.

The target designed by the experts working in the waste paper market is based on establishing a deinking mill using waste paper as raw material. According to this target a recovery rate of 34 per cent will be reached by 1980.

About 11 million metric tons of waste paper were recovered in *the United States* in 1969. While the consumption of paper and paperboard doubled during the period 1950—1970 the amount of consumed waste paper increased only by one third. Recovery rate decreased from 27 to 23 per cent from 1950 to 1970. A similar but even stronger trend was observed in utilization rate of waste paper.

The state of waste paper recycling in the United States has quite recently taken new lines of development. The major pressure for recycling more waste paper has come from the environmentalists' side. The proportion of waste paper in the total consumption of fibrous materials by the paper and paperboard industry was 19 % in 1970 and it has been projected to grow to 34 % by the year 2000. According to the predictions recovery rate is expected to increase from 23 to 35 per cent from 1970 to 2000.

The bulk of waste paper reused today goes to various paperboard products. The fiber making process essentially consists of pulping and screening. The effluent disposal problem is relatively minor compared to that of a deinking plant.

The conversion of waste paper into most other paper grades requires the separation of ink from the fibers. New deinking systems generating only a limited amount of waste effluent have been developed, and also fiber fractioning and cleaning systems for separation of the undesirable components of waste paper. On this front, however, a great deal of research and development will still have to be done.

Once consumed, most products of paper or paperboard can be recovered and again become raw material for new products. These cycles can continue several times. The *potential recovery* due to these repeated cycles is considerably higher than the simple recovery estimates. Specific equations to estimate this potential recovery were developed by the authors.

The generation of energy has lately become a vital environmental issue. Energy requirements of waste paper recovery and processing are generally lower than those of logging and processing of virgin fiber.

In about 15 years the *world consumption* of paper and paperboard is expected approximately to double according to FAO forecasts. Faced with the above prospects it seems likely that the global amounts of waste paper recovery will also grow strongly in the future. The recovery rate for waste paper could eventually grow from 23 to 35 per cent during the period 1970—2000 on a world-wide basis.

According to the global prospect with the recovery rates 23 % and 35 % the amount of recovery will be 60—90 million tons by the middle of the 1980's. This would mean from 120 to 230 million m^3 in pulpwood equivalents. However, in the first place paper and paperboard producing firms are the decision makers which finally determine to what degree waste paper will be used as a raw material in the future. In that respect the future price developments of waste paper, virgin wood fibers and synthetic fibers are of utmost importance.

The increase in waste paper recovery and use makes one step in the transformation from linear to circular technology. Recycling reduces the volume of municipal solid waste and in this way lowers the costs of waste disposal and pressure against ecosystems.

In a situation of scarce virgin fiber supply, where alternative sources of fiber are not competitive, an increase in waste paper recycling compensates extra timber cutting and in this way conserves forests. When waste paper substitutes for an equivalent amount of wood pulp, recycling reduces environmental deterioration by the difference in quantity of pollution caused by wood pulping from that of waste paper processing.

1. INTRODUCTION

1.1. Environmental economics

Man's relations to his physical environment have been comprehensively discussed at various occasions in recent years. There is a growing concern about future development of the human habitat. This has been reflected in new legislation by national governments and in numerous activities by international organizations.

The concept of physical environment has been briefly defined as the nature surrounding man (cf. S a a s t a m o i n e n 1971, p. 16). Environment has also often been identified as being land, water and air (cf. D a s m a n n 1968, p. 19). In most cases environment has not been defined at all or its definition has been somewhat vague (cf. D a h m e n 1970, p. 12—13).

In this paper the definition of the environment as applied in general systems theory is employed: »For a given system, the environment is the set of all objects a change in whose attributes affect the system and also those objects whose attributes are changed by the behaviour of system» (H a l l & F a g e n 1956). When »a given system» is replaced in this definition by a man, by a group of men or by the whole of mankind according to the problem at hand, a systematic content has been given to man's environment. Further on, if the objects are restricted to the physical, then we have arrived at a specific definition of man's physical environment. In the above definition, the degree of »affecting» and »changing» still remains to be determined by the factors relevant to the problem studied.

Environmental deterioration (ympäristön pilaantuminen in Finnish) has been defined as comprising physical, chemical and biological changes in the human environment which affect detrimentally man's health, either physical or psychic, or which hinder satisfaction of human material or mental needs. On the other hand, more or less the same phenomenon is called environmental pollution (ympäristön saastuminen in Finnish). (Vuoden 1970 ympäristön . . . 1970, p. 6.)

In another interpretation pollution is referred to in a more restricted sense as a change in environmental quality affecting man's health or satis-

faction of mental needs (Ympäristönsuojelun . . . 1972, p. 5—6). The latter convention is adopted in this paper.

In economics the concepts of externalities, public goods, etc. have been known for a long time. Until recently, externalities seem to have been regarded »as rather freakish anomalies in an otherwise smoothly functioning exchange system» (K n e e s e 1971b, p. 2). However, at the pace air and water have been disappearing from the classrooms as the traditional examples of free goods, the above situation has been changing fast. In recent years numerous papers have appeared in the field of environmental economics (cf. OECD 1972).

K e n n e t h B o u l d i n g (1950, p. 3—25) was one of the few early modern economists who used ecosystems as a premise in constructing economic theories. His interest lay mainly in the dynamics of ecological equilibrium. In recent years economists have perceived more clearly that man's physical environment is mainly composed of ecosystems. Consequently, there must be close connections between ecology and economics, the former studying the behaviour of ecosystems, the latter that of man. Accordingly, attempts have been made to fit these two ecosciences more smoothly together (cf. S a a s t a m o i n e n 1971).

1.2. Deterioration caused by production and consumption of pulp and paper

A number of different process methods are applied in the manufacturing of pulp and paper. Accordingly, operating conditions vary within a wide range from one process to another. Characteristics of the physical plant form another major contributor to this variation. Among other consequences, this situation is reflected by a great variation in effluent generation. In Fig. 1 the main effluent sources in pulp and paper manufacturing can be seen.

Water plays an important role in the manufacture of pulp and paper. This industry is one of the biggest water-using industries. The effluents discharged into the water-courses may contain dissolved organic compounds and chemicals used in the pulping process, fibers, fillers and additives, colour, bark, ash and lime sludge. The dissolved compounds originate mainly in the pulping processes but suspended solids are present in effluents from all stages and parts of the industry.

The impact of the effluent flows on water deterioration is measured by estimating water use and generation of suspended solids, total solids (suspended and dissolved) and BOD_5. The last indicator, Biochemical Oxygen Demand, measures the oxygen consumption of an effluent within five days from the time of generation.

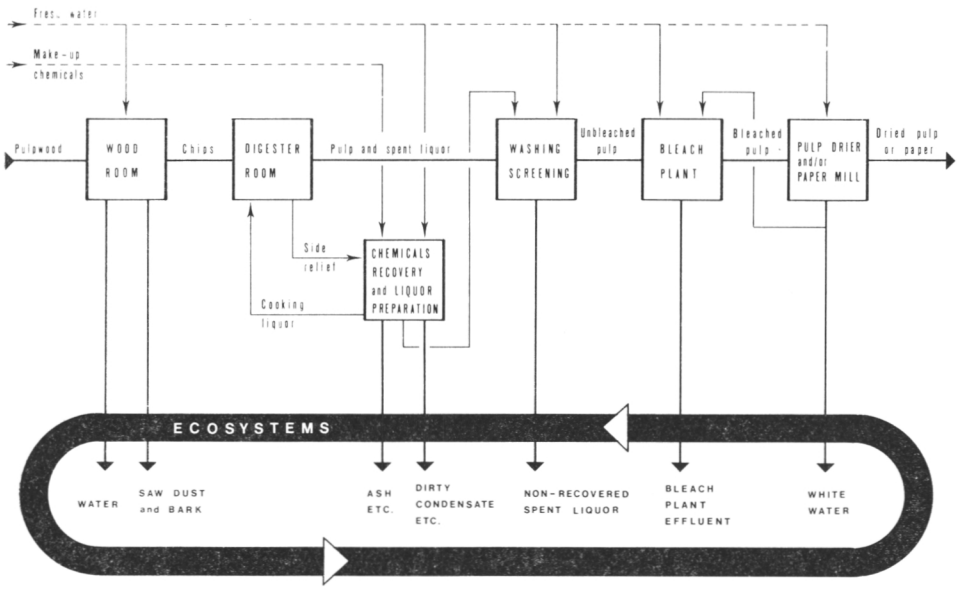


Figure 1. Water use and main effluent generation in pulp and paper manufacturing. (Cf. Hultin & Patoharju 1963)

An overall survey of the water deterioration situation in Finland was made in 1970. The share of the wood-based industries in the total waste water load was estimated according to four indicators as follows:

	%
— BOD_5	88
— total solids	84
— phosphorus (P)	28
— nitrogen (N)	23

These indicators are not commensurable. Only with certain reservations can integrative estimates be made. (Ympäristön pilaantuminen . . . 1970, p. III 113—115.)

In Finland, pulp and paper making is responsible for almost 100 % of the water deterioration by wood-based industries. As an integrative estimate the share of the pulp and paper industry is about 75 % of the total waste water load of the Finnish lakes (Mikola 1970, p. 229). In other major pulp and paper producing countries this industry is also regarded as one of the strongest contributors to water deterioration (cf. OECD 1973, p. 10—13).

On the other hand, not only water but also air is deteriorated by pulp and paper mills. This atmospheric deterioration normally comprises particulates, odorous gases and sulphur dioxide and almost all of it originates from the chemicals emitted by the pulp mills. Pollutants containing sulphur cause

most air deterioration problems. Air pollution problems are normally limited to the neighbourhood of pulp mills. (Cf. OECD 1973, p. 11—12.)

Considering water deterioration, the kraft process is overwhelmingly purer than the sulphite process. However, with respect to air deterioration the situation is reversed. The non-oxidized sulphur lost by the kraft mills in Finland form only about 4 % of the total sulphur losses to the atmosphere, but they are extremely bad-smelling in the form of specific sulphur compounds such as H_2S, CH_3SH, CH_3SCH_3 and CH_3SSCH_3. (Cf. B ä c k s t r ö m 1970, p. 46—47.)

In the Federal Republic of Germany the smells of the kraft process are considered so disturbing that this otherwise »pure» process is not favored. In the same country there have been cases where, to prevent additional air deterioration, the construction of burning facilities for the waste liquours of the calcium-based sulphite process has not been allowed, despite the fact that water deterioration could have been considerably reduced by this action. (Cf. W e s t e r b e r g 1970, p. 10.)

Solid wastes form the third category of environmental deterioration caused by production and consumption of pulp and paper. *Solid wastes comprise bark, lime sludge, ash, mud from water treatment plants, and in a wider sense, waste paper which is not recycled nor incinerated.*

The environmental problems of the pulp and paper industry have been widely studied and discussed in recent years in various countries (cf. OECD 1973; Ympäristön pilaantuminen . . . 1970; M i k o l a 1970; H a l l 1970; F r e y s c h u s s 1970). The Central Association of Finnish Woodworking Industries has even launched a »Programme for the water-protection policy» (1970) of its own. In these connections, however, consideration has usually been focused only on the production phase of pulp and paper, disregarding the deterioration effects of consuming these products.

The nature of consumption has not often been analysed. The flow of materials — minerals, fuels, gases and various organic stuffs, including timber — is initiated by extracting and harvesting them from nature. They are then used by producers and consumers. Although material residuals are generated during these processes, their mass must be about equal to that initially extracted from nature. »Accordingly, it is basically depletive to speak of the consumption of goods. The services which material objects can yield are used, but their substance remains intact.» (K n e e s e 1971a, p. 154—155.)

A majority of consumption residuals and a significant part of production residuals pile up as solid waste (municipal refuse). This is defined, in the broadest sense, to include all waste materials that are not handled by air or waterborne carriers (D r o b n y et al. 1971, p. 5). For example, the amount of municipal solid waste generated in the U.S.A. has been estimated at 136—145 million tons annually (D r o b n y et al. 1971, p. 3; A t c h i s o n

Table 1. Expected ranges in the composition of mixed municipal refuse in the U.S.A. (D r o b n y et al. 1971, p. 5).

Component	Per cent composition as received (dry weight basis)	
	Anticipated range	Nominal
Paper	37—60	55
Newsprint	7—15	12
Cardboard	4—18	11
Others	26—37	32
Metallics	7—10	9
Ferrous	6—8	7.5
Nonferrous	1—2	1.5
Food waste	12—18	14
Yard waste (grass, etc.)	4—10	5
Wood	1— 4	4
Glass	6—12	9
Plastic	1— 3	1
Miscellaneous	<5	3
		100
Moisture content:		
Range (per cent)	20—40	
Nominal (per cent)	30	

1972, p. ES-26). From the viewpoint of the problem at hand, it is interesting to know the estimated composition of this refuse. Illustrative figures are presented in Table 1.



About half of the municipal solid waste is of paper and board.

The share of paper and paperboard in the total municipal refuse has varied in the U.S.A. between 37 and 60 per cent (Table 1) according to different sources. It can be concluded that refuse composition is highly variable according to geographical location, climate, season, and the socioeconomic characteristics of the contributing population, and hence these figures must be used with certain reservations. *Although most countries lack this kind of information it can be supposed that waste paper has a significant role in nearly all industrialized countries as a major component of municipal solid waste.*

1.3. Paper recycling and its terminology

However, not all paper products cause deterioration of the environment after consumption. According to the FAO secretariat (FAO 1971, p. 2) the world industrial use of waste paper rose from about 18.8 million tons in 1962 to 24.8 million tons in 1967. Over the same period waste paper recovery constituted as a global average about 23 % of all paper and paperboard produced and consumed. The output and apparent consumption of paper and paperboard in the world was 106.7 million tons in 1967. Thus globally, in 1967 about 82 million metric tons of various paper products were not reused. The total world consumption of paper and board was 127 million tons in 1970 (a mean of the production figures from the years 1969—1971). (FAO. Yearbook . . .)

A portion of this quantity falls into a category of preserved products, for example books, a minor part is incinerated and another part may have some nonindustrial use, but the majority of this 82 million tons can be judged to deteriorate the environment in one way or another after being discarded.

In fact, recycling of materials has long traditions in the paper industry. For example, »on August the 19th in the year 1366, the governing body of the City of Venice issued a directive that all old papers and waste papers had to be salvaged and sent to a certain paper mill in Treviro» (L e h t o, p. 4). A somewhat later note about the reuse of printed paper dates from 1595 in Denmark, but it was not until 1800 that the British patent office issued a patent covering the reuse of printed papers (R i c h a r d s o n et al. 1971, p. 53).

Before wood was introduced as a raw-material base, rags were collected for industry for centuries. By the middle of the 19th century first efforts were made in Germany, France, Great Britain and the U.S.A. to collect waste paper in order to make new paper from it (R i c h a r d s o n et al. 1971, p. 53; cf. A a l t o, p. 17). Gradually there appeared specialized dealers to supply industry with this raw material. For example, the British Waste Paper Association was founded in 1921 to further the interests of member merchants (R i c h a r d s o n et al. 1971).

Generally speaking, traditional waste-paper markets in western countries have been functioning according to the laws of supply and demand without any remarkable ideological content or government interference. However, recent efforts to increase paper recycling, especially in the U.S.A., have been based on the environmental consciousness of consumers. Clean the environment and save the trees! This was to a great extent the driving slogan behind the American ecological movement when recently organizing nation-wide waste-paper collections for recycling (cf. H a n l o n 1971).

On the other hand, for example in Finland, there is constantly a strong pressure to expand pulp and paper production. The most limiting factor is timber resources. At present a contract between The Bank of Finland and The Central Association of Finnish Woodworking Industries specifies that new expansion can only be tolerated to the extent allowed by the timber output under sustained-yield forestry (L i n n a m i e s 1971, p. 212—214). Accordingly, much effort has been devoted in recent years to finding new wood raw-material sources from logging and industrial waste, branches and stumps of trees etc. (cf. E r v a s t i et al. 1970, p. 23—24).

Terminology in the waste paper trade has been somewhat unclear in various statistics. For this reason in part, the data presented can be regarded as approximations. The terms used in this study are defined as follows (cf. A t c h i s o n 1972, p. 41, 48).

Waste paper consists of a heterogenous mixture of discarded paper and paperboard in all its forms. Paperstock and secondary fiber are terms used for the reusable part of waste paper. Waste paper is generated mainly in the consumption phase of paper and board. Two essentially different cases occur:

(1) consumption of newspapers, magazines, packaging materials, napkins, etc. by *households* and
(2) consumption of containers, packaging papers, letters, punched cards, records, etc. by *business firms* and by *various other organizations*.

Lesser amounts of waste paper are generated in:

(3) *converting and printing of paper and paperboard* as trims and other waste
(4) the *production of paper and paperboard* at mills in the form of »spoils» and »broke». There seem to be some variations by countries as to whether the last item is included in waste paper. (Cf. R i c h a r d s o n et al. 1971, p. 3.)

Recovery or the amount of recovery is the amount of waste paper collected (recovered) for new industrial use.

Recovery rate is the amount of recovery as a percentage of total paper and paperboard consumed by final consumers. Synonymous terms, but not very

commonly used are »salvage rate» and »collection rate». Recovery rate is a clear and well-known term used by FAO and also in this report.

Furnish rate is the amount of waste paper furnished in paper and board manufacturing as a percentage of total utilization of fibrous materials. Consumption rate is identical to furnish rate but the latter is preferable.

Utilization rate has in some cases had the same meaning as furnish rate (for example, OECD: The pulp and paper industry). However, in this study utilization rate is defined as the amount of waste paper consumed in paper and board manufacturing as a percentage of total output of paper and paperboard.

Recyclable fraction is the fraction of the total paper and board consumption which theoretically can be recovered. Within the U.S.A. the recyclable fraction is normally considered to be about 75—80 % of the total paper and board consumed (A t c h i s o n 1972, p. 48). In Finland this fraction is estimated to be about 85 % (cf. M ä k e l ä 1973). The difference between these two estimates is due to different structures in the consumption of paper and board and slightly different estimating bases. »*Nonrecoverable paper and board*» is the difference between total consumption and the recyclable fraction.

Recycling rate is the amount of recovered waste paper as a percentage of the recyclable fraction. If the recovery rate were 40 % and the recyclable fraction 80 % the recycling rate would amount to 50 %.

Tons in this study are *metric tons*.

1.4. Outline of the study

The purpose of this study is to explore the economic and ecological prospects for waste paper recycling. This is carried out by attempting to identify factors favoring and limiting the increased industrial reuse of waste paper. The various stages of the study are as follows.

First the study problem is deliniated in more detail. (Chapter 2.).

In the theoretical frame of reference (Chapter 3.), elements of traditional economic theory relating to a firm and to a consumer and a model of linear technology for a paper production-consumption system are first introduced. Second, various objectives of a society are analysed. Contents of level of living and economic growth are briefly described. Special attention is focused on environmental quality (Section 3.2.3): the ecosystem concept is first analysed, then the idea of ecological equilibrium is introduced, and finally an outline is given of how to measure the state of environmental quality. Economic growth and environmental quality as simultaneous goals for a society are considered in Section 3.2.4. The theoretical frame of reference is concluded by describing a model of circular technology for a production-consumption system of paper (Section 3.3).

In the empirical analyses on the state of paper recycling the global situation with respect to the recovery and consumption of waste paper is first described. The recovery and consumption of waste paper is presented by world regions in Section 4.1.1. In the next stage an explanation of the variations in the amounts of recovery, and rates of recovery and utilization of waste paper in 16 OECD countries is attempted by applying regression and correlation analysis. International trade of waste paper is described in Section 4.1.3.

Finland is selected as a case of a country with scarce timber supply (Section 4.2). The specific characteristics of the Finnish waste paper market are deliniated. Explanation and forecasting models on the amount of recovery and on the recovery rate are developed. Also the situation in the United States is studied as a case where environmental pressure has recently affected the recovery of waste paper (Section 4.3).

The feasibility of increasing waste paper recycling is focused from the technological, economic and ecological aspects in Chapter 5. Finally, reservations concerning the study results and actions to increase waste paper recycling are discussed in Chapter 6.

2. STUDY PROBLEM

Two initial conclusions can be drawn from the definition of waste paper (p. 17). First, the amount of waste paper generated in each country depends primarily on the total consumption of paper and paperboard and secondarily on the total production of these products and of products based on them. Second, waste paper differs from pulpwood in that it is available mainly in heavily populated areas.

In Section 1.2. the various environmental deterioration effects of pulp and paper production and consumption were briefly introduced. Waste paper's substantial role in the accumulation of municipal refuse was also mentioned. The growing inadequacy of traditional methods of solid waste disposal is widely recognized. Suitable landfill areas near urban centers are becoming increasingly scarce and more costly to purchase. Many landfills are not properly operated and impose external costs through their effects on air, water and landscapes. Open burning is being outlawed in many cities because it causes air pollution. Open dumping is disfavored for many reasons, including health hazards, esthetic considerations, insect and rodent proliferation and water pollution. Finally, traditional incineration is becoming more costly because of air-quality standards. (Cf. D r o b n y et al. 1971, p. 3; Jätehuoltokomitean . . . 1970, p. 80—110; K n e e s e 1971b, p. 18—19.)

If the large-scale reuse of waste paper could be *considerably increased* from the present (cf. Section 1.3.) in a situation of a high ratio of timber drain to potential cut and where alternative sources of fiber are not competitive, two other environmental aspects are involved. The equivalent decrease in wood pulp requirements (1) prevents over-cutting of forests and (2) reduces environmental deterioration with the assumed difference in pollution (emissions, effluents and energy requirements) caused by wood pulping when compared to that by waste paper processing.

Social objectives are an attribute of culture. Hence they change according to time and place. For example, traditional economic growth as a principal objective for many countries is being replaced by environmentally balanced economic growth or by various social indicators. Goals and values are not absolute: both of them are interwoven and simultaneously determined in a

general relativistic system. With respect to the achievement of goals, values can be either positive or negative. A *resource* can be defined as something which has a positive net value either when used as an input in productive processes or when directly consumed. Consequently, resources have been changing and will continue to change due to changing social objectives and values in addition to other relevant factors such as technological change, etc. (Cf. D u e r r 1966, p. 43—54.)

The bulk of waste paper has so far been negatively valued as solid waste. In view of the considerations presented above, a substantial part of it might be converted into a resource.

The basic hypothesis underlying the study is that the high degree of environmental deterioration in many countries will affect (1) the paper and paperboard producing firms and (2) households, other firms and other organizations consuming these products and (3) governments with the result that paper recycling will be considerably increased.

Similar views have also been presented elsewhere. For example, a seminar by the American Paper Institute surmised that some factors may now contribute to the increasing use of waste paper such as »(a) greater consumer and industry interest and awareness of environmental problems; (b) diffi-

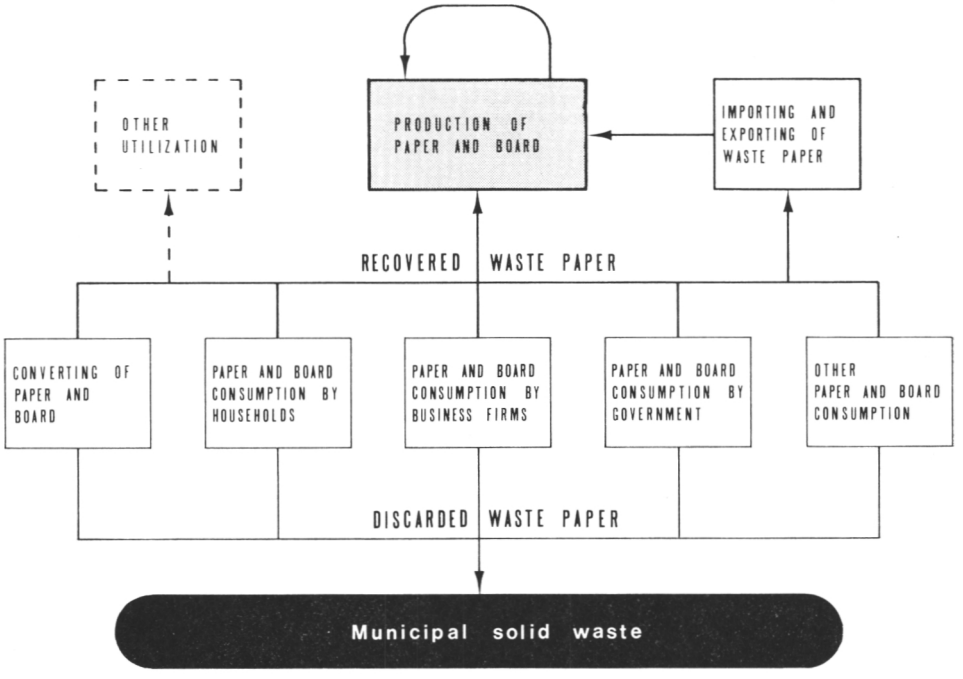


Figure 2. Study problem within a country.

culties in finding new sites for pulp mills; (c) rising wood costs; (d) the relatively low investment requirements of waste paper-based mills» (FAO 1971, p. 3).

Finally, one of the strongest incentives for increased paper recycling is the reduction of the delivery price at the consuming mill, allowing more favorable prospects for the supply of this raw material. At present the question concerns mainly the future development of the price ratio between secondary fibers and virgin pulp. This development can be affected partly by firms and partly by external factors. The profitable use of secondary fibers depends, on the other hand, on the demand for products based totally or partly on these fibers.

The study problem is depicted in Fig. 2. Five major sources of waste paper generation are identified in the middle of the figure. Discarded waste paper piles up as municipal solid waste in the lower part. Simultaneously, in the upper part waste paper is recovered for the production of new paper and board. *What is the theoretical frame concerning the interplay of economics and ecology applicable to this study problem? What are the terms of trade in the movement of waste paper in these two directions? What factors determine the functioning of the waste paper market? Why do the amounts of recovery, recovery rates and utilization rates vary by countries and from time to time?* An attempt has been made to clarify these basic questions when economic and ecological prospects for waste paper recycling are analysed in more detail in this study.

3. THEORETICAL FRAME OF REFERENCE

3.1. Economic theory and linear technology

The traditional theories of a firm and a consumer have until recently formed the basis of microeconomic theory. Under this system it was postulated that the goal of the firm is to maximize its profits. On the other hand, it was assumed that the consumer is motivated by his desire to maximize the satisfaction he gets from the commodities purchased in the market.

Assumed to have a given income, the consumer has the freedom of expressing his preferences in two respects: (1) how much to consume now and how much to save for later; (2) the mixture of goods and services to be consumed. In making these decisions, he is guided to a great extent by the prevailing price system.

When maximizing its profits the firm has to choose what kind of production technology to use. In a competitive market, a production technology is chosen which gives the lowest production costs, and production is carried on to the point where marginal costs of a product are equal to the marginal revenues.

In a competitive market, the demand for and the supply of a product largely determines its price. At the same time, it is not possible for a firm to produce over a long period an item whose price is lower than its average costs of production. Accordingly, the requirement for staying in business is that a minimum price is equal to minimum average costs.

An interesting question is what kind of items are included in the production costs of a firm. The answer is the following: those production factors having market prices, such as raw materials, labor, capital and land. Other factors such as water and air usually have been free. Furthermore, the social costs of deteriorating the environment are not included. Consequently, a firm can make its choice of a production technology considering only the production factors having market prices, without paying too much attention to the environmental pollution effects or other external costs.

Based on this theoretical outline a linear-technology model for a paper production-consumption system was developed (Fig. 3). In this model

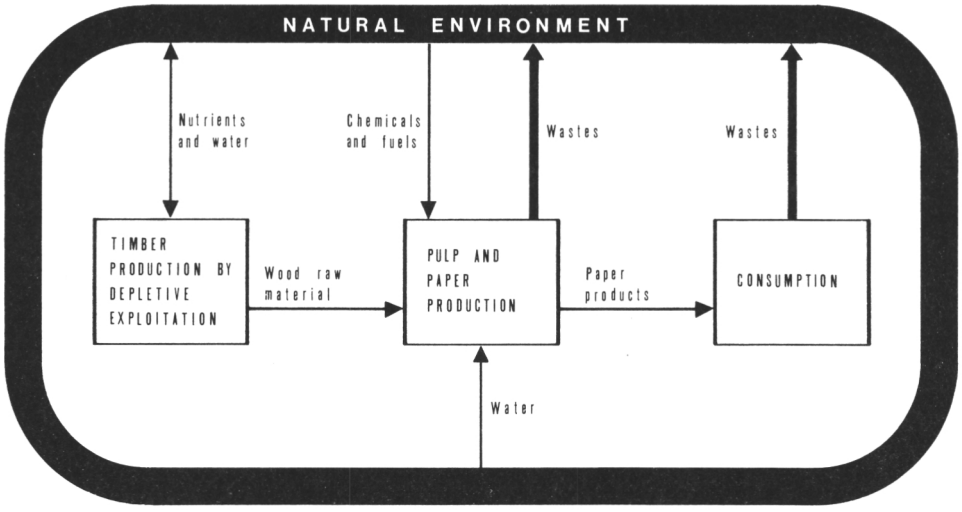


Figure 3. A theoretical linear-technology model for a paper production and consumption system.

wood raw material is extracted from the forest by a depletive exploitation method: no concern is given to the renewal of timber resources. Both in manufacturing pulp and paper and in consuming the products, wastes are dumped into water, the air and onto land without any reflection of the cost of resulting environmental deterioration in the prices of the products. The existence and functioning of natural ecosystems as a physical environment for production and consumption is not recognized.

Fig. 3 introduces a theoretical simplified model. In a few countries there already existed forest legislation to prevent depletive exploitation at the time of establishment of a wood-based paper industry. From the human point of view, linear technology close to the model of Fig. 3 worked satisfactorily at the earliest stage of industrialization. This was especially true in cases of abundant forest resources, scarce population and small-scale production.

However, before long wood raw material became scarce, particularly in Europe outside its eastern and northern regions, due to a growing demand for many purposes. Depletive exploitation of forests came to be prohibited more strictly and in more numerous countries, and specific legislation to this effect was passed. This development was reflected somewhat later also in Scandinavian and in many other countries as well. Consequently European foresters were, by and large, relatively early in applying the ecological principle of sustained yield to the management of forest resources.

On the other hand, for a long period after the beginning of the wood-based pulp and paper industry, in most countries there was plenty of carrying capac-

ity in the ecosystems for the wastes of linear production and consumption of pulp and paper products. No remarkable pollution or deterioration of the environment occurred. However, the rapid growth in both production, population and urbanization during the first decades of this century changed the situation totally.

3.2. Objectives of national society

3.2.1. Level of living

As long as human societies have existed they have defined, either explicitly or implicitly, certain objectives as desirable. Classical capitalism relied heavily on the free exchange of goods and services through the market. This belief was strengthened by the theory of welfare economics where, from the rigorous assumptions of the pure competition model, the conclusion was reached that when consumers maximize their satisfaction and producers their profits the system will automatically be steered in such a way that social benefit at a macro-level will also be maximized (in the sense of Pareto-optimum).

Employment, social security, distribution of income, economic growth, etc. are of comparatively recent origin as explicit objectives of societies. Usually they are conceived as *indicators of components of the level of living.* In addition, many concepts, such as standard of life, standard of comfort, standard of living, norm of living and level of aspiration, have been used to describe related phenomena in the sphere of social goals (cf. W a l l s 1963). In spite of a recent active interest in this topic, there still exists among researchers some confusion considering the content of these various concepts. Confusion is even stronger among politicians and the general public. More thorough theoretical and empirical examination of the level of living was lately carried out by H e i k i n h e i m o et al. (1974, p. 13—29).

By level of living in this study is understood the actual living conditions of a people (International definition . . . 1961, p. 1). The charter of the United Nations states that a higher level of living is one of its goals. This has also been approved as a main goal of several UN special organizations. Accordingly, there has appeared an international need for a specific definition of the concept of level of living.

Level of living refers to the degree of accomplishment of various human needs, both tangible and intangible. Knowing the strong variability of these needs according to place and time it is easy to understand the practical difficulties in measuring level of living. An early UN committee concluded that the most satisfactory approach to quantification was through the measure-

ment of clearly restricted aspects of the total life situation that *reflected generally accepted goals of social and economic policy at the international level.* The same committee pointed out a distinction between components and indicators of level of living. Level of living is composed from various components, which must first be determined. Each of these components is measured through particular quantifiable indicators. For example, mortality is considered as one of the indicators of the component of health, and unemployment rate indicates one aspect of the component of employment and conditions of work. (International definition . . . 1961, p. 1.)

As an interim guide for international comparisons of level of living a list of components and their indicators was approved by the UN in 1961 (International definition . . . 1961). According to this list the following components were included in level of living: (1) health, (2) food consumption and nutrition, (3) education, (4) employment and conditions of work, (5) housing, (6) social security, (7) clothing, (8) recreation and entertainment and (9) human freedoms. For components 1—5 there were 2—4 indicators for each proposed, but for components 6—9 no indicators were identified because of difficulties of measurement.

In addition to these components and corresponding indicators the following three general indicators were defined: (1) proportion of deaths at the age of 50 and over in relation to all deaths, (2) expenditure on food as a percentage of household expenditure, (3) ratio of agricultural male labour force to total male labour force. These three indicators were considered to reflect the general level of living, although they were not included in any specific component.

Considering the vast content of level of living it is understandable that no single comprehensive measure is able to describe it satisfactorily. Each particular indicator measures only a restricted aspect of level of living. No agreement exists on how to weight these various components and indicators.

3.2.2. Economic growth

Economic growth is an old phenomenon. It has particularly been connected with technological innovations, discoveries of new »lands» etc. However, by and large it was not until the Keynesian revolution in economic theory of the 1930s and 1940s that economic growth became the explicit principal objective for the economic policy of several western nations.

An information system for national accounts was created in most countries to produce indicators of economic activity. The growth of gross national product (GNP) per capita was generally chosen as an indicator to measure economic growth. Accordingly, for numerous countries raising GNP per capita as rapidly as possible within certain restrictions of inflation, balance of

payments, etc., was chosen as a main goal for economic policy. In broad terms this policy produced a higher level of employment and income for most members of a society.

In recent years growing criticism has been heard against using the traditional GNP per capita to measure economic growth. First, GNP measures the value of goods and services exchanged through the market (with minor exceptions), but it does not measure many activities such as laundry, haircutting, baking, etc. when carried out at home. Second, although natural resources form the essential base for production-consumption activities measured by GNP, no depreciation is made for the depletion of natural resources or the deterioration of the human environment. Generally, the concept has been criticised because it has concentrated on quantity rather than quality when fostering economic growth. (Cf. D a h m e n 1970; N i i t a m o 1970.)

The present ideology of economic growth can be summarized in the following way. If more commodities are produced this year than in the previous one, the economy has grown and welfare increased. The output of new commodities must be continuously increased in order to keep the rate of economic growth unchanged. The hypothesis here is that welfare depends only on the amount of new commodities produced. However, real economic growth should be defined as the quantity of new commodities produced in the current period less the quantity of commodities discarded over the same period. Accordingly a reduction in the amount of discarded commodities can increase »real economic growth» without any increase in production. This ideology makes it possible to increase welfare although the output of new commodities falls if the decrease in discarding exceeds this decline. Thus even »zero growth» alternative, as defined by the prevailing growth ideology, need not necessarily mean a decline in welfare. (Cf. P u l l i a i n e n 1972.)

The conflict between rapid economic growth and deterioration of the human environment is accentuated especially in highly industrialized countries, because large-scale and high waste generating industries coincide in space and time with large urban populations with only limited waste assimilative capacity. »A conservative estimate of waste flow in the United States currently would be 6—7 pounds of »active» waste produced per dollar of gross national product and there is some evidence that waste flow increases at a faster rate than income. This would undoubtedly be true for less developed economies attempting to industrialize with a very small services sector.» (d'A r g e 1971, p. 25.)

In the simple Harrod types of models describing economic growth, the greater the proportion of current output saved and invested the faster the economy is assumed to grow. In addition to the traditional expansion of production capacity, saving can also be a source for investment in the augmentation of waste-treatment plants, reservoirs and similar projects to increase the

capacity of the human environment for waste assimilation. On the other hand, the higher the saving rate in relation to depreciation or decay rates the smaller the current amount of wastes generated. (Cf. d'A r g e 1971, p. 31.)

There are four main categories of investment for reducing environmental deterioration: (1) recycling, (2) augmentation of the human environment's assimilative capability, (3) increasing efficiency of the existing production methods and (4) prolonging »life-time» of commodities and other measures of reducing increase in consumption of material goods. The last two categories will be excluded *in the following in accordance with d'A r g e* (1971, p. 31—32). Relationships between economic growth and environmental quality are described with a simple model of the Harrod type. *Assuming that production-consumption and waste generation are joint products*, the following equation can be formulated:

(1) $W = g_c (F—S)+g_f F$, where

W = a homogenous waste flow
F = the current output of material goods
S = saving
g_c = coefficient relating to the amount of waste flow from current consumption
g_f = coefficient relating to the amount of waste flow from current production

(2) $I_r = dK_r/dt$, where

I_r = investments in augmenting the assimilative capacity of the environment
K_r = measure of capital stock committed to augmenting the assimilative capacity of the environment
t = time

If density of wastes is postulated as properly measuring environmental quality, then the following equation can be constructed:

(3) $\dot{D} = \frac{1}{V} W—h\, I_r—\sigma$, where

$\dot{D}$ = dD/dt, when D = average waste density
V = a volume measure of the human environment
h = a coefficient
σ = natural assimilative capacity of the environment.

From equations (1) and (3) the following expression can be derived:

(4) $\dot{D} = \frac{1}{V}(g_c+g_f)\ F — \frac{1}{V} g_c\ S—h\, I_r—\sigma$

Changes in waste density are here related to investment in assimilative capacity, current saving and output. It is worthwile noting that even if investment (I_r) and saving (S) are both zero, there exists a positive rate of output which would yield no change in waste density. Expressing the same in ecological terms, an *ecological equilibrium* (cf. Section 3.2.3.2. below) is arrived at, where human waste generation is balanced by nature's ability to absorb it. If production-consumption activities increase over the above balance rate, then saving and investments to improve assimilation must be large enough to compensate for the extra wastes.

»*Economic growth and environmental quality are only compatible in the long run provided that as growth in output occurs, a significant proportion of investment is directed toward recycling wastes or increasing the assimilative capacity of the environment.*» (d'A r g e 1971, p. 40—41; cf. P u l l i a i n e n 1972, p. 120—122.)

3.2.3. Environmental quality

3.2.3.1. E c o s y s t e m c o n c e p t

Environmental quality is closely connected with the proper functioning of ecosystems. Although the modern concept of an ecosystem was already stated in the 1930s by the British botanist A. G. T a n s l e y (1935), its *wide* application had to wait until the ecological movement of the 1960s.

An ecosystem can be concisely defined as including organisms (plants, animals, microbes) and their habitat factors as elements viewed as a whole and connected by continual interchanges of various kinds, not only between organisms but also between the organic and inorganic elements. Ecosystems can vary enormously in kind and size. An ecosystem is a dynamic selfsteering system. The point of view of the researcher decides how an ecosystem is delimited for a particular problem (i. e. what elements and relationships are to be included in it). The ecosystem concept fits the framework of general system theory well. (Cf. P a l o 1971, p. 9—10, 53—54.)

For example, the forestry ecosystem can be broadly defined as that part of the general ecosystem which is concerned with making, distributing and consuming the goods and services of the forest. According to this definition, in addition to primary forestry production, the processing of its products and the distribution and the consumption of all goods and services originating from forests are included in the forestry ecosystem. Considering the same thing from another viewpoint: men, trees, other plants, animals, other organisms, machines, buildings, other facilities, soil, water and air are elements of the forestry ecosystem. The relationships between the various states of these elements and between different elements are also essential parts of the forestry ecosystem. (Cf. P a l o 1971, p. 18—19.)

According to the particular problem, different kinds of forestry ecosystems can be defined. Restrictions can be set, for example by geographical area, special functions, etc. An individual forest might be conceived of as an ecosystem. Basic ecological relationships are connected with the flow of energy. Accordingly, the description of energy flows through an ecosystem gives a tentative idea of its functioning. In every ecosystem solar energy is the only noticeable *original source of energy*.

In the case of a forest, there exist first of all green plants such as trees and grasses to synthesize solar energy and carbon-dioxide into various carbon compounds. These chlorophyll-containing plants are called *producers* or autotrophs (Fig. 4). Organisms such as squirrels and hares which get their energy by eating autotrophs are primary consumers or *herbivores*. On the other hand, secondary consumers or *carnivores* are animals such as owls and foxes which get their energy mainly by eating other animals. In many ecosystems (especially in aquatic ones) there are also tertiary consumers: carnivores eating carnivores.

In Fig. 4, there is still another group of organisms which are essential for the proper functioning of ecosystems: *decomposers*. They are mainly bacteria and fungi. Decomposers feed in a way totally different from consumers. By means of specific enzymes set on dead plants and animals, they absorb cer-

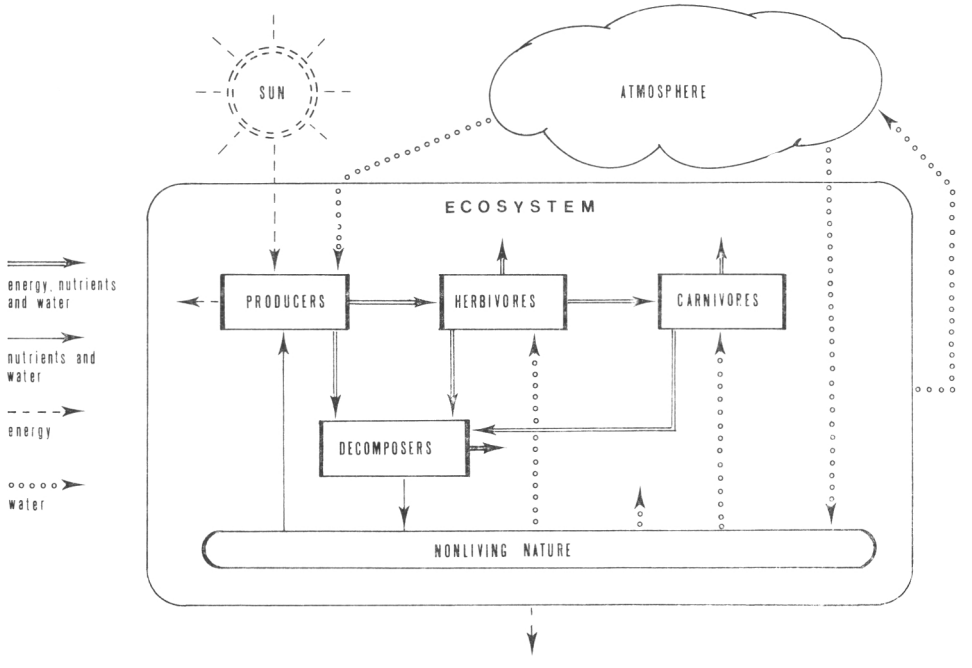


Figure 4. An ecosystem model depicting linear energy flows and cyclical nutrient and water flows.

tain decomposed stuffs. At the same time, decomposers mineralize organic compounds. *Decomposers are the key elements in the nutrient cycles of ecosystems.* By decomposing organic matter for their own nutrition, they make nutrients again available for plants or producers. (Cf. K o r m o n d y 1969, p. 14—18.)

Net primary output of the ecosystem is defined as total primary output less respiration of producers or the biomass of producers. It may be measured in kilograms or in calories over time. *The total biomass* of the ecosystem is defined as the summed biomass of producers, consumers and decomposers.

3.2.3.2. F u n c t i o n i n g o f e c o s y s t e m s

In ecosystems energy flows only in one direction (Fig. 4). Its route has been described as energy flowing through different trophic levels of a food chain. A food chain is formed by a series of organisms, in which organisms at the lower level are eaten by those at a higher level. At each transfer of energy from one trophic level to the next in this food chain, some energy is lost as heat, some is utilized to perform work and some is stored as chemical energy in the receiving organism's body. In accordance with the second law of thermodynamics, the utilization rate of energy from one level to another is poor, and ultimately all of it will be dissipated in heat. Consequently, food chains are generally short. (Cf. D a s m a n 1968, p. 34—35; C u n n i n g h a m 1974, p. 9.)

Energy flows along one-way routes through ecosystems and is utilized at all levels of the food chains to support life. Nutrients cycle predominantly from the soil to plants, from the plants to animals and through microbes again to the soil. The soil loses nutrients due to erosion, and the losses are replaced by the weathering of rock, by certain bacterial activities and from the atmosphere. *Water cycles* through closed routes from the atmosphere to the soil and watercourses and from these partly through ecosystems back to the atmosphere (Fig. 4). (Cf. D a s m a n 1968, p. 49—50.)

An ecosystem usually supports several populations of various organisms. The dynamics of each of these populations are governed by specific endogenic natality and mortality rates together with the age structure and number of individuals in the population. In addition there are several external factors affecting the development of populations. A general expression has been developed (cf. K o r m o n d y 1969, p. 80—82) to estimate the growth rate of a population (dN/dt):

(5) $dN/dt = rN\ [(K—N)/K]$, where

r = renewal capacity
N = actual number of individuals
K = maximum potential number of individuals in an ecosystem

In a steady state of population development the growth rate of the population equals zero. In equation (5), N and K are positive integers, and thus r must be zero in a steady state.

A steady state of population development is called its equilibrium state. However, population equilibrium does not mean a constant state but rather a dynamic variation around a specific mean. In some natural populations this variation is weak but there are also cases where this variation is quite strong and either regular or more or less irregular according to its nature. (Cf. K o r m o n d y 1969, p. 95—96.)

Because individuals within a specific population use the same kind of food, there always exists *competition* between individuals when the population grows. Competition is stronger the closer the actual number of individuals is to the maximum potential number. If two different populations use the same scarce nutrient, there is said to be competition between these populations. Those individuals and populations which have the best adaptation ability for the prevailing living conditions will survive. Under natural development the whole ecosystem changes, primarily as a result of competition, through different stages of *succession* towards a *climax* state. In the climax state, competition still continues but individuals and populations are so equal in strength that no considerable changes occur. (Cf. K o r m o n d y 1969, p. 101—121.)

A succession can be defined in this way. Organisms conquer a certain site under a process of continuous effects and counter-effects (competition). This leads through interplay to changes both in the organisms (populations) and in their physical environment (site). These changes are directed towards a climax state.

The most important properties for describing structural and functional aspects of an ecological succession are: (1) increasing diversity of species, (2) growth of structural complexity, (3) accumulation of organic matter and (4) a tendency towards an equilibrium in metabolism. Each of these properties has arrived at a largely steady state in a climax equilibrium. The diversity of species is the most essential factor. The stability of a climax state is assumed to depend heavily on this particular property. Accordingly, *an increasing diversity of species has a stabilizing effect on ecosystems*. Partly because of more diversified species, a tropical forest ecosystem is assumed to be steadier than a forest ecosystem in a temperate climate, and the latter similarly steadier than a tundra ecosystem, when all these ecosystems are considered in their climax states. (Cf. K o r m o n d y 1969, p. 164—169.)

The equilibrium size of each population in an ecosystem is assumed to be a function of the sizes of all the other populations. If the equilibrium sizes of the various populations are expressed by a, b, c, . . ., z, the following equations can be written:

(6) $a = f_a\ (b, c, \ldots, z)$
$b = f_b\ (a, \ldots, z)$
.
.
.
$z = f_z\ (a, b, \ldots)$

This problem has n equations and n unknowns. In a possible solution, which need not be unique, the size of each population is consistent with the size of every other. (Cf. B o u l d i n g 1950, p. 7—8.)

Although the climax state does not occur in most ecosystems, it is a useful theoretical concept, equivalent to a normal forest in forestry and pure competition in economics. Consequently a state of equilibrium in an ecosystem cannot always be defined as its climax. It is more useful to define a *dynamic ecosystem equilibrium as including all the states from which an ecosystem is able to return to a succession leading towards its natural climax.*

Agriculture and intensive forestry are examples of human exploitation of ecosystems. Both are based on the idea of decreasing the natural diversity of species. *Unfortunately, this development decreases the range of dynamic ecosystem equilibria.* The widespread use of pesticides and insecticides have had similar effects. The dynamic ecosystem equilibrium varies considerably according to many climatic and biological factors. Nowadays there are numerous examples particularly of aquatic ecosystems which have been distorted away from their dynamic equilibria by human pollution of water. (Cf. D a s m a n 1968, p. 57—63.)

Individual ecosystems vary a great deal in their capacity to tolerate and recover from human disturbances. This capacity can be called *the carrying capacity of the ecosystem* and it is very close to the concept of the dynamic ecosystem equilibrium. If within the time horizon of man nonreversible disturbances occur, the carrying capacity of the ecosystem has been exceeded. This may happen through one of the following human activities:

— in extracting benefits from ecosystems
— in managing ecosystems to stimulate production of extrable benefits
— in discarding wastes of human production and consumption back into ecosystems. (J a a t i n e n & C u n n i n g h a m 1974, p. 8—9.)

Another key criterion to asses the functioning of ecosystems is related to the concept of *efficiency of an ecosystem.* On one hand the ecosystem is defined to be the more efficient the smaller primary output (= the less energy and matter) is needed to maintain a given total biomass. On the other hand, the ecosystem is considered the more efficient the larger the total biomass maintained by a given amount of primary output. The efficiency of an ecosystem may also be interpreted as minimization of increases in entropy, the amount

of unavailable energy in an ecosystem. The more routes along which energy can move and the more subsystems through which matter can cycle, the larger is the storage capacity of the ecosystem and the smaller its entropy. (Jaatinen & Cunningham 1974, p. 5.)

In conclusion, it can be emphasized that the one-way flow of energy and the cyclical flows of nutrients and water are the fundamental phenomena in the functioning of ecosystems. They occur simultaneously, and in both processes losses appear throughout their routes (Fig. 4). In spite of huge technological innovations, the future of man still depends heavily on the energy produced by green plants. Thus the proper flows of energy, nutrients and water in ecosystems are of foremost importance.

3.2.3.3. State of environmental quality

Environmental deterioration in the sense defined in Section 1.1. may take one of the following forms: (1) disequilibrium of an ecosystem, (2) depletion of natural resources and (3) impoverishment and ruining the appearance of the environment. Environmental impoverishment refers to a decline in the number of plant or animal species and thus to the disappearance of genetic information. Ruining the appearance of the environment leads to the loss of esthetic and recreational values. Waste paper as an environmental problem is connected mainly with aspects (2) and (3).

Environmental deterioration is mostly an outcome of unsatisfactory functioning of the human economy in conjunction with the ecosystems (economy of nature). This results mainly from human activities which conflict with prevailing ecological »laws». The only rational way of steering the state of environmental quality in a more favorable direction is to introduce a new kind of control of human production and consumption activities.

To enable human production and consumption to be controlled in this way a system to measure the state of environmental quality must be created. In Finland, an attempt of this sort has recently been made by a section of the Government Economic Council (Ympäristönsuojelun tavoitteita . . . 1972).

In a statistical information system, the following hierarchic steps can be identified: individual statistical registers — particular statistics — statistical systems — social indicators. Statistical systems refer to compilations such as the System of National Accounts (SNA) or System of Demographic, Manpower and Social Statistics (SDMSS). Social indicators are constructed in such a way that relevant information from the viewpoint of social goals is transformed into the form of a few index numbers.

An information system describing the state of environmental quality must be designed in coordination with other major information systems. This requirement is necessary because the state of environmental quality has effects

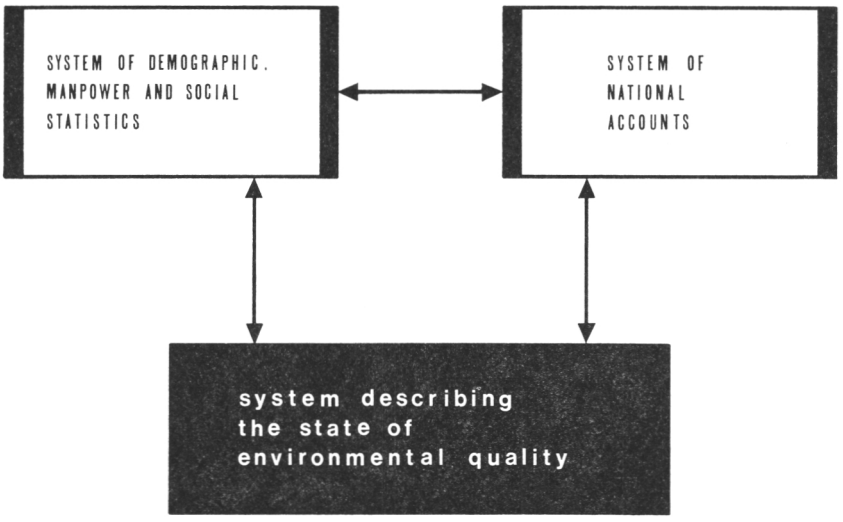


Figure 5. The interplay of major information systems.

and counter-effects on the social, health and demographic states of a society and also on the economic states of a society. Accordingly, the integrated use of these different information systems for decision-making is not effective without rationally coordinating their structures. This situation is described in Fig. 5. (Cf. Ympäristönsuojelun tavoitteita . . . 1972, p. 26—28.) *State of environmental quality should be included as a general indicator of level of living* (cf. p. 26).

3.2.4. Economic growth vs. environmental quality

As a measure of economic growth, GNP per capita indicates only the value of produced goods and services exchanged in the markets (with minor exceptions), but it has largely been considered as equivalent to level of living. Accordingly, comparisons of GNP per capita in different countries have been made. However, level of living (cf. Section 3.2.1. above) is such a wide concept that GNP per capita can hardly indicate more than one component of it.

As was pointed out in Section 3.2.2. economic growth and environmental quality are coupled together in such a way that, under strictly linear technology, increasing one diminishes the other and *vice versa*. If statistical indicators to measure environmental quality could be developed, better comparisons of trade-offs between environmental quality and economic growth would be possible.

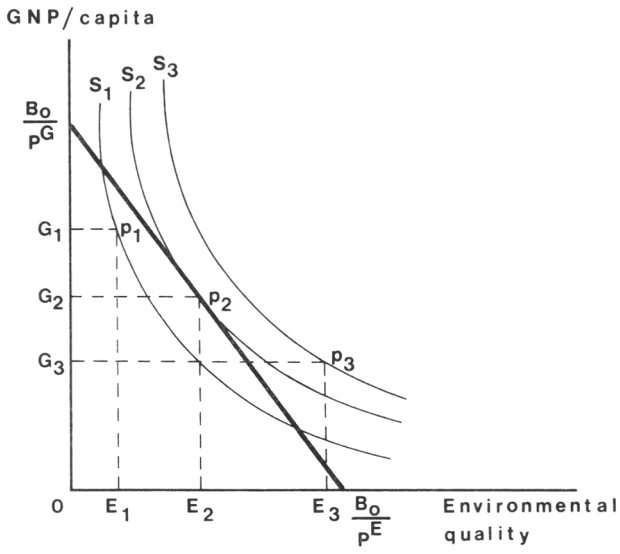


Figure 6. Indifference curves describing levels of living as a function of gross national product (GNP) per capita and environmental quality.

In Fig. 6, a theoretical model of indifference curves describing levels of living as a function of traditional GNP per capita (approximate material consumption) and environmental quality are introduced. For example, the curve S_1 represents all the combinations of GNP per capita and environmental quality producing a level of living S_1 preferred by a particular society. In other words a society considers all the combinations of S_1 with indifference with regard to their effect on society's level of living. On the other hand, all points S_2 represent a higher level of living than those on S_1 and points on S_3 again describe a higher level than those on S_2. The number of indifference curves could be infinite. Accordingly there might be a situation where a society prefers a bundle G_3E_3 to a bundle G_1E_1 (Fig. 6), although the amount of goods and services having a market value in the latter is markedly higher than in the former.

A budget constraint B_o (the straight line in Fig. 6) could specify what level of income a society is free to spend for fostering both economic growth and environmental quality. On the assumption that a society's budget available for these two purposes is B_o dollars and that the »price» of a unit of GNP per capita is P^G, then if the society decides to spend the whole budget it can obtain on promoting GNP, B_o/P^G could be achieved. Similarly, if the whole budget is used for improving environmental quality, an amount of B_o/P^E could be achieved. *Naturally these two cases are not possible in practice but they can be theoretically illustrative.* The slope of the budget line(s) is determined by

$$(7)\quad s = \frac{B_o/P^G}{B_o/P^E} = \frac{P^E}{P^G}$$

If a society wishes to maximize its level of living (in the restricted meaning of this Section), it will choose a combination of economic growth and environmental quality which lies on the budget line B_o (Fig. 6). The most preferred bundle is that which is associated with the highest level of living. In Fig. 6, this means finding a point on the budget line B_o which lies on the highest indifference curve. This is point p_2, which indicates G_2 units of GNP per capita and E_2 units of environmental quality, the combination forming the most preferred level of living.

The form of the indifference curves in Fig. 6 has been assumed convex to the origin. If it was supposed concave, it could be proved that the optimal combination would always involve only one good: either B_o/P^G of GNP per capita or B_o/P^E of environmental quality. Of course more specific forms of these indifference curves are not known. Under prevailing technology, they might be estimated by opinion polls.

Either a change in people's preferences (tastes) or a change in production technology can affect the form of the indifference curves in Fig. 6. The theoretical extreme in technological development is that the functional relationship between economic growth and environmental quality will totally disappear. A transformation of the traditional linear technology in this direction is introduced in the following Section.

The kind of model presented in Fig. 6 is a simplification best matching the conditions of linear technology. The real aggregative technical relationship between economic growth and environmental quality depends largely on the composition of economic growth and therefore it varies from country to country and from time to time. Some economists (cf. B e c k e r m a n 1972, p. 22) have even denied the existence of this relationship in today's real world.

3.3. Circular technology

In the functioning of the ecosystems the activities of production, distribution, exchange and consumption of »goods» is carried out. These goods might be energy, carbondioxide, molecules, foodstuff or whole organisms. It was pointed out in Section 3.2.3.2. that the functioning of the ecosystems is arranged in the most efficient way in long run perspective: mostly solar energy is utilized and the use of nutrients and water is predominantly based on circular flows.

In organizing human technology and economy man applies systems analogous to ecosystems. Production, distribution, exchange and consumption of

»goods» are also typical of man's systems. At present men are perhaps more generally starting to recognize their position in the ecosystems as a consumer at the end of many food chains. However the human production-consumption systems are still often too close to the model of linear technology (Fig. 3, p. 24). *Since traditional economic growth will apparently continue, serious ecological problems will be met in the long run* (cf. Sections 3.2.2. and 3.2.4.) *unless the human production-consumption systems will now be reorganized according to the pattern of the ecosystems.*

The performance of the human systems has been traditionally evaluated by measuring the gross flow of matter and energy through the production-consumption systems during some time period. The larger the flow-through of matter and energy (GNP per capita), the more successful, under certain restrictions, the human system (national economy, business firm) is judged to be (Section 3.2.2.). Knowing the relationship between traditional economic growth and environmental quality this »maximum flow-through» criterion will certainly no more be a rational way of evaluating the performance of the



Collection with bins and trucks is becoming the dominant mode for city housing.

human systems. Therefore *it is suggested that the efficiency criterion similar to that of the ecosystems (p. 33) should also be applied to the human production-consumption systems.* Thus the larger the total matter at man's disposal which can be maintained with a constant intake of new matter and energy during a given time period, the more efficient the production-consumption system. Conversely, the smaller the intake of new matter and energy needed to maintain the total matter at man's disposal of given size over time, the more efficient the production-consumption system. (J a a t i n e n & C u n n i n g h a m 1974, p. 5—8.)

According to this new criterion the efficiency of human systems can be improved, if matter is retained for a longer time at man's disposal (within a production-consumption system). *Apparently this can be implemented by prolonging the »life-time» of products and by reusing matter after it has been abandoned during the production process and after consumption.*

Energy cannot be recycled. The continual new energy requirements means that it is impossible to maintain the human production-consumption systems totally as closed cycles, no matter how efficiently matter is recycled. In continuation of economic growth even more matter and energy must be taken into the human systems. *Accordingly, a more effective use of energy will be another guiding principle for a new human circular technology.* Thus available energy and the *carrying capacities of the ecosystems* (p. 33) set the ultimate limits for the future growth of the human production-consumption systems.

In recent years, some efforts have been made to promote the transformation of the traditional linear technology (cf. Section 3.1.) towards a circular one. An engineer must ensure that he knows all the pollution effects connected with the equipment and processes under his responsibility. All new proposals in this field should also clearly point out the definite and potential environmental effects. (W e s t e r b e r g 1970, p. 11—12.)

We are in a transition from linear technology to circular technology. In a space economy everything must cycle around. There are two essential goals in environmental conservation: (1) pollution protection and (2) circular technology. (S t e n s t e d t 1970, p. 18.)

The principal idea in developing a new ecologically acceptable techno-system is to abandon the use of natural resources as a disposable commodity. Instead, multiple use of energy flows where possible and *especially circular flows for material utilization should be created.* Many difficult technical problems encountered in this field can be solved only through extensive technological-scientific research and development. (M a l a s k a 1971a and 1971b.)

A model of a new, ecologically-oriented technology for the pulp and paper production-consumption system is presented in Fig. 7 and can be contrasted with the model of linear technology of Fig. 3 (p. 24). Beginning from the left, sustained yield forestry with progressively increasing output up to certain

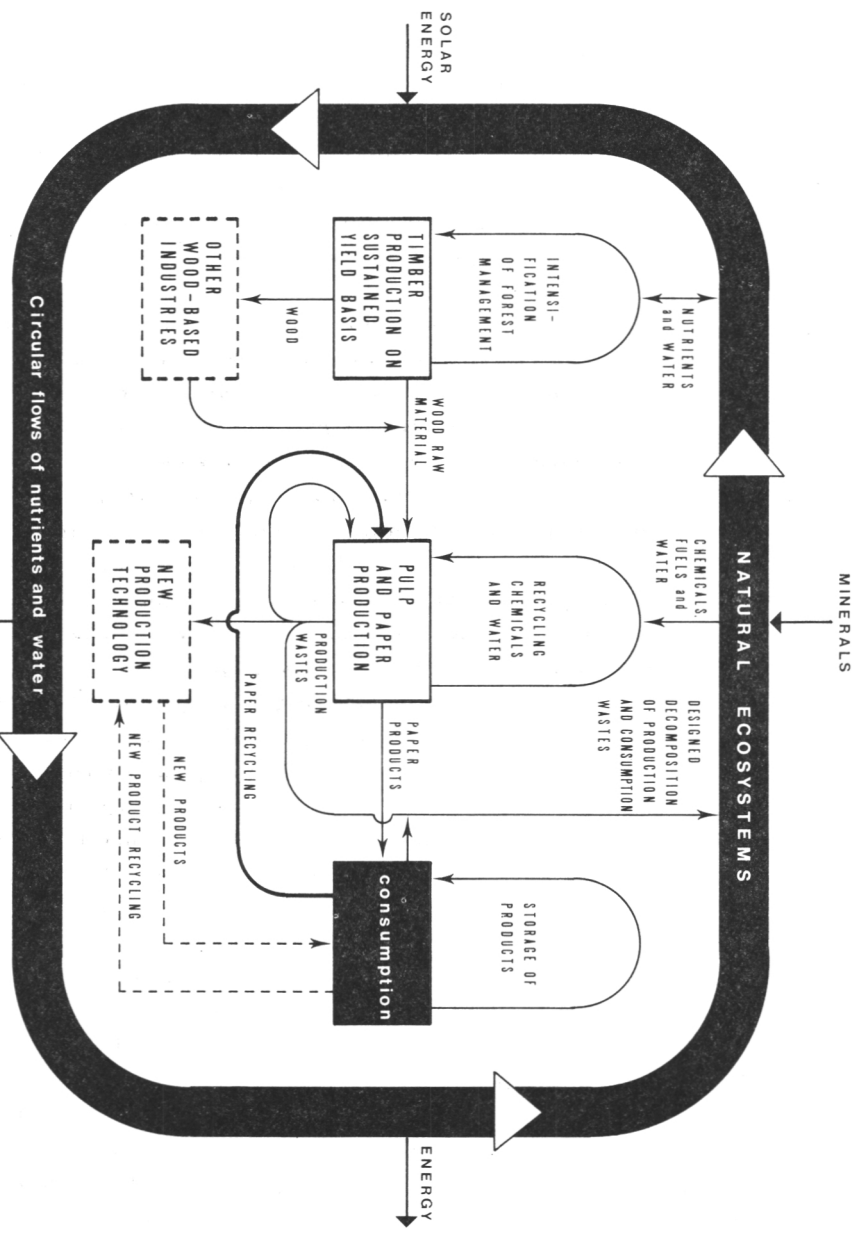


Figure 7. A theoretical circular-technology model for a paper production and consumption system.

limits (according to equation 5, p. 31) is assumed to be practised. By and large, this kind of forestry has been practised already for a good while, for example in Finland. Accordingly the pulp and paper industry can extract its wood raw material from a continuously renewable timber resource. However,

there still remain some reforestation problems, especially in Lapland. There are also some conflicts between foresters and conservationists regarding the degree of preservation for National Parks and other reservations for recreational purposes.

Next, the production phase of pulp and paper is considered. The ultimate aim is to develop a technology in which the water requirement per unit of output can be diminished, and in which all water used and a major part of the chemical and organic waste can be recycled for the new production of pulp and paper. For the remainder of the chemical and organic waste, new processes must be developed for the production of new marketable products. In this direction, much research and development (R & D) has already been carried out by the pulp and paper industries in the U.S.A., Canada, Sweden and Finland and in various other countries (OECD 1973, p. 37—43).

However, it is a well-known fact that the proportion of funds invested in R & D from the total turnover by the pulp and paper industry is relatively low when compared with other industries (cf. Svensk skogsindustri . . . 1971, p. 234—249). For example, in Finland the pulp and paper industry's proportion of R & D funds is the tenth highest among 18 industries counted in a recent study (Teollisuuden tutkimustyöllä . . . 1971). On the other hand: »The international comparison reveals that in 1970, except for the production of chemimechanical pulp and newsprint, Finland used more water, the solids losses of pulp production were greater and, for sulphate pulp, the BOD loads were also greater in Finland than in the OECD countries on average.» (Nilsen 1973, p. 845; cf. Section 1.2.) Consequently there seems still a great deal of work to be done. There even seems to be a chance that R & D investments could in the long run be profitable to the firm in question through savings in the use of wood and chemicals and also in the form of new products (cf. Dahmen 1971, p. 74; Kneese 1971a, p. 159). Furthermore, because many countries are preparing strict antipollution legislation to cover their pulp and paper industries (OECD 1973, p. 45—82), there will be extensive markets all over the world for new solutions to these problems.

For a long time it was assumed in microeconomic theory and also largely in practice that the only goal of a firm was to maximize its profits (cf. Section 3.1.). At present several simultaneous goals for a firm are generally accepted both in economic theory and in practice. Environmental quality, however, is not generally included among these goals. Therefore external pressure through legislation is needed to change the production technology to favor more this important component of the level of living.

In Fig. 7, the box at the right shows the consumption of pulp and paper products. Prospects for recycling more paper after consumption back into production is the concern of the rest of this paper.

In the long run maintaining reasonable environmental quality and the proper functioning of ecosystems necessitates major transformation towards the circular technology model in both the production and consumption of paper and paperboard. Accordingly from the ecological point of view and to enable economic growth, waste paper recycling should be increased to a rate determined mainly by waste paper generation and by the waste paper processing technology.

4. STATE OF PAPER RECYCLING — EMPIRICAL ANALYSES

4.1. Global situation

4.1.1. Regional variations

A global estimate for the consumption of waste paper is given in Table 2. World consumption of recycled paper rose from about 18.8 million tons in 1962 to about 24.8 million tons in 1967. Consumption of fiber rose from 84 million tons to 110 million tons. Thus both waste paper consumption and consumption of total fiber increased approximately by one third during the period 1962—1967. Over the same period 230 kg recycled paper was consumed per ton of paper and paperboard produced. Considerable variation occurs

Table 2. Consumption of waste paper *) and total fiber in paper and paperboard production 1962—1967 (FAO 1971, p. 1).

Region	Fiber consumption			Waste paper consumption				
	Thousand tons		kg per ton of paper and board Average 1962—1967	Thousand tons		kg per ton of paper and board		
	1962	1967		1962	1967	Average 1962—1967	Average 1962—1964	Average 1965—1967
North America ..	41 933	51 756	1 034	8 435	10 411	199	209	189
Western Europe .	21 680	28 482	1 023	5 319	6 984	251	248	254
Japan	6 101	9 718	1 069	2 220	3 536	389	386	392
Latin America ..	2 012	2 833	1 070	590	831	314	332	296
Africa	430	783	1 075	122	200	274	257	291
Asia, excl. Japan and People's Republic of China	1 232	1 743	1 084	238	336	209	210	208
Oceania	767	1 266	1 034	152	251	205	202	208
U.S.S.R	3 944	6 027	1 069	531	812	144	147	141
Eastern Europe .	3 103	4 067	1 050	638	837	246	267	225
People's Republic of China	2 845	3 535	1 079	519	645	197	194	200
World total	84 047	110 180	1 040	18 764	24 843	230	235	225

*) Data on all regions other than North America, Western Europe and Japan are estimates

among regions in this relative consumption of recycled paper. The top figure of 389 kg per ton of paper and paperboard produced was registered in Japan. The other extreme 144 kg was consumed in the U.S.S.R.

Measured in absolute quantities North America, Western Europe and Japan have the highest consumption levels of waste paper. These three regions together recycled 84 % of the world total in 1967, when their equivalent share of the total fiber consumption was 82 %. Waste paper recycling has such an important position in the world's fiber supply that recycling prospects have been reviewed from time to time by various international organizations.

In FAO's »World demand for paper to 1975» (1960, p. 52—53) it was briefly stated that the level of waste paper recycling is limited by waste paper quality and by its availability. Recovery rate, on the other hand, depends heavily on the structure of the paper and board industry; certain qualities of paperboard (for example chipboards) can be based entirely on waste paper, while some papers such as high-strength wrapping paper contains none. Paper consumption level, the density and distribution of population, alternative uses and the efficiency of collecting organizations are all assumed to affect waste paper recovery rates.

Forecasts made in 1960 and in 1965 by FAO concerning the future development of waste paper recovery rates are presented in Table 3. Increasing rates were predicted in the less developed regions based on the expected posi-

Table 3. FAO estimates for waste paper recovery rates by regions (FAO 1960, p. 53; FAO 1966, p. 58).

Region	1960 estimates			1965 estimates		
	1955	1965	1975	1959—61	1970	1980
	Recovery rates %					
North America	26	26	26	23	22	22
Latin America	20	21	23	23	24	25
Western Europe	25	25	25	23	23	23
Eastern Europe	22	23	24	23	24	25
U.S.S.R.	14	16	18	18	20	22
Africa	9	10	12	13	15	18
Near & Middle East	8	9	10	..	..	..
Near East	..	..	..	1	5	15
Middle East	..	..	..	13	15	18
Far East (Excl. Japan and People's Republic of China)	17	18	18	..	..	..
Asia (Excl. People's Republic of China)	..	..	..	26	26	26
Japan	25	28	29	..	..	..
People's Republic of China	12	14	16	14	16	16
Oceania	12	12	12	18	20	20
World average	..	..	..	22	22	22

tive effects of rising paper consumption levels and decentralization of the world's paper industry. In North America, Western Europe and Oceania the recovery rates were expected to remain unchanged. Later on the realization of these forecasts will be discussed.

In another FAO-sponsored publication »Pulp and paper prospects in Western Europe» (S u n d e l i n 1963, p. 83—90) the role of waste paper recycling is described in the region having the second largest consumption of paperstock in the world. First it was stated that recycled paper is the cheapest of all fibers supplied for the production of paper and paperboard. About 26—27 % of the products of this industry consumed in Western Europe from 1954 to 1961 were reclaimed and returned to the mills for processing into new paper and paperboard. *Assumptions were made that upward changes in per capita consumption of paper and in population density increase the recovery rate. On the other hand, it was assumed that increasing labor costs and the growing use of plastics and other contaminants in paper products limit paper recycling.* According to historical series it was judged that these positive and negative factors balance each other in Western Europe.

More recently a special survey was carried out by FAO (1969) on the recovery and utilization of waste paper. This survey covers the period 1963—1968. A questionnaire was circulated to major paper consuming countries in all regions of the world. Seventeen countries assembled the data inquired. A number of the replies must be considered rough estimates rather than proper statistics. However, since they are the best data available some of these results are reproduced here in Table 4. It introduces recovery rate as the percentage of waste paper reclaimed from the total paper and paperboard consumption. The data in Table 4 have been combined with a couple of other relevant sources so that the 13-year period 1961—1973 is covered.

Although in many cases there occurs a slight confusion about the exact recovery rate, mainly due to the difficulties in estimating consumption figures properly, Table 4 gives the best estimates available. Recovery rates in various countries have been fairly stable. No overall trend of change can be observed. When the forecasts of Table 3 are compared to Table 4 it can be seen that recovery rates in 1965 for Japan and Western Europe were underestimated, and for North America overestimated (Canada has no practical weight).

Japan is the world's second largest paper recycler. In 1970 paper stock recovery was 4.7 million tons. According to Table 4 Japan's paper recovery rate is the second highest among all countries varying between 36 and 39 % in recent years. These figures are only slightly below those of the Netherlands. In 1970 81 % of recycled paper was used in paperboard manufacturing and the rest (19 %) in paper making. The major part of paper stock is processed mechanically and only a minor part (15 %) chemically. (M a c L e o d 1971.)

Table 4. Waste paper recovery rates in the 16 OECD countries 1961—1973 (FAO 1969, p. 4; Sundelin 1963, p. 416; Paperinkeräys Oy).

Country	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973
Austria	22	23	24	25	26	26	29	..	32	30	33	..	30
Belgium	24	25	28	26	28	28	31	..	27	30	26	..	30
Denmark	23	20	..	..	..	..	..	..	18	18	19	24	18
Finland	24	21	21	25	25	26	24	25	27	26	23	19	20
France	27	27	27	29	27	27	27	27	26	29	28	..	29
Germany, Fed. Rep.	26	26	26	27	27	27	29	29	29	32	30	30	32
Italy	19	21	14	15	18	20	21	21	21	21	21	..	21
Netherlands	35	34	34	35	34	35	41	41	39	40	42	..	40
Norway	16	16	17	19	19	17	17	17	16	17	18	17	17
Spain	28	23	..	..	..	27	30	..	26	28	26	..	28
Sweden	27	22	..	..	..	24	19	..	22	22	24	25	24
Switzerland	30	32	35	34	32	35	33	..	33	31	35	..	31
United Kingdom	29	27	28	27	29	27	27	..	27	29	29	..	30
Canada	..	..	..	..	..	..	..	..	13	..	21	..	13
USA	22	22	22	20	21	20	21	20	22	23	23	..	..
Japan	35	37	39	39	38	40	39	37	37	38	36	..	38

A special feature supporting the functioning of the Japanese paper stock market is a strong supply by households. This reflects on one hand a situation where other sources have already largely been tapped, and on the other hand strong efforts by the Japan Waste Paper Association. For example, already in 1960 this group financed a study on paper recycling which was carried out by the Department of Sociology, Tokyo University (Collection and re-use . . . 1962).

The *Federal Republic of Germany* is the top paper stock consumer in Europe with a consumption of 2.5 million tons in 1970. The recovery rate has varied around 30 % recently. An interesting feature of Germany is that it apparently leads the world ranking in respect to waste paper and board output with a 45.5 % utilization rate in 1970. About 90 % of the total recovery flows through the paper stock trade, the remaining 10 % coming directly from the paper and board converting industry. Only about 2—3 % of the waste paper generated by households is recycled. The largest share of paper stock is used in packaging grades. These grades make up nearly half of the total paper and board output, which is a key factor behind recycled paper's high proportion in this production. In 1971 15 deinking plants were in operation with an estimated annual capacity of 140 000 tons. (Koenig 1971.)

In the *United Kingdom* the waste paper recovery rate has been slightly less in the last few years than that of the Federal Republic of Germany. Paper stock overwhelmingly represents the most important domestic fiber

source. Printers and converters play an important role in paper recycling as they generate by-product waste paper. Paper stock merchants obtain their supplies mainly from shops, offices and industrial premises by means of clearance contracts. Typical to the United Kingdom recycling system is that Local Authorities supply about 20 % of the total mill intake of paper stock. The present system still leaves almost untapped the potentially important source of households. Approximately 70 % of recycled paper in the U.K. is used for making paperboard. The average paper stock contents in the grades using this material have lately been estimated as follows:

	%
Unlined Chipboard	100
Container Middles	100
Fourdrinier Chipboard and Strawpaper	95
Fluting Medium other than Semi-Chemical	80
Test Jute Liner	80
Kraft Lined Chipboard	80
White Lined Chipboard	50+
Cream Lined Chipboard	50+
Other Lined Board	30
White Lined Triplex Board	30

The U.K.'s first two deinking mills have just started to process mainly overissue or once-read newspapers into newsprint. (H o d g e s 1971.)

4.1.2. Regression models of 16 OECD countries

4.1.2.1. Amount of recovery

Section 4.1.1. pointed out a strong world-wide variation among regions in both recovery and consumption of waste paper. A more detailed analysis of factors causing this variation has been performed. On the basis of the availability of data 16 OECD countries were chosen for this closer study. These countries and their respective amounts of recovered and consumed waste paper are presented in Fig. 8.

The United States clearly has the highest tonnages of waste paper recovery followed by Japan, the Federal Republic of Germany, the United Kingdom and France. On the other hand the lowest amounts of recovery among the 16 chosen OECD countries are observed in Norway, Denmark, Finland and Austria. The most significant factors causing such a great variation (from 11.3 to 0.1 million tons) in the amounts of waste paper recovery were investigated by correlation and linear regression methods with cross-sectional data of the 16 OECD countries from the year 1969.

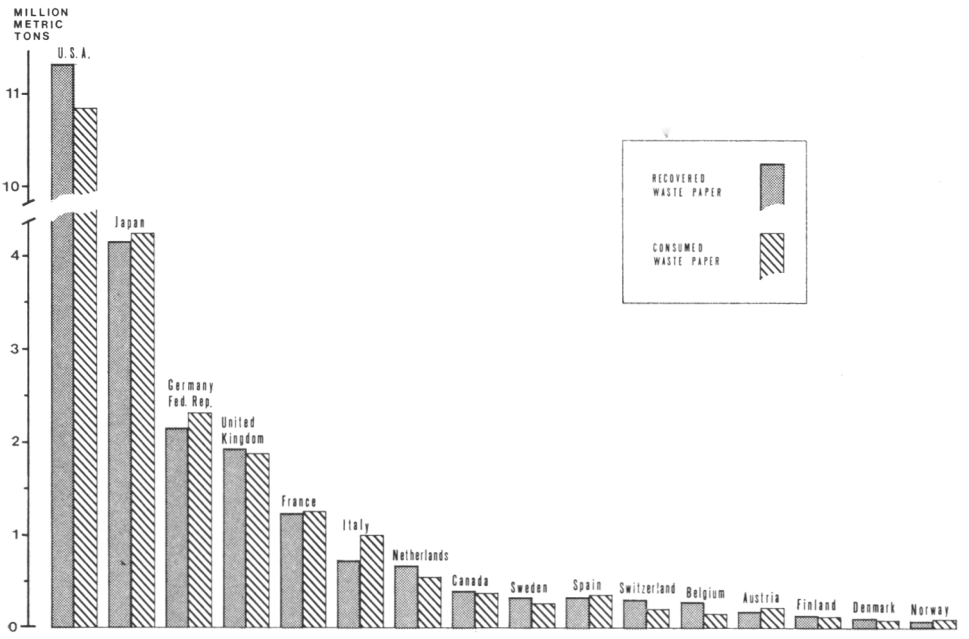


Figure 8. Recovered and consumed waste paper in the 16 OECD countries in 1969.

First of all the amounts and the prices of recovered waste paper in each country were considered to have a strong relationship. Both of these variables were assumed to be affected by (1) supply factors, (2) demand factors, and (3) factors external to supply and demand of waste paper (Fig. 9). In Fig. 10 an

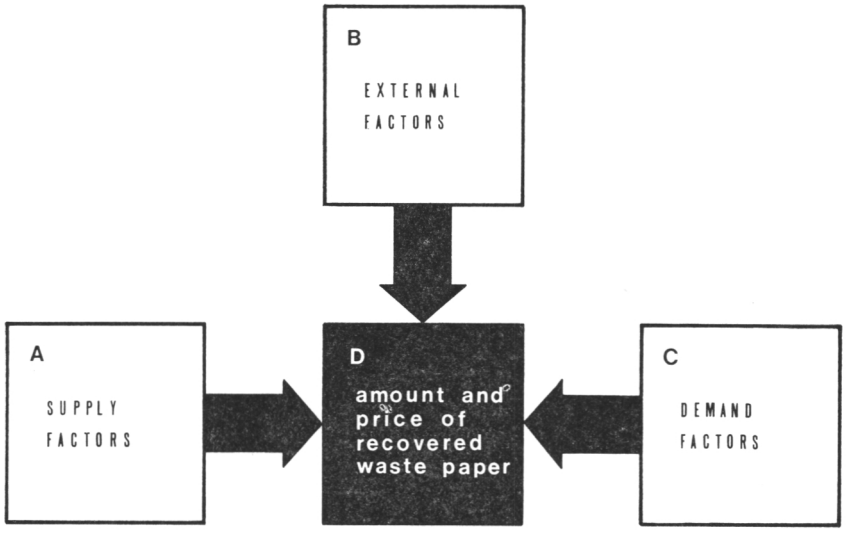


Figure 9. Major factor groups affecting waste paper recovery (for more detail see Fig. 10).

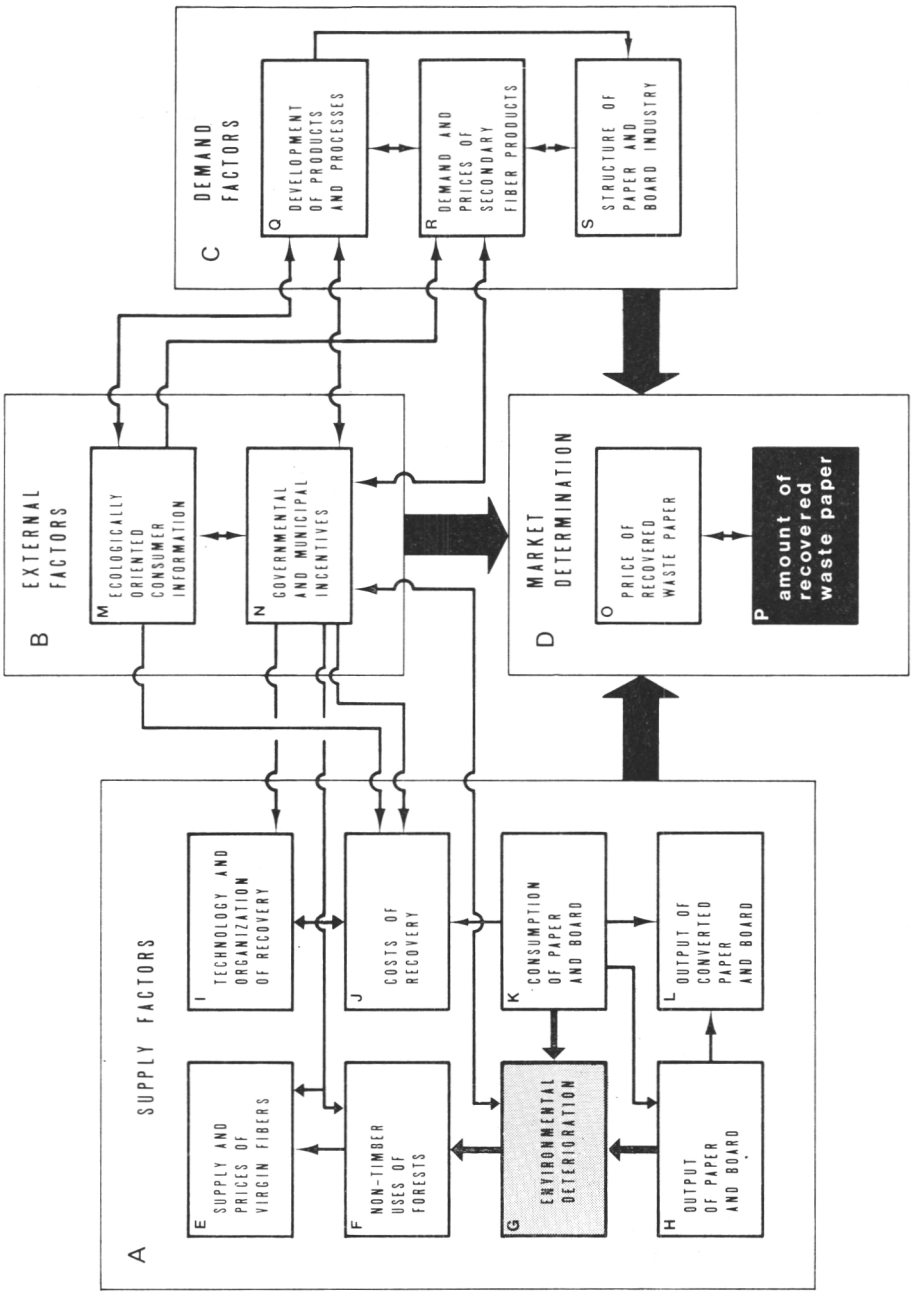


Figure 10. Hypothetical factors affecting waste paper recovery.

attempt is made to open the »black boxes» of Fig. 9. The arrows with one point in these figures refer to one-way relationships between factors (in boxes) and two-headed arrows refer to two-way (mutual) relationships.

An hypothesis was proposed (cf. Section 4.1.1.) that (1) technology and organization of waste paper reclamation, (2) costs of recovery, (3) level of consumption of paper and board and (4) output of converted paper and board (boxes I, J, K and L in Fig. 10) were the strongest *supply factors directly* affecting amounts and prices of recovered waste paper. The following factors were considered as strong *indirect* supply factors: (1) supply and prices of virgin fibers, (2) the rate of non-timber uses of forests, (3) the degree of environmental deterioration and (4) output of the paper and board industry (boxes E, F, G and H in Fig. 10).

In the group of *external factors*, ecologically oriented consumer information and governmental and municipal incentives (boxes M and N in Fig. 10) were regarded as affecting directly both the amounts and the prices of recovered waste paper.

Finally, the following *demand factors* were assumed to affect directly the amounts and prices of recovered waste paper: (1) development of waste paper based products and processes, (2) demand and prices of secondary fiber products and (3) structure of paper and board industry (boxes Q, R and S in Fig. 10).

In the next step a search was made for empirical variables to measure the chosen hypothetical factors. FAO, OECD and other UN statistical publications were used as the main data sources. Due to the uncertainties limiting the comparability of international statistics, cross-checking was done wherever parallel information was available. In this respect the A t c h i s o n (1972) report, »The outlook for timber in the United States» by the U.S. Forest Service (1973), Paperinkeräys Oy (the Finnish integrated company for waste paper reclamation) and statistics by BIR (Bureau International de la Recuperation) proved useful.

Empirical variables (34 altogether) were constructed to describe 10 of the 15 factors of Fig. 10. For the following five factors no empirical measures were found: (1) non-timber uses of forests, (2) technology and organization of recovery, (3) output of converted paper and board, (4) governmental and municipal incentives and (5) prices of recovered waste paper. The factor of supply and prices of virgin fibers was considered as one of the strongest influences on the recovery of waste paper. Hence 13 variables were constructed to measure this factor. Unfortunately a part of these statistics (growing stock and increment data) were not quite up to date (World forest inventory 1963), but because no rapid changes are likely in this field these variables were also tested in this study. The whole list of variables is presented in Appendix 1.

The correlation coefficients among amounts of recovered waste paper (variable 2) and other variables are presented in Appendix 2. The total consumption of paper and board (variable 10) and consumption of paper and board excluding newsprint & printing and writing paper (variable 11) correla-

ted positively and most strongly with the amounts of recovered waste paper ($r = .987$ and $.989$). Thus variable 11 alone »explained» 97.8 % ($100 \times r^2$) of the total variation of the dependent variable (2) among the 16 countries. This was a tentative explanation from the supply side of the waste paper market.

On the demand side the first two of the three variables (5, 6 and 7) which measure the structure of the paper and board industry produced high correlations with the amounts of recovered waste paper. The correlation coefficients were: (1) $r = .979$ for the output of paper and board excluding newsprint & printing and writing paper (variable 5) and (2) $r = .970$ for the output of wrapping and packaging paper and board (variable 6). Thus variable 5 alone »explained» 95.8 % of the total variation of the amounts of recovered waste paper among the 16 countries studied. Variable 5 contains mainly paperboard. Because the bulk of waste paper is consumed as raw material of various paperboard categories the high correlation between variables 5 and 2 is quite reasonable.

On the other hand, to avoid an »explanation above 100 %» it must be stated that »consumption» variables and »production» variables are *strongly intercorrelated*, for example $r = .995$ between variable 5 and variable 11. Accordingly this kind of regular correlation analysis gives no final causal explanation. All other independent variables highly correlated with the dependent variable (2) are also intercorrelated with these consumption and production variables. However, mainly on the basis of strong ex-ante hypotheses an initial conclusion can be reached that consumption of paper and board and the structure of the paper and board industry are the two factors dominating the variation in the amounts of recovered waste paper.

In the next step *linear regression analysis* was applied. In this study a number of the independent variables are strongly intercorrelated. It is a known fact that regression analysis is not in such a case the best method for constructing an explanatory model, but it was decided to use it with care anyway.

An explanatory model from the supply side was formed stepwise into the following form (standard errors in parentheses):

		R^2	F
(8)	$y_2 = \underset{(.015)}{20.071 + .364 x_{11}}$	.976	569
(9)	$y_2 = \underset{(.013)\ (.008)}{-9.442 + .368 x_{11} + .020 x_{29}}$	.985	413

y_2 = amount of recovered waste paper

x_{11} = consumption of paper and board excluding newsprint & printing and writing paper

x_{29} = output of paper and board per area.

The correlation matrix of the variables is as follows:

	y_2	x_{11}	x_{29}
y_2	1.000		
x_{11}	.989	1.000	
x_{29}	—.030	—.112	1.000

The intercorrelation between the independent variables 11 and 29 is weak ($r = -.112$). Therefore both models are formally simple and clear. However, the strong mutual dependence between the supply variable 11 and the demand variables measuring the structure of the paper and board industry must be carried in mind.

Variable 29, output of paper and board per area was initially introduced to measure the degree of environmental deterioration. However, variable 29 might also be interpreted as one kind of measure of the costs of waste paper recovery. This hypothesis is strengthened by the fact that variable 29 has the highest correlation coefficients with variables 13 and 8, which definitely measure the costs of waste paper recovery.

On the basis of hypotheses (Fig. 10) and correlation and linear regression analyses, a first final conclusion of this study can be made. *The variations in the amount of recovered waste paper among the 16 OECD countries studied are explained mainly by the consumption of paper and board, the costs of recovery and the structure of the paper and board industry.* These findings were not surprising because they had already been stated in earlier studies (p. 44), although no empirical verification was found.

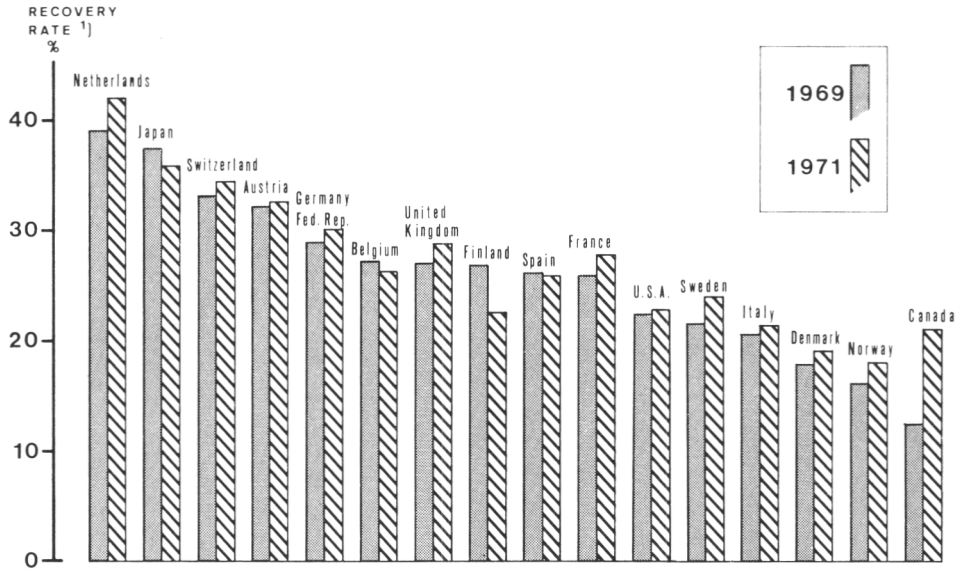
4.1.2.2. Recovery rate

The recovery rate of waste paper (R_w) is defined as a ratio of the amount of recovered waste paper (W_r) to total paper and board consumption (C_p) expressed in per cent or

$$(10) \quad R_w = 100\ W_r/C_p$$

This ratio describes the country's ability to transform »consumed» and discarded paper and board from a waste deteriorating the human environment into a useful resource (cf. p. 21). The recovery rates of the 16 OECD countries in 1969 and 1971 are presented in Fig. 11. The countries are ordered according to the 1969 figures. The Netherlands has the highest recovery rate in both years. It is followed by Japan, Switzerland and Austria all having recovery rates over 30 %. Recovery rates under 20 % are observed in Norway and Denmark.

Diverging opinions have been presented recently about the factors causing such a wide variation in recovery rates among countries. Accordingly a trial



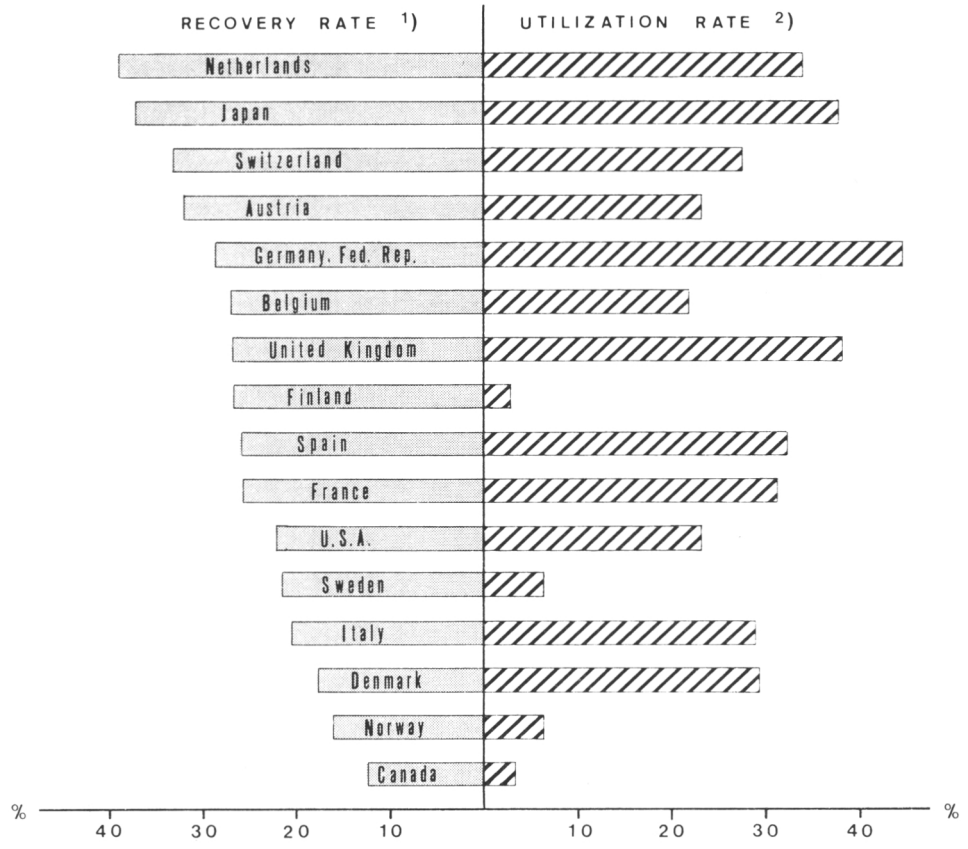
1) Recovery rate: waste paper recovered as a percentage of the total paper and board consumption.

Figure 11. Recovery rates of waste paper in the 16 OECD countries in 1969 and 1971.

to quantitatively explain this variation was one of the main purposes of this study. In order to facilitate this analysis the factors explaining the absolute amounts of recovered waste paper were analyzed in Section 4.1.2.1. In the following Section (4.1.2.3.) the utilization rate or the ratio of waste paper consumption to total output of paper and board will be studied in more detail. In this context only the highly diverging patterns of variation in recovery and utilization rates (Fig. 12) are pointed out.

According to equation (10) the recovery rate is computed from the following two components: (1) absolute amount of recovered waste paper and (2) total consumption of paper and board. When studying the variation in recovery rates the factors affecting both of these components must be considered. Thus in addition to the analysis of Section 4.1.2.1, factors determining the variation in paper and board consumption are to be investigated. Fortunately the numerous studies carried out mainly by FAO describe these factors quite satisfactorily. The most important of them are introduced in Fig. 13.

The level of income and the size of population are the two factors most frequently used to explain the consumption of paper and board. The former was measured here by GNP per capita and the latter by number of inhabitants (variables 36 and 39 in Appendix 1). The weighted mean of import and export prices of newsprint (variable 31) represented the prices of various paper and board products. This choice was based on the assumption that newsprint is one of the most homogenous commodities in all 16 countries and that



1) Recovery rate: waste paper recovered as a percentage of the total paper and board consumption.
2) Utilization rate: waste paper consumed as a percentage of the total paper and board output.

Figure 12. Recovery and utilization rates of waste paper in the 16 OECD countries in 1969.

its price is adequately correlated with the prices of other paper and board products (cf. p. 69). Factor E in Fig. 13, production costs of paper and board was measured by variables 32—35 representing average mill size, level of wages and price of capital. Factor F of Fig. 13 was already represented by several variables through the supply factors of recovered waste paper (Fig. 10, p. 49).

In addition to the above variables measuring the factors affecting the consumption of paper and board, according to equation (10), nearly all the variables measuring factors affecting amount of recovered waste paper (as described in Section 4.1.2.1. and listed in Appendix 1) were included into the present analysis of recovery rate variation. However, the variables 10—13 measuring paper and board consumption had to be excluded because this consumption was the denominator of the dependent variable 1.

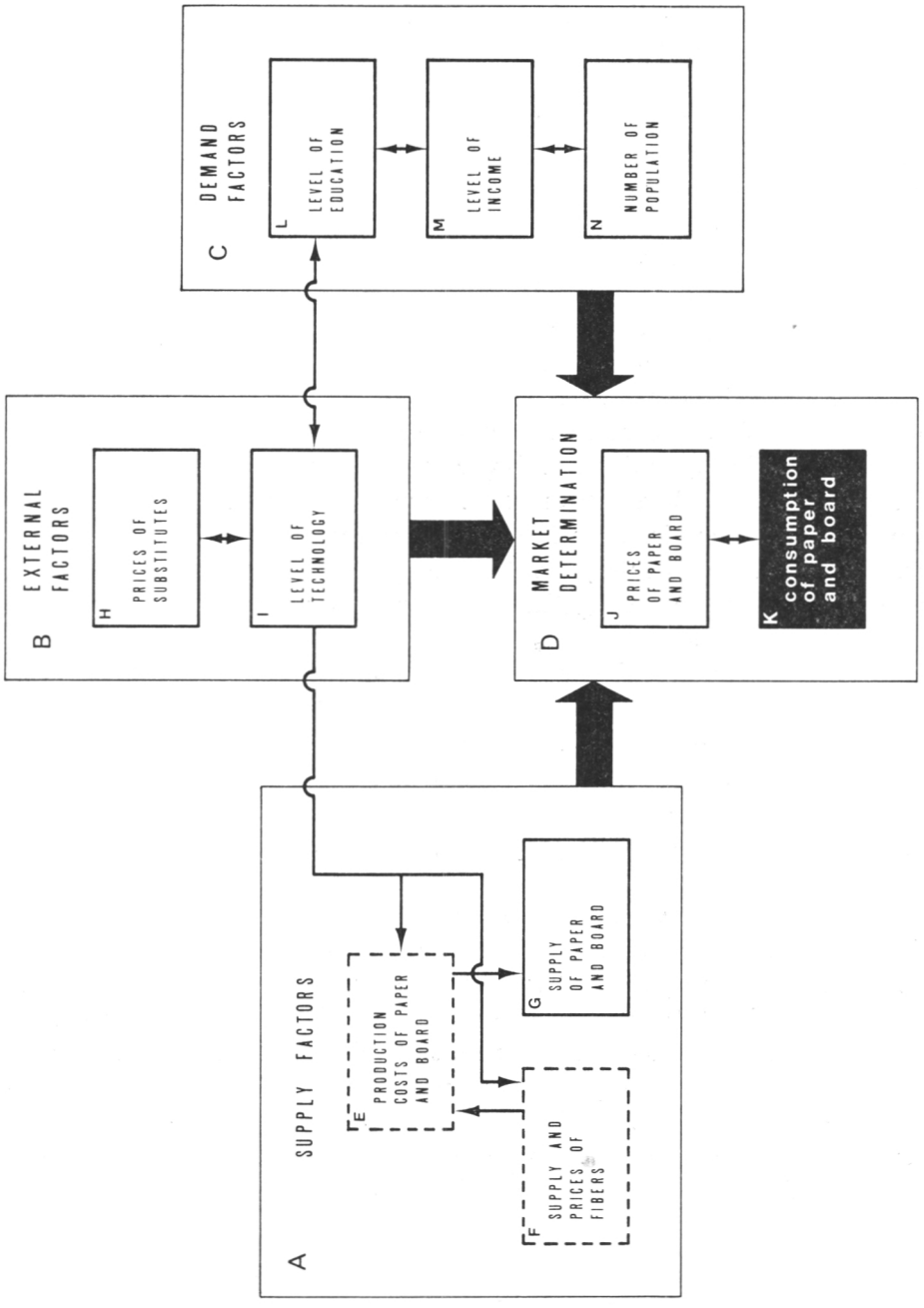


Figure 13. Hypothetical factors affecting consumption of paper and board.

The correlations between the recovery rate (variable 1, Appendix 1) and independent variables diverged distinctly from those concerning the amount of recovered waste paper (variable 2). *Output of paper and board per area (va-*

riable 29) had the strongest correlation (r = .804) with the recovery rate. This variable was earlier (p. 52) interpreted to measure indirectly the costs of waste paper recovery (collection costs). Variable 40 had the second highest correlation coefficient (r = .749) with the recovery rate. Variable 40 was composed as a product of GNP per capita and output of paper and board per area. Accordingly variable 40 also apparently measures mainly the costs of recovery (cf. Appendix 2: correlations between variable 40 and other variables).

Variable 8 had the third strongest correlation coefficient with the recovery rate (r = .669). The higher population density, the lower are the costs of waste paper recovery. In all these cases correlation coefficients were positive in accordance with the hypotheses.

Variables 14—26 measured the supply of virgin fibers. They all, except variable 26, correlated negatively with the recovery rate. It can be reasoned that when variable 26, total removals per net increment, is at a high level then the supply of virgin fibers remains low. Thus the hypothesis that a greater supply of virgin fibers leads to lower recovery rate of waste paper was not refuted. Pulpwood removals per volume of pulpwood imports (variable 19) was the particular one among these 13 variables which had the strongest correlation (r = —.650).

The saving rate of households (variable 37), as defined in national accounting statistics, was chosen to measure primarily the factor called »ecologically oriented consumer information». This interpretation can naturally be questioned. Variable 37 correlated rather strongly with the recovery rate (r = .612). The hypothesis can be maintained that the more ecologically oriented (or more willing to save) people are, the higher is the recovery rate of waste paper.

Next linear regression analysis was applied to derive a good explanatory model for the recovery rate. First an automatic free selection process was tried. Second, according to the hypotheses and the strength of correlations, one of the variables 8, 19, 29, 30 and 37 was selected at a time as a fixed variable in five models, and other independent variables were selected automatically by the computer. Finally a stepwise procedure was applied to test promising variable combinations with low mutual correlations. The explanation power of 33 independent variables were tested altogether. The following models were considered the best ones for explanation purposes:

			R^2	F
(11)	$y_1 =$	$373.6 + .409x_{29} + 1.528x_{31} - .312x_{34}$	.769	13.3
		(.098) (.932) (.143)		
(12)	$y_1 =$	$603.7 + 1.460x_{31} - .412x_{34} + .185x_{40}$	.761	12.8
		(.953) (.139) (.045)		

$$(13)\quad y_1 = -86.68 + .433x_{26} + .511x_{29} + 1.099x_{31} \qquad R^2 = .763 \qquad F = 12.9$$
$$(.209)\quad (.093)\quad (.930)$$

y_1 = recovery rate of waste paper (%), estimate of R_w (p. 52)
x_{26} = total removals per net increment
x_{29} = output of paper and board per area
x_{31} = weighted mean of import and export prices of newsprint
x_{34} = hourly wages in paper and paper products industry
x_{40} = (GNP per capita) x (output of paper and board per area).

The correlation matrix of the above variables was as follows:

	y_1	x_{26}	x_{29}	x_{31}	x_{34}	x_{40}
y_1	1.000					
x_{26}	.195	1.000				
x_{29}	.804	—.125	1.000			
x_{31}	.361	.005	.235	1.000		
x_{34}	—.516	(—.598)	—.329	.085	1.000	
x_{40}	.749	—.208	(.949)	.278	—.174	1.000

The correlations in parentheses do not refer to relationships within any single model. The mutual correlations of the independent variables within each of the models (11), (12) and (13) are low. The absence of multicollinearity among independent variables is regarded as one of the prerequisites for a good explanatory model.

The models (11), (12) and (13) are rather equal when simplicity, degree of determination and ease of interpretation are considered. In fact the models (11) and (12) are almost the same because variables 31 and 34 are common and variable 29 is one component of variable 40.

The results of the previous correlation analysis are strengthened when either variable 29, output of paper and board per area or variable 40, (GNP per capita) x (output of paper and board per area), are included in all of the above three regression models. They were the two variables which correlated most strongly with the recovery rate.

Variable 31, weighted mean of import and export prices of newsprint, came unexpectedly into all of the three regression models. All three coefficients of this variable are positive as well as the correlation coefficient between variable 31 and the recovery rate (r = .361). In spite of rather low correlation this variable proved to have a strategic position in these regression models. It can be observed from the correlation matrix (Appendix 2) that variable 31 is generally only weakly correlated with other variables used (strongest correlation r = —.572 with variable 21, pulpwood removals per paper and board consumption). It can be concluded that the following hy-

pothesis was strengthened: In countries where paper and board prices are high the recovery rate of waste paper tends also to be high.

Variable 34, hourly wages in paper and paper products industries, correlated negatively with the recovery rate ($r = -.516$). The same variable was also included in the models (11) and (12) with negative coefficients. Variable 34 was chosen to measure the production costs of paper and board. However, the correlation matrix (Appendix 2) shows that variable 34 has other quite strong correlations also, especially with the variables representing the supply and prices of virgin fibers. The most likely explanation could be that the pulp and paper industry is so capital-intensive that wages have only a minor role in the formation of production costs and variable 34 measures in the first place the general wage level. This explanation makes the negative correlation sensible, because waste paper recovery is a labor-intensive field.

Variable 26, total removals per net increment, came into model (13). This variable can be interpreted in the following way: The higher the removals per net increment the more scarce the supply of virgin fibers. Variable 26 correlated weakly with the recovery rate ($r = .195$) and no strong correlations occurred with other independent variables. The supply of virgin fibers was measured also with the variables 14—25. Some of them correlated relatively strongly with the recovery rate as was explained earlier. Based on the results of both correlation and regression analyses it can be concluded that the following hypothesis was strengthened: The more scarce the supply of virgin fibers the higher the recovery rate of waste paper.

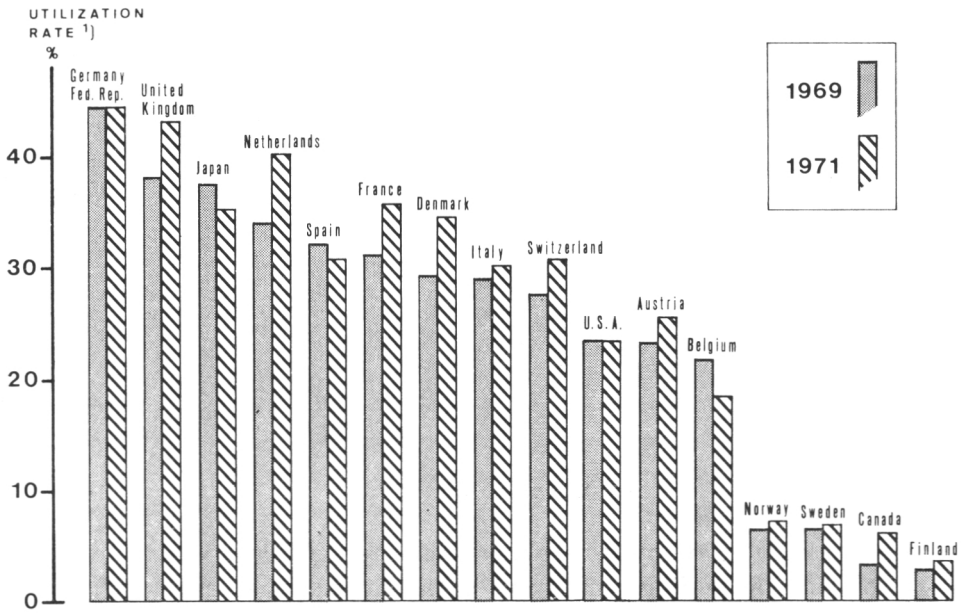
On the basis of the hypotheses (Figures 10 and 13) and correlation and regression analyses, a second final conclusion of this study can be made: *The variation in the recovery rate of waste paper among the 16 OECD countries studied are explained mainly by the costs of recovery, the supply of virgin fibers, wage level and the prices of paper and paperboard.*

4.1.2.3. Utilization rate

Utilization rate (U_w) is defined here as a ratio of consumed waste paper (W_c) to total paper and board output (Q_p). Utilization rate thus describes the relative importance of waste paper among the fibrous raw materials available for the paper and board industry in each country.

$$(14) \quad U_w = 100\ W_c/Q_p$$

Utilization rates in the 16 OECD countries in 1969 and 1971 are presented in Fig. 14. The countries are ranked according to the 1969 figures. In both years the Federal Republic of Germany had the top utilization rates: waste paper's proportion as a raw material of the total paper and board output was 46 %. The next highest utilization rates were found in the United Kingdom,



1) Utilization rate: waste paper consumed as a percentage of the total paper and board output

Figure 14. Utilization rates of waste paper in the 16 OECD countries in 1969 and 1971.

Japan and the Netherlands. In 1971 both the United Kingdom and the Netherlands reached utilization rates over 40 %.

On the other hand, Finland, Canada, Sweden and Norway formed a clearly distinct group in this respect. Each of them had a utilization rate of 7 % at most. These countries have relatively small domestic consumption of paper and board compared to the overall capacity of paper and board production because they all are rather heavy exporting countries of these commodities. The utilization rate had increased from 1969 to 1971 in 11 countries among the 16 in Fig. 14, in three countries a decrease was observed and in two countries no change occurred.

The factors causing variation in the utilization rate among countries were tentatively studied with correlation analysis without any ex ante hypotheses. Three variables (20, 21, 22), measuring the supply of virgin fibres, correlated negatively rather strongly with the utilization rate (r varied from —.750 to —.815). *Thus waste paper's relative importance as a fiber raw material for the paper and board industry seemed to increase in countries with relatively scarce supply of virgin fibers.* Also population density (variable 8) appeared to correlate with the utilization rate: The more inhabitants per square kilometer the higher the utilization rate (r = .700). Population density was interpreted to measure the collection costs of waste paper.

In countries where paper and board output, excluding newsprint and printing and writing paper, per total paper and board output (variable 7) was high the utilization rate also tended to be high (r = .587). Finally the price of newsprint (variable 31) correlated more strongly with the utilization rate (r = .537) than with either the absolute amount of recovery or the recovery rate. This price was assumed to measure the average price level of paper and board products. Hence the hypothesis was formed that this price level is directly related to the utilization rate.

The correlations of these variables with other independent variables were quite weak, making the interpretation easier. Even stronger correlations with the utilization rate occurred (e.g. variable 32: r = —.818) but those variables were also strongly correlated with other independent variables.

4.1.3. International trade

OECD countries are by far the most important producers and consumers of waste paper. Accordingly their role in the international trade of this com-

Table 5. International trade of waste paper in some OECD countries (Internationale Altpapiermärkte . . . 1972, p. 23).

Country	Imports			Exports			Net imports			Net exports		
	1968	1969	1970	1968	1969	1970	1968	1969	1970	1968	1969	1970
	1 000 metric tons											
Germany, Fed. Rep. ..	327.0	298.8	320.0	79.6	140.1	184.0	247.4	158.7	136.0	—	—	—
Belgium/Luxembourg	26.7	20.8	23.0	127.8	144.1	163.3	—	—	—	101.1	123.3	140.0
Netherlands	73.9	66.9	76.1	179.6	207.3	225.0	—	—	—	105.7	140.4	148.9
France	96.2	128.7	136.8	67.7	93.2	86.7	28.5	35.5	50.1	—	—	—
Italy	173.3	269.2	284.0	0.6	0.2	0.4	172.7	269.0	283.6	—	—	—
United Kingdom	16.7	53.6	26.3	99.7	93.8	99.3	—	—	—	83.0	40.2	73.0
Denmark	11.6	10.0	15.7	45.3	43.4	48.4	—	—	—	33.7	33.3	32.7
Norway	13.8	16.0	27.0	4.6	6.7	9.2	9.2	9.3	17.8	—	—	—
Sweden	5.4	13.6	20.3	91.3	82.2	91.3	—	—	—	85.9	68.6	71.0
Austria	51.8	64.5	99.2	11.3	18.7	12.4	40.5	53.2	86.8	—	—	—
Portugal	0.7	1.0	1.2	—	0.1	—	0.7	0.9	1.2	—	—	—
Switzerland	26.9	30.1	34.8	119.4	135.6	122.6	—	—	—	92.5	105.5	87.8
Finland	1.1	10.1	27.3	0.3	0.9	—	0.8	9.2	27.3	—	—	—
Greece	4.9	3.0	13.6	—	—	—	4.9	3.0	13.6	—	—	—
Ireland	17.7	18.8	16.4	4.4	7.0	4.9	13.3	11.8	11.5	—	—	—
Spain	22.2	38.4	36.1	1.8	3.3	1.7	20.4	35.1	34.4	—	—	—
Total OECD Europe	869.9	1 043.5	1 157.8	833.4	976.5	1 089.2	36.5	74.4	108.9	—	—	—
Canada	51.2	67.8	73.2	108.4	103.4	89.0	—	—	—	57.2	35.6	15.8
USA	94.5	79.9	60.6	229.2	262.0	370.4	—	—	—	134.7	182.1	309.8

modity is decisive. At the same time the best statistics available are compiled by OECD. The international trade in waste paper is relatively small, for example in 1969 the European OECD countries exported about 33 % of their woodpulp production (FAO, Yearbook of forest products 1971), while the corresponding percentage of waste paper was about 11.5 % (Table 5). However, there has been a fast-growing trend in the international trade of waste paper: the total OECD-European imports grew from 0.44 to 1.16 million metric tons or 160 % from 1960 to 1970 (OECD, The pulp and paper industry 1968, p. 72 and Table 5).

In Table 5 imports and exports of waste paper for OECD countries 1968—1970 are presented. OECD Europe has been a net importer of 109 000 tons in 1970, Canada and USA as a total being at the same time net exporters to the amount of 192 000 tons. There were no complete records available on Japanese foreign trade in waste paper, but for 1970 imports of more than 109 000 tons were recognized originating mainly from North America, Europe and Australia (MacLeod 1971, p. 85).

Considering individual countries, the Federal Republic of Germany is by far the largest importer of recycled paper. The other major importing countries are Italy, France and Austria. The situation in Germany can be reviewed as a case.

The pattern of waste paper consumption by the German industry in 1970 was approximately as follows:

	%
mixed waste	57
medium and better qualities	16
grades containing kraft paper	11
non-specified grades	16
	100

If the above distribution is compared to the recovery, the import requirement lies mainly in the higher quality grades. The share of imported paper stock has recently amounted to 12—13 % of total consumption. At the same time the share of paper stock exports in the total recovery has been 6—8 % (Koenig 1971, p. 87).

With the exception of Germany the leading waste paper exporters are not simultanously large importers. The Netherlands has been the top exporting country followed by the Federal Republic of Germany, Belgium, Luxembourg and Switzerland. In the Netherlands the share of exports from total recovery has lately amounted to 30—31 % (Koenig 1971, p. 22 and Table 5).

4.2. Finland—a case of scarce timber supply

4.2.1. Waste paper market

The Finnish exports have been composed mainly of wood and woodbased products. Even today about one half of the exports have their origin in the forests. Although the relative share of forest products in exports has declined to some extent, the absolute amount of these products has increased remarkably.

The annual cut has already nearly reached its upper limits under prevailing intensity of forest management. Total drain has varied during the past 20 years between 52 and 63 million m^3 (with bark) and has in several years exceeded the annual growth and the allowable cut. Accordingly, several forest management intensification plans have been launched (cf. Heikinheimo & Palo 1972). The most recent is the MERA III program which has high targets for increasing the allowable cut, but it has also received much criticism for being unrealistic.

A lot of research work is being done in order to intensify the yield of our forests. The utilization of stumps, branches, bark and needles is under research and to some extent also realized. By fertilization, forest drainage and other activities the production of our forests can also be increased. However, the long rotation time caused by the climate sets its own natural limits to activities in this field. There are good examples of scarcity of roundwood in Finland: The Bank of Finland has a control over investments by the forest-industry firms; the earlier net export of roundwood has turned to net import.

This situation makes one think how to satisfy the growing demand for raw material in the forest industry. The intensification of forest management, harvesting more logging residues than at present, and the development of more efficient processes in forest industry give an important but not any final solution to the problem.

Progress on these lines is expensive and many of them are not expected to increase wood availability in the near future. The possible future policy of removing large forests from timber production to nature conservation and recreational areas will have its own restrictive effects on the virgin fiber supply.

The idea of circular technology (cf. Section 3.3.) can be introduced as a natural partial solution to this scarcity problem. The absolute amounts of waste paper and its recovery in Finland are rather small because of fairly low total consumption of paper and board. However, the increased exploitation of this secondary fiber might be an important marginal addition in solving the wood raw material problem faced by Finland today.

In Finland there have been *waste paper recovery activities* on a large scale since the 1930's. An integrated waste paper recovery operation started in

1943, when the predecessor of the present Paperinkeräys Oy was established (the name of the firm at that time was Jätekeskus Oy and later Paperinkeräyskeskus Oy). The shareholders of this company are nine forest industry firms. The mission of Paperinkeräys Oy is to provide the mills of the shareholders with waste paper. The biggest users of waste paper are: Oy Tampella Ab, Inkeroinen mill; A. Ahlström Oy, Karhula mill and Enso Gutzeit Oy, Pankakoski mill. (Cf. A a l t o.)

The recovery company Paperinkeräys Oy has receiving stations in Helsinki, Tampere and Turku (the three largest cities). The receiving stations take in about one half of the recovered waste paper in the country. The company has agreements with suppliers who deliver waste paper directly to the mills. Paperinkeräys Oy also takes care of the country-wide PR work. Collection campaigns, especially aimed at households, have played an important role in waste paper recovery. This kind of concentrated organization in the paper stock field, which is unique in the world, has proved to be efficient.

The development of waste paper recovery in Finland is presented in Fig. 15 together with the output of board and consumption of paper and board. Waste paper recovery has fluctuated more heavily than the consump-

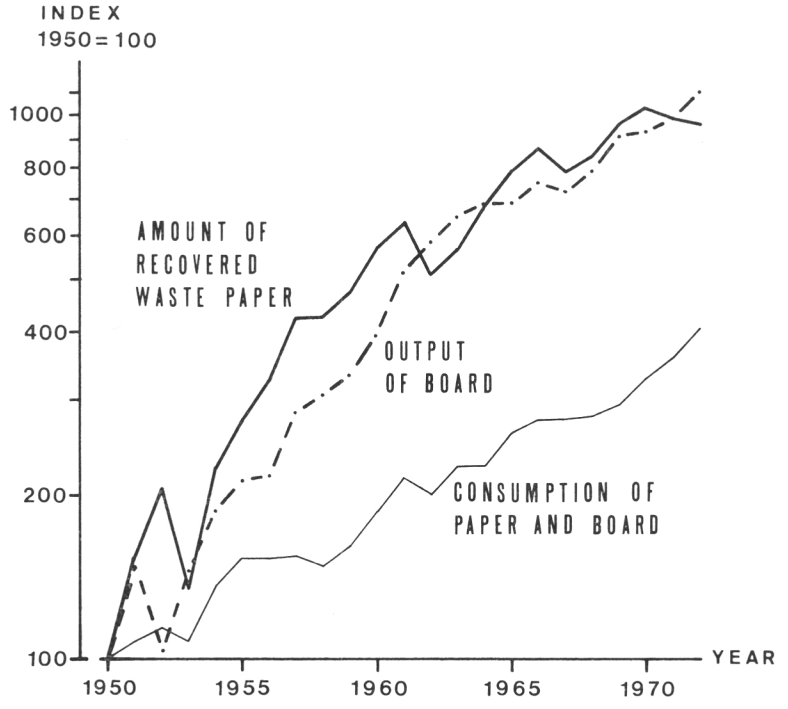


Figure 15. Amount of waste paper recovery, output of board and consumption of paper and board (indices, 1950 = 100, log scale) in Finland, 1950—1972.

tion of paper and board and the output of board. Sometimes the collection from the households has been motivated by campaigns. At other times the collection has been sharply restricted. The likely explanation for these switches lies mainly in the trade conditions of waste paper based products. Waste paper has been used as raw material in rather low quality boards for which the export demand has fluctuated strongly. These fluctuations have made it difficult to carry out long term planning in the recovery field. In general, the development of recovery has closely followed the growth of board production.

Table 6 presents recovery rates and the amounts of paper stock recovered since 1950. The absolute amount has increased ten times over that of two decades ago: from 14 000 tons to 140 000 tons. Recovery rate grew rapidly from 1950 to 1957, from 8 to 22 %. In 1957—1971 it has stayed over 20 per cent, reaching its peak of 26.9 per cent in 1969. In 1972 the recovery rate fell under 20 per cent again.

Table 6. Waste paper recovery and consumption of paper and board in Finland, 1950—1973 (Sources: The Central Association of Finnish Woodworking Industries; Paperinkeräys Oy; Statistical yearbook of Finland).

Year	A. Waste paper recovery	B. Consumption of paper and board [1]	C. Recovery rate (100 A/B)	D. Consumption of paper and board per capita
	1 000 metric tons		%	kilograms
1950	13.6	167	8.1	41
1951	20.7	182	11.4	45
1952	27.9	191	14.6	46
1953	18.3	179	10.2	43
1954	30.7	228	13.5	54
1955	37.8	256	14.8	60
1956	44.1	256	17.2	59
1957	57.4	258	22.2	59
1958	58.0	249	23.3	57
1959	63.8	268	23.8	61
1960	78.1	311	25.1	70
1961	86.3	362	23.8	81
1962	69.0	334	20.7	74
1963	78.0	374	20.9	82
1964	92.1	376	24.5	82
1965	106.4	435	24.5	95
1966	117.8	458	25.7	99
1967	108.0	457	23.6	99
1968	113.9	464	24.5	100
1969	131.1	487	26.9	105
1970	140.1	548	25.6	119
1971	135.4	596	22.7	129
1972	130.0	676	19.2	146
1973	148.5	762	19.5	164

[1]) estimated on the basis of production and foreign trade statistics

The development of paper and board consumption is also presented in Table 6. The consumption in 1972 was four times the level of 1950. Both in the world and in Finland the consumption of paper and board is increasing rapidly.

The sources of waste paper recovery in 1972 in Finland were the following (M ä k e l ä 1973):

	1 000 metric tons	%
(1) Paper and board converting industry	60	46
(2) Industry and offices	12	9
(3) Department stores and shops	12	9
(4) Households	46	36
	130	100

Almost all of the waste paper is collected nowadays in group (1), the paper and board converting industry. Recovery could be somewhat intensified in groups (2) and (3) especially as the quality of waste paper from these sources is fairly high. In households, group (4), waste paper is of poor and uneven



Paper is sorted according to technical and chemical properties and the degree of cleanness.

quality and it is created in small amounts at one place. The only real solutions to exploiting more waste paper from this source would be the establishment of a new mill with deinking facilities using paper stock as raw material, for which there are fresh plans (cf. p. 67), and the intensification of collection. In Finland waste paper has been divided into fourteen exactly specified grades, mainly according to technical and chemical properties and also partly according to source and degree of dirtiness.

The utilization rate in Finland has usually been about 3 per cent or somewhat less (cf. Fig. 14, p. 59). It is clear that in a forest products exporting country like Finland the utilization rate will stay low. Countries with scarce forest resources generally have high utilization rates (cf. Section 4.1.2.3.). The foreign trade in waste paper between Finland and other countries has been occasional and in small quantities.

In Finland waste paper is used mainly in the production of the following board types: plain chipboard, white lined chipboard and testliner. So far Finland's competitive advantages in the international market for waste paper based products have been stable quality and the benefits of large, modern production units.

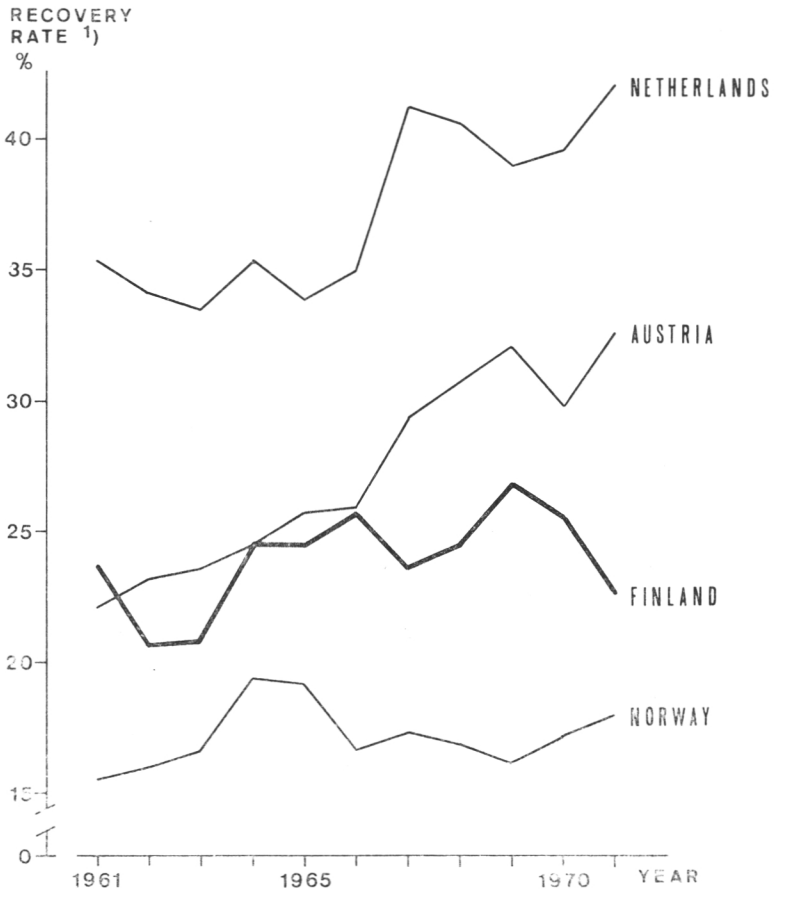
Decreases have occurred in both recovery rate and amount since the top recovery rate of 1969 and the top amount of 1970. Thus the recent development has resulted in a situation where more and more potential raw material of the paper and board industry goes to the increasing waste stream. The main reason for this kind of development is the unfavorable trading conditions of waste-paper based board products. Most countries importing paper and board products have a high level of waste paper recovery and a strong domestic supply of secondary fiber-based products.

During 1973 waste paper recovery grew again due to the increased international demand for paper and board. The price level has also risen so that in Finland even all the waste paper regularly collected from househols could be taken in. Waste paper recovery in 1973 rose to 148 500 tons.

The share of paper and board in Helsinki's municipal solid waste is about 40 per cent on an actual weight basis. This is one of the results of the study which was carried out at Paperinkeräys Oy's initiation (H e r m u n e n 1972). As Helsinki's solid waste amounts to over 300 000 tons per year, it is easy to estimate the quantities of potential raw material destroyed. If the waste paper recovery activities were increased, this would also create savings in solid waste management. These savings could perhaps be used as transportation subsidies for waste paper.

In order to have a recovery rate of 25 or even 30 per cent a new mill using waste paper as raw material is required. A preliminary study for this kind of mill was completed in 1973, and at present the studies are continued. Paperinkeräys Oy and eight paper industry firms established in 1974 a new company,

Keräyskuitu Oy which intends to build a pulp mill with deinking facilities. Fibrous raw material for the mill will be based totally on waste paper collected from households, mainly newspapers (80 %) and newsmagazines. The optimum capacity for this mill has been estimated at 60 000 tons per year. The investment costs would vary between 40 and 70 million Fmk. Total costs of running the mill can be divided into three categories of similar size: (1) raw material, (2) capital cost and (3) other production costs. The price of the deinked pulp produced would vary between 371 and 452 Fmk/ton (1973 prices). This price range approximately equals the prices of market pulp (420—450 Fmk/ton). The prices of pulp in integrated paper and board industry are lower. (Paperinkeräys Oy's information.)



1) Recovery rate: waste paper recovered as a percentage of the total paper and board consumption.

Figure 16. Waste paper recovery rates in the Netherlands, Austria, Finland and Norway, 1961—1971.

In order to guarantee the supply of raw material to the mill, the activities of national and municipal organizations, solid waste management, the paper and board industry and collection organizations should all be coordinated.

Development of products and processes is necessary in creating conditions for increasing paper recycling. In this work a joint effort of specialists both in production technology and in marketing is needed. First step in the development of processes should be the handling of contaminants (waxes, plastics, etc.).

Ecological consumer education is a vital factor to make circular technology successful: (1) to create more demand for waste paper based products, (2) to make the public willing to separate potential raw material from other trash already in the households and to give it to collectors. Other governmental and municipal actions needed are discussed later.

The Finnish development of the recovery rate is compared with three other OECD countries in Fig. 16. Norway represents a low recovery rate country, as the Netherlands is a case of high recovery rate. Austria has been chosen as an example how a country in many respects similar to Finland can remarkably raise its recovery rate.

4.2.2. Explanatory models

4.2.2.1. Amount of recovery

The cross-sectional analysis of Section 4.1.2 provided premises for this trial *to explain the major factors affecting the annual variations in both the recovery amount and the recovery rate of waste paper in Finland.* The hypothesis of Figures 10 and 13 and the results of the earlier correlation and regression analyses (p. 47—60) were applied to select proper variables for 1950—1970. Altogether 13 variables were constructed (Appendix 4).

All the variables were first transformed into indices (Appendix 5) and then into natural logarithms. The correlations of the logarithmic variables (Table 7) appeared to be somewhat higher than those of indices, especially between the recovery rate and the other variables. A strong intercorrelation among all the variables can be observed. This is quite typical for time-series data. The explanation for this phenomenon is that most economic variables are particularly closely correlated with the time-variable (number 5 in this study).

First the annual variation in the *amount of waste paper recovery* (Table 6 p. 64) during the period 1950—1970 was analysed. The waste paper recovery has changed from 13.6 (1950) to 140.1 (1970) thousand tons. The variables 3—8, 11 and 12 all correlated about equally strongly with the absolute recovery (variable 2) within the range: $r = .945—.967$. These variables measure

Table 7. The correlation coefficients of logarithmic indices of the 13 variables in analyses of waste paper recovery in Finland, 1950—1970.

Variables		1	2	3	4	5	6	7	8	9	10	11	12	13
Recovery rate ..	1	1.000												
Amount of recovery	2	.959	1.000											
Consumption of paper and board	3	.847	.963	1.000										
Paper and board consumption per capita	4	.834	.956	.999	1.000									
Time	5	.931	.967	.927	.916	1.000								
Output of paper and board	6	.862	.965	.990	.985	.940	1.000							
Output of board	7	.871	.961	.973	.966	.946	.993	1.000						
Output of waste paper based board	8	.889	.966	.966	.962	.923	.967	.955	1.000					
Price of newsprint	9	.862	.865	.803	.798	.832	.815	.818	.830	1.000				
Unit value of board exports	10	.771	.821	.806	.808	.740	.809	.804	.812	.956	1.000			
GDP per capita	11	.822	.945	.990	.990	.911	.988	.970	.951	.827	.838	1.000		
GDP (Gross Domestic Product)	12	.841	.956	.992	.990	.927	.993	.978	.958	.830	.831	.999	1.000	
Increment per total drain ...	13	-.591	-.536	-.443	-.436	-.499	-.463	-.520	-.457	-.424	-.394	-.401	-.416	1.000

Correlation coefficients

both consumption and output of paper and board in various ways as well as time.

The two price variables (9 and 10) also correlated rather strongly (r = .865 and .821) with the amount of recovery. An interesting aspect is that the correlation between the price of newsprint and the unit value of board exports was quite strong (r = .956). *This observation was in accordance with the hypothesis (p. 53) that the price of newsprint also measures adequately the prices of board, the most common waste-paper based commodity group.*

The increment per total drain (variable 13) correlated moderately but negatively with the absolute recovery (r = —.536) All other independent variables but one (variable 13) correlated more strongly with the amount of recovery (variable 2) than with the recovery rate (variable 1). The cross-sectional analysis of Section 4.1.2. achieved a similar result.

In the next phase *linear regression* analysis was applied. Reservations concerning the use of this method in cases of strong multicollinearity of independent variables, as here, was discussed on p. 51. Especially, degrees of determination (R^2) of the following models must be interpreted with care.

Eleven independent variables were tested. An automatic free selection process was applied. The following model was considered as best for explanation purposes (standard errors in parentheses):

$$(15)\quad \ln x_2 = 22921.9 + \underset{(.5464)}{1.968} \ln x_3 + \underset{(.1952)}{.8642} \ln x_9 - \underset{(2.088)}{9.845} \ln x_{11} + \underset{(2.075)}{7.512} \ln x_{12} \qquad R^2 = .982 \qquad F = 218$$

ln = 10 000 · natural logarithm
x_2 = index of amount of recovery (1950 = 100)
x_3 = index of consumption of paper and board (1950 = 100)
x_9 = index of price of newsprint (1950 = 100)
x_{11} = index of Gross Domestic Product per capita (1950 = 100)
x_{12} = index of Gross Domestic Product (1950 = 100)

Variables x_3, x_{11} and x_{12} measure various aspects of the same factor. On the basis of the hypotheses (Fig. 10, p. 49) and correlation and regression analyses the following conclusion can be made. *The consumption of paper and board, the price of paper and board and the structure of paper and board industry (cf. also Fig. 15, p. 63) can be assumed to affect the annual variation of waste paper recovery in Finland.* The consumption of paper and board represents the supply side and the price the demand side of the waste paper market (boxes K & R in Fig. 10, p. 49). The consumption of paper and board was also the best explanator of variation in the recovery amount among the 16 countries given on p. 50.

It must be borne in mind that the time factor (as measured in this study) alone explains »nominally» 93.5 % of the variation in the recovery amount (Table 7: $r = .967$, $r^2 = .935$) and that time (variable 5) and the consumption variables above (x_3, x_{11} and x_{12}) are strongly intercorrelated. However, the automatic selection process left the time variable out of the final model.

4.2.2.2. Recovery rate

The recovery rate describes the country's ability to transform »consumed» and discarded paper and board from a waste deteriorating the human environment into a useful resource.

During the period 1950—1970 the recovery rate in Finland has annually varied (Table 7, p. 69) from 8.1 % (1950) to 26.9 % (1969). A trial similar to that of Section 4.2.2.1. was made to reveal the major factors affecting the annual variation of the recovery rate in Finland from 1950 to 1970. The variables 3, 4, 11 and 12 (Table 7, p. 69 and Appendix 4) were excluded from this analysis, because they measure the denominator of the dependent variable (the recovery rate).

Among the independent variables time was the one which correlated most strongly with the recovery rate ($r = .931$). This fact could be understood in such

a way that a trend alone is a strong indicator of the development of the recovery rate. Time or trend is often considered to include changes in technological know-how and in level of other knowledge.

The next strongest correlation was observed between the waste-paper based board output (variable 8) and the recovery rate (r = .889). This statistical relationship refers only to the fact that the content of waste paper in the final products has not varied too widely, but has no additional relevance for causal analysis. The price of newsprint also displayed strong positive correlation (r = .862) with the recovery rate. This correlation was higher than that between the unit value of board exports and the recovery rate (r = .771).

The increment per total drain (variable 13) representing the factor of supply of virgin fibers, correlated moderately and negatively with the recovery rate (r = —.591).

In the next phase the annual variation in the recovery rate was studied by applying *linear regression analysis*. The explanatory power of seven independent variables was tested. An automatic free selection process was used. The following model was considered best for explanation purposes:

$$(16) \quad \ln x_1 = \underset{}{41225.2} + \underset{(.0578)}{.2633} \ln x_5 + \underset{(.2026)}{.4348} \ln x_9 - \underset{(.3020)}{.6019} \ln x_{13} \qquad R^2 = .912 \qquad F = 59$$

ln = 10 000 · natural logarithm
x_1 = index of recovery rate (1950 = 100)
x_5 = index of time (1950 = 100)
x_9 = index of price of newsprint (1950 = 100)
x_{13} = index of increment per total drain (1950 = 100)

The price of newsprint and the increment per total drain are the two »explanatory» variables of this model.

On the basis of the hypotheses (Fig. 10 and 13) and correlation and regression analyses the following conclusion can be drawn. *The price of paper and board and the supply of virgin fibers can be assumed to affect the annual variation of the recovery rate in Finland.*

A very interesting aspect is that both of these factors were already recognized as strategic ones when explaining the variation of the recovery rate by countries in the cross-sectional analysis on p. 57—58.

4.2.3. Forecasting models

4.2.3.1. Trials of function forms

The explanatory models have formed a good basis for the construction of forecasting models. Long-term forecasts were needed for both the amount of

recovery and the recovery rate. The long-term viewpoint influenced the choice of independent variables in such a way that only a few of them could be considered. Furthermore, a necessary condition for the potential independent variables was that they must themselves be amenable to accurate forecasting.

Proper form of function was thought to be an important prerequisite for a good long-term forecasting model (cf. Sundelin 1963, p. 35—38). *A priori*, the true causal relationship between the explanatory variables and the recovery rate (amount of recovery) is unknown. Therefore, a common procedure is to deploy a set of plausible functions and to select the best one by comparing the results achieved by experimenting with these functions, with the observations and the relevant theory and other knowledge.

Certain key functions were tried. The logistic curve model was first taken to fit for forecasting of the recovery rate:

$$(17) \quad y = \frac{1}{a + be^{-x}}$$

y = recovery rate
x = independent variable
e = 2.71828 (the base of natural logarithms)

The consumption of paper and board and time were tried as independent variables of the logistic model. Both results were unsatisfactory mainly because the saturation phase came too early.

On the other hand, experience with various functions in forecasting paper consumption was available (cf. FAO 1972, p. 4—10). The next test employed the same type of logarithmic function as that applied in the previous section on explanatory models:

$$(18) \quad \ln y = a + b \ln x$$

First the consumption of paper and board was forecast by using gross domestic product as an independent variable. Then the amount of recovery was forecast, based on this consumption forecast. These forecasts were compared with the empirical observations and the relevant theory and they appeared to grow too sharply.

4.2.3.2. Alternative forecasts

After various trials of models to produce some development lines for the future consumption of paper and board, the simple linear function was finally selected as the most useful for the purpose of this study:

(19) $x_3 = -99.68 + .03984 x_{11}$ $(R^2 = .984)$

x_3 = consumption of paper and board (1 000 metric tons)
x_{11} = gross domestic product at factor cost, 1954 prices (million Fmk)

The time series for the years 1950—1972 formed the basic data. The low (3.7 %) and high (5.2 %) medium-term forecasts of The Economic Planning Centre (Growth Prospects . . . 1972, p. 59) were taken as explicit forecasts of the annual growth of gross domestic product. Thus using model (19) and the forecasts of gross domestic products as inputs, the low and high forecasts for paper and board consumption were produced.

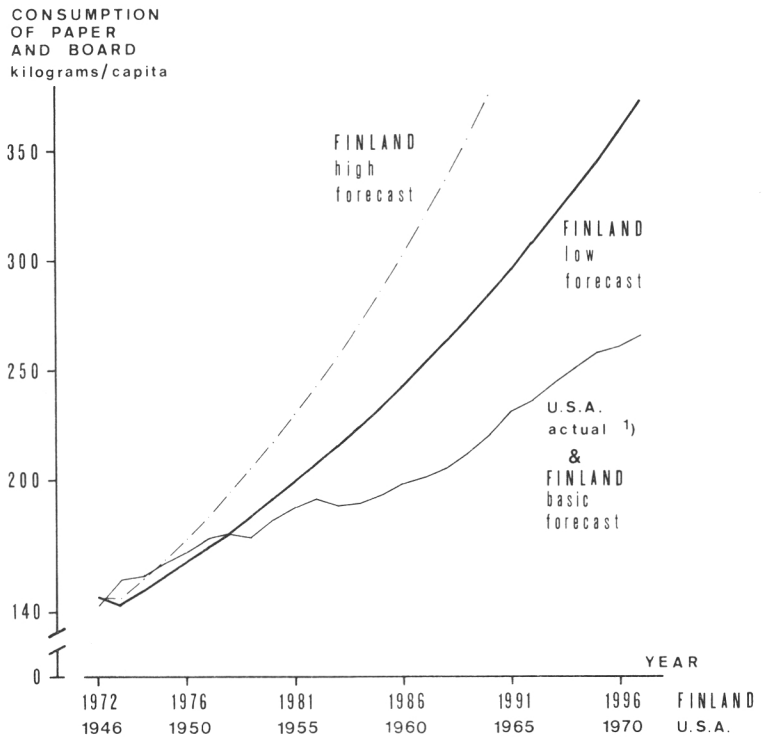
Now it must be carried in mind that the growth forecasts were made at a time when expectations of economic growth were high. The development of the energy crisis in the fall of 1973 has changed a great deal the economic situation. The energy crisis has resulted in a change of economic attitudes and it is most difficult to make forecasts of the growth prospects. These items must be kept in mind when examining the forecasts made in this paper.

According to the forecasts the consumption of paper and board in Finland would be 879 000—998 000 tons in 1980 and 1 074 000—1 315 000 tons in 1985. This means an annual increase of about from 4 to 6 per cent in consumption.

In Fig. 17 forecasts of paper and board consumption are presented as per capita figures. The population has been assumed to stay at 4.6 million during the forecast period. The grounds for this assumption are that official forecasts made a couple of years ago showed a decline in population. The most recent statistics have, however, shown a slight population increase and earlier forecasts have been rejected (cf. Statistical yearbook of Finland 1972). In the face of this uncertainty the constant-population assumption was made for the sake of simplicity.

The high forecast in Fig. 17 is based on 5.2 per cent annual growth in GDP. The low forecast in the figure is based on 3.7 per cent annual growth in GDP. The consumption of paper and board per capita in the U.S.A. in 1946 was at about the same level as in Finland in 1972. In order to get some basis for comparison of the potential future development, the U.S. consumption per capita is also presented in Fig. 17 as three-year moving averages. The past U.S. consumption can also be regarded as a basic forecast for Finland. The authors assume that the probable future development will vary between the low and the basic forecasts. However, knowing the bases of these forecasts it is finally up to the reader to make his own judgements about the future development. The low forecast shows in 1980 a consumption of 191 kilograms per capita.

In order *to forecast the waste paper recovery* a model was developed in which consumption of paper and board was used as the independent variable:



[1]) three-year moving averages, includes hardboard and insulation board

Figure 17. Three alternative forecasts for consumption of paper and board per capita in Finland.

$$(20) \qquad x_2 = -20.79 + .2757x_3 \qquad (R^2 = .913)$$

x_2 = amount of recovery (1 000 metric tons)
x_3 = consumption of paper and board (1 000 metric tons)

Thus the forecasting of waste paper recovery was carried out in two steps. First the consumption of paper and board was forecast by using model (19) and two explicit growth forecasts of gross domestic product. Second, using these projections and model (20) the forecasts of waste paper recovery were produced.

Another way of forecasting waste paper recovery was also tried. In this case the amount of recovery was the dependent variable and the gross domestic product was the independent variable. The forecasting model constructed in this way gave results similar to the »two step» forecast.

In Table 8 are presented the high and low forecasts of paper and board consumption and of waste paper recovery as given by models 19 and 20. These figures were applied for computations of the recovery rates. Both of

Table 8. Consumption and recovery of paper and board in Finland, 1950—1973 and forecasts up to 1985.

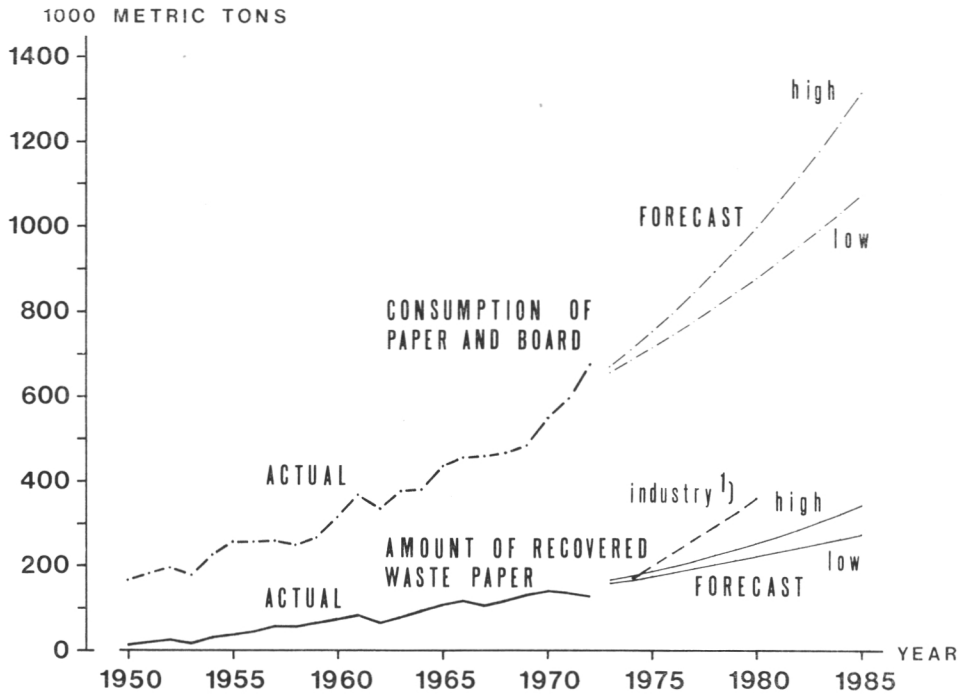
Year	A. Consumption of paper and board		B. Recyclable fraction (0.85 · A)		C. Waste paper recovery		D. Nonrecovered paper and board (B—C)		E. Recovery rate (100 · C/A)	
	1 000 metric tons								%	
1950	167		142.0		13.6		128.4		8.1	
1955	256		217.6		37.8		179.8		14.8	
1960	311		264.4		78.1		186.3		25.1	
1965	435		369.8		106.4		263.4		24.5	
1970	548		465.8		140.1		325.7		25.6	
1971	596		506.6		135.4		371.2		22.7	
1972	676		574.6		130.0		444.6		19.2	
1973	762		647.7		148.5		499.2		19.5	
	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast	Low forecast	High forecast
1978	810	892	689	758	203	225	486	533	25.0	25.2
1980	879	998	747	848	222	254	525	594	25.2	25.5
1985	1 074	1 315	913	1 118	275	342	638	776	25.6	26.0

the two forecasts show a very slow increase in the recovery rate. According to the forecasts the recovery rate in 1980 would be about 25 per cent and the amount of recovery 222—254 thousand tons.

It has been estimated that the proportion of non-recoverable paper and board in consumption in Finland is about 15 per cent. Non-recoverable paper includes tissue paper, building paper and board, etc. The amounts of the recyclable fraction (see definition on p. 18) and forecasts of it have been calculated in column B of Table 8. The amounts of non-recovered paper and board were 128 000 tons in 1950 and 445 000 tons in 1972 (column D). Estimates show that in 1980 the amount of non-recovered paper would be 525—594 thousand tons. These figures illustrate the theoretical potential secondary raw material base for the paper and board industry.

The past development and the forecasts of Table 8 are visualized in Fig. 18. Recovery rate up to 1985 according to the forecasts would be about 25 %. The difference between the lines of consumption and recovery show the tonnage of non-recovered paper. According to the forecasts more and more potential raw material for the paper and board industry will be destroyed.

The forecasts made are typical mechanistic trend projections and based on the data of years 1950—1972. Thus the forecasts include the assumption that the conditions in the waste paper market will develop in the future in the same way as they have done in the past. In the same Fig. 18 is presented also the waste paper recovery forecast made by Paperinkeräys Oy (the Finnish integrated company for waste paper reclamation). This »industry forecast» is based on the assumption that a new deinking mill using waste paper as raw material will be established. This would mean a remarkable increase in waste



1) forecast by Paperinkeräys Oy (the Finnish integrated company for waste paper reclamation)

Figure 18. Consumption and recovery of paper and board in Finland, 1950—1972 and forecasts up to 1985.

paper recovery. This forecast made by the specialists working in the waste paper market shows the amount of recovered waste paper in 1980 as 364 000 tons. According to Paperinkeräys Oy this means a recovery rate of 34 per cent which can be regarded as an industrial goal as well.

Another approach in forecasting is applied in Table 9, where four alternative *normative forecasts* of waste paper recovery are presented. First of all there is the low consumption forecast of paper and board from Table 8 for the years 1978, 1980, 1985 and 2000. After that there are presented four alternative recovery rates (25, 30, 35 and 42.5 per cent). Normative refers here to the idea of forecasting where the decision makers can choose the most suitable recovery rate alternative to act as their goal and then find the corresponding forecast of waste paper recovery. The recovery rate level of 25 % is the result of the forecasts made in Table 8 and is also close to the maximum level of the past in Finland.

It has been estimated that the maximum recovery of the recyclable fraction under present conditions would be around 50 per cent, as part of the paper consumed will stay in permanent records, libraries, etc. and also

Table 9. Four alternative normative forecasts of waste paper recovery in Finland.

Year	Consumption of paper and board (forecast based on 3.7 % annual increase in GDP)	Waste paper recovery							
		25 % recovery rate		30 % recovery rate		35 % recovery rate		42.5 % recovery rate	
		total amount	increase from 1973	total amount	increase from 1973	total amount	increase from 1973	total amount	increase from 1973
	1 000 metric tons								
1978 ...	810	203	55	243	95	284	136	344	196
1980 ...	879	220	72	264	116	308	160	374	226
1985 ...	1 074	269	121	322	174	376	228	456	308
2000 ...	1 924	481	333	577	429	673	525	818	670

there are other uses for discarded paper and board. It is likewise not reasonable to extend the collection to remote areas and those of low population density. The 50 per cent recovery of recoverable kinds of paper and board would yield a 42.5 per cent recovery rate, the highest alternative in Table 9. This means that the share of non-recoverable paper and board is assumed to be 15 per cent of the total consumption ($.5 \times 85 = 42.5$). These percentages will and can be changed during a long-term period because of changes in technology, consumption habits, legislation, etc. (see the factors in Fig. 10, p. 49). The recovery rate of 42.5 % is also the highest level heretofore realized in industrialized countries, for instance the Netherlands (Fig. 11 p. 53).

The total amount of recovery and the increase in this amount from the year 1973 are calculated for each alternative recovery rate (Table 9). The amount of recovery was 148 000 tons in 1973. The increase forecasts give some idea of what additional capacity of industry using waste paper as raw material would be needed in the future, according to the recovery rate in question and the low forecast of paper and board consumption. The present mills could use some additional waste paper, but new capacity would be necessary in order to fully exploit the future prospects in the waste paper field.

According to recovery rates the extra capacity demand to 1980 would be: 25 %: 72 000 tons; 30 %: 116 000 tons; 35 %: 160 000 tons; 42.5 %: 226 000 tons. Households would be the main source of the additional tons of recovered waste paper. This would require a deinking method to be applied in the potential new mill in order to acquire better market conditions than today for secondary-fiber based products. *It is up to the various decision makers to choose a national target recovery rate.*

4.3. U.S.A.—a case of environmental pressure

4.3.1. Past development

»The outlook for timber in the United States» by the U.S. Department of Agriculture, Forest Service (The outlook ... 1973) and »Waste paper re-

cycling» by Joseph E. Atchison Consultants, Inc. (A t c h i s o n 1972) are the two major literature sources for Sections 4.3.1. and 4.3.2.

In this Section 4.3. the paper and board consumption figures concerning the U.S.A. include also building board (insulating board and hardboard). Therefore the U.S. recovery rates are not internationally comparable.

For example, the difference in the content of paper and board consumption in 1969 caused a difference of about one per cent unit in the recovery rate between OECD and U.S. statistics, the »U.S. recovery rate» being smaller. The United States of America has been the number-one country in the international statistics of paper and board consumption. In 1969 the U.S. consumption was about 40 per cent of the total paper and board consumed in the world. The total consumption of paper and board and the per capita figures (incl. building board) are presented in Table 10. The consumption has doubled during the period 1950—1970, from 26 million tons to 53 million tons. The consumption of paper and board per capita was 263 kg (without building board) in 1972. In the same year the respective figure in Finland was 146 kg. This comparison illustrates the magnitude of the U.S. paper consumption.

Along with the consumption figures are presented the respective gross national products per capita. It can be clearly seen how strongly paper con-

Table 10. Consumption of fibrous materials and paper and board in the U.S.A., 1929—1972 (converted into metric tons from: The outlook . . . 1973, p. 331, 349, 354).

Year	Consumption of fibrous materials				Consumption of paper and board [2]		Gross national product per capita
	Total	Wood pulp	Waste paper	Other [1]	Total	Per capita	
	Million metric tons				Kilograms		1967 dollars
1929	10.5	5.7	3.5	1.3	12.2	100	1 966
1935	10.0	5.8	3.3	.9	11.6	91	1 564
1940	14.1	8.9	4.2	.9	15.2	115	2 014
1945	17.2	9.8	6.2	1.2	18.0	128	2 972
1950	23.5	15.0	7.2	1.3	26.4	173	2 743
1955	28.9	19.5	8.2	1.2	31.7	191	3 104
1960	32.4	23.3	8.2	.9	35.6	197	3 173
1965	40.9	30.8	9.3	.8	44.7	230	3 739
1966	44.0	33.5	9.6	.9	47.8	243	3 936
1967	43.3	33.6	9.0	.8	47.2	238	3 995
1968	47.6	37.5	9.3	.8	50.6	252	4 140
1969	50.4	39.6	9.9	.8	53.5	264	4 209
1970 [3]	49.5	39.2	9.6	.8	52.7	257	4 143
1971 [3]	50.8	40.1	10.0	.8	54.1	262	4 213
1972 [3]	53.3	42.3	10.2	.8	58.4	279	4 446

[1]) cotton, bagasse and other fibers
[2]) includes hardboard and insulation board
[3]) preliminary

sumption per capita is correlated with the gross national product per capita. The U.S. correlation coefficient ($r = .990$) for the years 1950—1972 is exactly the same as the corresponding coefficient in Finland for 1950—1970 (Table 7, p. 69).

Domestic production of paper and board has covered about 90 per cent of the consumption. In 1972 the output was 54 million tons, whereas the consumption was 58 million tons. The share of domestic production has gradually risen and the same trend can be seen in the projections made by the Forest Service.

The general categories of waste paper consumed in the U.S. are as follows (cf. A t c h i s o n 1972, p. 349):

Category of waste paper	Distribution of consumption		
	1963	1967	1969
Mixed	35	32	30
News	20	20	20
Corrugated	28	33	33
High grade pulp substitutes	11	10	12
High grade deinking	6	5	5
Total	100	100	100

After World War II the recovery and consumption of waste paper has continuously dropped. Recovery rate declined from 27 to 23 per cent from 1950 to 1970. Furnish rate (waste paper consumed as a percentage of total consumption of fibrous materials) fell from 31 to 19 per cent within the same period.

The foreign trade of waste paper has had only minor importance in the U.S. Imports have generally been below 100 000 tons and exports between 200 and 300 thousand tons. However, exports have increased during the past few years. The increase of exports has been recommended as one solution for recycling more paper. Freight rates and handling costs, however, probably restrict large scale increase in waste paper exports.

Paper recovery in the U.S. reached its peak during World War II. The recovery rate in 1944 was 35.1 per cent. The recyclable fraction was then estimated to be 62 per cent of the total consumption of paper and board. Thus the recycling rate became as high as 56 per cent (cf. A t c h i s o n 1972, p.64).

The nonrecoverable proportion of paper and board was estimated to be 24 % of the whole consumption in 1970. This was composed of building paper and board, tissue, book and writing paper going into permanent records, packaging papers and boards and industrial converting papers which are not recoverable. In several other countries the proportion of nonrecoverable paper and board is estimated to be about 15 %. The difference is explained by the different structure of consumption and different calculation bases.

If the maximum recycling rate is estimated to be 50 % this would mean that in the U.S. the upper limit for the recovery rate would now be 38 %. This corresponds with the calculations by S l a t i n (1972), who got an upper limit of waste paper use below the 40 per cent level. Also empirical data show that this rate has so far been about the maximum even in the most advanced »paper recycling countries».

From 1946 waste paper's share as a raw material for paper and board manufacturing has continuously decreased in the U.S. In fact, many predictions have been made with estimates that the use of waste paper would continue to decrease in the U.S. while increasing in many other countries.

As a major result of this development 11 million tons of potential raw material of the paper and board industry ends in the rapidly growing solid waste stream of the U.S.A. The following factors are assumed to have affected this development (cf. The outlook . . . 1973, p. 194—196; A t c h i s o n 1972, p. 81).

— In the U.S. market there has been a plentiful supply of virgin fiber paper and board products, which in some sectors have been produced at lower cost than similar grades made of waste paper.
— All kinds of consumers, the private individuals, the government agencies, the commercial and industrial buyers, have preferred virgin fiber products to waste-paper based products.
— The fast growth in costs of collecting, sorting, cleaning and transporting has lessened the competitiviness of waste paper as a raw material.
— Quality standards of paper, the modifying of paper and board (waxes, plastics, foils, etc.) resulting in more contamination and potential dangers to health from waste paper reuse have also worked against paper recycling.
— Some combination board mills utilizing a high proportion of waste paper have been forced to close down. This has partly resulted from uneconomical operating levels, from the wide fluctuations in prices of waste paper and from a lack of interest in developing new processes and products based on waste paper.
— Integration of the industry, with production of both pulp and paper concentrated in large complexes designed to fully utilize the timber, has tended to favor production of virgin pulps over waste paper use.
— Both the pulp and paper industries have concentrated in large units with long distances from cities, the major sources of waste paper.
— The advertising of the paper industry that wood is a renewable resource and that wood growth can be intensified has made the general public feel no concern for the rapidly increasing consumption of paper or for the sufficiency of wood.

4.3.2. Future trends

The major pressure for recycling more paper in the United States has come from the environmentalist side. Their main arguments have been: The rapidly expanding exploitation of forest resources, the environmental deterioration caused by the paper and board industry and the rising mountains of solid waste.

Accordingly, the state of paper recycling in the United States has quite recently developed along new lines. The expectations of increased paper recycling in the U.S. can be seen in projections made by the Forest Service (Table 11 & Fig 19).

Three alternative projections for the consumption of fibrous materials up to 2 000 are presented in Table 11. The projections are based on alternative assumptions about growth in population and economic activity. The consumption projections of paper and board for 1990, as an example, are as follows: 93 (low), 105 (medium) and 120 million tons (high). The heavy demand for fibrous raw materials is evident even according to low projections. This and also the expanding world-wide demand for paper and board products is supposed to have an effect of increasing pulpwood prices.

As general environmental concern has grown it has been recommended by some groups that wilderness preserves should be expanded. If realized, this development would remove more forests from the production of pulp-

Table 11. Three alternative projections for consumption of fibrous materials and paper and board in the U.S.A. up to 2000 (converted into metric tons from: The outlook . . . 1973, p. 144, 189, 190, 195).

Year	Consumption of fibrous materials				Consumption of paper and board [2]		Gross national product per capita
	Total	Wood pulp	Waste paper	Other [1]	Total	Per capita	
	Million metric tons				Kilograms		1967 dollars
			Low projections				
1980	68.9	52.8	15.4	.6	70.9	314	5 500
1990	91.6	64.0	26.7	.9	93.0	375	7 080
2000	117.7	76.5	40.0	1.2	118.3	445	9 310
			Medium projections				
1980	73.5	56.3	16.4	.7	75.4	331	5 730
1990	104.3	72.9	30.4	1.0	105.3	413	7 580
2000	142.1	92.4	48.3	1.4	142.0	505	10 180
			High projections				
1980	78.9	60.6	17.6	.7	80.7	348	5 910
1990	119.8	83.7	34.9	1.2	120.4	452	8 000
2000	173.5	112.9	59.0	1.7	172.5	573	10 970

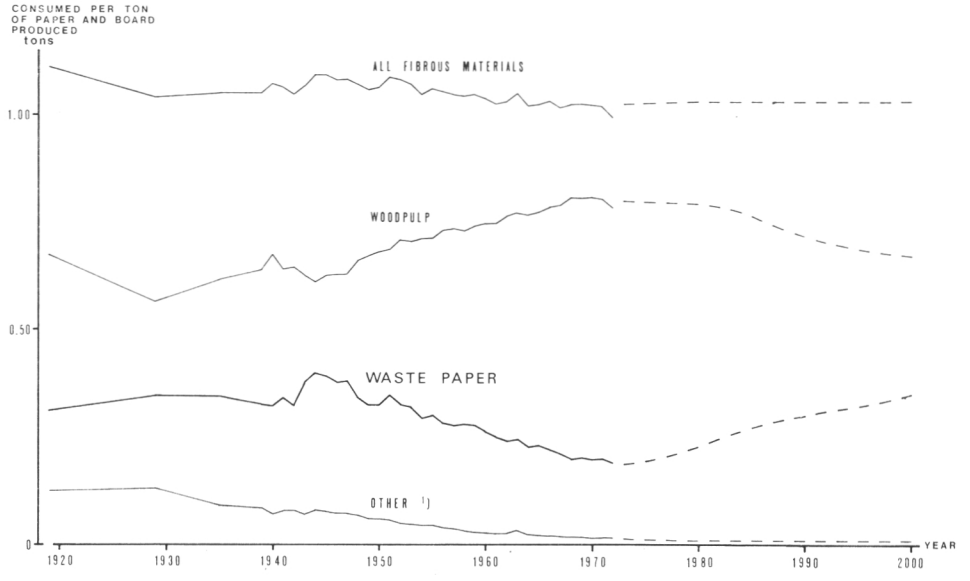
[1]) cotton, bagasse and other fibres
[2]) includes hardboard and insulation board

wood. Pulpwood prices will also tend to increase because of the necessity of harvesting more inaccessible areas. The same trend is favored due to increasing competition for timber by sawmills and other wood-using industries.

The recent decisions of the Federal Government and those of many states and municipalities to increase purchases of paper and board with higher waste paper content will have a stimulating effect on paper recycling. Tax policy is also one of the government's tools for promoting paper recovery. Research is being stepped up to identify other ways of increasing use of waste paper. (Cf. A t c h i s o n 1972, p. 174.)

As the consumption of paper and board doubled during the period 1950—1970, the amount of waste paper consumed as a fibrous raw material grew only by one third, from 7.2 million tons to 9.6 million tons. The consumption of waste paper per ton of paper and board produced was 326 kilograms in 1950. In 1970 the figure had come down to 198 kg. However, this trend has been expected to change its direction in the future. The three projections concerning waste paper consumption per ton of paper and board produced give the following results: 230 kg. in 1980, 300 kg. in 1990 and 350 kg. in 2000. This development can be seen as well in Fig. 19, which presents the past development and projections for the future of the fibrous materials consumption.

An important contribution to paper recycling in the U.S. has been made by the *Garden State Paper Company*. It operates four paper machines in



1) cotton, bagasse and other fibers

Figure 19. The U.S. consumption of fibrous materials per ton of paper and board produced 1919—1972, with projections up to 2000. (The outlook ... 1973, p. 194.)

various locations, utilizing 100 % old newspaper as fiber furnish to produce newsprint.

Production of each machine is about 300 tons of newsprint daily. *Capital cost for this kind of a newsprint mill has been estimated at about $ 60 000 per daily ton. The capital cost for a completely integrated newsprint mill, based on the use of 100 % virgin fiber, is more than double this amount.* (A t c h i s o n 1972, p. ES-33). Of special significance is the fact that the salvaged newspapers are recycled into a product which meets the original quality requirements.

The expansion plans of the pulp and paper industry indicate that during the early 1970's the use of waste paper is not likely to increase appreciably as a proportion of total fibrous materials used. In the longer run factors favoring higher recovery rates will certainly lead to substantial growth in paper recycling. (Cf. The outlook . . . 1973, p. 196.)

Waste paper *furnish rate* is expected to be 22 per cent in 1980 and then rise to 29 per cent by 1990 and to 34 per cent by 2000. A realistic national goal for the overall waste paper *recovery rate* in the U.S. might be 25—27 % by 1985, 30 per cent by 1990 and 35 per cent by 2000 (cf. A t c h i s o n 1972, p. ES-54). The achievement of these goals will require maximum use of new technology, incentives and household cooperation.

5. FEASIBILITY OF INCREASED RECYCLING

5.1. Technological aspects

Recent developments in processes and equipment have favored waste paper recycling. The U.S.A. and the Federal Republic of Germany have been the most advanced countries in developing new techniques for waste paper use.

There are two principal categories in the use of waste paper. In the more usual method no washing or deinking is done. The main product in this case is board. The process essentially consists of pulping and screening. The effluent disposal problem is relatively minor compared to that of a deinking plant.

Deinking means the separation of ink from the fibers. Two methods are in use in the deinking process (1) flotation and (2) washing. New deinking systems generating only a limited amount of waste effluent have been developed, and also fiber fractionating and cleaning systems for separation of the undesirable components of waste paper. The ability of mills operating on some types of waste paper to run with a completely closed water system without any liquid effluent to the sewer, and the development of successful systems for effluent treatment at reasonable cost for recycling mills have been positive factors for developing waste paper recycling (cf. Future Prospects . . . 1971).

A deinking plant should be designed so that any sort of contaminant will be removed. This is not possible with the equipment available at the present state of the art, but it should be the aim (D o a n e 1971).

D o a n e also says that »research work in the deinking field has been woefully small. If recycling for both board and fine papers is to come of age a great deal of research will have to be done». However, already today an increasing number of firms in the leading countries of recovery are rather successfully utilizing various deinking methods (cf. p. 82).

In general it could be said that without deinking waste paper is suitable for certain boards and low grade papers, but for higher grade papers the deinking method is necessary. (See the sample in the beginning of this paper.)

For traditional waste paper reclamation it is important to keep waste paper separated from other refuse and the efficient use of this raw material would also require sorting out the different grades of waste paper. In paper stock preparation there have so far not been any major improvements to eliminate the hand labor in sorting. However, intensive research has been carried out and even pilot plants have been operated in segregating waste paper fibers from mixed municipal refuse.

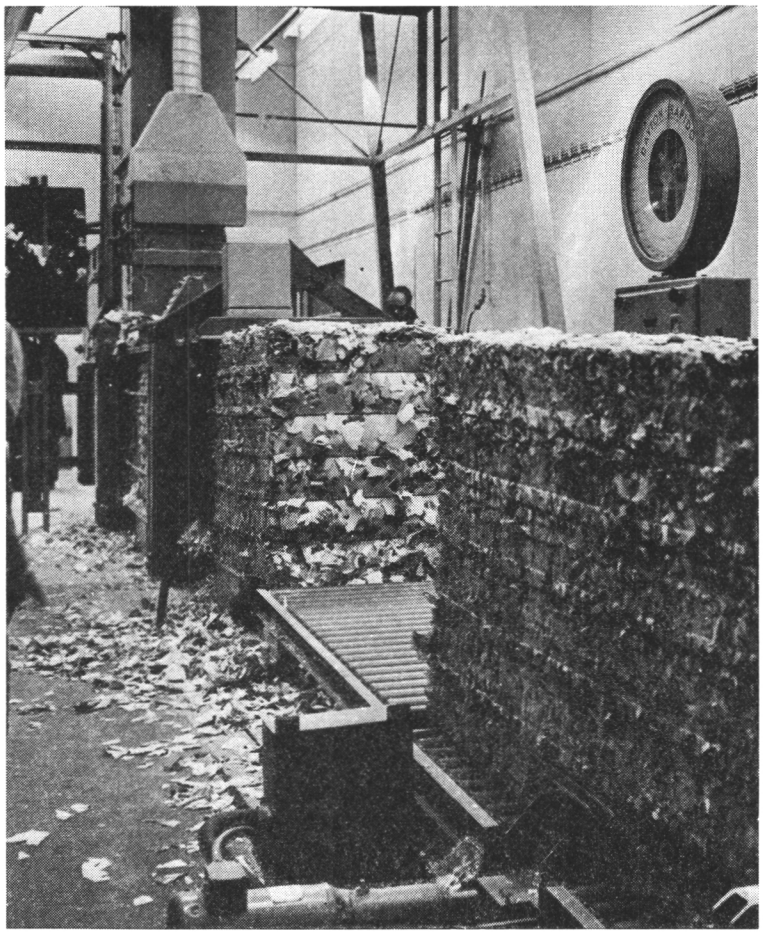
The new technology involves the entire chain of recovery. To supplement the old procedure a number of new processes are under development toward separation of fiber from municipal refuse. In new *fiber fractionation processes* it may be possible to separate long and short fibers as well as groundwood from mixed papers. If these new processes could be succesfully implemented in practice they would play an important role toward increased recycling of waste paper (A t c h i s o n 1972, p. ES-38).

Pernicious contraries form a problem very difficult to solve. Contraries such as stones, rubber, metal string, carbon papers, etc. are more easily dealt with than the pernicious contraries. When these additives arise in recovered paper they become »pernicious» because even in very small quantities they do harm disproportionate to the value of the material being used by ruining the paper and board being produced, or by damaging the machinery and thus causing serious production delays (R i c h a r d s o n et al. 1971, p. 33).

New forms and applications of pernicious contraries arise continuously, but practically they fall into nine main groups, as follows: Bitumen, wet strength resins, polythene and cellulose film, wax laminates, natural latex, non-water soluble adhesives, synthetic latices, vegetable parchment laminates, and brittle plastics. *In fact certain waste paper grades can be so contaminated with pernicious contraries that recovery is not a viable or economic proposition.* In recent years a number of steps have been taken to limit the problems of pernicious contraries in recovered paper, by waste paper utilizing mills, by waste paper associations and by various research organizations (cf. A t c h i s o n 1972, p. ES-40).

The faster growth of virgin fiber paperboard output in comparison with waste-paper based combination board has been due partly to less efficient *boardmaking machinery* for the latter. The recent development of the new models of multiformers promises a rapid change in this situation. Now machines of high speed and much greater width are possible for combination board production. These new machines also provide great flexibility in use of fibrous furnish in the multiple layer structure of combination board. (A t c h i s o n 1972, p. ES-39.)

At the Institute of Paper Chemistry in the U.S.A. studies have been carried out on the changes in the properties of pulp that has been recycled several times in a closed cycle into the same grade of paper (cf. M c K e e



A modern waste paper shredder and baling press.

1971). The most important findings of the effects of repulping on sheet characteristics were as follows:

(1) Recycling the fibers and refining to the same freeness lowers fiber bonding and therefore bursting and tensile strength. The first repulping cycle lowered the bursting strength approximately 14 per cent and after six repulping cycles the bursting strength decreased approximately 38 per cent.

(2) Tearing strength and stiffness, which are inversely related to fiber bonding, are improved with each cycle.

(3) The repeated mechanical attrition in refining the pulps in each cycle does not greatly shorten fiber length.

(4) Repulped-fiber sheets have greater opacity compared to virgin-fiber sheets. This is a beneficial characteristic of deinked stock especially for printing papers. When brightness is considered the repulped-fiber sheet exhibits a slightly lower brightness than the virgin-fiber sheet. However, here it should be pointed out that contamination due to collection, hauling and storage was not a factor in the experiments made.

The fiber losses in waste paper recycling processes vary a great deal depending on the grade of waste paper and method used in the process. Several studies have been made with different methods and raw materials. They gave shrinkage percentages from 5 to 55, the most common being 10—20 per cent. (Cf. O j a n e n — J u s e l i u s 1960, p. 120—125; R a n t o 1968 and A t c h i s o n 1972, p. 126—128.)

The term »recovery rate» is usually an annual figure telling how much of the consumed paper and board is recovered in a country. This percentage does not, however, tell the *total potential recovery* of a given amount of virgin-fiber paper and board consumed. The reason for this is the basic idea of recycling: once consumed a product can be recovered and be raw material for a new product again. These cycles can continue many times, some estimates saying that the number of successful repulpings could be six, but it can also be higher depending on the process.

The following equation was developed by the present authors in order to estimate the potential recovery of virgin-fiber paper and board consumed when recycling occurs several times and the recovery rate stays continuously at the same level.

$$(21) \quad A_r = C_{vf} \sum_{i=1}^{n} \left((1-s)\frac{W_r}{C_p}\right)^i = C_{vf} \sum_{i=1}^{n} \left((1-s)\, R_w/100\right)^i$$

A_r = amount of potential recovery
n = number of cycles
s = shrinkage of waste paper raw material in the production process
C_{vf} = amount of virgin-fiber paper and board comsumption in the first cycle
W_r = amount of recovered waste paper
C_p = consumption of paper and board
R_w = 100 W_r/C_p or recovery rate.

Accordingly the rate of potential recovery of virgin-fiber paper and board consumption (R_r) is as follows:

$$(22) \quad R_r = 100\left[C_{vf} \sum_{i=1}^{n} \left((1—s)\, R_w/100\right)^i \right] /C_{vf}$$

$$= 100 \sum_{i=1}^{n} \left((1—s)\, R_w/100\right)^i$$

The use of these models requires uncertain assumptions. However, it is important to realize the potential benefits of circular technology as the recycling can occur several times.

Let us take a simple case to illustrate the models. Paper and board consumption (C_p) is 100 tons and the amount of recovered waste paper (W_r) is 30 tons. This means a recovery rate (R_w) of 30 per cent which is assumed to stay continuously at the same level. The losses of waste paper fiber (s) in the production process are assumed to be 10 %. Accordingly this yields 0.9 for (1—s). This factor is not fixed during the future cycles, but we take it here as stable. The number of cycles (n) is estimated at six and fiber disappears from the process after six repulpings. The amount of virgin-fiber paper and board consumption (C_{vf}) is 60 tons. The final assumption is a closed economy without any exports or imports.

In this case applying the data above and equation (21) we get the amount of potential recovery (A_r) of the virgin-fiber paper and board consumption of 22.2 tons. This can be compared to the first-round recovery of 18 tons (30 % of 60 tons) and a conclusion can be drawn that in this case the potential recovery was 23.2 % higher than the first-round recovery of virgin-fiber paper and board consumption.

Using equation (22) we get 37 per cent for the rate of potential recovery of virgin-fiber paper and board consumption (R_r). This is markedly higher than the recovery rate (R_w) which in this case was 30 %. The rate of potential recovery (R_r) is much easier to compute than A_r because C_{vf}, which is difficult to estimate, is not needed.

5.2. Economic aspects

The world consumption of paper and board was 127 million metric tons in 1970. According to a recent FAO (1972) study this consumption was forecast to grow to the level of 260—282 million tons in 1985. In other words, in about 15 years the world consumption of paper and board is expected approximately to double. This outlook poses two vital questions for the industry. »Firstly, can production be stepped up as much as the outlook assumes? Secondly, can the raw material supply — still and likely to remain predominantly wood — be maintained or developed to an economic level consistent with the level of pulp production envisaged?» (FAO 1972, p. 49.)

A tentative answer to the latter question can be found from the same study (p. 43): »On a world scale there is little evidence that the increased demand for pulp will lead to a raw material crisis by 1985. But there are shortages in some regions. The trouble is that the wood is no longer readily available where the industry and the markets are. The only answers in the long run are to use something else, to move the wood to the industry, to move the industry to the wood or to create forests where the industry is. Whatever way things go there is little doubt that the course of development of the world's pulp industry is going to be very different from what it has been».

According to our earlier analysis based on the 16 OECD countries (Sections 4.1.2. and 4.2.2.) the growth of paper and board consumption is the strongest factor which increases the amounts of recovered waste paper. Faced with these prospects it seems likely also that the global amounts of recovered waste paper will grow strongly in the future. Another important question in this connection is the development of the waste paper recovery rate. Paper and board output per unit area, paper and board prices and the scarcity of the virgin fiber supply appeared to be the major factors affecting the recovery rate. The world prospects are for an intensification in these factors which again stimulates the recovery rate of waste paper. On the other hand the likely future growth of the wage level tends somewhat to decrease the recovery rate, although this impact will apparently not be as strong as the increasing tendencies.

The waste paper recovery rate of 23 % has recently been estimated as a world average. It has been forecast to grow in the future. »The recovery rate for waste paper could eventually reach a rate of 35 % on a worldwide basis, by the time the U.S. reaches this goal in the late 1990s» (A t c h i s o n 1972, p. ES-13). »It seems likely that the recovery rate will increase in the future, and that consequently the use of waste paper as a raw material input in the paper industry will grow more rapidly than the use of wood pulp» (OECD 1973, p. 37).

Utilization rate was defined as a ratio of consumed waste paper to total paper and board output. Scarcity of virgin fibers, population density, paper and board output excluding newsprint and printing and writing paper per total paper and board output, and the price of paper and board were the major factors which affected the utilization rate. A trend of growth in all these factors can be expected. Consequently, most likely up to 1985 both the recovery and utilization of waste paper will increase.

The foregoing projections were carried out at the macro level. However, in the first place *paper and board producing firms* are the decision makers which finally determine to what degree waste paper will be used as a raw material in the future. The future prospects for waste paper recycling can be examined also on the basis of factors which regulate the demand for

waste paper. With certain reservations the demand for waste paper can be assumed to depend on the following factors (cf. Bergstrom 1968; Lehto; Nevala 1973, p. 5—6):

$$(23) \quad D_w = f(P_y/P_w, P_y/P_v, P_y/P_s, X_m, T_r, D_y)$$

D_w = demand for waste paper
P_y = price of waste-paper based products
P_w = price of waste paper
P_v = price of virgin fiber
P_s = price of synthetic fiber
X_m = amount of fixed production factors
T_r = rate of technology
D_y = demand for waste-paper based products

According to this function the demand for waste paper is affected first of all by the three price ratios: (1) price of waste-paper based product to price of waste paper, (2) price of waste-paper based product to price of virgin fiber, and (3) price of waste-paper based product to price of synthetic fiber. The competitiveness of the first price ratio with the two others determines to a great extent the future demand for waste paper from the individual firm's viewpoint.

The amount of fixed production factors (X_m) determines, in the short run, the potential maximum for waste paper demand. The demand for waste-paper based products (D_y) causes cyclical variation in the demand for waste paper. Finally the rate of technology (T_r) determines the quality of products the firm is able to process from waste paper. The role of these technological aspects was discussed in Section 5.1.

The statistics available are inadequate for any detailed analysis of the development and future trends concerning prices of waste paper, virgin fiber and their potential substitutes (e.g. synthetic fiber). According to Atchison (1972, p. ES-22—24) very little accurate information has been published concerning these price relations in the United States. This report's observation, that waste paper prices proved to be much more unstable than those for wood pulp may have relevance also in some other countries. Atchison (1972, p. ES-24) found the following long range economic prospects concerning waste paper recycling in the United States:

(1) »Long range factors which are expected to result in increased costs of paper products manufactured from virgin fiber, in addition to increased operating costs are:

a. Anticipated shortages of pulpwood in the late 1980s as well as higher prices it will command because of competition from other wood using industries,

b. Required installations of expensive pollution control facilities, and
c. Recognized need for an increased rate of return on investment in the paper industry.

These factors could favor mills based on utilization of waste paper».

(2) »Profitability expectations will be very important in attracting new capital to urban mills based on utilization of recycled fiber. Such mills may be favored because of the lower capital costs per daily ton of production as compared to mills based on utilizing virgin fiber. New waste paper mills would have lower costs relative to air and water pollution control facilities, and may also have lower costs for transportation of raw materials and finished products».

The characteristics of the two main pulp raw materials such as roundwood density, defects etc. and waste paper grade, contamination etc. vary over rather wide ranges. Also the roundwood and waste paper requirements for various products and processes vary a great deal. Accordingly difficulties are met when comparisons between roundwood and waste paper quantities are to be made. However, a case for Finland is developed to get some guidelines.

So far in Finland waste paper has been raw material only in the paperboard industry. In this case the most precise comparisons can perhaps be made between mechanical pulp and pulp made of waste paper. According to the fresh plans, use of the deinking method seems to be likely in the near future of the Finnish waste paper utilization. The quality of deinked waste paper pulp is approximately the same as that of chemical pulp. Thus bleached coniferous sulphate pulp was chosen as another comparison standard. Mechanical pulp represents low roundwood demand per ton of pulp and bleached coniferous sulphate pulp high roundwood demand per pulp ton.

Mechanical pulp requires 3.5 m^3 of Norway spruce pulpwood as an average and bleached coniferous sulphate pulp 7.4 m^3 of Scots pine pulpwood as an average (piled measure, without bark and the last annual ring, two-meter long bolts). (Cf. W e g e l i u s 1968, p. A 1/6.) In solid volume these figures would amount to 3.1 m^3 and 6.4 m^3 (with bark). If it is estimated that a ton of pulp requires 1.15 tons of waste paper *an average estimate that a ton of waste paper equals 2.7—5.6 m^3 of pulpwood* (solid volume, with bark) is obtained. According to another estimate (Yhdyskuntien . . . 1974, p. 35) one ton of waste paper is estimated to equal about 4 m^3 of roundwood as an average.

The amount of recovered waste paper in Finland was 130 000 tons *in 1972*. According to the estimates above this amount would equal 0.4—0.7 million m^3 of pulpwood. In the same year the Finnish pulp industry consumed 20.7 million m^3 of domestic roundwood. The amount of nonrecovered paper and board was 444 600 tons *in 1972* (Table 8, p. 75). This equals 1.2—2.5 million

m³ pulpwood. According to the high and low forecasts made earlier in this paper the waste paper recovery *in 1980* will be 222 000—254 000 tons. This corresponds to 0.6—1.4 million m³ pulpwood. *The normative forecast based on the recovery rate of 35 % showed for 1980 waste paper recovery of 308 000 tons or 0.8—1.7 million m³ in pulpwood equivalents.*

If this kind of comparison is extended on *a global basis* more difficulties are met. However, in order to get some idea of the relative importance of waste paper some approximations are presented concerning the substitution between waste paper and roundwood.

If waste paper is considered to substitute for an equal amount of mechanical pulp we can estimate that a ton of waste paper equals about 2 m³ of pulpwood (solid volume, without bark). If the deinking method is used waste paper could substitute for an equal amount of chemical pulp. In this case a ton of waste paper represents in roundwood equivalent about 4 m³ of pulpwood. (For roundwood equivalents of mechanical and chemical pulp see for example FAO, Yearbook of forest products 1970, p. 223). When calculating the equivalents a shrinkage of 20 % in waste paper utilization was assumed.

The consumption of paper and board in the world was about 107 million tons in 1967. In the same year the recovery of waste paper was 24.8 million tons. This equals approximately 50 million m³ of pulpwood while total pulpwood consumption was 265 million m³ (solid volume, without bark). The total world consumption of paper and board was 127 million tons in 1970 (a mean of the production figures from the years 1969—1971).

The FAO-forecast of 260 million tons of paper and board consumption in 1985 is used in the following as calculation basis. Alternative recovery rates are used. The lowest recovery rate, 23 per cent, is the approximate world average today. On the other hand the highest, 42.5 per cent, describes the theoretically highest potential recovery rate under the present conditions. The roundwood equivalents of 2.0 and 2.6 m³ for a ton of waste paper are applied. Today about one tenth of the recovered waste paper is deinked, but its proportion is likely to grow in the future. The 2.6 m³ estimate is based on the assumption that in 1985 about one third of the waste paper utilization might be based on deinking methods.

Consumption of paper and board in 1985	Alternative recovery rates and amounts of recovery		Waste paper recovery expressed in pulpwood equivalents million m³ (solid volume, without bark)
	%	million tons	
260 million tons	23	60	120—160
	30	80	160—210
	35	90	180—230
	42.5	110	220—290

These quantities must be understood only as rough approximations to show the growing importance of waste paper recovery according to alternative assumptions. *If the reader agrees with the assumptions made, this global prospect shows that by the middle of the 1980's the magnitude of waste paper recovery might equal around 50—100 % of the world's total pulpwood consumption in 1967.*

These approximations confirm the hypothesis that in times of scarcity of roundwood, waste paper's role as a marginal raw material base for the paper and board industry is of increasing significance. This is further emphasized by the fact that marginal roundwood quantities required by the industry to use its capacity effectively have higher costs and lower quality than pulpwood in general (the use of small dimension pulpwood, branches, stumps etc.).

5.3. Ecological aspects

The increase in waste paper recovery and use makes one step in the transformation of the paper production-consumption system from linear to circular technology. (Cf. Sections 3.1. and 3.3.) Recycling reduces the volume of municipal solid waste and in this way lowers the costs of waste disposal and prevents losses in esthetic and recreational values of the human environment.

In countries with a situation of scarce virgin fiber supply, where practically all wood residues are already in use, a large-scale increase in waste paper recycling compensates extra timber cutting and conserves forests in this way.

When waste paper substitutes for an equivalent amount of wood pulp, recycling reduces environmental deterioration by the difference in the pollution caused by wood pulping from that generated by waste paper processing.

Waste paper utilizing mills cause only minor air pollution problems compared to virgin fiber pulp mills. If the waste paper utilizing mill is properly constructed and operated and if acceptable fuel is used, air pollution from new waste paper mills is relatively nonexistent. (A t c h i s o n 1972, p. ES-24.)

On the other hand, the role of waste paper mills in water pollution is more complicated. »It can be concluded that the technology exists for satisfactorily treating effluent from a new paper or paperboard mill based on waste paper. Some mills can be completely closed with respect to waste water. In others, the treatment cost will be proportional to the BOD load. Deinking mills will have a sludge disposal problem.» (A t c h i s o n 1972, p. ES-26). Until today deinking has played a minor role in the total use of waste paper, e.g. in Finland no deinking plant exists. About one tenth of the recovered

waste paper in the world was deinked in 1970. However, deinking is likely to grow in the future.

The generation of energy has lately become a vital environmental issue. Energy requirements of waste paper recovery and processing are generally lower compared to logging and processing of virgin fiber. Energy requirements differ a great deal according to processes and products. For example B e r r y and M a k i n o (1974) compared the energy costs per ton of paperboard pulp produced from virgin fiber and produced from waste paper. They got the total energy cost of 1069 kwh/ton of pulp from waste paper, and paperboard pulp from virgin fiber requires 2116 kwh/ton. This means a saving of 50 % in energy cost when waste paper is used as raw material for paperboard pulp. The components of energy consumption per ton of paperboard pulp from waste paper were the following: 176 kwh. for transportation of waste, 265 kwh. for baling and handling, 165 kwh. for transportation to mills and 463 kwh. for the pulping operation to produce one ton of pulp. The deinking process demands an extra 250—300 kwh/ton. According to another estimate (Yhdyskuntien . . . 1974, p. 35) the energy consumption per ton of paper when virgin fiber is used as raw material equals 0.25—0.35 tons oil. When using waste paper as raw material the energy consumption decreases to an amount which equals about 0.1 ton of oil.

In Section 3.3. new ecologically oriented efficiency criteria for human production-consumption systems were described. According to them the intake of new raw material from the ecosystems and energy consumption should be minimized. Sections 5.1.—5.3. show rather promising prospects available in developing the global production-consumption system of paper and paperboard according to these criteria. Also prolonging the »life-time» of paper and board products might have some applications in the future.

6. DISCUSSION

6.1. Reservations

Especially in the late 1960's and in the 1970's waste paper recycling has been the object of numerous articles and studies. For example, M a n n i n g (1972) listed a bibliography of 67 publications on the economic aspects of waste paper recycling. The growing environmental concern has been without doubt the strongest impetus for such an active interest, especially in North America. Since this project was started in 1971 some other activity has appeared also in Finland. A feasibility study on a deinking mill was carried out in 1973 and a new firm, Keräyskuitu Oy, was established in 1974 to build and manage a deinking mill.

One of the major handicaps in reading the papers on waste paper recycling was that quite often the terminology applied was not clear. In this study an attempt was made to define explicitly all the essential terms. The principal guide here was the study by A t c h i s o n (1972).

In the empirical analysis the main problem was to ensure the proper content of the statistics available, especially those concerning waste paper. The lack of standardized definitions for international waste paper statistics was also pointed out by A t c h i s o n (1972, p. ES-10—13). For example, wallboard and other construction board (fiber board) was included in the U.S. paper and board statistics but excluded in the FAO and OECD statistics. In this study the statistics have been made as comparable as possible, but the results of this study still carry some degree of unreliability due to the statistical base.

One limitation of the available statistics was that waste paper recovery and utilization were here studied as aggregates. A more detailed analysis by specific waste paper grades might have given more informative results, especially for the decision makers of the firms. In Great Britain, for example, 38 waste paper grades are recognized (R i c h a r d s o n et al. 1971, p. 30—36).

The theoretical frame of reference concerns partly economics and partly ecology. The economics for an economist and the ecology for an ecologist

may appear elementary. However, the idea was to try to describe the field of environmental quality from both aspects in a concise form. On the other hand an attempt was made to bridge some viewpoints of a national economy and a firm. The necessity to transform the processes of the production-consumption system of pulp and paper industry more towards the model of circular technology was based on the theoretical approach selected. There could also have been alternative ways of setting up the theoretical frame of reference.

The essential empirical results of this study were the models explaining waste paper recovery and utilization in the 16 OECD countries and in Finland (Sections 4.1.2. and 4.2.2.). *An interesting general remark was that the cross-sectional analysis of the 16 OECD countries and the time-series analysis of Finland yielded results which confirmed each other.* For example, both analyses revealed that both high paper and board prices and scarce supply of virgin fibers tend to raise the waste paper recovery rate. The latter factor was referred to in some earlier papers but not the former. There existed no other empirical studies for comparison of the results obtained.

A reservation concerns the results of the cross-sectional analysis. They were based on the single year 1969. Studies of some other years (diverging phases of business cycles) could have given more reliable results, but this idea was abandoned because of the difficulties in getting proper statistics. Finally, in time-series analysis of Finland in Section 4.2.2. an application of difference variables, instead of the present practice, might have improved the results by eliminating timebound multicollinearity among the independent variables.

The long-term future of waste paper recovery in a country or in the world is very difficult to forecast, because there exist many instrumental variables rather readily available for the decision makers to strongly effect this development. In this study the authors have tried first of all to find out some heavy tendencies in the determining of national objectives. The general prospect towards the model of circular technology in developing the production-consumption system for pulp and paper was pointed out. The basic ideas of this model are also applicaple for another human production-consumption systems. The future development of waste paper recovery will be mostly determined in various planning activities, where hopefully the prospects and forecasts of this paper could be utilized while keeping carefully in mind the assumptions made.

The basic alternatives to ensure the growing fiber demand in the world might be classified as follows:

— Expanding logging to earlier inaccessible forest areas and tree species.
— Utilizing more effectively the wood residues available (including »the complete tree concept»).

— Intensification of timber growth.
— Prolonging »life-times» of paper and board products.
— Reuse of fibers abandoned during production processes.
— Waste paper recycling.
— Use of other than wood-based fibers.

More detailed answers about the future roles of these basic alternatives would have required a research input and capabilities which were beyond the possibilities of the authors. Apparently more cost-benefit types of comparisons and more data on various prices, energy requirements, pollution effects etc. would have been needed.

6.2. Actions to increase recycling

A major finding of this study is that there exist no strict technological, economic or ecological factors to prevent increasing waste paper recycling in most of the OECD countries. Both the ecological and economic considerations favor transformation of paper production-consumption system towards the model of circular technology. As an important component of this process, waste paper recycling should be considerably expanded wherever possible. Finally ten recommendations are set out to pinpoint the most important actions, common to most of the OECD countries, which might increase waste paper recycling.

1. Coordination centers for waste paper recycling should be established at the national level, and international ones, such as those of BIR, OECD and FAO should be enlarged. These centers should include experts in the several technical, economic, ecological, management and public relations aspects of waste paper recycling.

2. Better definition of terms and improved statistics on waste paper should be established without delay.

3. More research and development on waste-paper based products, on segregation, collection and storage of waste paper and on pulping and deinking of waste paper must be organized both privately and by government financing.

4. National goals for waste paper recycling should be set up as a part of long-term planning to increase waste paper recycling.

5. Government agencies, business firms and other consumers should review their existing specifications from a performance standpoint to determine whether waste-paper based products or other recyclable products might be used satisfactorily in more applications.

6. Researchers, producers and consumers must pay more attention to eliminate pernicious contraries (contaminants) in paper and board products

7. General legislation and taxation should be developed to specifically favor waste paper recycling.

8. Various government subsidies, for example for storage and transportation of waste paper, could be established to improve the profitability of waste paper utilization.

9. The paper and board producing firms will have to expand their utilization of waste paper by increasing the consumption of the existing mills and by establishing modern, large and well-located new mills.

10. An introduction of a »futures market system» or some other effective measures are needed to stabilize the strong price fluctuations of waste paper.

REFERENCES

Aalto, Teemu. Paperinkeräys Oy. Historiikki 1943—1968. Helsinki. 124 p. Mimeograph.

d'Arge, Ralph 1971. Essay on economic growth and environmental quality. The Swedish Journal of Economics, Vol. 73:1, p. 25—41.

Atchison, Joseph E. Consultants, Inc. 1972. Waste paper recycling. A comprehensive study on utilization of waste paper, its role in solid waste management, and prospects for increased waste paper recycling rates in the future. New York, N.Y. 404+59 p.

Bäckström, Olav 1970. Sulfaattitehtaiden hajuongelmien ratkaisut. Ekono 127 a, p. 46—59. Helsinki.

Beckerman, Wilfred 1972. Environmental policy issues: real and fictitious. In »Problems of environmental economics», p. 19—38. OECD. Paris.

Bergstrom, D. W. 1968. Economics of secondary fiber usage. Tappi Vol. 51:4, p. 76A—77A.

Berry, Stephen R. & Hiro Makino 1974. Energy Thrift in Packaging and Marketing. Technology Review. February, 1974. p. 33—43.

Boulding, Kenneth E. 1950. A reconstruction of economics. John Wiley and Sons, Inc. USA. 311 p.

Collection and re-use of waste paper. 1962. Japan Waste Paper Association. In »Pulp and paper prospects in Asia and the Far East» Volume II, p. 514—523. FAO. Bangkok.

Cunningham, James P. 1974. An energetic model linking forest industry and ecosystems. Seloste: Metsäteollisuuden ja ekosysteemien välisen vuorovaikutuksen energiamalli. Commun. Inst. For. Fenn. 79.3. Helsinki. 51 p.

Dahmén, Erik 1970. Elintilamme hinta. Sininen Kirja Oy. Hämeenlinna. 110p.

—»— 1971. Environmental control and economic systems. The Swedish Journal of Economics Vol. 73:1, p. 67—75.

Dasmann, R. F. 1968. Conservation and rational use of the environment. Report submitted by Unesco and FAO at 44th session of UNESOC.

Doane, Foster P. 1971. Whither Waste Paper Use? and What about Deinking? Paper Trade Journal. April 12, 1971. p. 38—41.

Drobny, N. L. & H. E. Hull & R. F. Testin 1971. Recovery and utilization of municipal solid waste. U.S. Environmental Protection Agency. 11. 118 p.

Duerr, William, A. 1966. Man and the forest. Resource management in the face of change and uncertainty. Second draft. 274 p. Mimeograph.

Ervasti, Seppo and Kullervo Kuusela 1968. Suomen metsätase vuosina 1953—66. Summary: Forest balance of Finland in 1953—66. Folia Forestalia 49. Helsinki. 42 p.

Ervasti, Seppo, Lauri Heikinheimo, Kullervo Kuusela & Veikko O. Mäkinen 1970. Forestry and forest industry production alternatives in Finland, 1970—2015. Folia Forestalia 88. Helsinki. 65 p.

FAO. Yearbook of forest products. Various years.

FAO 1960. World demand for paper to 1975. Rome. 159 p.

FAO 1963. World forest Inventory. 113 p.

FAO 1966. Pulp and paper development in Africa and the Near East. Volume 1, Rome. 454 p.

FAO 1969. Trends in the recovery and use of waste paper. FAO advisory committee on pulp and paper. FO/PAP/69/8 and 8.1/Rev.1. Rome. 7 p. Mimeograph.

FAO 1971. Note on waste paper re-use. Second consultation on world pulp and paper demand supply and trade. FAO advisory committee on pulp and paper. FO:PAP/DST/71/2.2. Rome. 4 p. Mimeograph.

FAO 1972. Outlook for pulp and paper consumption, production and trade to 1985. FO/PAP/DST/71/1.1/Rev. Rome. 66 p. Mimeograph.

Freyschuss, Stig 1971. Cellulosaindustrin och miljövården i Sverige (with English summary). Paperi ja Puu 1971: 4 a p. 175—182. Helsinki.

Future Prospects for Increased Waste Paper Recycling. 1971. Paper Trade Journal. September 13, 1971. p. 58—64.

The growth of world industry. Volume I. General industrial statistics, 1960—1969. United Nations. New York. 1972.

Growth Prospects for the Finnish Economy up to 1980. The Economic Planning Centre 1972. Helsinki. 183 p.

Hall, A. D. & R. E. Fagen 1956. Definition of a system. Yearbook, Society for the advancement of general systems theory. Vol. 1, p. 18—28.

Hall, J. Alfred 1970. Wood, pulp and paper, and people in the Northwest. P. N. Forest and Range Exp. Sta. Forest Service. Portland, Oregon. 34 p.

Hanlon, Joseph 1971. Cycling the paper round. New Scientist and Science Journal. April 29/71, p. 258—260.

Heikinheimo, Lauri, Matti Heikinheimo, Martti Lehtinen & Aarne Reunala 1974. Level of living of forest workers in Finland. Tiivistelmä: Metsätyömiesten elintaso. Commun. Inst. For. Fenn. 81.1 Helsinki. 148 p.

Heikinheimo, Lauri & Matti Palo 1972. Increasing Investments in Finnish Forestry. Loggers Handbook Vol. XXXII 1972. Portland, Oregon, U.S.A. p. 16—17, 169—184.

Hermunen, Keijo 1972. Tutkimus jätepaperin osuudesta Helsingin kaupungin kaupunkijätteessä. Teknillinen korkeakoulu, puunjalostusosasto. 14 p. Mimeograph.

Hodges, H. K. W. 1971. The situation abroad—Great Britain. Paper Trade Journal, September 13, p. 88—90.

Hultin, Sven & Ora Patoharju 1963. Pulp and Paper Mill Effluents and their Disposal. Ekono 87. Helsinki. 40 p.

Huttunen, Terho 1972. Suomen puunkäyttö, poistuma ja metsätase vuosina 1970—72. Summary: Wood consumption, total drain and forest balance in Finland in 1970—72. Folia Forestalia 166. Helsinki. 48 p.

International Atlas. Kansainvälinen suurkartasto. WSOY etc.

International definition and measurement of levels of living. An interim guide. 1961. United Nations. New York. 18 p.

Internationale Altpapiermärkte in der Konjunkturwende. Eine Altpapierbilanz der OECD. 1972. Rohstoff—Rundschau 2/72, p. 22—24.

Jaatinen, Esko & James P. Cunningham 1974. Ecological criteria for rational use of natural resources. In Seminar on Ecological Aspects of Economic Development Planning. ECE. Rotterdam (Netherlands), 7 to 11 April 1975. 28 p. Mimeograph.

Jätehuoltokomitean mietintö. 1970. Komiteanmietintö 1970: B 114. Helsinki. 293 p. Mimeograph.

Kneese, Allen V. 1971 a. Environmental pollution: Economics and policy. Journal of American Economic Association, p. 153—166.

—»— 1971 b. Background for the economic analysis of environmental pollution. The Swedish Journal of Economics Vol. 73:1, p. 1—24.

Koenig, Franz 1971. The situation abroad—Germany. Paper Trade Journal, September 13, p. 86—87.

Kormondy, Edward J. 1969. Concepts of ecology. Prentice Hall Inc. Englewood Cliffs, New Jersey. 205 p.

Kuusela, Kullervo 1972. Suomen metsävarat ja metsienomistus 1964—70 sekä niiden kehittyminen 1920—70. Summary: Forest resources and ownership in Finland 1964—70 and their development 1920—70. Commun. Inst. For. Fenn. 76.5. Helsinki. 126 p.

Lehto, Bjorn O. The economics of recycling. Chas. T. Main, Inc. 9 p. Mimeograph.

Linnamies, Olavi 1971. Metsäteollisuuden laajennukset ja puuraaka-aineen riittävyys. Summary: Expansion of the capacity of Finnish forest industries and the sufficiency of wood raw material. Silva Fennica 1971:3, Vol. 5, p. 201—214. Helsinki.

MacLeod, Martin 1971. The situation abroad—Japan. Paper Trade Journal, September 13, p. 84—85.

Mäkelä, Veikko 1973. Keräyspaperin talteenotto ja käyttö raaka-aineena. Paperinkeräys Oy. Helsinki. 4 p. Mimeograph.

Malaska, Pentti 1971 a. Prospects of future of technical man. Turun Kauppakorkeakoulun Julkaisuja. Sarja AI—4:1971. Turku. 15 p.

—»— 1971 b. Ecosystem and technosystem—a problematic relation. Turun Kauppakorkeakoulun Julkaisuja. Sarja B II—2:1971. Tampere. 4 p.

Manning, Glenn, H. 1972. An annotated bibliography on the economic aspects of waste paper recycling. Information report E—X—14. Forest Economics Research Institute. Ottawa, Ontario. 11 p. Mimeograph.

McKee, Robert C. 1971. Effect of Repulping on Sheet Properties & Fiber Characteristics. Paper Trade Journal. May 24, 1971. p. 34—40.

Mikola, Peitsa 1970. Metsä- ja puutalouden tehtävät luonnonsuojelussa. Summary: The role of forestry and forest industries in conservation. Silva Fennica 1970:4, p. 219—229. Helsinki.

National Accounting in Finland in 1948—1964. Tables. Helsinki 1968. Tilastollinen päätoimisto, tilastollisia tiedonantoja. N:o 43, 106 p.

National Accounting 1964—1972/I—II. Tilastokeskus. Tilastotiedotus N:o KT 1972:4, Helsinki, 1972.

Nevala, Markku 1973. Jätteiden hyödyntäminen maataloustuotannossa taloudelliselta kannalta. The Agricultural Economics Research Institute, Finland. Research Reports, N:o. 21. Helsinki. 10 p. Mimeograph.

Niitamo, O. E. 1970. SNA:n rakenteeseen liittyvistä ongelmista ja puutteista. Summary: On some problems and drawbacks of the structure of the SNA System. Kansantaloudellinen Aikakauskirja 3/70, p. 181—197. Kansantaloudellinen Yhdistys. Helsinki.

Nilsen, Hannu 1973. Suomen metsäteollisuuden jätevesikuormitus ja sen kehitysnäkymät. Summary: The waste water load of the Finnish forest industry and its development prospects. Paperi ja puu 11/1973, p. 845—852. Helsinki.

OECD. The Pulp and Paper Industry. Various years.

OECD 1968. International Statistical Year for Research and Development. A study of resources devoted to R & D in OECD Member countries in 1963/64. 2. Statistical Tables and notes. Paris. 396 p.

OECD 1972. Problems of environmental economics. Record of the Seminar held at the OECD in summer 1971. Paris. 278 p.

OECD 1973. Pollution by the pulp and paper industry. Report of the joint ad-hoc Group of the Environment Committee and the Industry Committee on pollution by the pulp and paper industry. NR/ENV/73. 13; DIE/IND/POLL. PP/73.2. Paris. 142 p. Mimeograph.

The OECD Observer. N:o. 50, February 1971.

Ojanen, Helvi & Arne Juselius 1960. Katsaus jätepaperin käsittelyyn ja jalostukseen. Oy Keskuslaboratorio. Kirjallisuuskatsaus N:o. 86. 165 p.

The outlook for timber in the United States 1973. U.S. Department of Agriculture. Forest Service. Forest Resource Report N:o. 20. Washington D.C. 367 p.

Palo, Matti 1971. A systems-oriented frame model for planning research projects in forestry. Tiivistelmä: Metsällisen tutkimusprojektin suunnittelun systeemiteoreettinen kehysmalli. Commun. Inst. For. Fenn. 72.4. Helsinki. 60 p.

Pöntynen, V. 1963. Suomen puun käyttö vuosina 1947—61. Summary: Finland's wood utilization in 1947—61. Commun. Inst. For. Fenn. 56.3. Helsinki. 185 p.

Programme for the water-protection policy. 1970. The Central Association of Finnish Woodworking Industries. Helsinki. 16 p.

Pulliainen, Kyösti 1972. Taloudellisen kasvun ekologinen kritiikki. Summary: An ecological critique of economic growth. Kansantaloudellinen Aikakauskirja 2/72, p. 111—123. Kansantaloudellinen Yhdistys. Helsinki.

Ranto, Heikki 1968. Jätepaperia pääraaka-aineena käyttävän kartonkitehtaan materiaalihäviöt. Diplomityö. Teknillinen korkeakoulu, puunjalostusosasto. 92 p.

Richardson, Arthur & Eric Haylock & Gordon Hughes 1971. Waste paper. The British Waste Paper Association & Hughes Sanders & Howard Ltd. West Nolesey, England. 138 p.

Saastamoinen, Olli 1971. Luonnonsuojelu ja talousteoria. Kansantaloustieteen pro gradu-tutkielma. University of Helsinki. 69 p. Mimeograph.

Slatin, Benjamin 1972. Fiber requirements of the paper industry in the seventies and eighties. Tappi, Vol. 55:4, p. 499—505.

Statistical Yearbook of Finland. Various years. Central Statistical Office. Helsinki.

Statistical Yearbook 1971. United Nations. New York. 1972.

Stenstedt, Erik A. 1970. Voimalaitokset ja ympäristö. Ekono 127 a, p. 16—32.

Sundelin, Arne 1963. Pulp and Paper Prospects in Western Europe. FAO & BLV Gmb H. Munich. 456 p.

Svensk skogsindustri i omvandling—utvecklingen sedan 1950. Summaries in English. Skogsindustriernas Samarbetsutskott. Stockholm. 1971. Vol. 1, 456 p., Vol. 2, 389 p.

Tansley, A. G. 1935. The use and abuse of vegetational concepts and terms. Ecology 16:3, p. 284—307. Brooklyn Botanic Garden. New York.

Teollisuuden tutkimustyöllä lisää kansainvälistä kilpailukykyä. Talouselämä 1971:4, p. 12.

The Trade Statistics of Finland. Various years. Official Statistics of Finland.

Vuoden 1970 ympäristönsuojelutoimikunnan mietintö I, 1970. Komiteanmietintö 1970: B 25. Helsinki. 72 p. Mimeograph.

Walls, George 1963. Elintaso. Yhteiskuntatieteen Käsikirja I, p. 115—119. Kustannusosakeyhtiö Otava. Keuruu.

Wegelius, Theodor 1968. Puu ja muut kuituraaka-aineet. In »Puumassan valmistus», Suomen Paperi-insinöörien Yhdistyksen oppi- ja käsikirja II. Helsinki. p. A1/1—A1/28.

Westerberg, E. Norman 1970. Ympäristönsuojelu—ongelmia ja ratkaisuja. Ekono 127 a, p. 3—15. Helsinki.

Yearbook of Labour Statistics 1972. International Labour Office, Geneva.

Yearbook of national accounts statistics 1969. Volume II. International tables. United Nations. New York. 1970.

Yhdyskuntien vesi- ja ympäristöprojekti 1974. Kotitalouksissa syntyvien erilaatuisten jätteiden kertyminen ja mahdollisuudet vaikuttaa niiden määrään, laatuun ja lajittumiseen Suomessa. E 13. SITRA. Helsinki. 71 p. Mimeograph.

Ympäristön pilaantuminen ja sen ehkäiseminen 1970. SITRA. Sarja B, No. 2. Helsinki.

Ympäristönsuojelun tavoitteita tutkivan työryhmän raportti. 1972. Elämisenlaatu, tavoitteet ja mittaaminen: liite 4. Talousneuvosto. Helsinki. Mimeograph.

SELOSTE

Puumassa- ja paperiteollisuuden aiheuttama veden ja ilman saastuminen on ollut jo pitkään tutkimuksen ja keskustelun kohteena. Kiinteät jätteet muodostavat kolmannen lohkon puumassan ja paperin tuotanto-kulutussysteemin aiheuttamasta ympäristön pilaantumisesta. Paperijäte, jota ei ole kerätty uudelleenkäyttöön tai käytetty jätteenpolttolaitoksissa, on näiden kiinteiden jätteiden pääkomponentti.

Keräyspaperin käyttöä on harjoitettu jossain määrin jo vuosisatojen ajan, mutta maailmanlaajuisesti keräyspaperin talteenottoprosentti ei ole koskaan noussut kovin korkeaksi. Koko maailman paperin ja kartongin kulutus vuonna 1970 oli 127 milj. tonnia. Noin 23 % tästä määrästä on kerätty uuden paperin ja kartongin raaka-aineeksi.

Valtaosaa »kulutetusta» ja poisheitetystä paperista ja kartongista on viime aikoihin saakka pidetty arvottomana ja haitallisena jätteenä. *Tämän tutkimuksen tarkoituksena oli selvittää keräyspaperin käytön ekonomisia ja ekologisia perusteita ja mahdollisuuksia.* Tähän pyrittiin etsimällä keräyspaperin teollisen käytön lisäämistä suosivia ja toisaalta sitä rajoittavia tekijöitä.

Teollistumisen varhaisessa vaiheessa laskettiin jätteet sekä puumassan ja paperin valmistuksessa että näiden tuotteiden kulutuksessa veteen, ilmaan ja maahan ilman että ympäristön pilaantumisesta aiheutuneet kustannukset olisivat heijastuneet tuotteiden hintoihin. Tällainen lineaarinen teknologia toimi tyydyttävästi teollistumisen alkuvaiheessa.

Nykyisin ympäristön laatu on hyväksytty yhteiskunnan olennaiseksi päämääräksi useissa maissa. Tämän vuoksi on pyritty muuntamaan perinteistä lineaarista teknologiaa kohti kiertoteknologiaa, jossa tuotanto ja kulutus ovat sopusoinnussa ekosysteemien toiminnan kanssa. Puumassan ja paperin tuotanto-kulutussysteemin kiertoteknologia vaatii toteutuakseen myös keräyspaperin käytön voimakasta lisäystä.

Talteenottoprosentti (recovery rate) määriteltiin keräyspaperin talteenoton suhteena paperin ja kartongin kulutukseen. Talteenottoprosentti kuvaa maan kykyä muuntaa kertaalleen käytetty paperi ja kartonki ympäristöä pilaavasta jätteestä raaka-aineeksi. Tutkimuksen kohteena olleista 16 OECD-maasta oli Hollannilla korkein talteenottoprosentti (39 %) vuonna 1969. Sitä seurasivat Japani, Sveitsi ja Itävalta. Norjassa, Tanskassa ja Kanadassa oli talteenottoprosentti alle 20 %. Talteenottoprosentin maiden välistä vaihtelua selittivät parhaiten keräyskustannukset, paperin ja kartongin hinnat, palkkataso ja raakapuun tarjonnan niukkuus.

Käyttöprosentti (utilization rate) määriteltiin teollisuudessa käytetyn keräyspaperimäärän suhteena paperin ja kartongin tuotantoon. Käyttöprosentti kuvaa keräyspaperin suhteellista tärkeyttä kunkin maan paperi- ja kartonkiteollisuuden raaka-aineiden joukossa. Viime aikoina on Saksan Liittotasavallan käyttöprosentti ollut korkein (46 %). Seuraavaksi korkeimmat käyttöprosentit ovat olleet Isossa-Britanniassa, Japanissa ja Hollannissa.

Toisaalta Suomi, Kanada, Ruotsi ja Norja muodostavat selvästi erottuvan ryhmän käyttöprosentin suhteen. Kaikilla näillä mailla on käyttöprosentti alle 7 %. Näillä mailla on suhteellisen pieni paperin ja kartongin kulutus verrattuna tuotantokapasiteettiin ja ne ovatkin huomattavia paperi- ja kartonkituotteiden viejämaita. Lisäksi käyttöprosentin vaihteluun näyttivät vaikuttavan raakapuun tarjonnan niukkuus, keräyskustannukset, paperi- ja kartonkiteollisuuden rakenne sekä paperin ja kartongin hintataso.

Suomi oli tässä tutkimuksessa esimerkkitapauksena maasta, jossa vallitsee raakapuun tarjonnan niukkuus. Yksityiskohtaisempi analyysi perustui aikasarjaan vuosilta 1950—1970. Tänä ajanjaksona on keräyspaperin talteenottomäärä vaihdellut 14 000 tonnista 140 000 tonniin. Paperin ja kartongin kulutus oli Suomen osalta keräysmäärien vaihteluiden paras selittäjä. Samanlainen tulos saatiin OECD-maiden poikkileikkausanalyysissä. Lisäksi paperin ja kartongin hinnoilla oli jonkin verran selitysvoimaa.

Vuosina 1950—1970 vaihteli talteenottoprosentti Suomessa välillä 8—27 %. Tätä vaihtelua selittivät parhaiten aikatekijä, paperin ja kartongin hinnat sekä raakapuun tarjonnan niukkuus. Kaksi viimeistä tekijää olivat selittäjinä mukana myös 16 OECD-maan analyysissä. Aikatekijän katsotaan usein sisältävän muutoksia teknologian ja tiedon tasossa.

Vaihtoehtoisia ennusteita Suomen keräyspaperin talteenotolle vuoteen 1985 kehiteltiin käyttäen yksinkertaisia lineaarisia regressiomalleja. Ennusteiden teko tapahtui kahdessa vaiheessa. Aluksi ennustettiin paperin ja kartongin kulutus käyttäen kahta bruttokansantuotteen kasvuennustetta. Seuraavaksi, käyttäen kulutusennusteita lähtökohtana ennustettiin keräyspaperin talteenotto. Tämän entisen kehityssuunnan (trendin) jatkumiseen perustuvan ennustamismenettelyn mukaan talteenottoprosentti Suomessa vuonna 1985 tulisi olemaan noin 26 % ja keräyspaperin talteenotto 275 000—342 000 tonnia.

Neljää eri talteenottoprosenttia ja alempaa paperin ja kartongin kulutusennustetta käytettiin toisena lähestymistapana tuottaa vaihtoehtoisia ennusteita keräyspaperin talteenotolle Suomessa. *Keräyspaperin talteenoton lisäys vuosina 1973—1985* olisi 121 000—308 000 tonnia eri talteenottoprosenttiolettamusten mukaan. Pienin talteenottoprosentti (25 %) edustaa trendiennusteen mukaista tasoa ja suurin (42.5 %) korkeinta oletettua toteuttamisen puolesta mahdollista talteenottoprosenttia. Tämänkaltaiset normatiiviset ennusteet ovat hyödyksi keräyspaperitoimintojen suunnittelussa ja tavoitteenasettelussa. *Ennusteen mukaan, joka pohjautui 35 % talteenottoon, olisi keräyspaperin talteenotto 308 000 tonnia vuonna 1980. Raakapuumääränä tämä vastaisi 0.8—1.7 milj. m³.*

Keräyspaperikentän asiantuntijoiden tavoitteiden mukaan saavutettaisiin vuoteen 1980 mennessä talteenottoprosentiksi 34 %. Tämä tavoite perustuu suunnitelmiin keräyspaperia raaka-aineena käyttävän massatehtaan perustamisesta.

Yhdysvalloissa kerättiin noin 11 miljoonaa tonnia paperia vuonna 1969. Samalla kun paperin ja kartongin kulutus kaksinkertaistui vuosina 1950—1970 kasvoi keräyspaperin käyttö vain kolmanneksen. Talteenottoprosentti laski 27 prosentista 23 prosenttiin vuosina 1950—1970. Käyttöprosentin suhteen on havaittavissa samanlainen suuntaus.

USA:ssa on laadittu ennusteita ja suunnitelmia, joiden mukaan keräyspaperin käyttö lisääntyisi huomattavasti. Pääasiallinen paine keräyspaperin käytön lisäämiseksi on tullut ympäristönsuojelijain taholta. Keräyspaperin osuus paperi- ja kartonkiteollisuuden koko kuituraaka-aineesta oli 19 % vuonna 1970. Sen on ennustettu kasvavan 34 prosenttiin vuoteen 2000 mennessä. Talteenottoprosentin odotetaan puolestaan kasvavan 23 prosentista 35 prosenttiin vuosina 1970—2000.

Tällä hetkellä suurin osa talteenotetusta keräyspaperista käytetään erilaisten kartonkien valmistuksessa välikerroksen raaka-aineena. Keräyspaperin käyttö useimpien paperilaatujen valmistuksessa vaatii painovärin poistamista keräyspaperista. Viime aikoina on kehitelty painovärinpoistomenetelmiä, joiden yhteydessä syntyvän jätteen määrää on pyritty vähentämään ja menetelmiä, joilla pystytään tehokkaasti erottamaan keräyspaperin haitalliset komponentit. Tällä rintamalla tarvitaan edelleen voimakasta tutkimus- ja kehityspanosta. Kulutetun paperin ja kartongin talteenoton ja uudelleen jalostuksen energiatarve on keskimäärin pienempi kuin puun korjuun ja jalostuksen energiatarve.

Kertaalleen kulutettu paperi- tai kartonkituote voidaan useimmiten kerätä uuden tuotteen raaka-ainepohjaksi. Tällainen paperinkierrätys voi tapahtua useamman kerran. Potentiaalinen keräyspaperin uudelleenkäyttö on näiden toistuvien kiertojen ansiosta huomattavasti suurempi kuin mitä pelkät talteenottoprosentit osoittavat. Tässä tutkimuksessa kehiteltiin yhtälöitä, joiden avulla potentiaalinen keräyspaperin käyttö pystytään arvioimaan.

Noin 15 vuodessa odotetaan FAO:n ennusteiden mukaan maailman paperin ja kartongin kulutuksen kaksinkertaistuvan. Näiden näkymien valossa näyttää todennäköiseltä, että maailman keräyspaperin käyttö kasvaa voimakkaasti tulevaisuudessa. Maailmanlaajuisesti voisi keräyspaperin talteenottoprosentti erään ennusteen mukaan nousta nykyisestä 23 prosentista 35 prosenttiin vuoteen 2000 mennessä.

Talteenottoprosentteja 23 ja 35 % käyttäen keräyspaperin talteenottomäärä maailmassa olisi 60—90 milj. tonnia vuonna 1985. Raakapuumääränä tämä vastaisi 120—230 milj. m^3. Kuitenkin paperi- ja kartonkiteollisuusyritykset ovat ensisijassa ne päätöksentekoyksiköt, joissa lopulta määritellään missä määrin keräyspaperia käytetään raaka-aineena tulevaisuudessa. Tässä suhteessa keräyspaperin, raakapuun ja keinokuitujen keskinäinen hintakehitys on avainasemassa.

Keräyspaperin käytön lisääminen merkitsee askelta eteenpäin siirryttäessä lineaarisesta teknologiasta kiertoteknologiaan. Lisäys keräyspaperin käytössä vähentää kiinteiden jätteiden määrää ja alentaa tällä tavoin jätehuollon kustannuksia ja ekosysteemeihin kohdistuvaa painetta. Lainsäädännöllä ja muilla valtiovallan ja kuntien toimenpiteillä on huomattava vaikutus keräyspaperin tulevaan käyttöön.

Appendix 1. List of variables of the 16 OECD countries.

1. Recovery rate of waste paper	(0.01 %)	OECD, The pulp and paper industry; BIR; Paperinkeräys Oy
2. Amount of recovery	(10 000 metric tons)	OECD, The pulp and paper industry; BIR; Paperinkeräys Oy
3. Utilization rate of waste paper	(0.01 %)	OECD, The pulp and paper industry; BIR; Paperinkeräys Oy
4. Expenditures on R & D (business enterprise sector, paper industry) per output of paper and board	(US $/1 000 metric tons)	OECD 1968, International statistical year for research and development
5. Output of paper and board excluding newsprint and printing and writing paper	(10 000 metric tons)	FAO, Yearbook of forest products
6. Output of wrapping and packaging paper and board	(10 000 metric tons)	FAO, Yearbook of forest products
7. Output of paper and board (excluding newsprint and printing and writing paper) per output of paper and board	(× 10 000)	FAO, Yearbook of forest products
8. Population density	(inhabitants/10 km²)	The OECD Observer
9. The population of the five biggest metropolitan areas per total population	(× 10 000)	International Atlas
10. Consumption of paper and board	(10 000 metric tons)	OECD, The pulp and paper industry
11. Consumption of paper and board excluding newsprint and printing and writing paper	(10 000 metric tons)	FAO, Yearbook of forest products
12. Paper and board consumption per capita	(0.1 kilograms)	
13. Paper and board consumption per area	(10 kilograms/km²)	
14. Total wood removals	(100 000 m³, round)	FAO, Yearbook of forest products
15. Industrial wood removals	(100 000 m³, round)	FAO, Yearbook of forest products
16. Pulpwood removals	(100 000 m³, round)	FAO, Yearbook of forest products
17. Total removals/roundwood imports	(× 100)	FAO, Yearbook of forest products
18. Industrial wood removals/industrial wood imports	(× 100)	FAO, Yearbook of forest products
19. Pulpwood removals/pulpwood imports	(× 10)	FAO, Yearbook of forest products
20. Total removals/paper and board consumption	(100 m³, round/metric ton)	
21. Pulpwood removals/paper and board consumption	(100 m³, round/metric ton)	

22.	Paper and board output/paper and board consumption	($\times$ 1 000)	
23.	Growing stock	(10 mill. m^3)	FAO, World forest inventory 1963
24.	Growing stock, conifers	(10 mill. m^3)	FAO, World forest inventory 1963
25.	Net increment	(100 000 m^3)	FAO, World forest inventory 1963
26.	Total removals per net increment	($\times$ 1 000)	
27.	Output of paper and board	(10 000 metric tons)	FAO, Yearbook of forest products
28.	Output of pulp	(10 000 metric tons, air dry weight)	FAO, Yearbook of forest products
29.	Output of paper and board per area	(10 kilograms/km^2)	
30.	GNP per area	(100 US \$/km^2)	The OECD Observer
31.	Weighted mean of import and export prices of newsprint	(0.1 US \$/metric ton)	FAO, Yearbook of forest products
32.	Output of paper and board per number of establishments of paper and paper products (ISIC 341)	(10 metric tons)	FAO, Yearbook of forest products; UN, The growth of world industry
33.	Output of paper and board per number of establishments of pulp, paper and paperboard (ISIC 3411)	(10 metric tons)	FAO, Yearbook of forest products; UN, The growth of world industry
34.	Hourly wages in paper and paper products industry	(0.001 US \$)	ILO, Yearbook of Labour Statistics
35.	Rate of discount of central banks	(0.001 %)	UN, Statistical Yearbook
36.	GNP per capita (at market prices, current prices and exchange rates)	(US \$)	The OECD Observer
37.	Saving of households (1968)	(0.01 %)	UN, Yearbook of national accounts statistics
38.	Area	(1 000 km^2)	The OECD Observer
39.	Population	(100 000)	The OECD Observer
40.	GNP per capita $\times$ output of paper and board per area	$\left(\frac{\text{US \$}}{\text{capita}} \times \frac{\text{10 metric tons}}{\text{km}^2}\right)$	

Appendix 2. The correlation coefficients of the 40 variables for the 16 OECD countries.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
1	1 000																			
2	31	1 000																		
3	565	188	1 000																	
4	—194	310	—578	1 000																
5	—69	979	38	379	1 000															
6	—82	970	11	396	998	1 000														
7	304	433	578	—132	379	363	1 000													
8	669	—69	700	—200	—201	—225	278	1 000												
9	215	—341	—72	72	—370	—360	—154	400	1 000											
10	—51	987	126	325	994	990	394	—142	—377	1 000										
11	—51	989	121	326	995	991	392	—143	—372	1 000	1 000									
12	—190	628	—243	658	686	701	196	—201	18	662	661	1 000								
13	681	—12	658	—85	—135	—151	303	965	440	—80	—82	—9	1 000							
14	—264	876	—202	457	942	948	148	—399	—395	919	921	725	—325	1 000						
15	—267	873	—206	465	938	945	138	—393	—372	916	919	741	—313	999	1 000					
16	—307	819	—316	566	903	912	99	—437	—331	869	871	773	—351	988	989	1 000				
17	—456	520	—469	548	647	665	85	—596	—265	596	597	764	—500	803	808	862	1 000			
18	—456	522	—479	571	647	664	67	—578	—232	596	597	792	—476	805	811	867	998	1 000		
19	—650	8	—446	145	108	122	—283	—456	43	79	87	402	—386	377	392	427	595	608	1 000	
20	—223	—223	—750	472	—105	—86	—390	—579	—103	—186	—181	10	—550	84	77	174	252	254	224	1 000
21	—298	—208	—815	618	—86	—67	—349	—592	—74	—173	—168	164	—538	111	108	226	378	384	279	961
	1 000																			
22	—221	—210	—756	517	—110	—93	—430	—522	—93	—187	—182	5	—487	58	51	143	160	167	157	976
	941	1 000																		
23	—465	545	—374	380	628	637	—266	—435	—249	606	612	610	—363	831	840	843	753	764	746	166
	194	140	1 000																	
24	—489	466	—409	370	553	563	—328	—443	—220	530	537	577	—373	777	788	797	734	747	786	196
	226	169	996	1 000																
25	—318	835	—244	459	906	913	63	—407	—354	884	887	737	—326	992	994	984	810	816	465	85
	115	63	890	845	1 000															
26	195	—236	343	—531	—238	—235	210	44	—272	—221	—225	—653	—89	—291	—312	—337	—253	—315	—297	—131
	—240	—220	—362	—362	—332	1 000														
27	—149	956	—38	407	986	985	267	—254	—378	977	980	705	—186	977	975	945	698	701	238	—47
	—26	—53	743	678	957	—287	1 000													
28	—284	849	—273	511	919	925	104	—415	—339	888	893	749	—333	993	994	993	821	826	424	136
	175	116	855	807	992	—344	963	1 000												
29	804	—30	494	34	—137	—155	265	891	405	—113	—112	—28	926	—311	—304	—321	—466	—442	—463	—308
	—300	—239	—382	—390	—326	—125	—187	—301	1 000											
30	620	—66	660	—130	—181	—193	243	956	436	—118	—123	—59	968	—360	—350	—388	—532	—509	—400	—583
	—583	—533	—398	—407	—363	—58	—235	—383	847	1 000										
31	361	464	537	—189	382	368	174	375	157	433	436	240	408	279	285	216	—2	0	3	—535
	—572	—559	227	193	283	5	376	256	235	410	1 000									
32	—394	—33	—818	671	107	130	—427	—611	—79	30	34	413	—514	359	364	469	601	616	548	859
	909	826	533	566	396	—396	205	424	—330	—567	—404	1 000								
33	—385	147	—499	543	244	266	—392	—291	66	217	219	591	—153	481	499	555	600	626	767	388
	447	376	789	821	565	—490	373	537	—136	—225	18	755	1 000							
34	—516	483	—461	522	584	604	—80	—438	—4	550	553	862	—292	751	769	801	842	868	754	126
	240	99	841	834	804	—598	661	788	—329	—321	85	559	766	1 000						
35	—278	—15	11	119	—9	—1	154	39	360	4	3	231	96	67	78	108	214	226	512	—11
	43	—69	209	224	95	—170	39	77	—50	96	135	134	397	303	1 000					
36	—386	538	—312	513	612	633	—9	—350	—58	599	594	904	—184	714	729	746	734	762	509	—10
	112	—22	676	651	740	—650	652	719	—269	—151	213	381	563	884	262	1 000				
37	612	—152	293	—100	—238	—272	—38	593	99	—239	—230	—273	515	—307	—311	—325	—465	—448	—379	—92
	—121	—56	—311	—308	—329	—43	—254	—300	627	546	157	—239	—337	—422	—343	—310	1 000			
38	—472	578	—344	356	660	670	—238	—436	—282	643	648	604	—366	850	857	854	747	756	718	126
	147	103	996	987	906	—324	769	867	—399	—398	244	488	761	830	195	676	—352	1 000		
39	49	962	326	166	920	899	466	1	—453	941	944	471	8	807	800	732	432	428	—26	—291
	—290	—287	497	421	761	—108	902	770	—26	—40	497	—137	58	342	—5	391	—74	531	1 000	
40	749	23	451	144	—60	—66	270	834	391	—34	—38	171	921	—218	—207	—216	—328	—302	—411	—342
	—300	—283	—314	—327	—230	—208	—114	—217	949	877	278	—282	—59	—174	—31	—32	557	—327	—20	1 000

Appendix 3. Some variables measured for the 16 OECD countries in 1969.

	(1) Recovery rate of waste paper %	(2) Amount of recovery 1 000 metric tons	(3) Utilization rate of waste paper %	(10) Consumption of paper and board 1 000 metric tons	(12) Paper and board consumption per capita kilograms	(27) Output of paper and board 1 000 metric tons	(29) Output of paper and board per area tons/km²	(31) Weighted mean of import and export prices of newsprint US $/m.ton	(34) Hourly wages in paper and paper products industry US $	(36) GNP per capita US $
Netherlands	39.0	686	34.0	1 760	137	1 608	43.9	133.1	1.4	2 190
Japan	37.4	4 160	37.6	11 135	109	11 310	30.6	153.5	1.0	1 630
Switzerland	33.2	296	27.5	892	143	690	16.7	157.2	1.4	3 030
Austria	32.1	172	23.1	536	73	943	11.3	132.3	1.2	1 690
Germany, Fed. Rep.	28.8	2 148	44.5	7 453	123	5 181	20.8	137.6	1.3	2 520
Belgium	27.1	280	21.7	1 034	107	723	23.7	145.2	1.2	2 360
United Kingdom ...	27.0	1 923	38.1	7 129	128	4 937	20.2	149.6	1.2	1 970
Finland	26.9	131	2.8	487	105	4 060	12.0	122.3	1.1	1 940
Spain	26.0	326	32.1	1 256	38	1 123	2.2	139.2	0.5	870
France	25.9	1 209	31.1	4 666	93	3 997	7.3	139.0	1.0	2 770
U.S.A.	22.3	11 325	23.4	50 817	250	46 491	5.0	152.1	3.2	4 660
Sweden	21.6	330	6.4	1 526	192	4 113	9.1	123.0	2.3	3 550
Italy	20.6	730	28.9	3 547	66	3 461	11.5	127.6	0.9	1 520
Denmark	17.8	114	29.3	641	131	276	6.4	137.2	2.0	2 860
Norway	16.2	71	6.4	438	114	1 374	4.2	120.2	1.5	2 530
Canada	12.5	409	3.3	3 271	155	11 354	1.1	139.4	3.1	3 460

Appendix 4. List of variables in the Finnish analyses.

	Source
1. Recovery rate	The Central Association of Finnish Woodworking industries; Paperinkeräys Oy
2. Amount of recovery	Paperinkeräys Oy
3. Consumption of paper and board (estimated on the basis of production and foreign trade statistics)	The Central Association of Finnish Woodworking industries
4. Paper and board consumption per capita	The Central Association of Finnish Woodworking industries; Statistical yearbook of Finland
5. Time	
6. Output of paper and board	The Central Association of Finnish Woodworking Industries
7. Output of board	The Central Association of Finnish Woodworking Industries
8. Output of waste paper based board	Finnboard
9. Price of newsprint	Official statistics of Finland, Foreign trade
10. Unit value of board exports	Official statistics of Finland, Foreign trade
11. GDP per capita (at factor cost, 1954 prices)	Central statistical Office of Finland, National Accounting
12. GDP,Gross domestic product (at factor cost, 1954 prices)	Central statistical Office of Finland, National Accounting
13. Increment/total drain	Folia Forestalia 49; 166; Commun. Inst. For. Fenn. 56.3; 76.5

Appendix 5. Indices of the 13 variables used in analysis of waste paper recovery in Finland, 1950—1970, (1950 = 100).

Year	Recovery rate	Amount of recovery	Consumption of paper and board	Paper and board consumption per capita	Time	Output of paper and board	Output of board	Output of waste paper based board	Price of newsprint	Unit value of board exports	GDP per capita	GDP (Gross Domestic Product)	Increment per total drain
	1	2	3	4	5	6	7	8	9	10	11	12	13
1950	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1951	140.1	152.6	109.0	108.1	200.0	116.1	149.6	114.5	175.7	198.8	108.4	109.3	90.2
1952	180.1	205.9	114.4	112.0	300.0	108.2	104.4	103.2	174.6	161.7	109.8	112.2	102.7
1953	126.1	135.2	107.2	103.8	400.0	122.6	146.7	95.2	134.5	109.9	109.6	113.2	109.0
1954	166.2	226.8	136.5	130.6	500.0	143.1	188.1	137.1	140.2	123.5	118.2	123.5	94.7
1955	182.0	278.9	153.3	145.1	600.0	168.8	211.9	159.7	145.8	132.1	124.7	131.7	84.8
1956	212.2	325.1	153.3	143.5	700.0	181.6	217.8	180.6	151.4	135.8	125.6	134.2	90.8
1957	274.2	423.5	154.5	143.3	800.0	202.0	285.2	204.8	169.4	154.3	127.8	137.8	89.4
1958	287.2	427.9	149.1	137.3	900.0	205.6	308.1	208.1	204.6	172.8	127.9	138.9	88.0
1959	293.6	470.8	160.5	146.5	1 000.0	222.0	334.1	195.2	199.0	171.6	135.4	148.3	86.1
1960	309.7	576.5	186.2	168.8	1 100.0	257.5	397.8	200.0	197.2	174.1	147.3	162.5	76.1
1961	293.8	636.6	216.8	195.0	1 200.0	312.0	517.0	238.7	194.6	180.2	156.4	173.8	72.2
1962	254.7	509.2	200.0	178.6	1 300.0	328.8	587.4	222.6	193.7	181.5	160.6	179.8	78.4
1963	257.2	575.9	224.0	198.5	1 400.0	359.2	649.6	230.6	194.3	182.7	164.2	185.2	82.0
1964	302.0	679.6	225.1	198.5	1 500.0	389.4	685.9	238.7	192.5	191.4	173.6	196.9	83.3
1965	301.6	785.2	260.5	228.8	1 600.0	419.0	688.9	246.8	192.4	195.1	181.0	206.1	88.4
1966	317.0	869.1	274.3	239.6	1 700.0	452.4	752.6	329.0	194.5	191.4	184.0	210.7	91.6
1967	291.5	797.1	273.7	237.8	1 800.0	443.0	719.3	329.0	210.9	202.5	187.9	216.3	92.4
1968	302.6	840.4	277.8	240.6	1 900.0	474.4	791.9	353.2	248.7	240.7	192.7	222.5	93.8
1969	331.9	967.5	291.6	253.5	2 000.0	530.7	908.1	374.2	248.7	248.1	210.3	241.9	88.3
1970	315.3	1 034.1	328.1	286.1	2 100.0	556.6	907.4	375.8	257.5	270.4	227.2	260.6	86.9

PALO, MATTI & OLLI NISSILÄ

1975. Waste paper recycling: economic and ecological prospects. — COMMUN. INST. FOR. FENN. 82.5. 112 p. Helsinki.

A theoretical frame of environmental economics and some models of linear and circular technology of the production-consumption system of pulp and paper are introduced. The global state of paper recycling is described with Finland and the U.S.A. as more thorough cases. Correlation and regression analyses are used when explaining the variations in recovery rates and amounts of recovered waste paper in 16 OECD countries. For Finland forecasts are also developed. Technological aspects and feasibility of increased recycling are discussed.

Authors' address: The Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki 17, Finland.

PALO, MATTI & OLLI NISSILÄ

1975. Waste paper recycling: economic and ecological prospects. — COMMUN. INST. FOR. FENN. 82.5. 112 p. Helsinki.

A theoretical frame of environmental economics and some models of linear and circular technology of the production-consumption system of pulp and paper are introduced. The global state of paper recycling is described with Finland and the U.S.A. as more thorough cases. Correlation and regression analyses are used when explaining the variations in recovery rates and amounts of recovered waste paper in 16 OECD countries. For Finland forecasts are also developed. Technological aspects and feasibility of increased recycling are discussed.

Authors' address: The Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki 17, Finland.

PALO, MATTI & OLLI NISSILÄ

1975. Waste paper recycling: economic and ecological prospects. — COMMUN. INST. FOR. FENN. 82.5. 112 p. Helsinki.

A theoretical frame of environmental economics and some models of linear and circular technology of the production—consumption system of pulp and paper are introduced. The global state of paper recycling is described with Finland and the U.S.A. as more thorough cases. Correlation and regression analyses are used when explaining the variations in recovery rates and amounts of recovered waste paper in 16 OECD countries. For Finland forecasts are also developed. Technological aspects and feasibility of increased recycling are discussed.

Authors' address: The Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki 17, Finland.

PALO, MATTI & OLLI NISSILÄ

1975. Waste paper recycling: economic and ecological prospects. — COMMUN. INST. FOR. FENN. 82.5. 112 p. Helsinki.

A theoretical frame of environmental economics and some models of linear and circular technology of the production-consumption system of pulp and paper are introduced. The global state of paper recycling is described with Finland and the U.S.A. as more thorough cases. Correlation and regression analyses are used when explaining the variations in recovery rates and amounts of recovered waste paper in 16 OECD countries. For Finland forecasts are also developed. Technological aspects and feasibility of increased recycling are discussed.

Authors' address: The Finnish Forest Research Institute, Unioninkatu 40 A, 00170 Helsinki 17, Finland.