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Factors Influencing Availability of Biomass Resources and Efficiency of its Procurement for Energy Generation

A regional study for the Banská Bystrica Region, Slovakia

Ján Ilavský, Juha Laitila, Timo Tahvanainen, Ján Tuček, Milan Koreň, Vladimír Pápaj, Mária Žiaková and Július Jankovský

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Title

Factors influencing availability of biomass resources and efficiency of its procurement for energy generation. A regional study for the Banská Bystrica Region, Slovakia

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Abstract

The paper presents results of the study analysing the whole chain from methodology of overall and available biomass resources calculations in the region, the most efficient technologies and procurement methods, logistics and economy of biomass supply to the consumer, up to the economic and ecological gains from the conversion of boilers for co-firing wood and brown coal. The study was conducted for the Banská Bystrica region, Slovakia.

There is a combined heat and power plant (CHP) in town Zvolen. CHP, originally commissioned in 1954. Overall installed output is 311 MW in heat production and 44, 3 MW in power. Annual supply to the consumers was some 790.000 GJ of heat and 103.000 GJ of electricity during the last few years. Some 60 % of heat production was used for heat and hot water supply to more than 9.000 houses and apartments and 40 % to industrial consumers. It has been using pulverized lignite with up to 1 % of sulphur content as fuel. The content of sulphur in emitted flue gas was as high as 3.500 – 4.000 mg SO_2/m^3. It causes serious environmental problems in the region. New national limits for greenhouse gases emissions are 1.700 mg SO_2/m^3 and 600 mg NO_x/m^3 with the effect from 1 January 2007. CHP has not been able to achieve them without substantial improvement of technology. Shift from lignite to low-sulphur content brown coal with co-firing of biomass has been identified economically the most feasible and environmentally acceptable solution. Two boilers, each of them with the output of 108 MW_t, will be reconstructed for co-firing of pulverized low sulphur content brown coal and biomass. Biomass will share up to 30% of the combusted fuel.

The first part of the study was focused on identification of biomass resources for energy use from forestry, wood processing industry and agriculture in the region, with the use of GIS tools. Ecological, economic and operational factors limiting utilization of potential biomass resources were identified and factored into calculations. Logistics of wood supply have been precisely analysed. Costs of wood chips supply from forest residues for three different supply chains have been calculated taking into account ecological, economic and technical limiting factors and transport distances. Also environmental issues have been analyzed. Emissions of greenhouse gases after the reconstruction of boilers will be within the limits in force after 1 January 2008, i.e. 1.400 mg SO_2/m^3, 600 mg NOx/m^3, 250 mg CO/m^3 and 50 mg fly ash/m^3.

Keywords

bioenergy, biomass resources, ecological impacts, procurement methods

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Contents

List of acronyms and abbreviations

a. s.	joint stock company
CHP	combined heat and power
DEM	Digital Elevation Model
GJ	Gigajoule
m^3 u. b.	cubic meter under bark
MW	Megawatt
MW_e	Megawatt electric
MW_t	Megawatt thermal
NLC	National Forestry Centre
SKK	Slovak Crowns
VUC	Regional Administrative Unit

1 Introduction

The use of renewable resources of energy becomes significant factor in the regional development. In addition to the environmental benefits, it provides preconditions for intensified economic development. The use of so far unrealised local resources of renewable raw materials supports development of small and medium size enterprises, creation of new work places and increase of the income of inhabitants, especially in the regions with high unemployment rate. The Banská Bystrica Region belongs to the most forested regions of Slovakia (48.9 %). Typical countryside in the region is showed in the picture on the cover. Woodworking industry has also been developed in the region. High accumulation of the secondary sources of wood as well as of other biomass suitable for energy generation is thus rather typical for this region. Several development projects and construction of several small- and middle-size boilers combusting wood has been implemented in the region. The reconstruction of two brown coal firing boilers in the Zvolenská teplárenská a.s. to the co-firing of low sulphur brown coal and wood is the biggest undertaking of its kind in the region, however. Large development projects, like this one, require big investment. Investors may have doubts to invest into expensive combustion technologies unless there are reliable analyses and information concerning the resources of wood available for energy generation. A competent analysis of the resource of wood and other biomass may thus be critically important for any similar project. Regarding the fact that a regular market with biomass fuel has not been developed so far in Slovakia, each investment requires also detailed analysis of technological, technical and economic conditions for production and supplies of energy biomass from forests and of their most appropriate logistic coverage. These aspects influence stability of biomass supplies, its quality, production costs, and subsequently the price and efficiency of the use of biomass for energy generation.

This study was worked out according to the order of the Zvolenská teplárenská a.s., and with its financial support. The Finnish Forest Research Institute participated in the study in the framework of the research project “The Forest Energy Potential and Technology Market in European Union and International Bioenergy Trade”, funded by the Finnish Development Agency TEKES within the research programme “ClimBus – Business Opportunities in Mitigating Climate Change”, the project “Comparative studies of forest policies and structural changes in the forest sector of selected Central and Eastern European countries” and the project “Progress towards the sustainable and competitive forest sector in countries with economies in transition – consequences for the Finnish forest sector”, financed by the Finnish Forest Research Institute.

2 Basic information about the project of conversion of coal fired boilers to co-firing of low sulphur brown coal and woodchips in the Zvolenská Teplárenská a.s.

Zvolen, a town of 45,000 inhabitants, is located in Central Slovakia. The main heat supplier for inhabitants and for the industry is CHP plant “Zvolenská teplárenská a. s.”, providing district heat for 9.000 houses and apartments with some 30,000 inhabitants, e.g. to ⅔ of the population. It provides energy also for several industrial enterprises. CHP produces also electricity for the electrical grid.

Particular private family houses have their local heating systems using mainly natural gas. There are also several small boiler houses based on natural gas boilers, run by a joint venture company owned by the city of Zvolen and a private Austrian investor. Wood processing plant Bucina has also a CHP plant utilizing own sawmill by-products for self-consumed energy.

Thus the market situation is quite complicated with a strong competition. Therefore the city decided to conduct "A Communal Energy Concept of Zvolen up to 2020" in which energy demand under different scenarios and contribution of different suppliers were analysed. The concept showed that the Zvolenská teplárenská joint-stock company will be also in the future the most important district heating supplier, providing that technical and organizational measures improving the efficiency and reducing the negative environmental impact will be taken. One of the proposed solutions was to convert their boilers for combustion of other fuels, including biomass.

Zvolen CHP plant was originally commissioned in 1954. Overall recent installed output is 311 MW thermal and 44.3 MW in power production. There are two boilers, each of them with the output 108 MW, combusting low quality brown coal (lignite), two 38 MW gas and oil burning boilers and one mobile 19 MW gas boiler. There are also three back-pressure turbines (25, 5.8 and 4.4 MW) and one 9.1 MW condensing turbine for electricity production.

Annual supply to the consumers was some 790,000 GJ of heat and 103,000 GJ of electricity during last few years. Some 60 % of the heat production was used for heat and hot water supply to more than 9,000 houses and apartments. Supply to industrial consumers represents 40 % of produced heat, of which 9 % to public buildings (schools, administrative and social buildings) and 31 % to industrial enterprises. Heat is used also in industry mainly for buildings heating. Only very small portion of heat is used for technological purposes.

Picture 1. Zvolen CHP plant before reconstruction. Photograph Július Jankovský

The plant uses pulverised lignite with up to 1 % of sulphur content as fuel. Annual consumption is 180,000 tons of lignite with the energy content 11.09 $GJ.t^{-1}$. The content of sulphur in emitted flue gas is as high as 3,500 – 4,000 mg $SO_2.m^{-3}$. It causes serious environmental problems in the region. New national limits for flue gas emissions are 1,700 mg $SO_2.m^{-3}$ and 600 mg $NOx.m^{-3}$ with the effect from 1 January 2007. It was clear, that old boilers will not be able to achieve those limits without substantial technical improvement and large investments. Therefore the CHP plant ordered a study analysing different technical solutions from the point of view of their impact on ecological acceptability and economical feasibility of its operation in the future. The alternative of conversion of two boilers for co-firing of low-sulphur brown coal and biomass was economically the most efficient and environmentally positive solution. It was calculated that the proportion of brown coal will be 70 % and biomass 30 %.

Two biggest boilers, each of them with the output of 108 MWt, are being reconstructed for co-firing of pulverised low-sulphur brown coal and biomass. After the conversion, one boiler will remain with the same output of 108 MWt and the other will be with the output of 65 MWt. Power will be produced by the back-pressure 25 MWe turbine. Chips will be stored in 9,000 m^3 open depot and in two silos with the volume of 3,000 m^3.

Also substantial modernisation of the information and controlling system, registration and monitoring of emissions and optimisation of the whole production control has been envisaged in the project.

The main problem, which is the reduction of greenhouse gas emissions, will be solved by the implementation of the project. Flue gas emissions after the conversion will be lower than allowed limits which will be force after1 January 2008, i.e. 1,637 mg $SO2.m^3$, 600 mg $NOx.m^3$, 250 mg $CO.m^3$ and 50 mg fly $ash.m^3$.

Picture 2. New conveyor (yellow) and storage silos (dark blue) for feeding wood chips into the boiler
Photograph Ján Ilavský

Main ecological effects will be as follows:

- reduction of SO_2 emissions by 1,000 tons, e.g. 47 % comparing to 2004
- achievement of SO_2 emissions limits after 2008 and thus possibility to continue in operation
- reduction of CO_2 emissions by 37,000 tons, e.g. 17 % in comparison to 2004
- automatic continual control of emissions level and production process control
- reduction of ash production by one third – from 25,000 tons to 16,700 tons annually
- improvement of the automatic control of the combustion process and, thus, significant reduction of all pollutants

There will be also significant positive economic effects after the project implementation. The main of them are as follows:

- reduction of fuel procurement costs up to 10 %
- lower energy prices for consumers
- creation of new job opportunities in the region for biomass harvesting and transport
- increase of electricity production – it is expected that up to 80 % of local electricity consumption will be produced by the Zvolen CHP plant
- increase of the income for the plant due to the higher price of electricity produced from renewable energy sources and supplied to the grid
- reduction of the load of pollutants in the region and improvement of the environment will bring significant indirect economic profit due to improvement of living conditions of citizens and their health state

Conversion of the first boiler was launched in spring 2006, after the end of the heating season. It has started its operation in February 2007. The second boiler will be converted until the end of 2007.

The Slovak Republic is a country highly dependent on the import of all kind of fuels. More than 90 % of the primary energy sources are being imported. Mainly fossil fuels are used for production of heat and electricity. Because of the large use of brown coal also production of pollutants, including greenhouse gases, is very high. That causes serious environmental problems.

On the other hand there are quite large domestic renewable energy resources, which have not been utilized yet. There is very small market, only several thousand tons of chips from forests a year. Forest owners, forest logging companies and contractors do not want to invest into the specific technology for harvesting, chipping and transport of forest biomass because there is little demand for it. Owners of boilers and power plants worry to invest in boilers replacement or conversion for biomass combustion, because of weak market with biomass.

Therefore the implementation of the project is very important not only due to the direct effects in one power plant. It is even more important to help break out of the vicious circle in biomass for energy utilization. There will be the opportunity to create at least the local market for biofuels, to develop logistics in biomass procurement methods, and to force the expansion of the entrepreneurship.

3 Methods and approach

The study has been worked out for the gravitation territory of the Zvolen CHP plant, territorially delimited by the administrative region Banská Bystrica. The area has been demarcated in a way that allows information about various sources of biomass within the administrative units (region, district, cadaster). While the sources of forest biomass can be related, e.g., to the forest management units or regional forest enterprises in the case of the State Forest Enterprise, sources from woodworking industries and from agriculture have no other common spatial identification but the administrative district. The administrative district was therefore chosen a basis for localisation of the sources of biomass. The administrative map of the Banská Bystrica Region with the boundaries of districts, road infrastructure, forest coverage and position of the Zvolen CHP Plant is in Annex 1.

3.1 Assessment of the volume of forest tree biomass (dendromass)

The baseline information for the assessment of the volume of dendromass comprised basic data about forests in the Banská Bystrica Region, which result from the detailed forest surveying within decennial upgrades of the forest management plans. With the regard to the thematic focus of the present study, information about the production potential of forests and data relevant for quantification of the total volume of fuel biomass in the region, were subject to the analysis.

The information basis of the assessment of disposable biomass in the region comprises the forest stands area, growing stock of wood and annual allowable cuts. Furthermore, the age structure of forests, tree species composition, planned and real yield of roundwood assortments, functional forest categories, ownership and management structure of forests were taken into the account.

Based on the detailed analysis of all information characterising the production potential of the woody biomass in the region, the following sequence of steps was followed in assessing the volume of dendromass available for energy generation:

a) Selection of the forest compartments (stands) from the forest database of the whole Banska Bystrica Region – creation of the baseline database containing data from actual Forest Management Plans, agglomeration of basic information on forests in the Region to tables and charts.
b) Definition of limiting criteria, constraining the total amount of forest compartments to the disposable ones. Accordingly, the following ones were excluded from the basic set:
    - forest stands belonging to the category of protective forests, where the drain of biomass is not allowable due to nature protection regulations,
    - forest stands under the 5th degree of the IUCN nature conservation categories - non-intervention reserves,
    - forest stands which, according to the site quality, belong to the groups of forest management types, where the drain of biomass other than large wood (over 7 cm in diameter) is not appropriate due to the high soil acidity or, vice versa, unbalanced nutrient contents on carbonate parent rocks, rocky and skeletal soils etc. Based on the available research results, forests on naturally nutrient-poor sites, particularly with deficient Ca, Mg and K, were excluded. Furthermore, sites with extreme properties in regard to the texture, proportion of skeleton or water contents, and also those with nutrient unbalances in regard to the surplus of Ca and Mg but deficient K and P.

These sites are identified by the following forest management types (HSLT) in the forestry databases: 101, 104, 107, 117, 131, 191,199, 201, 203, 204, 217, 292, 295, 296, 299, 301, 303, 304, 317, 392, 395, 396, 401, 404, 407, 417, 492, 495, 496, 497, 498, 499, 501, 504, 514, 517, 518, 521, 524, 531, 584, 589, 590, 591, 592, 594, 595, 596, 597, 598, 599, 601, 604, 614, 617, 618, 621, 622, 623, 624, 627, 628, 633, 634, 637, 644, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 719, 729, 739, 749, 759, 769, 789, 815, 820, 830, 840, 850, 860, 511, 611, 685, 665, 666, 675, 105, 109, 112, 205, 216, 305, 315, 316, 405, 415, 416, 425, 435, 445, 505, 506, 515, 516, 525, 526, 536, 546, 556, 605, 606, 616, 626, 636, 646, 655.

- forest compartments with slope inclination (grade) over 50%, where the access for dendromass harvesting is limited for the ecological (mostly the category of protective forests under higher nature protection grade), technical and economic (requirement of skyline hauling increases harvesting costs excessively) reasons.

c) Development of algorithm and application software for computation of the total volume of dendromass based on the data for individual tree species originating in the stand-wise forest inventories – including the mean diameter, mean height, mean stem volume, growing stock and allowable cut.
d) Stand-wise assessment of the total dendromass by tree species, taking their productive capacity into the account. Only those forest stands were considered, where final felling and thinning are planned. The estimated volume of small-dimension wood of 18% was added to the planned volume of harvested large-sized wood thicker than 7 cm over bark uniformly for all tree species and felling types.
e) Stand-wise assessment of the energy dendromass: The total volume of the above-ground dendromass was reduced by the volume of assortments appropriate for industrial use, i.e. the roundwood and pulpwood measured under bark. Their volume was determined in the assortment surveys of planned felling according to the tree species.
f) Creation of the directory of forest compartments available for energy dendromass supply, resulting from the comprehensive analysis of forest data in the Banská Bystrica Region. The directory provides volumes of available energy dendromass and allows their aggregation according to the age classes.
g) Processing of the output information aggregated for the district and regional levels, and interpretation of results by means of tables, charts and maps.

3.2 Processing of geographic data

The main objectives of geographical data processing and analysis were to prepare a geographical database of Banska Bystrica Region, and to derive information needed for estimation of biomass availability and costs. The methodology consists of the four interconnected procedures (Figure 1):

1. Data import and pre-processing.
2. Calculation of transportation distances.
3. Specification of limiting factors.
4. Determination of available biomass.

Geographical database, data import, spatial analysis, reports design and printing, production of maps were done in ArcGIS system with support of external programs.

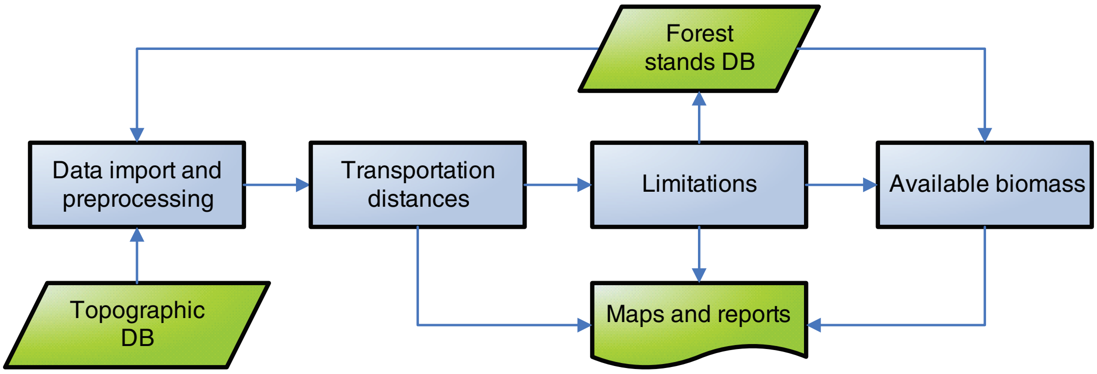

Figure 1. Diagram of geographical data processing and analysis

3.2.1 Data import and processing

To reach the given aims the comprehensive geographical database was built. It contains the raster and vector thematic layers: digital elevation model, forest stands, roads and other features (Map 1).

The boundaries of forest stand units (Map 6) were imported from digital maps of the Institute of Forest Resources and Informatics in Zvolen. The unique identifier was assigned to every forest stand unit. The forest stand unit can be composed from several polygons. The thematic layer contains 146,354 polygons and 87,372 forest stand units. Topographic and elevation data were imported from geographical database of the Topographic institute in Banska Bystrica. The data set includes:

1. Digital elevation model (DEM) with 10 meters resolution (Map 2, 3).
2. Vector thematic layers: administrative boundaries, road network, railways, settlements, rivers and lakes. Data were updated 28.2.2006.

The raster digital elevation model was provided in UTM-34 projection on WGS-84 ellipsoid, the topographic layers in Lambert projection. The precise cartographic transformations were used to transform all layers to the national coordinate system S-JTSK.

Linear and polygonal topologies were checked. The additional attribute data provided by the Institute of Forest Resources and Informatics were imported from separate database files and linked to digital map of forest stands.

3.2.2 Calculation of the transportation distances

Availability of biomass and expensiveness is highly affected by transportation distances and costs. To estimate availability and expenses the shortest transportation distance for each forest stand was calculated. The input road network layer contains all road categories: highways, main and secondary roads, back roads, field and forest roads (Map 4).

The resulting transportation distance approximates the sum of forwarding and truck transportation distances. It was calculated in three consecutive steps (Figure 2):

1. Determination of road distances to the heating plant for road pixels. The length of the shortest route was assigned to every pixel of raster representing the road network. The algorithm starts at heating plant location and iteratively processes all neighbourhood cells. It stops when a global optimum is reached.
2. Determination of the shortest road distance to the heating plant for any pixel of the given raster. The algorithm starts at pixels of roads and iteratively grows until the shortest distance is not calculated for every cell of the region (Map 5).
3. Classification and overlay. The resulting raster with the shortest distance values was classified and 10 km distance zones created. Distance zones and slope categories were intersected and cross-tables generated. The forest stand layer was overlaid with transportation distances raster, summary tables and maps produced (Map 8).

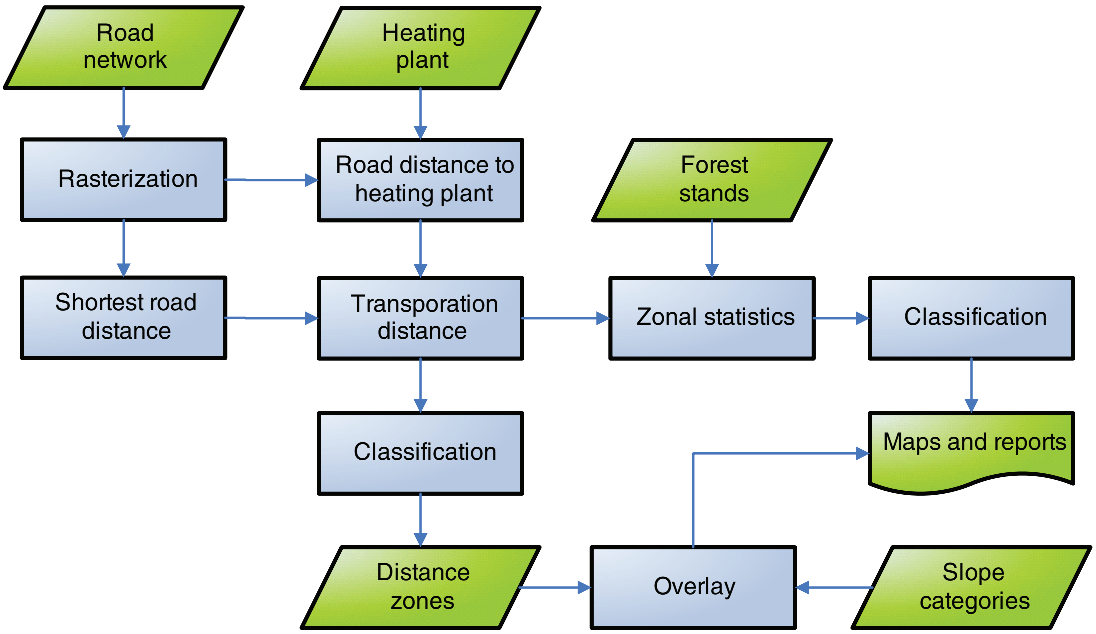

Figure 2. Scheme of calculation of transportation distances

3.2.3 Specification and calculation of the limiting factors

The slope is one of the most important factors influencing the selection of logging and transportation technologies. The morphometric parameters of relief were calculated from raster digital elevation model by use of standard ArcGIS modules. The slope, aspect and elevation level were computed for every pixel of DEM (Map 2 and 3). The minimal, maximal, mean and standard deviation of slope and elevation were estimated for each of forest stand units (Map 7). Because the forest stand may include several polygons, the functions of zonal statistics were used (Figure 3). The results were stored in forest stands database tables, from where summary tables and maps were generated.

Several limiting factors were taken into account during selection process. The forest stands with average slope above 50% were excluded (Map 9). Also protected forests and regions in IUCN protection level 5 were left out (Map 10, 11, 12). Further limits were adopted from forest management plans database (e.g. some types of forest and terrain categories).

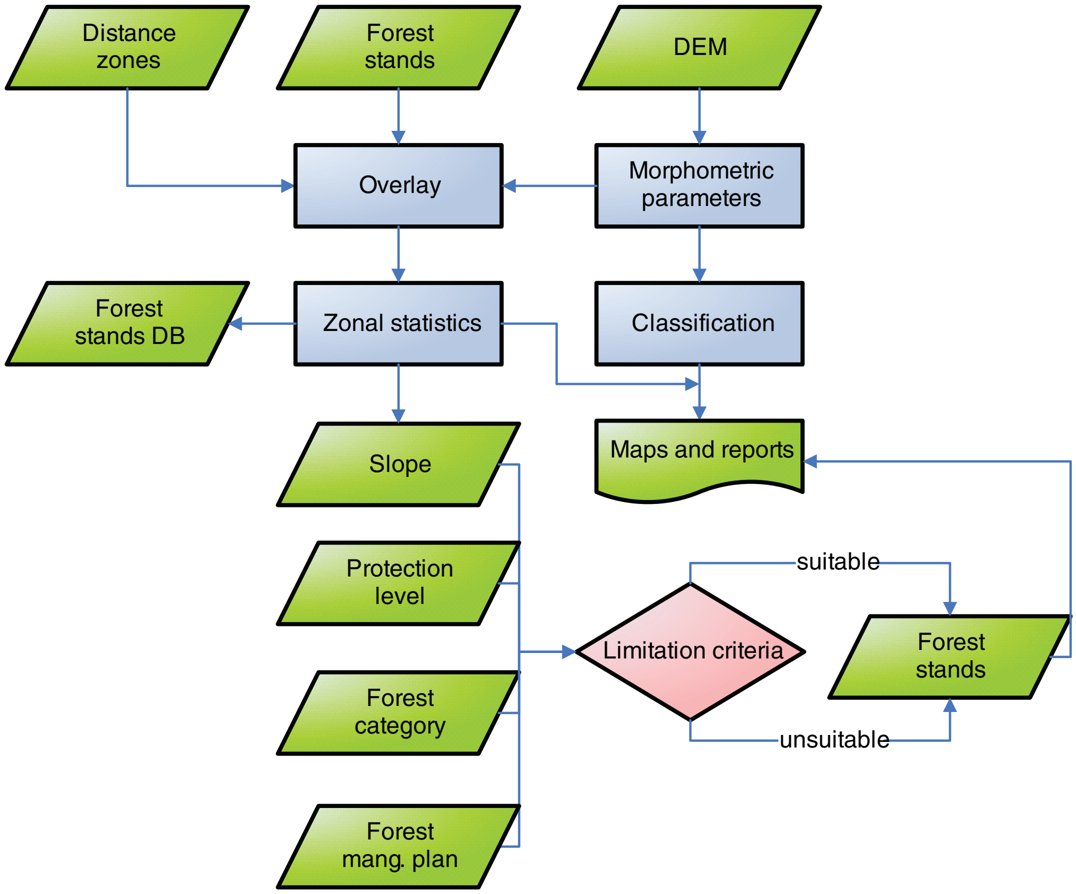

Figure 3. Process of limiting factors calculation

3.2.4 Determination of the available biomass

The final geographical database contains all information needed for the final analysis and reports: the digital map of forest stands, the transportation distances and the limiting factors. Data were exported to the database of biomass resources, where the final determination of the available biomass was done. The results were linked to the forest stands layer and the final reports (Tables 11 and 12) and maps generated (Map 13, 14).

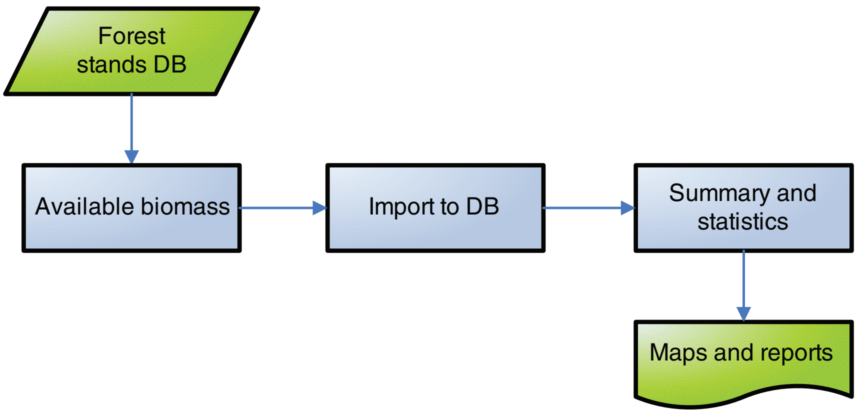

Figure 4. Diagram of the available biomass determination

3.3 Assessment of the volume of biomass from energy plantations on farmlands not used for agricultural production

Determination of disposable lands appropriate for energy crops and plantations of fast growing tree species excluded parcels on land under conventional agricultural production, i.e. crop farming followed by the use of plants in animal husbandry, direct sale of crops for food and fodder, or further technical processing in the industry.

It means that only those lands were considered, which are not used for farming and therefore are not covered by the EU subvention scheme for agriculture. Such abandoned plots frequently represent a source of weeds invading neighbouring cultivated lands, provide for overpopulation of the rodent pests and deteriorate the quality and amenity values of the landscape.

The information sources have included information on the recipients of subventions, which have been subject to annual monitoring by the Slovak Chamber for Agriculture and Food (SPPK) and its Regional Chambers (RPPK), Statistical Yearbook on Land in Slovakia, and complementary land registry data regarding the identification of parcels not used for agricultural production.

3.4 Assessment of the sources of wood residues from wood processing industries

The volumes of wood residues available from wood processing industries were assessed in all enterprises involved in primary wood processing in the region. It was done by means of personal interviews with their owners or managers. The annual volumes of processed timber, produced wood residues and sawdust were the subject of investigation. Volume of residues used for technological purposes (manufacturing of wood-based panels, pulp production) and self-supply of energy, were excluded from the biomass potentially available for energy generation. The obtained information was agglomerated according to the administrative districts and the region.

The volumes of utilisable biomass coming from the maintenance of parks, greenery and recycling were collected by means of personal or telephone interviews with heads of environmental departments of municipal authorities. The identified volumes have been quite small and irregularly distributed, however. Their use for a larger-scale energy generation therefore was not considered in further calculations.

3.5 Technologies for harvesting and transport of dendromass to the combined heat and power plant

The aim of this part of the study was to evaluate suitability of various methods of dendromass harvesting in the local conditions of the Banská Bystrica Region. According to the place where woodchips are made, three main technological schemes have been considered:

- Chipping at the roadside landing
- Chipping at the central wood yard (terminal) of the supplier
- Chipping at the CHP's yard

Production costs of woodchips following the above technological schemes are compared. Hourly costs of mechanised works were calculated for the newly acquired machines and equipment. The price of standing wood was not included in the calculations. Reference data concerning the outputs of machines and their sets are based on information from well established supply chains and practical work of experienced machine operators (Laitila 2006). The structure and logistics of suppliers' production lines and basic work stages are described in Figure 5.

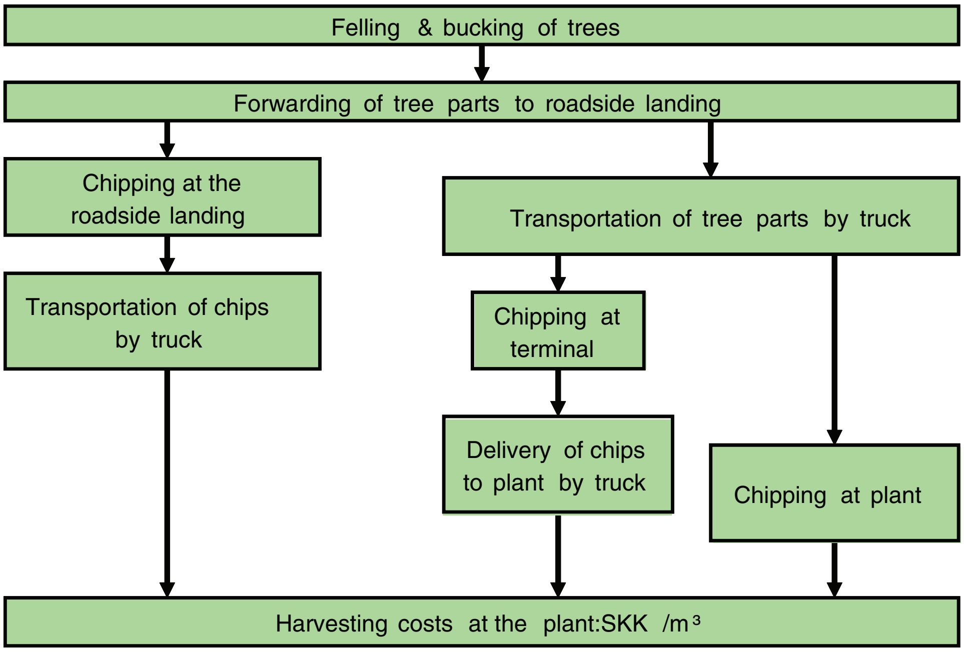

Figure 5. Harvesting chains analysed in the study.

Technological processes of thinning and final felling were subject to the assessment. According to the age of forest stands, thinnings were divided into those under 50 and above 50 years. The accessibility to the dendromass according to the hauling distance and site inclination represented other criteria taken into the account. For site inclinations below 40 %, drain of the dendromass was considered possible in all forest compartments unless not restricted for ecological reasons. In forest compartments with the mean inclination from 40 to 50 %, the drain of some 35 % of dendromass was considered possible. Compartments with site inclinations over 50 % were not considered because of their technical inaccessibility for forwarders.

The total calculated cost of individual production processes comprised the investment, operational and personnel costs. These are further divided into the fixed and variable costs. Variable costs are inversely proportional to the size of activities or intensity of operation, e.g. on the time economy of machines in a given period. Fixed costs are not proportional to the extent or intensity of work, but to the time. The investment costs include depreciations and interests on capital, which are fixed costs. Operational costs include the fuel and lubricants, maintenance and repair, which are variable costs. They also include fixed costs of the insurance and administration. The personnel costs include wages plus directly related additional costs and the profit margin. These costs are also treated as fixed.

The comparisons of cost types among different production schemes have not revealed significant differences. As far as no specific field assessment was carried out in Slovak conditions, hourly operation costs of harvesting machinery were adapted from the case study which was carried out in Bialystok/Poland as a part of the research project "The Forest Energy Potential and Technology Market in European Union and International Bioenergy Trade" by the Finnish Forest Research Institute and VTT (Virkkunen 2006).

The operational costs determined for each machine and harvesting method (SKK/operating hour), were combined with data concerning stands and dendromass accumulation (Tables 11, 12). The harvesting costs were calculated separately for 10% inclination classes and 10 km transportation distances (Table 9). Costs are expressed in Slovak Crowns per cubic meter. In the calculation 1 € was 37.71 SKK.

The costs and their structure for different harvesting methods were assessed as a summary for the following partial operations:

a) Costs of felling and bucking of trees:

   The overall costs of felling and bucking of trees were determined as the average of prevailingly moto-manual felling at three regional state forest enterprises – Čierny Balog with mostly mountain sites covered by predominantly coniferous forests; Hnúšťa with mixed site types covered by the both conifers and broadleaves; and Bardejov with broadleaves predominating. The costs were calculated separately for conifers and broadleaves, and, as to the felling type, for final and intermediate felling.

   The costs of intermediate felling were further divided into the costs of thinning in younger stands under 50 years and older stands over 50 years. The tables of the Finnish Performance Standard were used for their calculation (Metsäalan palkkaus 2003). The mean tree volume is the most important variable predetermining the felling costs. Different correction factors were therefore applied to the adjustment of mean felling costs in stands below and above 50 years because of obviously smaller dimensions of trees coming from thinning of younger stands in comparison with the older ones (Metsäalan palkkaus 2003). The thinning cost in the younger stands was calculated multiplying the intermediate felling cost by the coefficient 1.45. In older stands the intermediate felling cost was multiplied by the coefficient 0.95. The applied factors are expert estimates based on the results of field assessments in the Finnish conditions. The projected cost of felling and crosscutting for individual felling types and tree species, applied in further assessments, are provided in Chapter 5.

b) Costs of forwarding:

   The forwarding costs of dendromass in thinnings and in final fellings were calculated using productivity models based on the time studies in Finnish conditions (Asikainen et al 2001, Laitila et al 2007). Forwarding distances, load sizes and biomass concentration in stands were independent variables in the model. As to the model assumptions, mean hauling distance was set to 450 m, and mean load size to 5.2 m³ for thinning and 6.8 m³ for final felling. The assumed dendromass accumulation for thinning and final felling was set to 10 m³ and 63 m³ per hectare, respectively. The cost of operating hour was set to 1,497 SKK for a forwarder in thinnings (see Picture 3: Small forwarder for thinnings) and to 1,759 SKK for a forwarder in final fellings (see Picture 4: Heavy forwarder for final fellings). The speed of a forwarder including driving during loading, loaded and unloaded driving was adjusted by a correction factor according to the results of Brunbergs (2004) for forest compartments with inclination 10 – 40 %, and using an expert estimate for slope grades from 40 – 50 %. The values of correction factors and forwarding costs are present in Chapter 5.

c) Transporting costs

Large-capacity chip trucks (Picture 5) or special trucks for transport of branches, tree-tops, tree crowns and small dimension trees, equipped with hydraulic system for compression of transported biomass (Picture 6), have been considered in the study.

The assumed load volumes were 25.6 m³ of net (64 m³ of bulk) chips and 18 m³ (solid) of wood in the form of uncut biomass. The mean transportation speed of 42 km/h has been considered. Estimated hourly costs were 2,137 SKK/h for truck driving, and 1,306 SKK/h for loading and unloading. The expected loading time has been 0.85 hour (chipper output 75 m³ of bulk chips per hour), unloading time in the CHP 0.26 hour, and auxiliary time 0.4 hour per load. Corresponding values for transportation of uncut biomass have been 2,223 SKK/h for truck driving and 1,343 SKK/h for loading and unloading. The expected duration of loading has been 1.04 hour, unloading 0.89 hour, and auxiliary time 0.4 hour per one load.

d) Costs of chipping

Costs of chipping have been assessed for a truck-mounted chipper, which acquisition price is approximately 15,000,000 SKK (Picture 7). Data regarding its output capacity are based on the field research in Finnish conditions (Laitila 2006).

The costs of woodchips handling at terminals of suppliers and their transport to consumers also refer to baseline information from the praxis in Finnish conditions. The calculation assumes the mean distance between suppliers' terminal and the CHP 7 km, and chips transported by the large capacity chip trucks.

4 Resources of wood and other biomass in the region

4.1 Basic data on forests in the region

The forest cover percentage is 48.9 % in the Banská Bystrica Region. The total forest stand area is 453,106 ha, i.e. 23.5 % of its total in Slovakia. The total growing stock is 102.9 million m³ (41.3 million m³ of coniferous and 61.6 mil. m³ of broadleaved) wood under bark, i.e. 23.7 % of the total growing stock in Slovakia. The mean annual felling is approximately 1.7 mill. m³, comprising 0.7 mill. m³ of coniferous and 1.0 mill. m³ of broadleaved timber. This volume represents 25.2 % of the total yearly volume felled in Slovakia. The administrative districts Brezno (18.5 %, 22.1 % and 23.9 %), Rimavská Sobota (11.7 %, 11.1 % and 10.4 %) and Banská Bystrica (10.4 %, 10.9 % and 10.8 %) have the highest proportions in the region's forest area, growing stock and annual felling.

Further forest-related information according to the administrative districts of the region follows in Table 1, and Figures 6 - 8.

Table 1. Basic information about forests in the Banská Bystrica Region (forests together)

	Forest land		Growing stock				Planned annual felling			
District			Conifers	Deciduous	Together		Conifers	Deciduous	Together	
	ha	%		m^3 u.b.		%		m^3 u.b.		%
Banská Bystrica	45956	10.14	6325336	4937594	11262930	10.94	103270	75442	178712	10.83
Banská Štiavnica	16760	3.70	705938	3018985	3724923	3.62	11738	60968	72706	4.41
Brezno	83786	18.49	19131802	3633286	22765088	22.11	327951	66108	394059	23.89
Detva	18801	4.15	2907587	1755719	4663306	4.53	62233	31796	94029	5.70
Krupina	20567	4.54	209720	3540694	3750414	3.64	3175	45274	48449	2.94
Lučenec	32149	7.10	422231	5162416	5584647	5.42	8162	78491	86653	5.25
Poltár	23877	5.27	971471	4180270	5151741	5.00	14176	76369	90545	5.49
Revúca	42437	9.37	2455685	7029329	9485014	9.21	27507	74464	101971	6.18
Rimavská Sobota	52999	11.70	2079764	9458700	11538464	11.21	36135	154579	190714	11.56
Veľký Krtíš	25233	5.57	130616	3789273	3919889	3.81	1424	61473	62897	3.81
Zvolen	37812	8.35	2717536	6712309	9429845	9.16	51935	130276	182211	11.05
Žarnovica	26595	5.87	1195151	4777981	5973132	5.80	14619	65430	80049	4.85
Žiar nad Hronom	26134	5.77	2072946	3633299	5706245	5.54	23445	43132	66577	4.04
Region together	453106	100.00	41325783	61629855	102955638	100.00	685770	963802	1649572	100.00

Definitions used hereinafter:

- Forest land – land covered by forest tree species and classified as a forest in the Land Registry.
- Growing stock – volume of living trees in forest stands, which diameter exceeds 7 cm under bark at the height of 1.3 m above ground.
- Dendromass – above- and below-ground mass of a tree or forest stand expressed in the cubic (m^3) or weight (ton) units; only the above-ground dendromass is considered in the study.
- Dendromass available for energy generation – above ground tree mass minus industrial roundwood.
- Planned annual felling – timber volume which is allowed for harvesting in a given forest unit each year during the 10-year period of validity of a forest management plan.
- Age class (VS) – mean age of a stand graded in 10-year intervals (VS 1 = stands under 10 years of age, VS 2 = 11 to 20-year stands...)

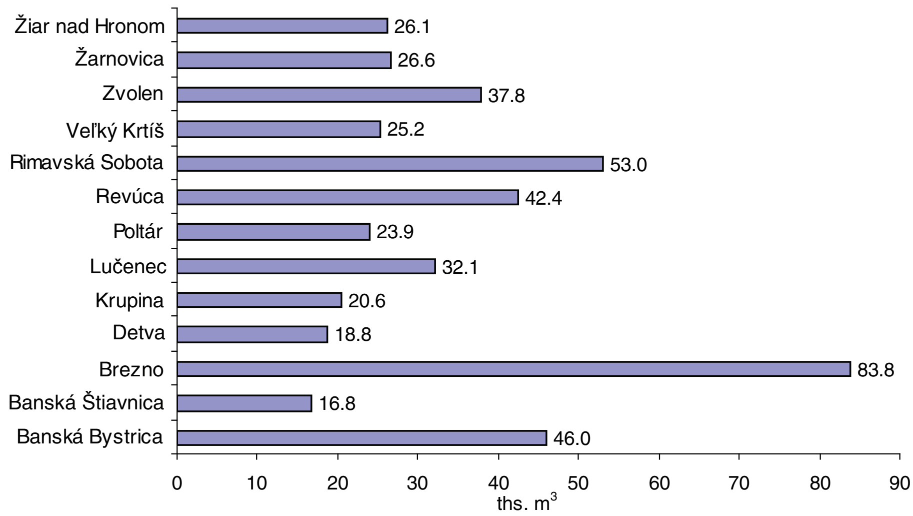

Figure 6. Forest stands area in the districts of the Banská Bystrica Region

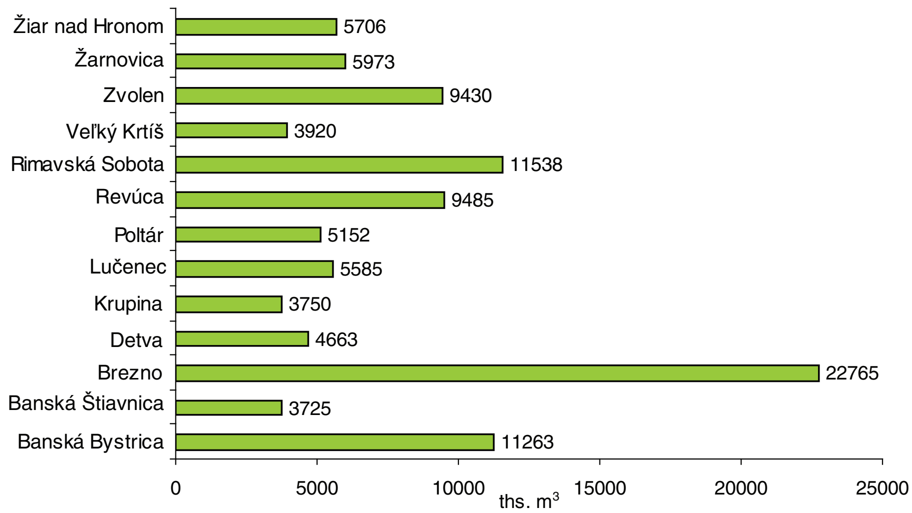

Figure 7. Growing stock in the districts of the Banská Bystrica Region

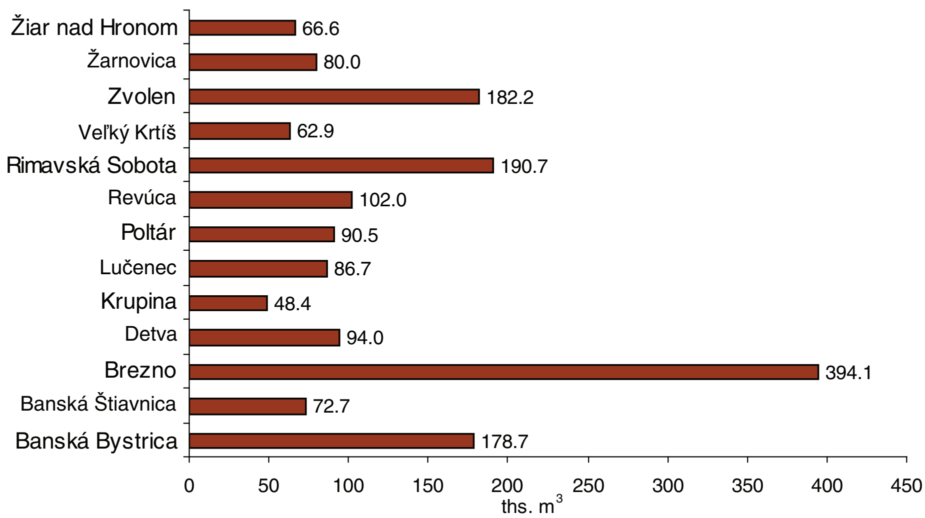

Figure 8. Planned annual felling in the districts of the Banská Bystrica Region

4.1.1 Age Structure of Forests in the Banská Bystrica Region

The age structure of forest stands is not even within the region. The age structure does not correspond to the structure of growing stock and planned annual felling. While the spatial proportions of age classes 1 to 9 are relatively even, there is an obvious surplus of 60- to 100-year stands (AC 6 to 10) and slight deficiency of younger 10 – 50 -year stands (AC 1 to 5) according to the growing stock. Distribution of the age structure of planned felling does not follow the age structure based on the forest stand area and growing stock. The intensity of intermediate felling planned in younger 20 – 80 -year stands (up to AC 8) is twice to three times lower than intensity of regeneration felling in the stands over 90 (AC 9 – 15+). This fact will influence the age structure of the predicted volume of energy dendromass, subsequently. We can therefore assume larger volumes of available dendromass towards lower age classes. This may be due to the higher yield of roundwood and pulpwood in the total volume of regeneration felling. Detailed information about the age class distribution based on the area of forest stands and growing stock, and of planned annual fellings, follows in Table 2 and Figures 9 to 11.

Table 2. Age structure of forests in the region by area, growing stock and annual felling

Age class	State owned forests			Non-state forests			Together		
	Stands area ha	Growing stock m^3 u.b.	Annual felling m^3 u.b.	Stands area ha	Growing stock m^3 u.b.	Annual felling m^3 u.b.	Stands area ha	Growing stock m^3 u.b.	Annual felling m^3 u.b.
1	20476	2746	21	14984	6773	25	35460	9519	46
2	22996	382520	5604	22248	444564	5530	45244	827084	11134
3	17475	1733257	26554	18884	1754938	22749	36359	3488195	49303
4	15447	2654208	34808	13652	2077053	26680	29099	4731261	61488
5	15948	3698061	36713	16128	2959740	38528	32076	6657801	75241
6	20873	5744153	43603	27607	5929558	54537	48480	11673711	98140
7	22000	6566450	35759	28649	6932270	39041	50649	13498720	74800
8	18384	6099467	24219	25007	7007949	39339	43392	13107416	63558
9	19891	7346973	91750	21852	6961872	77600	41743	14308845	169350
10	17855	7332569	182061	15675	5726294	144018	33530	13058863	326079
11	11129	4780121	175424	9337	3611760	124096	20466	8391881	299520
12	7135	3186232	140441	3905	1583391	67625	11039	4769623	208066
13	3823	1612470	68826	2010	759703	28848	5833	2372173	97674
14	3113	1038521	34710	1850	630322	20830	4962	1668843	55540
15+	9299	3312586	36219	3543	1079117	20986	12842	4391703	57205
Together	225845	55490334	936712	225330	47465304	710432	451174	102955638	1647144

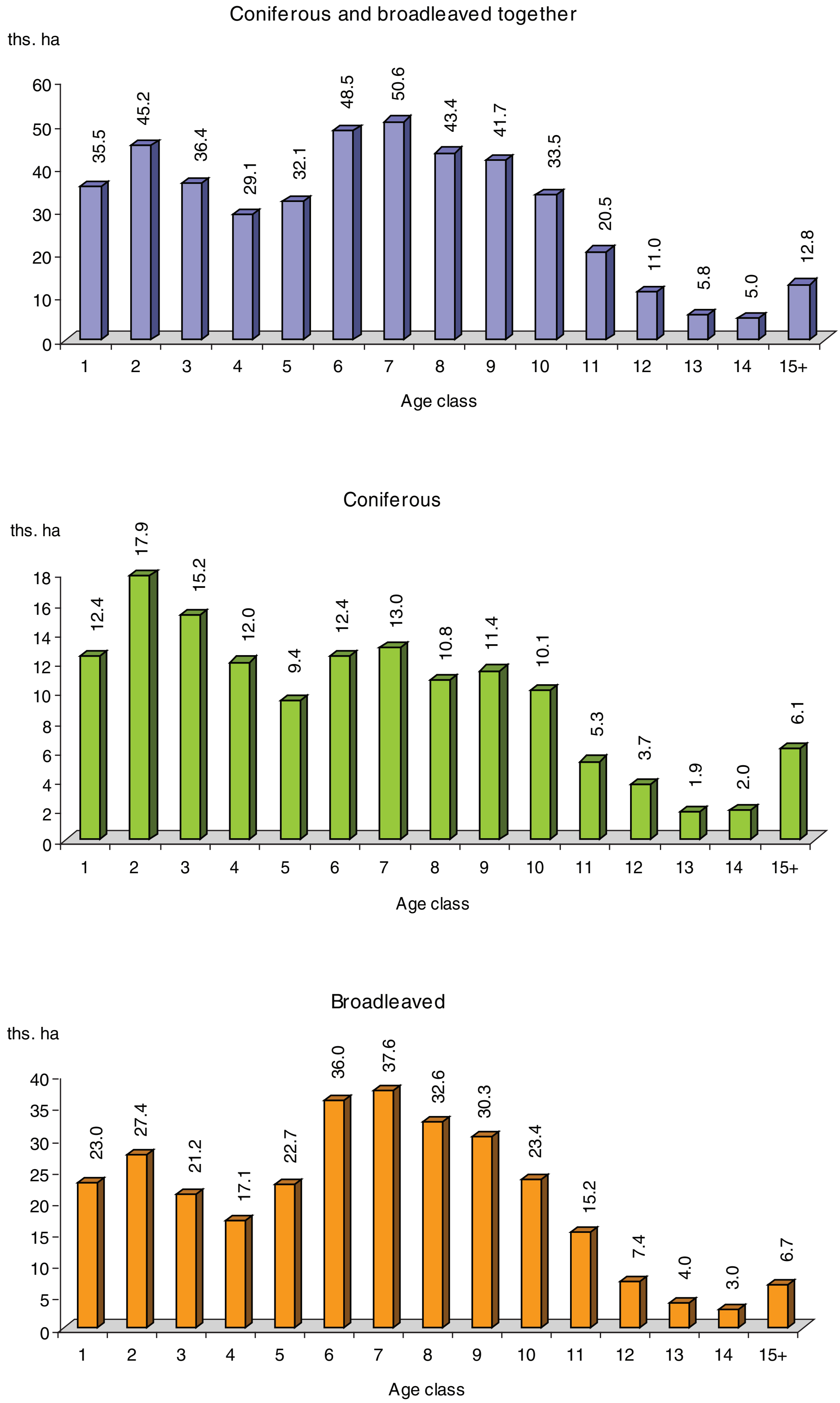

Figure 9. Age structure of forest stands area in the region by tree species groups

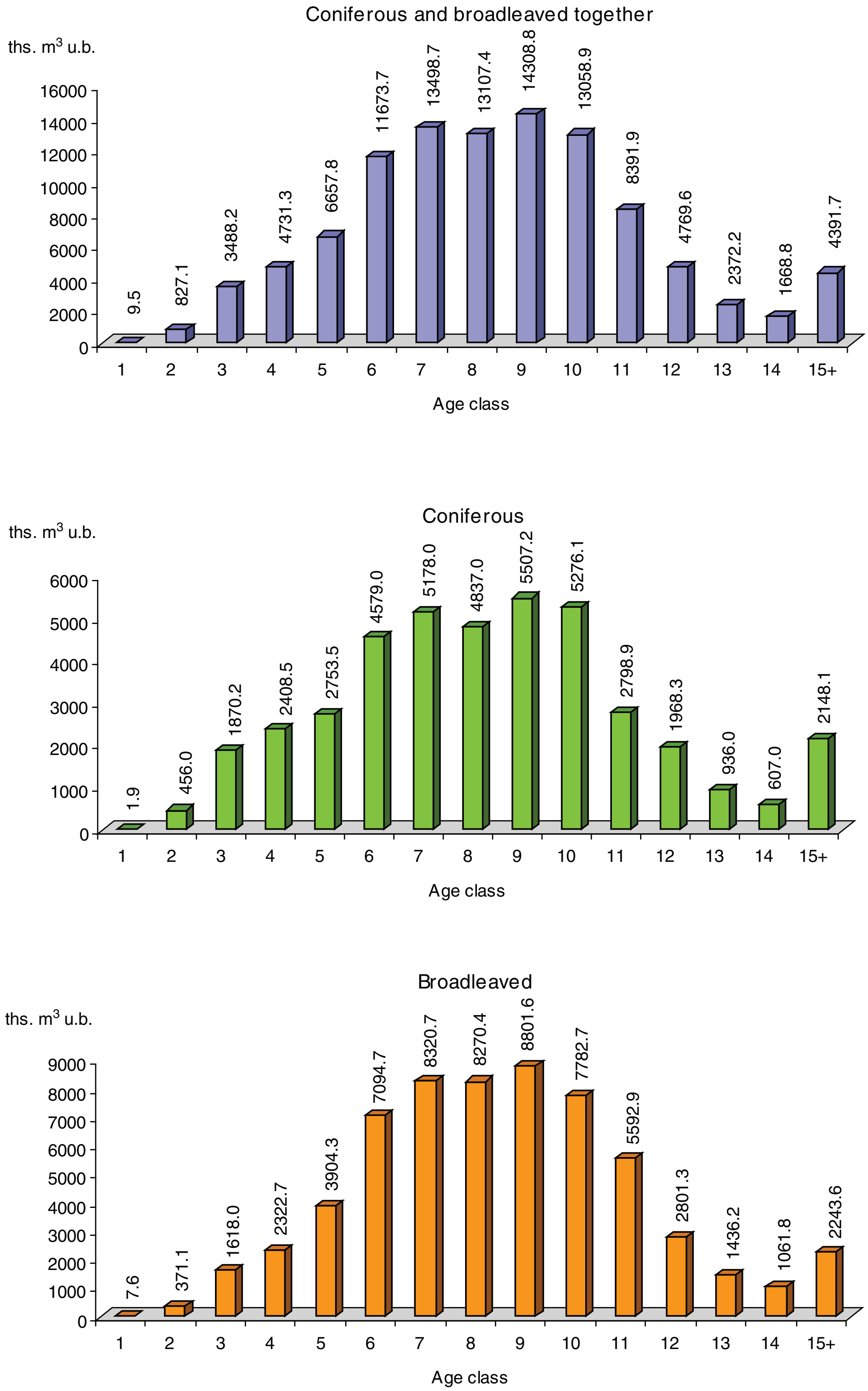

Figure 10. Age structure of growing stock by tree species groups

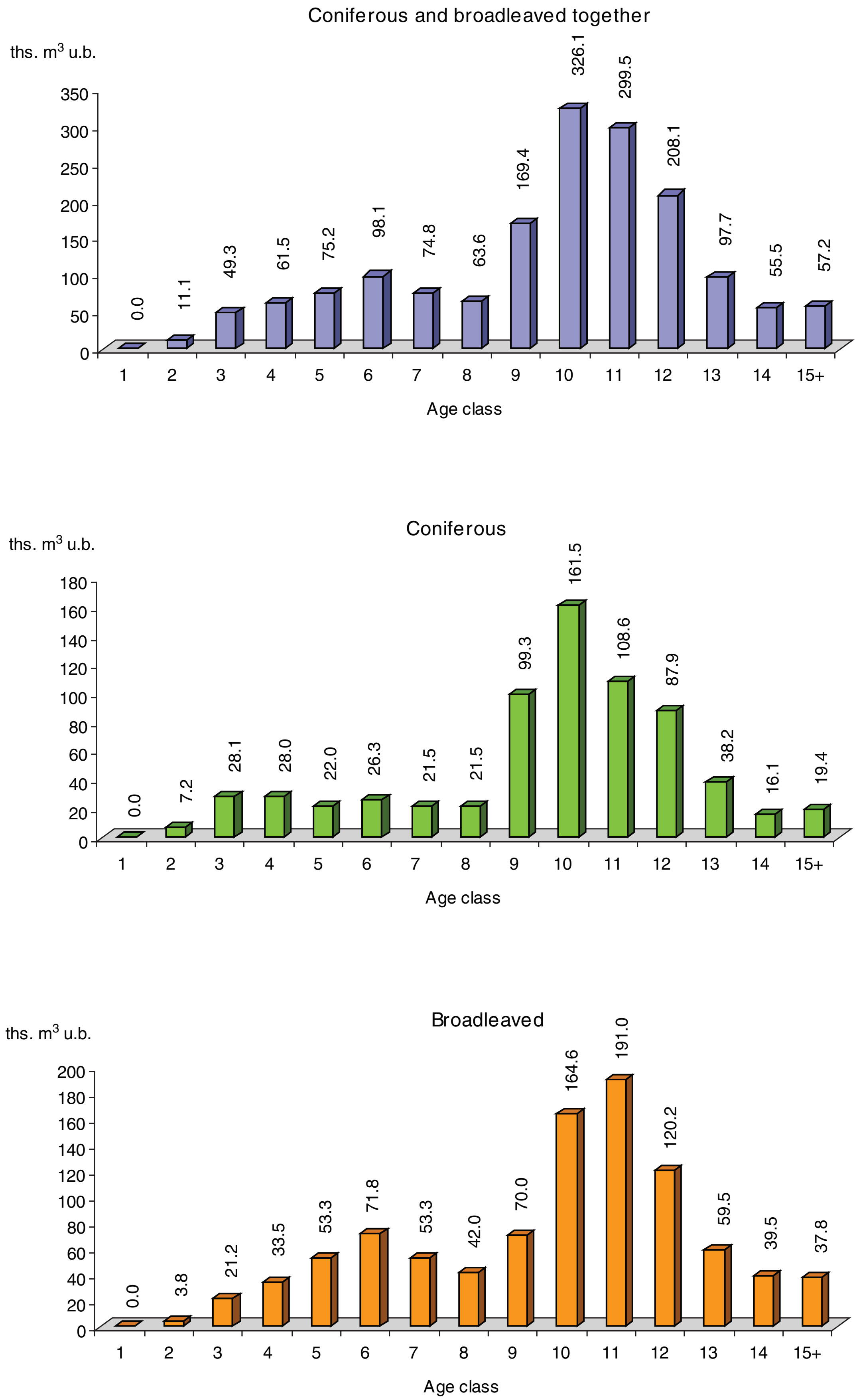

Figure 11. Age structure of planned annual felling

4.1.2 Assortments yield from planned felling

The yield of industrial logs and pulpwood is important determinant of the potential volume of energy dendromass (Figure 12). Calculation of the yield of individual assortments (qualitative classes I, II, IIIA, IIIB, pulpwood, firewood and residues according to the Slovak Technical Norm) was carried out at the level of forest compartments and species, using the valid yield tables. Following of this approach, the yield of assortments from the total planned annual felling in the region is as follows: roundwood of the qualitative classes IIIA and B 59.5 %, top quality roundwood of classes I+II 9.9 %, small-sized industrial wood 28.8 %, fuelwood 1.8 % and residues 0.1 %. These figures indicate the effect of assortment yield on the availability of energy dendromass. It could be pointed out, that the annual production of firewood ranges between 430 and 500 ths. m³ in Slovakia from 1990. Its energy value is 4,085 to 4,750 TJ. Somewhat increasing volume of available firewood is due to rising proportions of unplanned salvage fellings, lowering the overall quality of wood removals and shifting the assortment structure towards lower quality classes.

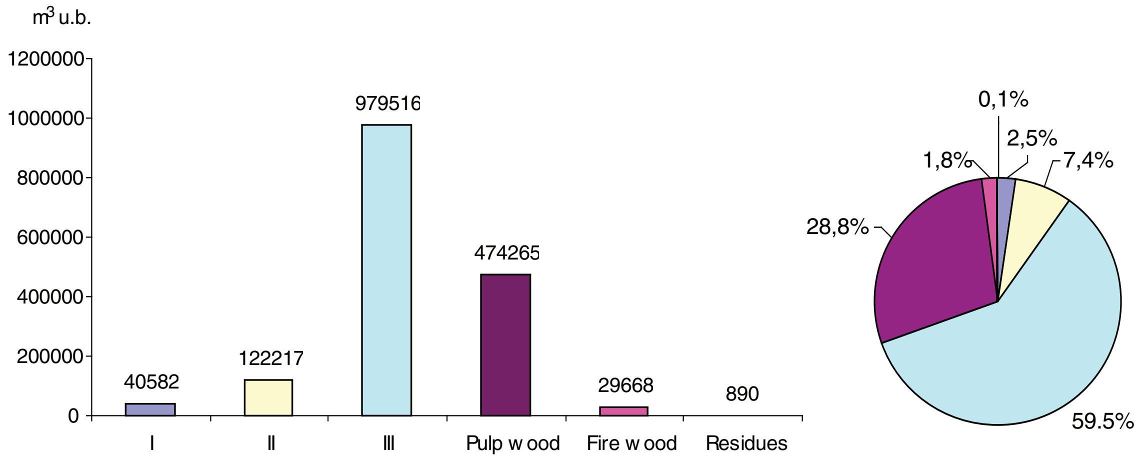

Figure 12. Assortment structure of planned annual felling

4.1.3 Tree species composition

The tree species composition is another factor influencing the yield of energy dendromass to some extent. Broadleaved tree species prevail in the region with the share of 68.3 %. Beech is the most common broadleaves (30.3%), followed by oak (13.6%) and Turkey oak (19.8%). Hornbeam, black locust and other broadleaves tree species with higher proportion of lower quality wood assortments suitable for energy generation could also be mentioned. Conifers (31.7 %) are represented mainly by Norway spruce (22.6%), the share of silver fir is 3.8%, Scots pine 3.2%, and other conifers 2.0%. Figure 13 illustrates the tree species structure of region's forests.

Relatively high share of broadleaves with higher proportion of low- dimension wood, suggests a positive trend in the production of energy dendromass in the region.

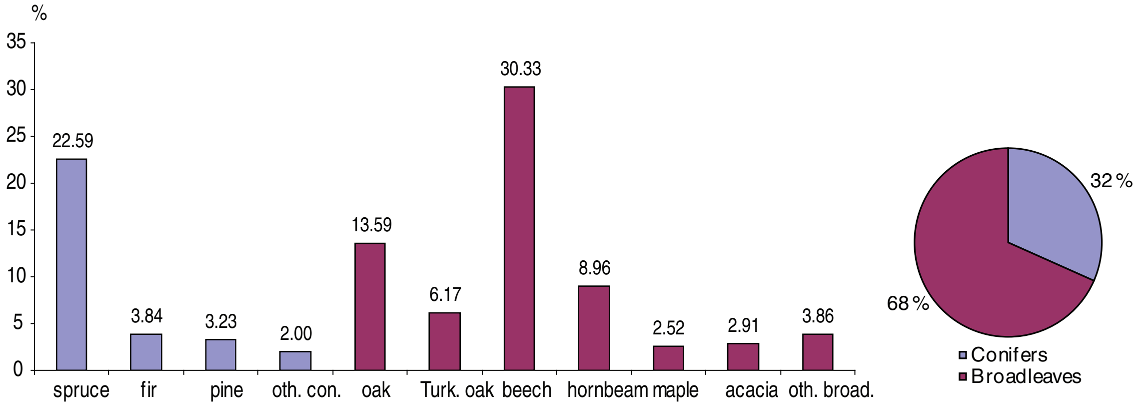

Figure 13. Tree species composition of the Banská Bystrica Region

4.1.4 Forest categories

Three categories of forests are recognised in regard to the prevailing forest function: Commercial Forests where the main goal is production of quality timber, providing that all other forest functions are guaranteed; Special Purpose Forests fulfilling specific tasks according to the public demands; and Protective Forests, which primary purpose is predetermined by natural conditions and forest management aims at the improvement of their protective and conservation functions.

The category of commercial forests prevails in the region, sharing 75.1 %. The share of protective forests is 13.9 % and special purpose forests 11.0 % (Figure 14). The forest category is important indicator for a potential yield of energy dendromass. Especially protective forests and forests under higher degree of nature protection (nature reserves and their protective zones, protected areas etc.) had to be excluded from the total number of forest compartments (and total forest stand area), which are considered a potential source of dendromass for energy generation.

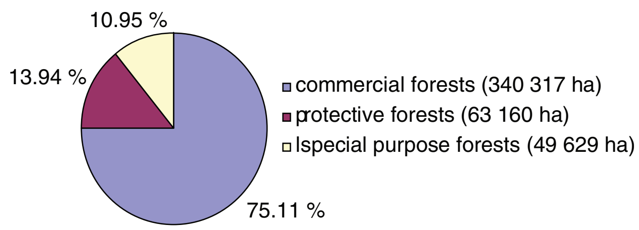

Figure 14. Proportions of forest categories in the Banská Bystrica Region

4.1.5 Ownership and management structure of forests

Information on forest ownership is important for the wood chain from its supplier's to the customer in regard to the potential producers of energy dendromass. The state owned forest land is managed by several public enterprises, with the state enterprise Forests of the Slovak Republic in Banská Bystrica dominating, and the State Forests of the Tatra National Park in Tatranská Lomnica, state enterprise Forest-Farming Estate in Ulič, Forestry Schools and the Army Forest Estate (VLM) managing smaller areas. Non-state forests are owned by individuals and legal bodies, such as land associations, municipalities, church and cooperatives.

Referring to Figure 15 describing the ownership structure, the state possesses 50 %, individuals 15.5 %, land associations 15.3 %, municipalities (towns and villages) 11.9 % and church 3.2 %. The proportion of forests, which owners are not known or they are not claimed - 4.0 % - is relatively high. These forests are administered by the Slovak Land Fund. The smallest part of forests, 0.1 %, is owned by the agricultural cooperatives and other bodies.

Management and ownership patterns are not identical (Figure 16). The state forest enterprises manage 71.6 % of forestland. Their higher proportion is either due to tenancy agreements with owners of non state forests or due to the fact that the Forests of the Slovak Republic administer also forest lands not yet returned to their original owners due to still not fully complete land ownership restitution. They do it on behalf of the Slovak Land Fund.

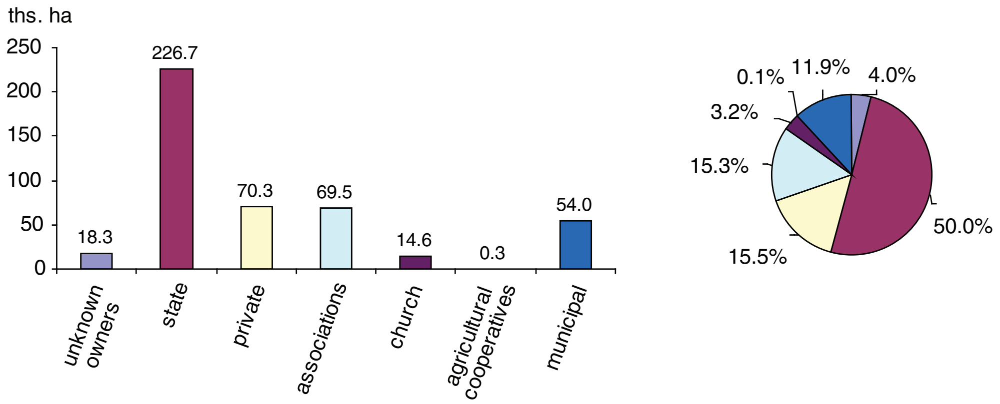

Figure 15. Ownership structure of forests in the Banská Bystrica Region

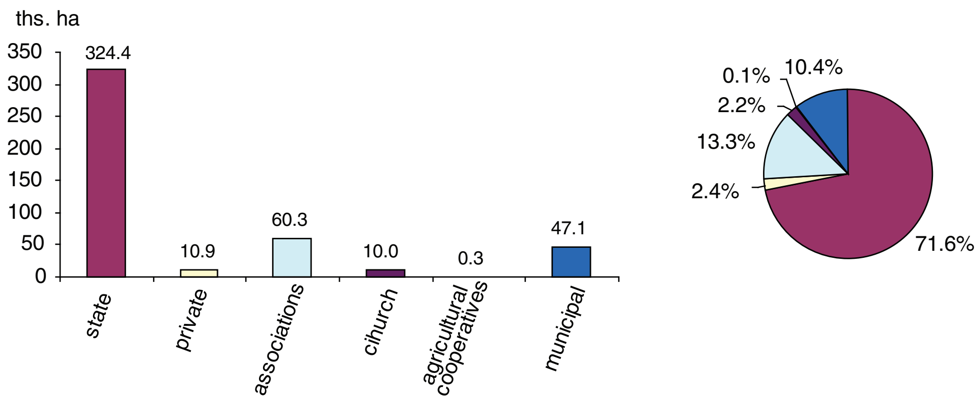

Figure 16. Management structure of forests in the Banská Bystrica Region

4.2 Total and energetically utilisable forest dendromass in the region

The total forest land area of the Banská Bystrica region is 453,000 ha. When the limiting criteria referring to the forests categories, their nature protection and site fertility were applied, the forest area for calculation of the total wood resource and energy dendromass has decreased to 258,300 ha (57.0 %) and the growing stock of dendromass to 1,245.1 mill. m³. Application of another limiting factors of technical nature described in Chapter 3 (especially slope inclination), resulted in the potential volume of dendromass for energy generation of 302.4 mill.m³, what equals to

18.3 % of the planned annual cut and 24.3 % of the region's total available dendromass resource. The highest calculated volume of dendromass available for energy generation is located in the districts Rimavská Sobota (47.9 ths. m³), Zvolen (34.3 ths. m³) and Lučenec (31.7 ths. m³), while the lowest one in Brezno (5.8 ths. m³).

The volumes of total dendromass and dendromass available for energy generation were assessed according to the criteria described in Chapter 3. Results of the assessment have been aggregated according to the age structure (age classes), tree species composition (conifers and broadleaves), ownership and management structures by the administrative districts and for the whole region.
The age structure of projected annual volumes of energy dendromass follows planned annual felling only partly due to the higher share of available energy dendromass in younger stands than in the stands where final felling is planned. It is partly due to a higher yield of roundwood and pulpwood from planned final felling and lower share (and thus also total volume) of a small dimension timber in the total tree mass.

The share of energetically usable dendromass coincides with the forest tree species composition in individual districts.

In regard to the ownership and management structure, the projected volume of energy dendromass follows the ownership and management structure of forests. Its main part is present in the forests managed by the public enterprises (67.6 %), followed by holdings owned by land associations (16.9 %), municipalities (10.3 %), individuals (3.5 %), church (1.8 %) and agricultural cooperatives (0.2 %).

Data on the region's total resources and for energy production available dendromass according to the districts are provided in Table 3 and Figure 17. The total resource of the above ground dendromass excluding foliage is more than 1.2 million m³ per annum. When the limiting criteria are applied, calculated available volume of energy biomass is 302,400 m³, which is about one quarter of the region's total resource of energy dendromass.

Table 3. Annually available energy dendromass according to the administrative districts

District	Available energy biomass (ths. m³)	Total biomass (ths. m³)	%
B.Bystrica	24.0	126.6	18.96
B.Štiavnica	20.3	85.1	23.85
Brezno	5.8	32.0	18.13
Detva	15.4	84.2	18.29
Krupina	19.4	63.4	30.60
Lučenec	31.7	100.2	31.64
Poltár	26.7	106.5	25.07
Revúca	20.5	85.2	24.06
R.Sobota	47.9	192.8	24.84
V.Krtíš	26.1	78.9	33.08
Zvolen	18.8	84.3	22.30
Žarnovica	11.5	52.2	22.03
Žiar n. Hronom	34.3	153.2	22.39
Total - Region	302.4	1244.6	24.30

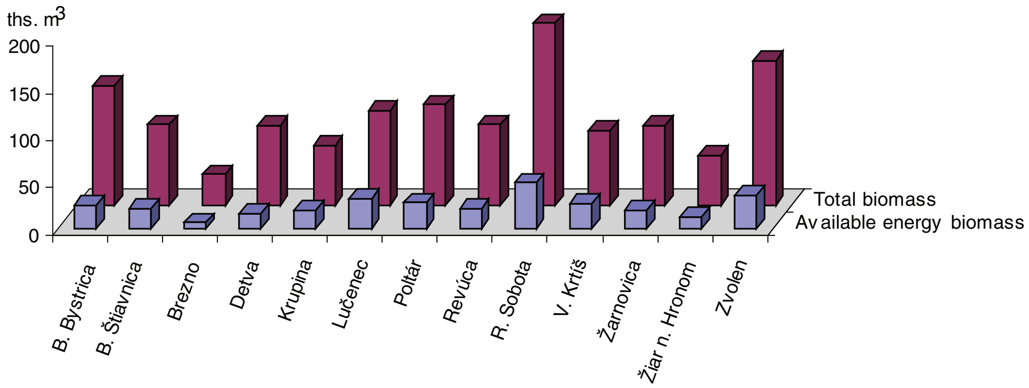

Figure 17. The region's resources of the total and available energy dendromass according to the administrative districts

Figure 18 provides summary information about the potential volume of energy dendromass according to the age classes, ownership and management of forests.

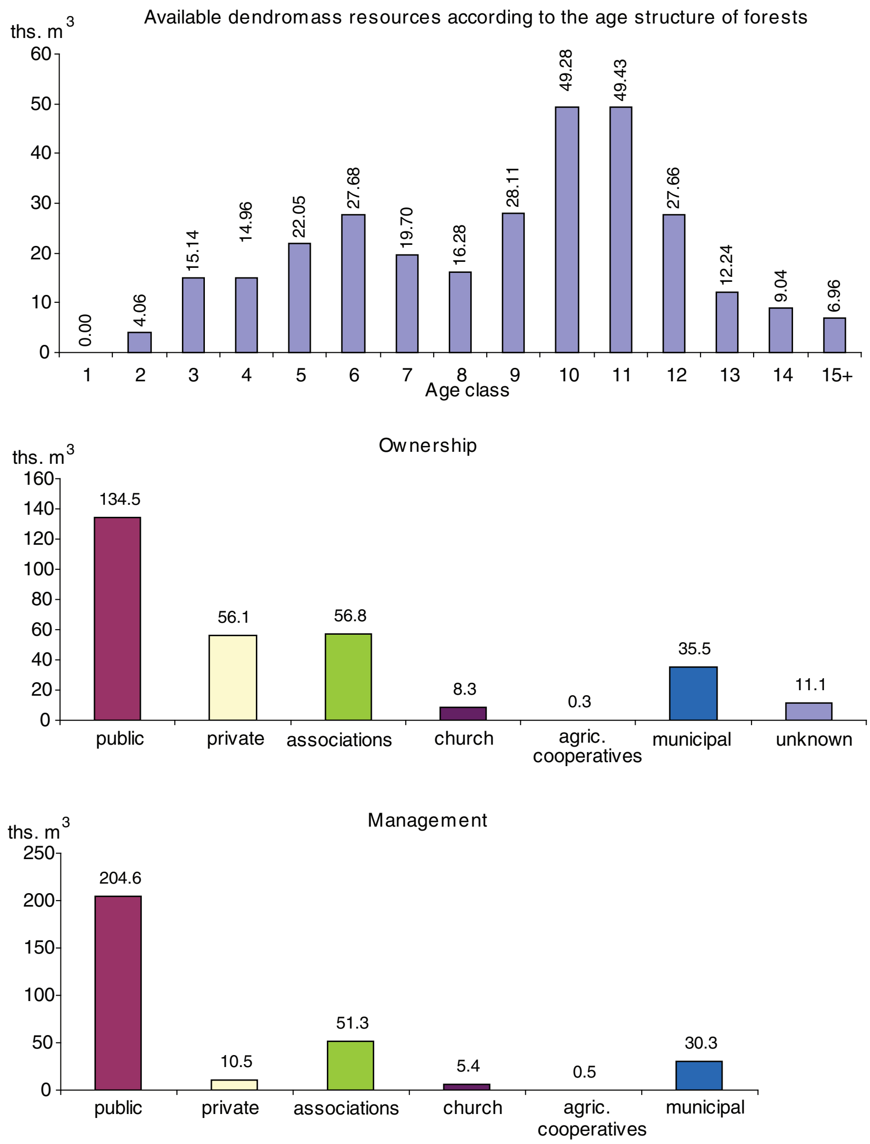

Figure 18. Available dendromass resources according to the age structure, ownership and management of forests in the region

4.3 Results of the analysis of ecological, technical and economic availability of energy dendromass by means of geographical information methods

Summary data on potential resource of energy dendromass according to the administrative districts and for the entire region do not provide sufficiently detailed image about its real distribution and real availability in regard to the harvesting and transport costs, most appropriate method of felling, transportation and logistics safeguarding continuous supplies to the customer. While a market-regulated production and supplies of energy biomass in bigger volumes have not been present in Slovakia by now, such more detailed analysis is utmost important for the most realistic planning of the supplier-customer relationships and logistical safeguarding of the heating plant operation under various regimes from winter maximum to summer minimum outputs.

Digital surface model was the basis for analyses. Other layers of digital information were inserted into it following the methodology described in Chapter 3. In order to identify and exclude from further calculations forest stands with protective functions, endangered by erosion and with difficult access, information about the topology of the region, including the altitudes and slope inclinations, were used. These were further combined with data on forest areas within the Banská Bystrica region. The analysis resulted in numerical and graphical information about the areas of forests classified according to the altitudes and slope inclinations, provided in Tables 4 and 5, and maps in Annex 3, 7 and 9.

Table 4. Area of forest stands according to the altitude.

Elevation level (m)	Forest area (km²)	Forest area frequency (%)	Cummulative forest area (km²)	Cummulative forest area frequency (%)
0 – 200	27.3	0.6	27.3	0.6
200 – 400	1076.3	24.3	1103.6	24.9
400 – 600	1203.5	27.2	2307.1	52.1
600 – 800	950.6	21.5	3257.7	73.6
800 – 1000	666.0	15.0	3923.7	88.6
1000 – 1200	334.6	7.6	4258.3	96.1
1200 – 1400	122.8	2.8	4381.1	98.9
1400 – 1600	39.4	0.9	4420.5	99.8
1600 – 1800	8.3	0.2	4428.8	100.0
1800 – 2000	0.1	0.0	4428.9	100.0
Total	4428.9	100.0		

Table 5. Area of forest stands according to the inclination classes.

Slope level (%)	Forest area (km²)	Frequency of forest area (%)	Cummulative forest area (km²)	Cummulative forest area frequency (%)
0 – 10	337.3	7.6	337.3	7.6
10 – 20	816.8	18.4	1154.0	26.1
20 – 30	986.4	22.3	2140.5	48.3
30 – 40	940.3	21.2	3080.8	69.6
40 – 50	675.4	15.2	3756.2	84.8
> 50	672.7	15.2	4428.9	100.0
Total	4428.9	100.0		

The obtained data indicate that 70 % of the region´s forests are situated in lower altitudes up to 800 meters above the sea level, on more gentle slopes with mean inclination less than 40 %. As shown on the maps in Annex 7 and 9, forest stands in higher elevation and on steeper slopes concentrate in the Low Tatra Mts. and in the northern part of the Slovak Ore Mts.

In regard to the limiting factors of ecological, technical and economic nature, the calculation of production costs and proposal of best technologies considered all energy dendromass available in forest stands with mean slope inclination below 40 %, and only 35 % of it in stands with mean inclination from 40 to 50 %. Energy biomass in stands on slopes steeper than 50 % is not considered available for the both economic and technical reasons.

In further steps, the length of public roads of all categories, roads under construction, and of all field and forest roads was assessed. Complete road network in the region is visualised on the map in Annex 4. Road lengths in the region according to their categories are summarised in Table 6. Proportion of roads of individual categories was taken into the account in estimation of the expected mean speeds, and subsequently of the performance and cost of the biomass transportation.

Table 6. The road length in the Banská Bystrica regio

Class of the road	Length (km)	Frequency (%)
Highways	48.8	0.7
1st class roads	1311.4	18.9
2nd class roads	1867.1	26.9
3rd class roads	682.2	9.8
Stabilized roads	1205.7	17.4
Field and forest roads	1810.4	26.1
Roads in reconstruction	6.5	0.1
Total	6932.0	100.0

For each place in the region, the shortest transport distances to the heating plant were computed and grouped into the 10 km distance zones. The distribution of the shortest transport distances, where individual zones are marked by different colours, is provided on the map in Annex 5.

When data on the area and number of forest stands, growing stock and availability of energy dendromass within them, were imported into the map of the shortest transport distance, distribution of the biomass resources in the 10 km transport distance zones was obtained. The areas of forest stands according to these transport distance zones are summarized in Table 7, and similar information concerning growing stocks, annual felling and available energy dendromass in Table 8. Concentrations of the available energy dendromass in individual stands within the transport distance zones are present in the map in Annex 14.

Table 7 shows that more than one half of the forest stand area (53.1 %) is within the transport distance of 60 km from the power plant, favourable in regard to the transportation costs. Concentration of the available dendromass in a closer neighbourhood of the plant is even higher: Over 90,000 m³ of the available energy dendromass, a triple of the planned annual consumption of the plant, is within the distance of 40 km (Table 8).

Table 7. Area of forest stands in 10 km transport distance zones around the Zvolen CHP

Distance (km)	Forest area (km^2)	Forest area frequency (%)	Cummulative forest area (km^2)	Cummulative frequency of forest area (%)
0 – 10	54.2	1.2	54.2	1.2
10 – 20	182.2	4.1	236.4	5.3
20 – 30	358.2	8.1	594.6	13.4
30 – 40	467.9	10.6	1062.5	24.0
40 – 50	692.2	15.6	1754.7	39.6
50 – 60	598.8	13.5	2353.5	53.1
60 – 70	518.4	11.7	2871.9	64.9
70 – 80	359.8	8.1	3231.8	73.0
80 – 90	267.3	6.0	3499.1	79.0
90 – 100	265.4	6.0	3764.5	85.0
100 – 110	341.5	7.7	4106.1	92.7
110 – 120	252.3	5.7	4358.4	98.4
120 – 130	62.0	1.4	4420.4	99.8
130 – 140	8.1	0.2	4428.4	100.0
Total	4428.4	100.0		

Table 8. Annually available resources of energy biomass within 10 km transport distance zones around Zvolen CHP

			1 year	
Distance (km)	Growing stock (m^3)	Annual available cut (m^3)	Available biomass (m^3)	Cummulative available biomass (m^3)
0 – 10	122825	21531	5759	5759
10 – 20	470507	100033	24136	29895
20 – 30	851233	146193	32698	62593
30 – 40	1063750	169306	30792	93385
40 – 50	1498481	245805	46040	139425
50 – 60	1243793	187661	38161	177586
60 – 70	1187562	201374	40494	218080
70 – 80	798597	140548	26958	245038
80 – 90	680416	133463	15406	260444
90 – 100	630963	89097	14900	275344
100 – 110	824833	104039	16322	291666
110 – 120	548725	55446	8634	300300
120 – 130	135858	15865	2032	302332
130 – 140	7058	101	28	302360
Total	10064601	1610462	302360	

In order to compute harvesting costs for various combinations of technologies and harvesting sets, information about forest stands and dendromass within them, were divided into the mean slope classes defined by 10 % inclination intervals.

As mentioned in the above, our assessment of expected costs considered all energy dendromass available on slopes with inclination less than 40 %, while only 35 % on the slopes from 40 to 50 %. The energy dendromass on slopes steeper than 50 % was not considered to be available at all.

The stand-wise data concerning the availability of dendromass were further combined with 10 km transport distance classes for a more precise determination of the total transportation costs to the CHP. Resulting Table 9 provides stand areas within individual inclination classes and transport distance zones. It shows that the biggest share of stands on slopes from 20 to 40 % is situated in a distance 30 to 70 km from the heating plant.

The type of felling and tree species composition are additional important factors for calculation of felling costs and selection of the most efficient harvesting system. These two factors influence decisions on the suitability and possibilities for fully mechanised cut-to-length method of harvesting by means of harvesters and forwarder.

From this point of view, the database of the sources of dendromass was subdivided into the subsets for coniferous and broadleaved species, as well as for the thinning of stands under and above 50 years, and final felling. Summary concerning the areas of forest compartments according to the felling type is provided in Table 10. It indicates relatively even proportions - approximately one third per each category of the forest area with intermediate felling below 50 and above 50 years, and final felling. Their geographical distribution depicted in the transport distance from the plant is also rather even, except of under-representation of forest stands closer than 10 km and above 110 km. The closest neighbourhood of the power plant is occupied by the town, however, and the majority of distant forests in the eastern Low Tatra and Slovak Ore Mountains were excluded from calculations due to nature protection and extreme topography.

Table 9. Areas of forest stands according to the inclination classes and transport distance zones

Distance (km)	Area of slope category (%) in km²						
	0 – 10	10 – 20	20 – 30	30 – 40	40 – 50	> 50	Total
0 – 10	4.8	11.9	13.1	11.5	6.7	6.1	54.0
10 – 20	17.1	41.9	49.2	39.2	20.3	14.6	182.3
20 – 30	20.6	72.5	96.2	78.6	49.6	40.7	358.2
30 – 40	23.4	78.5	109.4	104.2	75.3	77.3	468.1
40 – 50	45.4	128.7	158.2	139.2	105.1	115.5	692.1
50 – 60	53.7	113.5	122.4	118.7	91.8	98.9	599.1
60 – 70	40.8	98.2	121.1	113.6	75.2	69.7	518.6
70 – 80	35.0	65.2	71.2	69.7	52.2	66.7	360.0
80 – 90	23.7	40.5	49.4	62.9	49.0	41.9	267.3
90 – 100	18.7	38.3	53.5	60.7	45.4	48.9	265.5
100 – 110	24.6	57.6	74.1	79.8	57.0	48.0	341.1
110 – 120	20.9	53.4	52.3	47.4	38.4	40.0	252.4
120 – 130	7.6	14.1	13.9	13.4	8.9	4.3	62.1
130 – 140	1.0	2.6	2.4	1.3	0.6	0.3	8.1
Total	337.3	816.8	986.4	940.3	675.4	672.7	4428.9

Table 10. The area of forest stands in hectares with available energy dendromass according to the transport distance zones and type of felling

Distance (km)	Final felling	Thinning < 50 years	Thinning > 50 years	Total
0 – 10	6.27	7.95	5.75	19.97
10 – 20	27.30	23.42	19.63	70.36
20 – 30	39.22	52.48	40.40	132.10
30 – 40	33.64	49.47	31.96	115.07
40 – 50	52.44	57.12	59.64	169.20
50 – 60	41.78	58.31	47.98	148.07
60 – 70	50.56	45.18	45.98	141.72
70 – 80	31.43	20.76	28.95	81.14
80 – 90	19.56	13.05	25.70	58.31
90 –100	18.08	19.07	32.12	69.28
100 – 110	25.05	21.93	58.23	105.20
110 – 120	9.75	14.15	44.13	68.02
120 – 130	1.84	2.93	11.16	15.93
130 – 140	0.01	0.33	0.20	0.55
Total	356.92	386.15	451.83	1194.90

Tables 11 and 12 provide information about the available energy dendromass according to the tree species and logging type over the next 10 years. Even distribution of available energy dendromass supplies would require annual felling corresponding to one tenth of the total decennial volume. The prevalence of deciduous tree species in the region influenced the distribution of sources of available energy dendromass. It has been most remarkable for the dendromass from stands under final fellings, where the volume of energy dendromass of broadleaves is almost 5-times higher as compared to conifers. This parameter is favourable also because of the higher energy value of the wood of broadleaves. The prevalence of broadleaves in final fellings is more difficult from the technical point of view, however, because fully mechanized cut-to-length method cannot be applied there (e,g. Asikainen et al. 2006).

Table 11. Concentration of the dendromass from final fellings (10 year)

Distance (km)	Biomass (m^3)	Conifers m^3	Broadleaved m^3
0 – 10	57587	8146.78	34195.22
10 – 20	241359	50359.66	142141.34
20 – 30	326984	62476.31	166933.67
30 – 40	307923	78268.05	141284.95
40 – 50	460398	64434.10	272343.90
50 – 60	381608	32339.72	249382.28
60 – 70	404936	21006.90	299102.10
70 – 80	269584	15624.86	204615.14
80 – 90	154061	14203.49	107488.42
90 – 100	149000	10074.36	95614.64
100 – 110	163219	18106.48	92367.52
110 – 120	86341	6319.42	51632.58
120 – 130	20320	1043.03	11048.97
130 – 140	278	0.00	62.00
Total	3023598	382403.17	1868212.76

Table 12. Concentration of biomass from thinnings (10 years)

Distance (km)	Biomass (m³)	< 50 years		> 50 years	
		Conifers	Broadleaved	Conifers	Broadleaved
0 – 10	57587	1638.24	6487.76	787.77	6331.23
10 – 20	241359	5829.59	19395.41	2865.72	20767.28
20 – 30	326984	14104.69	44810.31	7151.16	31507.84
30 – 40	307923	20499.78	34425.22	7491.15	25953.85
40 – 50	460398	21149.00	47975.00	5328.54	49167.46
50 – 60	381608	16323.09	43253.91	4059.46	36249.54
60 – 70	404936	11846.28	34253.72	2963.23	35763.77
70 – 80	269584	6345.51	17235.49	1645.83	24117.17
80 – 90	154061	3269.09	11017.91	1843.56	16238.44
90 – 100	149000	3615.29	18869.71	1435.65	19390.35
100 – 110	163219	4927.55	13662.45	2033.76	32121.24
110 – 120	86341	3083.60	7010.40	1831.15	16463.85
120 – 130	20320	409.12	1935.88	163.74	5719.26
130 – 140	278	32.00	155.00	0	29.00
Total	3023598	113072.83	300488.20	39600.76	319820.28

The volume of dendromass from thinnings of stands below and above 50 years is almost the same, including 5-times higher proportion of broadleaves than conifers. Volume of energy dendromass available from coniferous stands over 50 years is particularly small.

4.4 Estimation and energetic potential of lands suitable for energy crops and plantations of fast growing tree species

Any decision about the further use of farmlands not covered by farming activities requires taking considerable additional cost of their reclamation (sometimes also drainage or irrigation) into the account. Their owners and managers usually do not have additional financial resource for this purpose available. In addition, many conventional crop-farming products are redundant in the long-term and their cultivation would be a low profit to loss making.

Still incomplete transformation of ownership in agriculture and forestry makes even justified attempts to restore original cultural use of many abandoned land lots complicated. The ownership of these lands is fragmented, variable, and with unsettled inheritance in terms of the law on land records.

The comparison of total farmland area of the region with the area on which subsidies are provided, revealed that unused farmland represents 5.55 % of the total farmland fund and 2.46 % of the total area of the Banská Bystrica region.

In order to illustrate the level of fragmentation of the ownership of unused farmlands, Table 13 provides related numbers of municipalities, cadastral areas, parcels and ownership entries, onto which unused parcels are registered.

Table 13. The ownership structure of unused farmlands

Region	Districts	Municipalities	Number of Cadasters Register C	Parcels	Entry files	Entries
B. Bystrica	13	516	621	946.272	206.405	502.443

Table 14 provides information about the area of unused farmlands and their production potential in regard of the energy crops and fast growing tree species according to the districts and for the whole region. Graphical projection of their potential production of energy crops and fast growing tree species follows in Figure 19.

The review indicates obvious differences between the administrative districts. It reflects overall bio-climatic conditions, ratios of arable land and hay meadows to total farmland, traces of older and more recent activities including collectivisation, land reclamation and amelioration, riverbed translocations, industrialisation, infrastructure development, etc.

Site quality indices and location of individual land lots must be considered in any qualified decision about the most appropriate energy crop or plantation of fast-growing tree species. The analysis must be always done in cooperation with the owner or body managing a land lot of interest.

Our calculation of potential future resource of energy biomass on unused farmland in the region is based on the results of research of production of various tree species on trials planted at various site conditions. These trials proved it realistic to expect more than 10 tons of biomass per hectare and year. Referring to the aforementioned area of 23,267 ha of unused farmland, annually available volume of energy biomass can be raised by approximately 250,000 tons in the Banská Bystrica region.

Table 14. Potential annual production of energy dendromass in the region

District	Acreage of set-aside agricultural land (ha)	Potential of dendromass production (t)
Banská Bystrica	1533	16464
Banská Štiavnica	385	4135
Brezno	2227	23918
Detva	691	7421
Krupina	978	10504
Lučenec	1223	13135
Poltár	712	7647
Revúca	1353	14531
Rimavská Sobota	1975	21212
Veľký Krtíš	1490	16003
Zvolen	8838	94920
Žarnovica	536	5757
Žiar nad Hronom	1326	14241
Banská Bystrica region	23267	249888

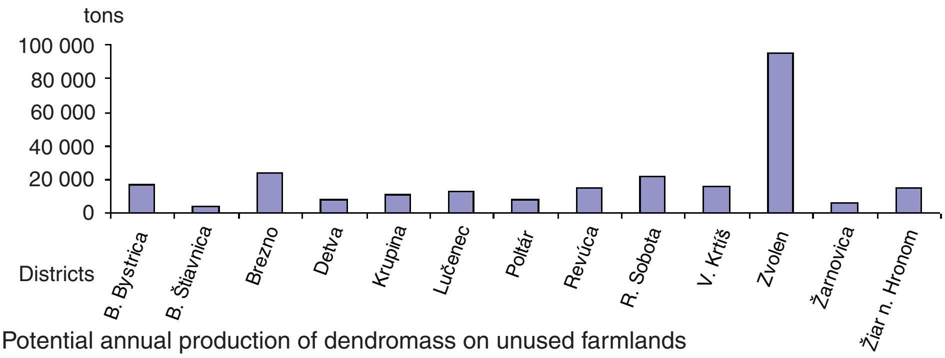

Figure 19. Potential annual production of dendromass on unused farmlands

4.5 Estimation of available wood residues from wood processing industries

The biggest wood processing companies of the region, Kronospan Zvolen and Smrečina Banská Bystrica, use residues from primary wood processing for their own production of wood-based panels and for energy. They even buy additional wood residues from other enterprises. Residues from wood processing are thus available from other smaller wood processing facilities.

Our survey covered 90 sawmilling facilities. Facilities processing less than 500 m³ were omitted because of their instable and irregular operation. While a part of the wood residues was used at the place of origin, only the remaining part was considered available for energy generation. The results of quantification are provided in Table 15.

The mean lumber yield in sawmill varies from 60 to 62 %. As to the structure of wood residues, larger particles represent 65% and sawdust 35%. When the raw lumber is further processed in sawmill, the proportion of the secondary source of energy dendromass may reach 70 % of initial roundwood volumes.

Table 15. Annually available secondary energy dendromass from wood processing

District	Annually processedroundwood m³	Available dendromasstn cuttings	sawdust	together
Banská Bystrica	62100	11348	5458	16806
Banská Štiavnica	24500	6790	3550	10340
Brezno	256000	46440	25030	71470
Detva	22500	4860	1700	6560
Krupina	36000	9460	5090	14550
Lučenec	102000	18730	10080	28810
Poltár	6000	1400	750	2150
Revúca	56600	11920	6250	18170
Rimavská Sobota	92800	21300	11440	32740
Veľký Krtíš	94000	29530	14820	44350
Zvolen	12500	3020	1590	4610
Žarnovica	15100	3010	1620	4630
Žiar nad Hronom	71200	12570	5800	18370
Banská Bystrica region	851300	180378	93178	273556

5 Most appropriate technologies for harvesting, transport and handling of energy dendromass

Final calculation of the production and delivery costs for energy biomass was carried out using the input data listed in Chapter 3.5. Pursuant to the application of technical limiting factors, according to which all above ground dendromass was considered available in forest compartments with slope inclination less than 40 %, only 35 % of it on slopes from 40 to 50 %, and no dendromass on slopes over 50%, the total available dendromass resource was reduced from original 302,400 m³ to 228,307 m³. Of this figure, 169,992 m³ comes from final felling, 31,200 m³ from thinning of stands less than 50 years, and 27,115 m³ from thinning of stands over 50 years.

The costs of felling and handling of wood in forest stand were derived as an average for conventional moto-manual felling using chainsaws at three regional state forest enterprises. Summarised data according to the felling type and tree species are present in Table 16.

Table 16. Cutting cost of tree parts according to logging type and tree species

	Deciduous tree, SKK/m³	Conifer, SKK/m³
Thinning < 50 year	333	332
Thinning > 50 year	249	257
Final felling	114	128

The costs of extraction were calculated for the use of forwarders. The use of forwarders for extraction has several advantages over the conventional skidding of trees or crown sections by skidders or tractors with winches:

- Extraction of shortened crown sections reduces damage to the remaining standing trees as compared to the whole-tree or whole-log skidding.
- Forwarder is capable to lay crown sections into high stacks, without a demand on larger landing area.
- When stacked, crown sections of trees do not crossover as it happens during their edging by skidder's blade. It increases the productivity of subsequent loading (or chipping at the landing).
- Wood is not fouled by mud with small rock particles and other undesirable ballast.

The input assumptions for calculation of extraction costs were as follows:

- mean forwarding distance 450 m,
- mean load size of 5.2 m³ in the interim and 6.8 m³ in final felling,
- mean biomass accumulation of 10 m³/ha in the interim and 63 m³/ha in final felling,
- productive hourly costs of a forwarder for interim felling 1,497 SKK (see Picture 3 for such a forwarder) and of a forwarder for final felling 1,759 SKK (see Picture 4 for a heavy forwarder)
- mean speed of a forwarder including driving during loading and loaded and unloaded driving was reduced by a correction factor according to the results of Brunbergs (2004) for sites with inclination 10 – 40%, and using an expert estimate for slope inclinations 40 – 50%. Correction factors are listed in Table 17.

Table 17. Driving speed factors in different slope categories

Slope category	0 – 10 %	10 – 20 %	20 – 30 %	30 – 40 %	40 – 50 %
Driving speed factor	1.00	1.11	1.35	1.79	2.78

The costs of extraction in SKK/m³ result thus from combination of forwarding productivity models, forest site variables, operating hourly costs of machines, and correction factors for forwarding speed. Table 18 provides forwarding costs in thinnings and final fellings according to the site slope classes.

Picture 3. Small thinning forwarder Timberjack 810 B. Photograph Juha Laitila.

Picture 4. Medium size forwarder (Ponsse Bison) for final fellings. Photograph Antti Ala-Fossi.

Table 18. Forwarding cost, SKK/m³, in thinnings and final fellings in different slope categories

Slope category	0 – 10 %	10 – 20 %	20 – 30 %	30 – 40 %	40 – 50 %
Final felling	223 SKK/m³	237 SKK/m³	268 SKK/m³	324 SKK/m³	451 SKK/m³
Thinning	378 SKK/m³	398 SKK/m³	442 SKK/m³	522 SKK/m³	703 SKK/m³

Transport by high-capacity chip trucks with volume of 64 m³ (Picture 5) or by trucks equipped with special hydraulic pressing system for uncomminuted dendromass (Picture 6), was considered. Transport costs of chips and uncomminuted dendromass to different transport distances with the use of data quoted in methodology in the chapter 3.5 are present in Table 19.

Picture 5. Chip truck at the terminal. Loading by the wheel loader. Photograph Juha Laitila.

Picture 6. Truck-and-trailer unit for transporting uncomminuted biomass. Photograph Ján Ilavský.

Table 19. Transporting cost of chips and loose material according to the transporting distance, SKK/m³

Distance to Zvolen km	Transportation cost of chips, SKK/m³	Transportation cost of loose material, SKK/m³
10	117.0	232.7
20	157.0	291.5
30	196.0	350.3
40	236.8	409.1
50	276.8	467.9
60	316.7	526.7
70	356.6	585.5
80	396.6	644.3
90	436.5	703.1
100	476.4	761.9
110	516.4	820.7
120	556.3	879.5
130	596.2	938.3
140	636.2	997.1

The costs of chipping at roadside landing by a truck-mounted chipper (Picture 7), which purchase price is approx. 15,000,000 SKK, are estimated to 212.40 SKK/m³, and chipping at the supplier's terminal or in CHP plant to 144.80 SKK/m³. Costs of chipping at the terminal of a supplier are lower thanks to the higher chipper use efficiency.

Picture 7. Chipping at roadside landing by a truck-mounted chipper. Photograph Juha Laitila.

The costs of handling of woodchips at the terminal of supplier and their transport to the heating plant were calculated to 122.70 SKK/m³. The costs of chipping by means of different technological processes are present in Table 20.

Table 20. Chipping costs when using different chipping systems

	Chipping at landing	Chipping at terminal	Chipping at plant
Cost, SKK/m³	212.40	144.80 + 122.70 = 267.50	144.80

6 Overall evaluation of resources, logistics and economics of the use of wood for energy generation in Zvolenská Teplárenska a.s.

Total expected costs of production and transport of energy dendromass were evaluated for 9 different basic production technologies. In the basic division, the expected costs of energy dendromass were calculated for final felling, interim felling below 50 years and above 50 years. The three basic schemes were further subdivided according to the place of chipping to the chipping at the roadside landing, suppliers' terminal and central chipping at the CHP plant. For partial operations, the costs derived in the previous chapter were used. Figure 20 provides total costs for individual production technologies and also according to partial operations. The summary costs refer to average conditions with forwarding in forest stands with mean slope grade 20 to 30 % and mean transport distance 40 km.

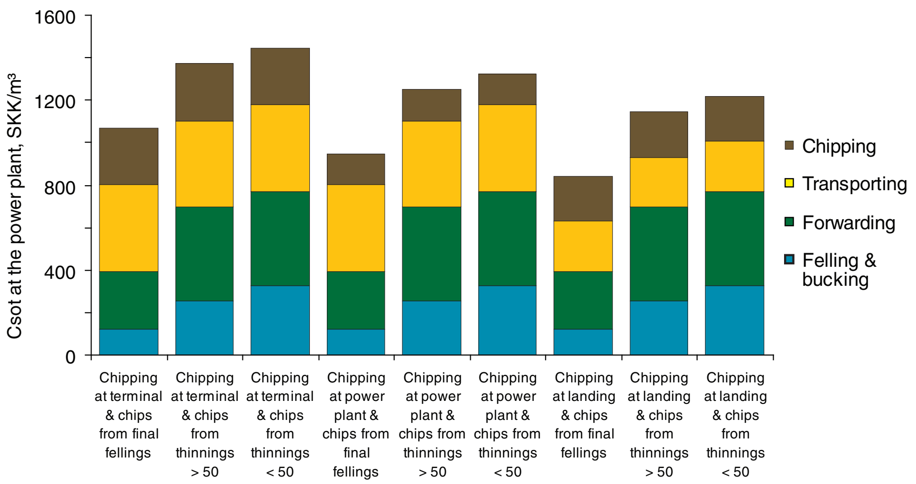

Figure 20. Cost structure of forest chips at the plant.

The lowest costs are when chips are produced from harvesting residues from final fellings, chipped at the roadside landing and directly transported to the customer. Production costs for chips originating from thinnings are by 50 – 60 % higher due to the increased felling and forwarding costs. The biggest difference between the schemes considered is in the cost of transportation. The lowest ones are when chips are transported. Although the costs of chipping are lower if it is done at the suppliers' terminal or centrally at the CHP plant, this saving does not compensate for obviously higher transportation costs due to lower volumetric weights of transported uncomminuted dendromass, lower usage of the carrying capacity of trucks, and subsequently higher transport cost per transported weight unit. The cost of chipping at the terminal is also increased by the cost of additional handling of uncomminuted dendromass and chips.

Table 21 and Figure 21 provide information about production costs, including the costs of partial operations from final felling in stands with slope inclination 20 – 30 % to the delivery of woodchips to the CHP plant, taking different technological schemes and transportation distances into the account. The figures prove the lowest total production costs in the case of chipping at the roadside landing, followed by the transport to the customer. Presented data also demonstrate how the differences in costs boost with increasing transportation distance.

Table 21. Costs of chips production and transport by different chipping methods and transport distances

Distance to CHP km	Chipping at terminal SKK/m³	Cipping at CHP SKK/m³	Chipping at landing SKK/m³
10	892.2	770	721
20	951.0	828	761
30	1009.8	887	801
40	1068.6	946	841
50	1127.4	1005	881
60	1186.2	1064	921
70	1245.0	1123	961
80	1303.8	1181	1001
90	1362.6	1240	1040
100	1421.4	1299	1080
110	1480.2	1358	1120
120	1539.0	1417	1160
130	1597.8	1475	1200
140	1656.6	1534	1240

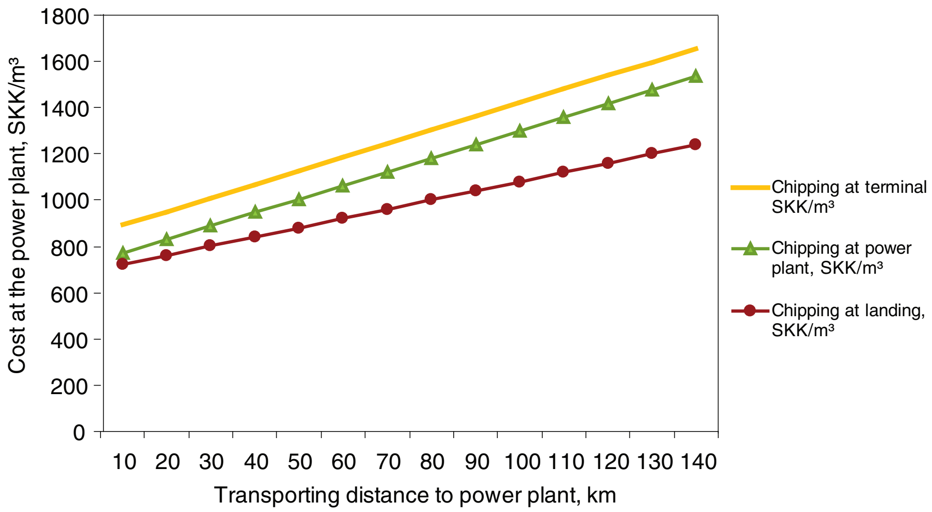

Figure 21. Cost of forest chips from final felling according to the transporting distance and chipping method

Production costs were estimated also in regard to varying annual volumes demanded by the customer. Again, the sources of dendromass for production of chips were subdivided into the final felling and interim felling for stand ages below and above 50-years. With the increasing annual volume, mean transportation distance increases. In addition, it requires harvesting of dendromass also in forest compartments with higher expected costs, e.g. from steeper slopes, and also thinning of younger stands. Figure 22 illustrates woodchip production and transport costs for various production technologies at increasing yearly supplied volumes. The production costs increase due to more expensive transport of bigger dendromass volumes on longer distances. When the maximum annually consumed volume of dendromass was 40,000 m³ and chipping was done at roadside landing, the production cost of chips was 784 SKK/m³ (Figure 22). It has to be noted, however, that this cost includes only direct production costs, excluding the price of wood and organizing costs of the procurement activities. It is obvious that the presented figure must not be identified with the real price of chips.

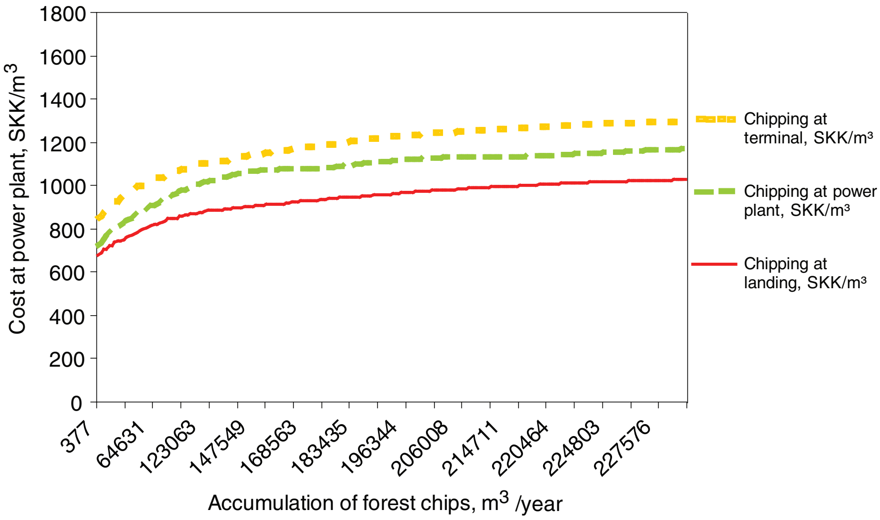

Figure 22. Production and transport costs o chips in relation to the availability of chips

Table 22 shows the total costs of woodchips production and transport to the Zvolen CHP Plant with the step of 15,000 m³ up to the whole region's technically available volume of energy dendromass 228,307 m³. Total expected costs were calculated separately for the dendromass originating in the final felling, thinning of stands below and thinning of stands above 50 years. Up to the volume of 100,000 m³, only dendromass from final fellings was taken into consideration, due to significantly lower harvesting costs. Above this volume, a part of the available dendromass from intermediate fellings in younger stands close to the heating plant was considered in order to maintain the total costs at the same level – because of the increased cost to the dendromass from final felling due to longer transportation distances. This approach allows even reduction of mean costs per cubic meter of delivered dendromass when the required volume ranges from 130,000 to 170,000 m³. When all available dendromass from final felling is utilised at about 170,000 m³, only sources from thinnings will become available. Their use shall raise mean production costs considerably, however, what has to be taken into the account in relation to a more intensive use of the region's available dendromass. Mean total production costs at different volumes of delivered dendromass are described on Figure 23.

Table 22. Chips production costs according to the felling type and required annual accumulation by the volume classes of 15,000 m³.

Cost, SKK/m³	Final felling, m³	Thinning < 50, m³	Thinning > 50, m³	Total, m³
737.3	15102			15000
766.4	31596			30000
783.9	43095			45000
801.8	56918			60000
822.8	75035			75000
839.0	89361			90000
857.0	106505		63	105000
869.4	118261		442	120000
886.7	133458	72	1383	135000
903.9	146226	488	2969	150000
922.3	156569	2798	5082	165000
942.4	164820	6434	8511	180000
964.1	168343	13249	13462	195000
989.1	169931	21338	19425	210000
1018.2	169992	29382	25946	225000
1026.1	169992	31200	27115	228306

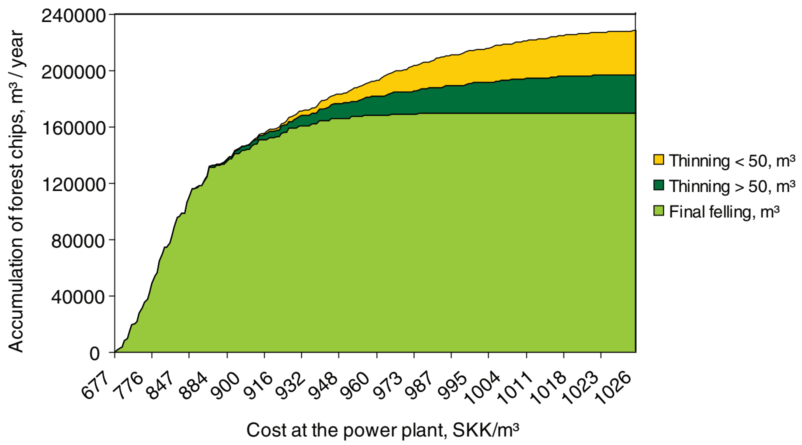

Figure 23. The average production cost and accumulation of forest chips types, when the harvesting method is based on chipping at roadside landing.

7 Prices and economics of the use of wood for energy generation

Information about the prices of energy wood at the local market was adopted from the statistics of the Institute of Forest Resources and Information of the National Forest Centre. Mean prices of conventional fuelwood and energy chips, subdivided into the conifers and broadleaves as well as for state forests and private forest holdings, are listed in Table 23. As the use of pulpwood for energy generation is also discussed sometimes, although it would influence the availability of wood for industrial processing, the reference prices of pulpwood are also provided.

Table 23. Mean prices of fuelwood, forest woodchips and pulpwood at the local market

Wood prices SKK/m³	State Forests	Year 2005 Non-state holdings	State Forests	1st half 2006 Non-state holdings
Coniferous fuelwood	378	420	490	408
Broadleaved fuelwood	714	729	841	960
Coniferous chips	380	323	-	267
Broadleaved chips	1.070	419	-	280
Coniferous pulpwood	756	809	778	957
Broadleaved pulpwood	992	1.014	1.067	1.127

Prices of woodchips from the non-state sector have been excluded from further comparisons because the statistical data available do not correspond to real prices. It is most likely due to an erroneous record, where the loose cubic meter was referred to instead of the solid cubic meter equivalent of wood, which volume is approx. 2.5 times bigger. The real market price of broadleaved wood chips was approx. 1,070 SKK/m³ in the reference period. The present data indicate remarkable increase of the fuelwood prices, which follows the general growth of the prices of other energies. While we assume that the price of woodchips follows the price of fuelwood, which is their most common raw material, its further increasing is to be expected. Finally, with regard to additional costs of chipping and hauling, the expected complete prices of energy woodchips shall be by 300 – 400 SKK/m³ higher than the price of fuelwood.

The comparison of the prices of fuelwood and pulpwood appears to be quite interesting particularly in the case of broadleaves. Their difference was only 150-200 SKK/m³. Under a stable market demand in the energy dendromass, simpler and thus cheaper production may attract the interest of producers towards chipping of whole crown sections and younger trees instead of currently prevailing separation of pulpwood and firewood.

It is quite important to relate the price of energy wood to its energy value and thus the price of energy contained in a purchased fuel. The energy value of wood of 12 GJ/t and 1,000 kg/m³ – as a mean value for heavy hardwoods in a dry state according to the Slovak Technical Norm 48 0010 – was used in further comparisons. Taking the price of hardwood chips 1,070 SKK/t, the resulting energy unit price is 89.20 SKK/GJ. Also this calculation demonstrates competitive advantage of the use of wood for energy generation. In addition, its use is accompanied by invaluable environmental benefits when compared to the fossile fuels.

8 Prices and economics of other fuels

Records of the prices of energy generated from other types of fuel were adopted from the web sites of their producers or retailers. Collected prices of brown coal, natural gas and electricity were compared on the common price-unit basis SKK/GJ subsequently.

The below information is adopted from the internet site of the Upper Nitra Mines Inc. (Hornonitrianske bane Prievidza, a.s.) http://www.hbp.sk/produkty/rdtab.html.

Table 24: Costs of household heating based on retail prices of different fuel types.

Type of fuel –energy carrier	Period	Unit	Unit price SKK	Heating capacity GJ/unit	Energy price including fixed fees SKK/GJ
Brown Coal - Graded Lump Coal BH	Year 2005– from 01. 10	t	2.935	17	215.81
	Year 2006	t	3.013	17	221.54
Natural Gas	Year 2005 – from 01. 10	1000 m³	12.660	33.84	437.40
	Year 2006	1000 m³	14.559	33.84	502.99
Electricity	Year 2005 – from 01. 10.	MWh	1.607	3.6	596.39
	Year 2006	MWh	1.687	3.6	626.17

For brown coal, our calculation refers to the mean final retail price of the most common size-graded “Lump Coal” produced by Baňa Handlová in the reference period January – May 2003 with the forecasted price growth of 5 % per annum.

Its current retail price, including VAT and transport to the distance of 15 km, is some 4,241 SKK/t (www.paskosice.sk), however. When converted to an energy unit at the calculated thermal efficiency of a burner 80%, the price is 311.84 SKK/GJ. This comparison of two calculation approaches is to point out uncertainty of forecasting of the fuel prices for the next years. It also has to demonstrate that the price of wood fuel is expected to follow other fuels, although regular market conditions for the wood fuel are only being formed. It needs to be noted that present calculations refer to the fuel price component of the final energy price. The differences in the investment and operation costs associated with different fuel types have not been included in them, but they are important pre-determinants of the price of energy wood with regard to the production and use efficiency for both its producers and users.

The aforementioned calculations are valid for retail customers. Zvolenská teplárenská a.s., as a big purchaser, benefits of the wholesale market prices, however. In the case of unsorted brown coal, its real reference price was 115 SKK/GJ excluding VAT, at thermal value 13 GJ/t. The price of natural gas was 12.30 SKK/m³ excluding VAT, what equals to 363.50 SKK/GJ for the period of elaboration of the present study.

For reference and estimation of possible development of domestic fuel and energy prices in Slovakia, prices of different energy sources in Finland are provided.

For the wholesale purchaser – producers of energies – the early 2006 prices (VAT excluded) of fuels were as follows:

Table 25. Prices of reference fuels in 2006.

In energy production (VAT 0%):	€/MWh	€/GJ	SKK/GJ
Heavy fuel oil[1]	31.15	8.65	326
Natural gas[1]	19.41	5.39	203
Energy peat[1]	8.05	2.24	84
Coal[1]	14.26	3.96	149
Wood chips[1]	10.51	2.92	110
For households (VAT included):	**c/kWh**	**€/GJ**	**SKK/GJ**
Electricity[1]	7.90	21.94	828
Light fuel oil[1]	6.10	16.94	639
District heat[1]	4.93	13.70	517
Pellets[4]	3.80	10.56	398
Chopped firewood[3]	3.70	10.28	388
Wood chips[2]	1.26	3.50	132

Sources:

[1] Slioor, S. 2006. Statistics. Kauppa- ja teollisuusministeriö. Energy review. 1/2006. pp 30-51.

[2] Electrowatt-Ekono. 2006. Polttoaineiden hintatilasto - Elokuu 2006. Bioenergia 4/2006. p. 48. (In Finnish)

[3] MottiNetti. 2006. [http://www.mottinetti.fi]. Kymppivoima Oy. [Cited 9. Nov. 2006].

[4] Anonymous price information 9. Nov. 2006. Source: Reseller Agri-Market

Extension:1 MWh = 3.6 GJ; 1 € = 37.71 SKK

9 Conclusions and recommendations

The aim of the study was to evaluate potential resources and evaluate technical and economical availability of the energy dendromass from forests in the gravitational area of the Zvolen CHP Plant, which boilers are being converted towards co-firing of wood and brown coal. It also aimed at identification of the most suited technologies of dendromass harvesting, processing and transport, analysis of logistic aspects of its supplies, and assessment of expected production costs. The expected annual consumption of energy wood in the CHP plant will be approximately 30,000 tons.

The gravitation area subject to the assessment included the Banská Bystrica region. The total forest biomass resource contained in the planned annual felling (conventional fuelwood plus larger-dimension residues of harvesting) and the secondary resource generated in the course of wood harvesting (branches, treetops, whole smaller trees), represent more than 1.2 mill. m³ per year in the area. Pursuant to the application of limiting factors of ecological, economic and operational nature, the total annual volume of available energy dendromass was reduced to 302,000 m³. When also technological factors constraining the use of most appropriate technologies of energy dendromass production and transport to the power plant were implied, net annual volume of the available dendromass has been somewhat less than 230,000 m³, i.e. not more than 25 % of the total dendromass resource of the region. This fact is important in relation to frequent discussion whether a drain of a whole aboveground dendromass can impede overall production capacity of Slovakian forests.

More detailed localisation of available dendromass resources by means of the geographical information system proved that the desired volume of dendromass is available within the transportation distance of 50 kilometres from the CHP plant. The lowest production costs have been proved for the use of harvesting residues originating from final felling.

As to the applied technologies for dendromass production, our analyses are based on the data for machine sets verified in the long-term practice in Finland, adjusted for the local conditions of Slovakia. The following technological scheme is recommended as the most appropriate:

- harvesting and bucking by chainsaw,
- extraction of wood by forwarders,
- chipping of wood by mobile truck-mounted chippers at the roadside landing,
- direct transport of woodchips to the customer

Transport of uncomminuted dendromass to the CHP plant is not recommended for technological and economic reasons. The transport costs of uncomminuted wood are quite high due to lower utilisation of the carrying capacity of trucks and also due to the need to use special hydraulic compression systems. Better capacity utilisation of a mobile chipper at the plant’s yard does not compensate for higher transport costs of uncomminuted dendromass. Because of a relatively small volume of energy wood to be used, creation of a stationary crushing or chipping facility at the CHP plant is not recommended for economic reasons.

Due to seasonally oscillating demand for energy wood (high winter and low summer extremes), it is important to secure demanded volumes of woodchips without a need of their longer storage, which may cause degradation of their energy value. In regard to the thermal efficiency, it is not desirable to deliver fresh cut dendromass directly to the CHP plant as well. Countries where energy wood is used in larger volumes (including Finland), resolve it by means of an interim, several-month-lasting storage of uncomminuted dendromass at roadside landing.

Such a mid-term storage of uncut crown sections, branches, treetops, as well as whole trees from thinning in younger stands requires rather large storage areas, however. It is particularly in cases, when winch-equipped skidding tractors are used. Forwarders appear to be much better option from this point of view. In addition to reduction of required storage area by high stacking, they prevent surface dragging and accompanying it fouling by mud containing undesirable rocky particles.

The economic analysis revealed, that the energy dendromass for the Zvolenská teplárenská, a.s., can be acquired at advantageous rates, and that final prices of energy wood proved to be fully competitive to the other fuel types.

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WWW:

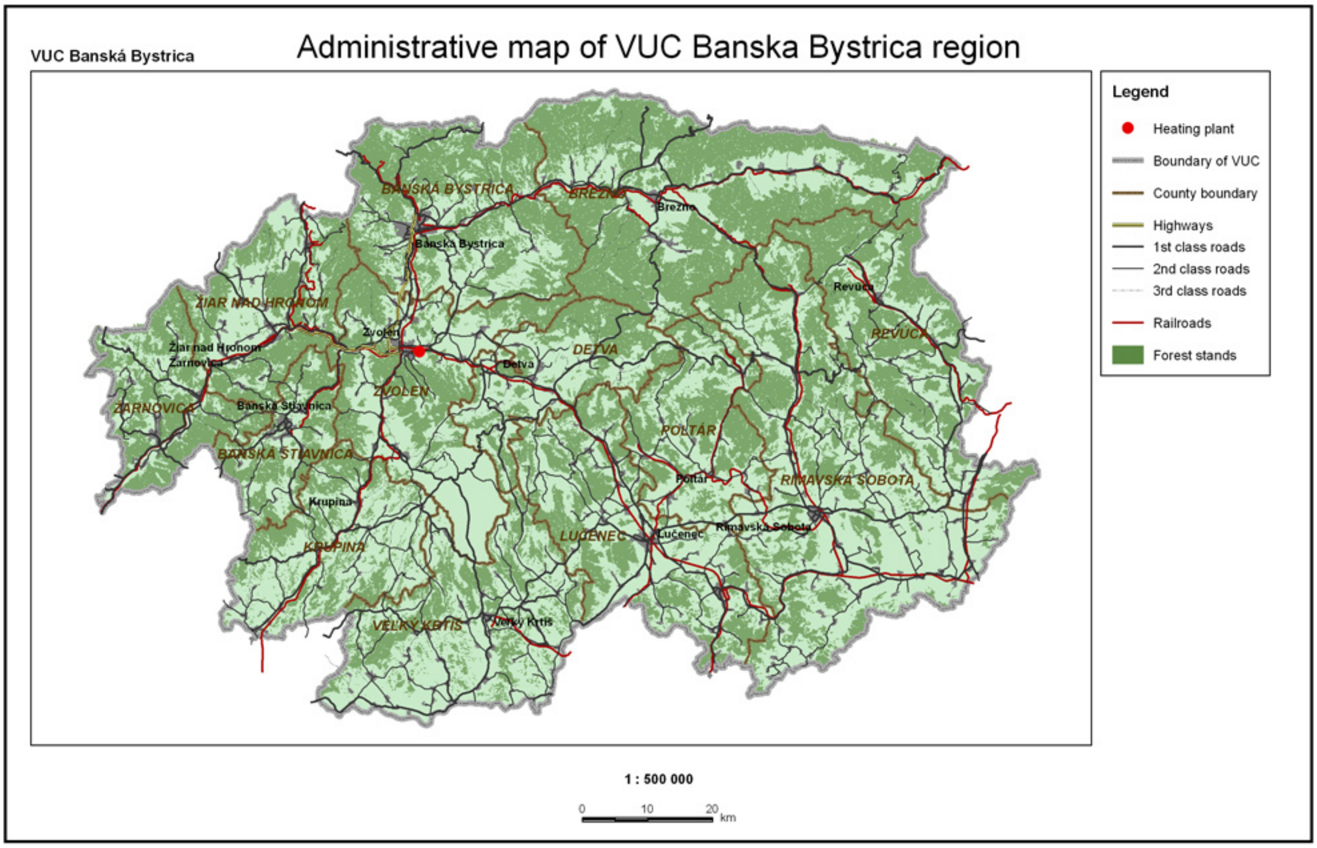
http://www.hbp.sk/produkty/rdtab.html , navštívená 19.9.2006

www.paskosice.sk, navštívená 19.9. 2006

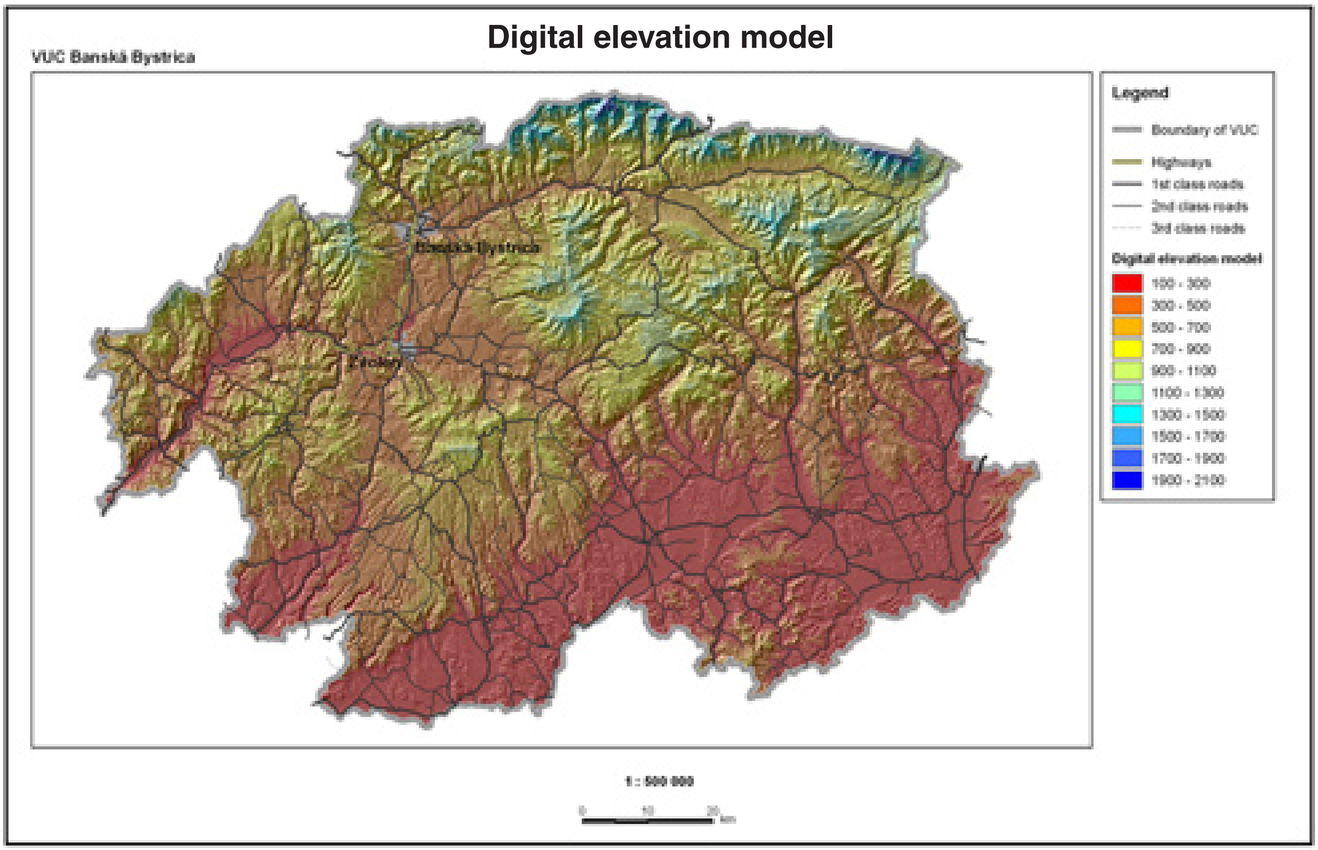
Motti Netti. www.mottinetti.fi

Attachments - List of maps

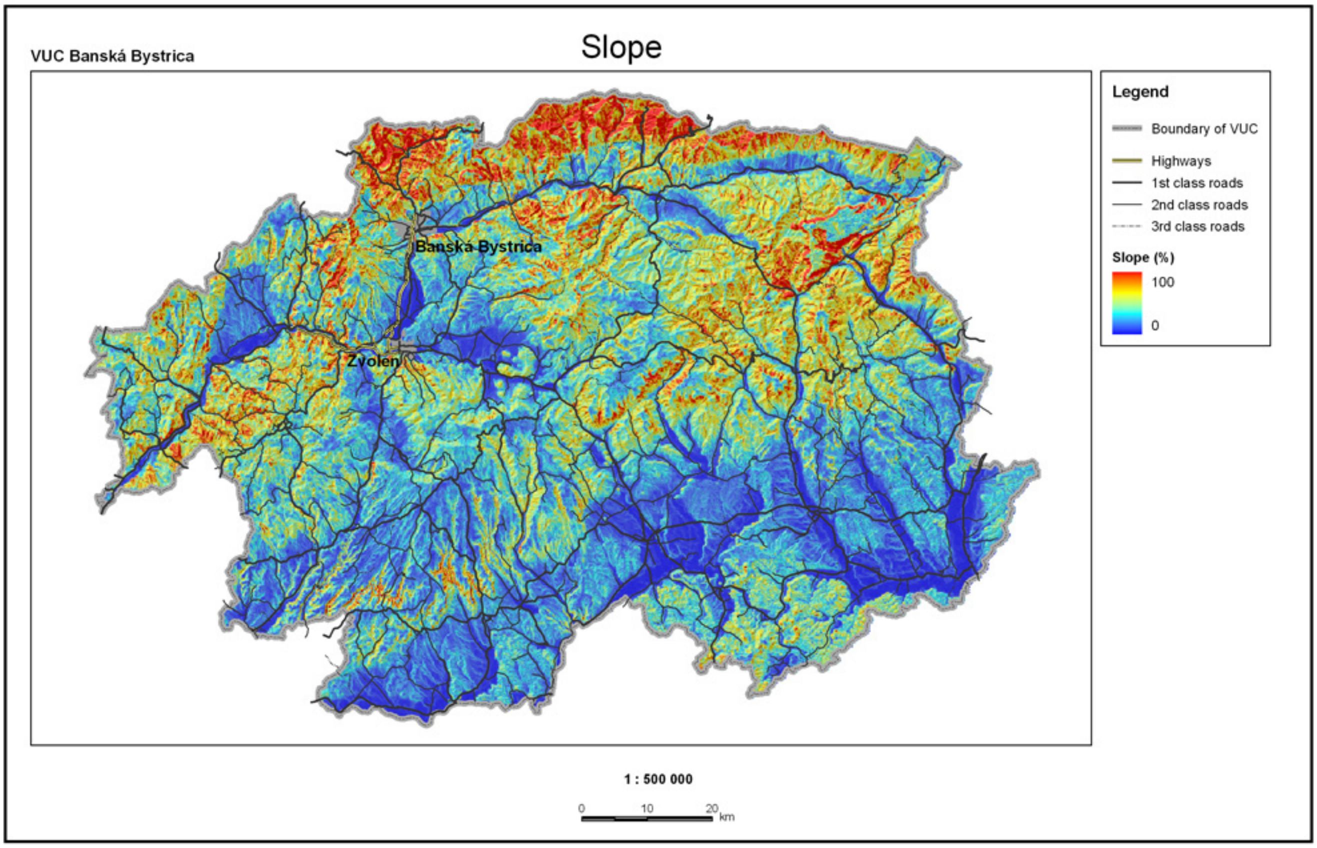
Map 1


VUC Banská Bystrica
Administrative map of VUC Banska Bystrica region
Legend
Heating plant
Boundary of VUC
County boundary
Highways
1st class roads
2nd class roads
3rd class roads
Railroads
Forest stands
BANSKA BYSTRICA
BREZNO
Brezno
Banska Bystrica
ZIAR NAD HRONOM
Zvolen
Revuca
REVUCA
DETVA
Detva
ZVOLEN
ZARNOVICA
Banska Stiavnica
BANSKA STIAVNICA
POLTAR
Poltar
RIMAVSKA SOBOTA
Rimavska Sobota
Krupina
KRUPINA
LUCENEC
Lučenec
VELKY KRTIS
Velky Krtis
1 : 500 000
0
10
20
km

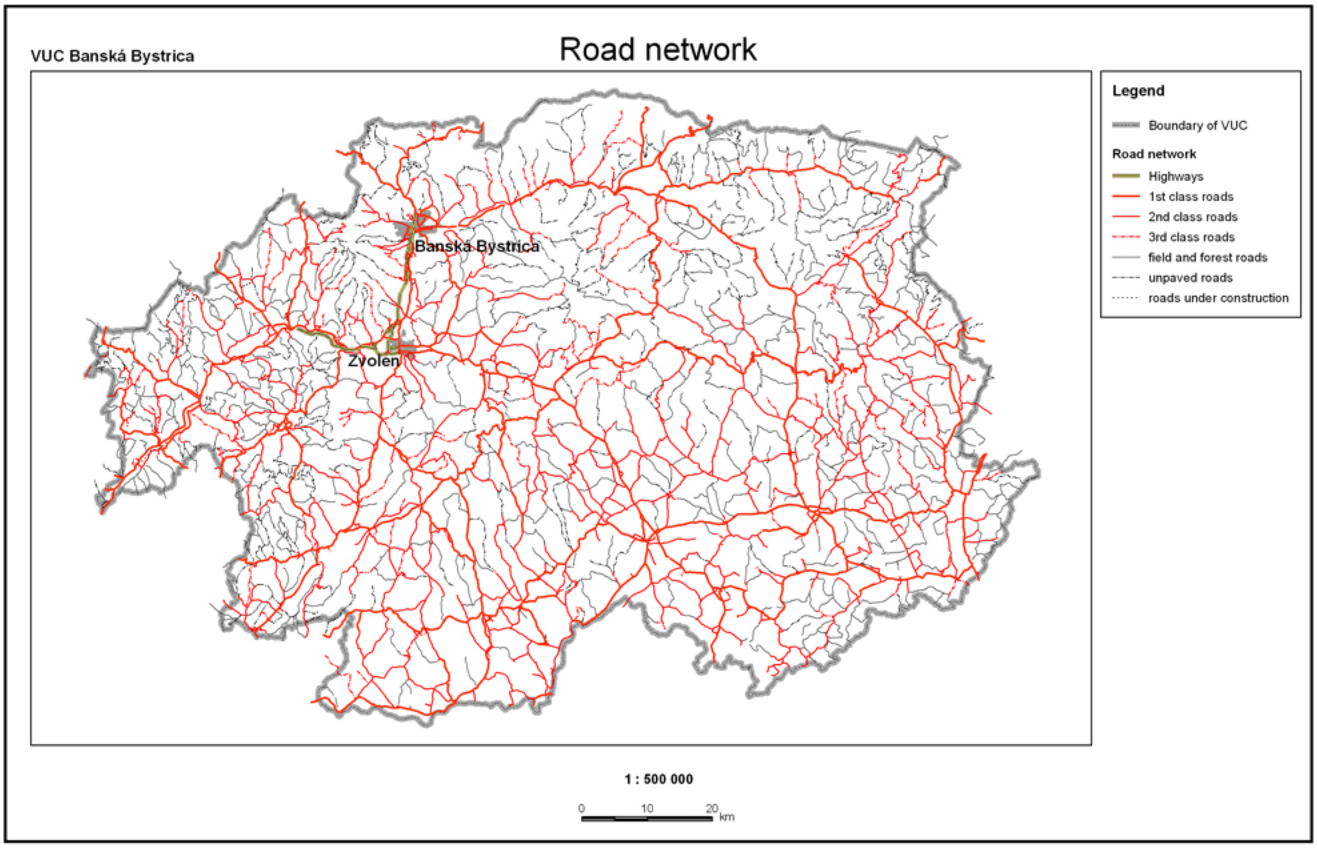
Map 2


VUC Banská Bystrica
Digital elevation model
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Digital elevation model
100 - 300
300 - 500
500 - 700
700 - 900
900 - 1100
1100 - 1300
1300 - 1500
1500 - 1700
1700 - 1900
1900 - 2100
Banská Bystrica
Zvolen
1 : 500 000
0
10
20
km

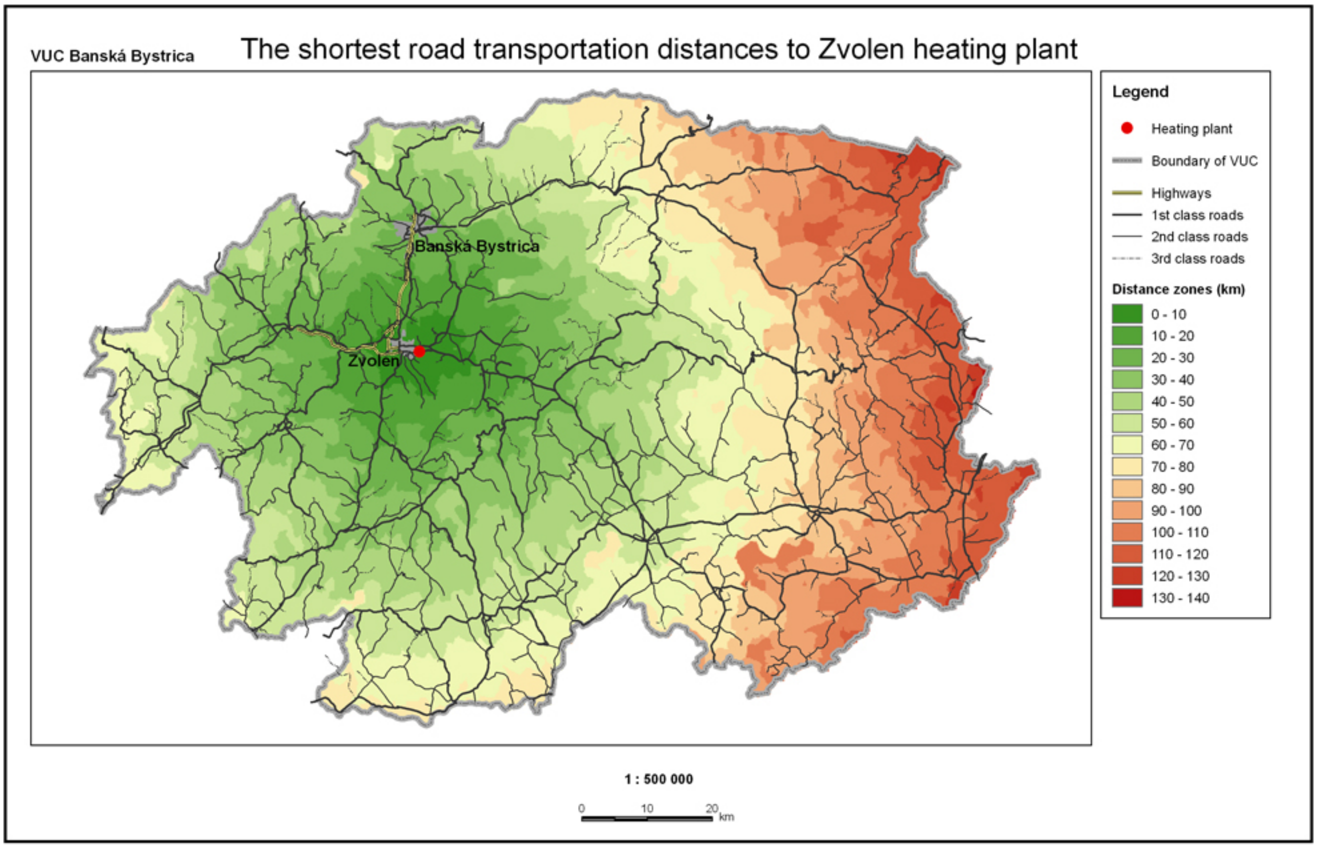
Map 3


VUC Banská Bystrica
Slope
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Slope (%)
100
0
1 : 500 000
0
10
20
km

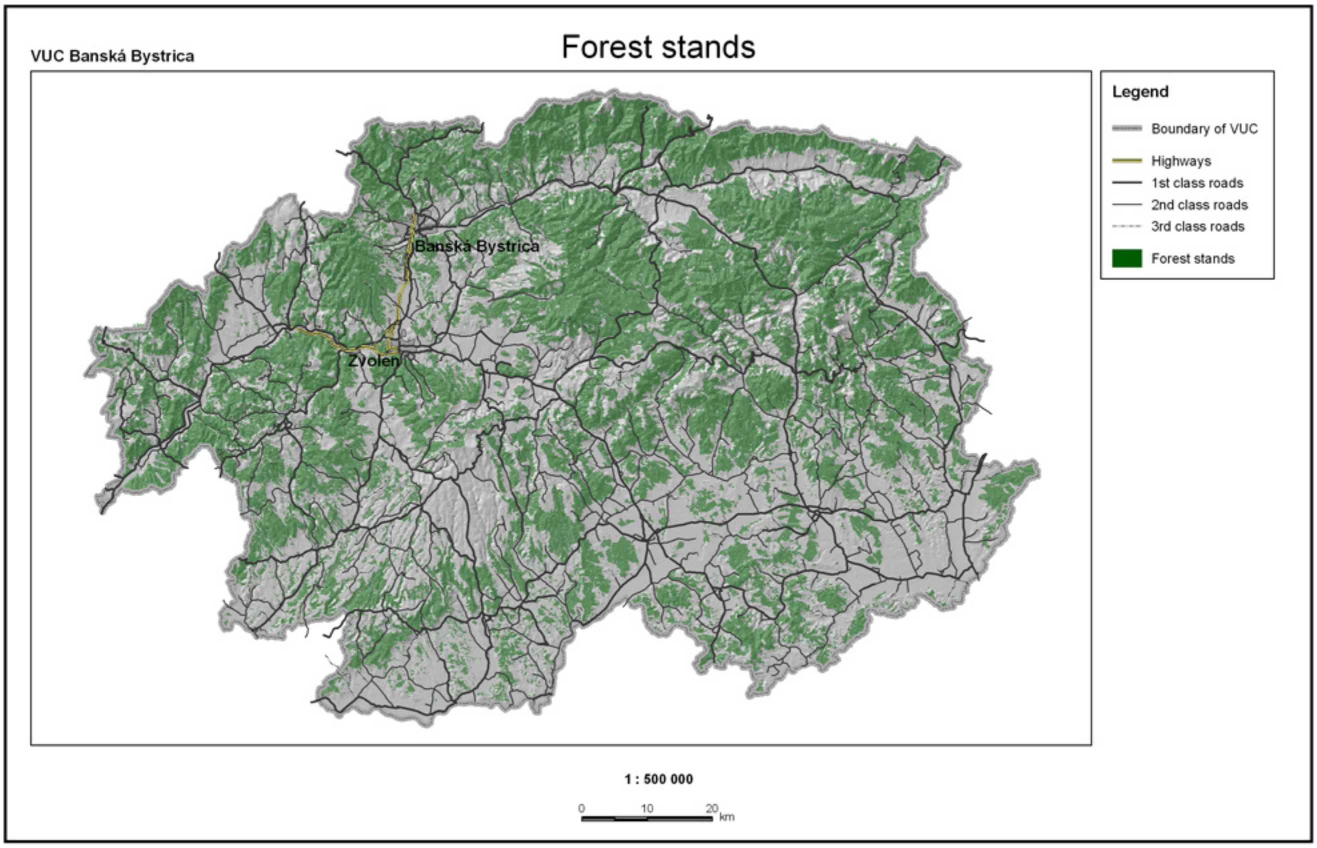
Map 4


VUC Banská Bystrica
Road network
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Road network
Highways
1st class roads
2nd class roads
3rd class roads
field and forest roads
unpaved roads
roads under construction
1 : 500 000
0
10
20
km

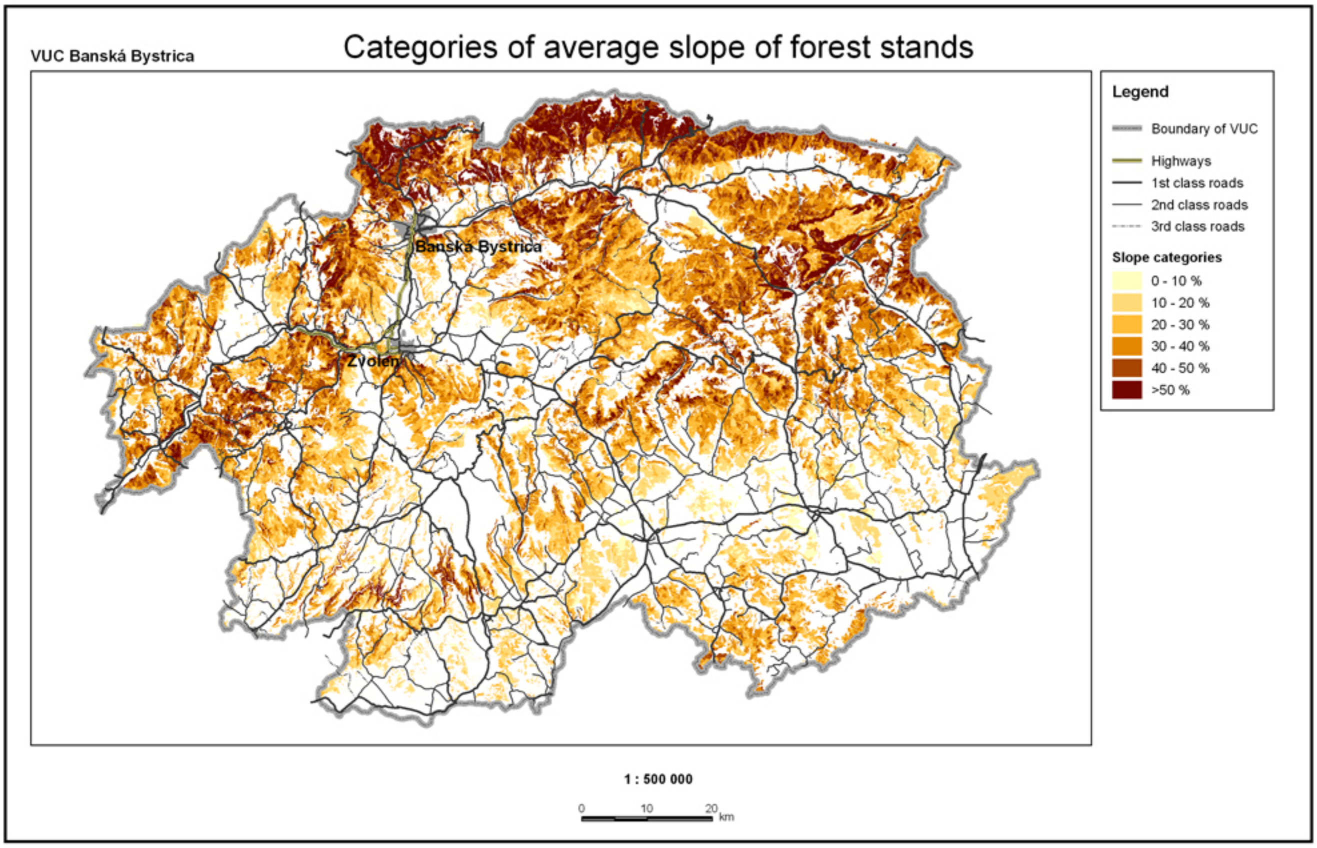
Map 5


VUC Banská Bystrica
The shortest road transportation distances to Zvolen heating plant
Banská Bystrica
Zvolen
Legend
Heating plant
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Distance zones (km)
0 - 10
10 - 20
20 - 30
30 - 40
40 - 50
50 - 60
60 - 70
70 - 80
80 - 90
90 - 100
100 - 110
110 - 120
120 - 130
130 - 140
1 : 500 000
0
10
20
km

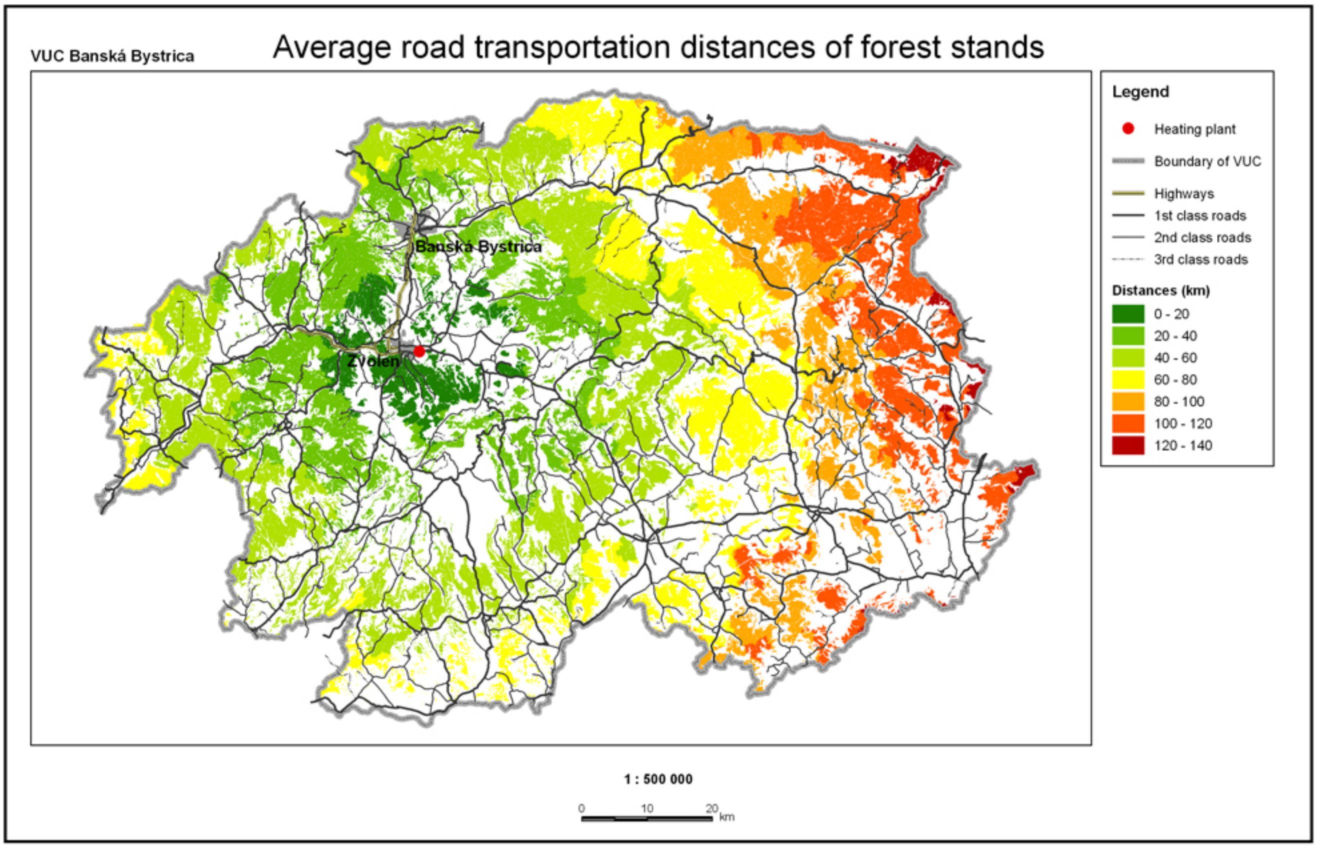
Map 6


VUC Banská Bystrica
Forest stands
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Forest stands
1 : 500 000
0
10
20
km

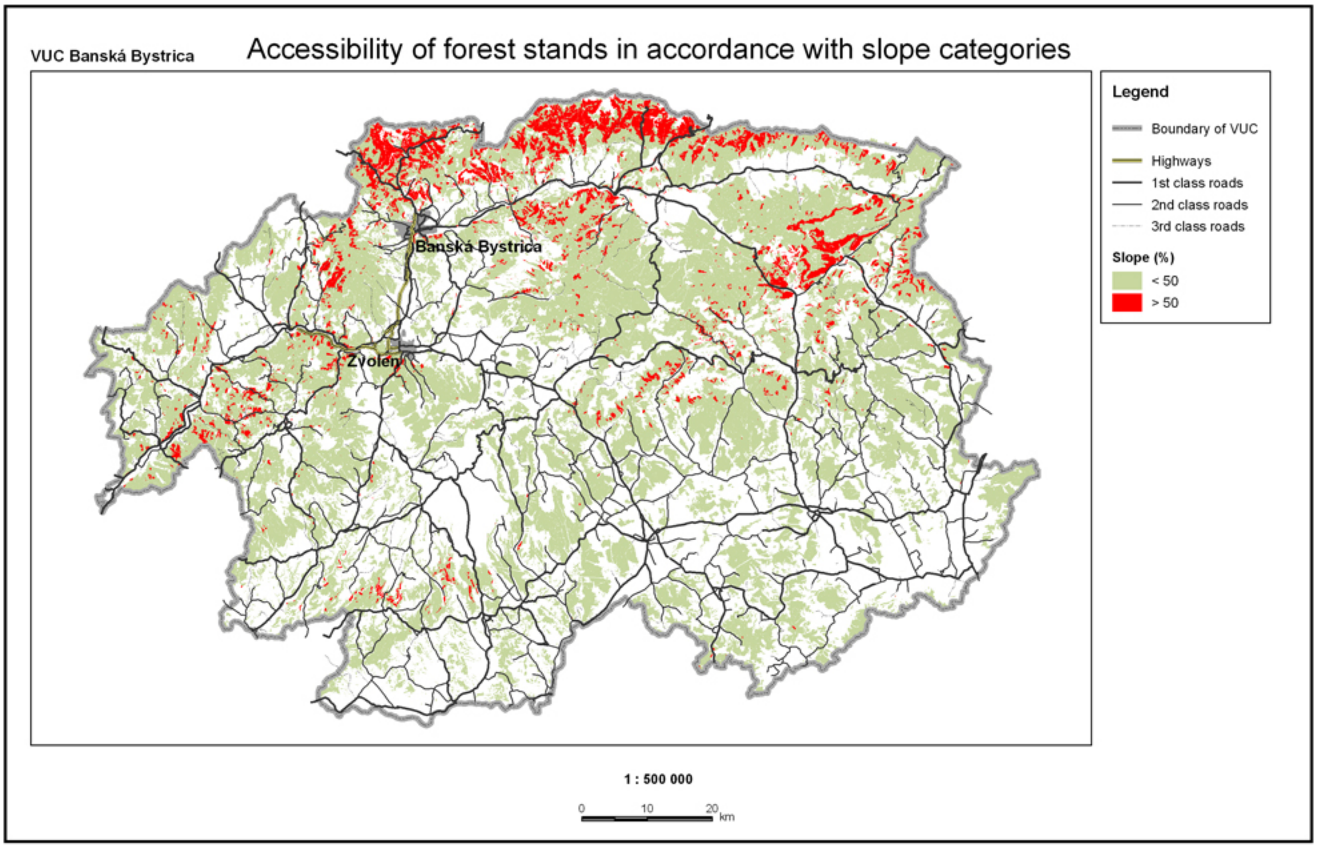
Map 7


VUC Banská Bystrica
Categories of average slope of forest stands
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Slope categories
0 - 10 %
10 - 20 %
20 - 30 %
30 - 40 %
40 - 50 %
>50 %
1 : 500 000
0 10 20 km

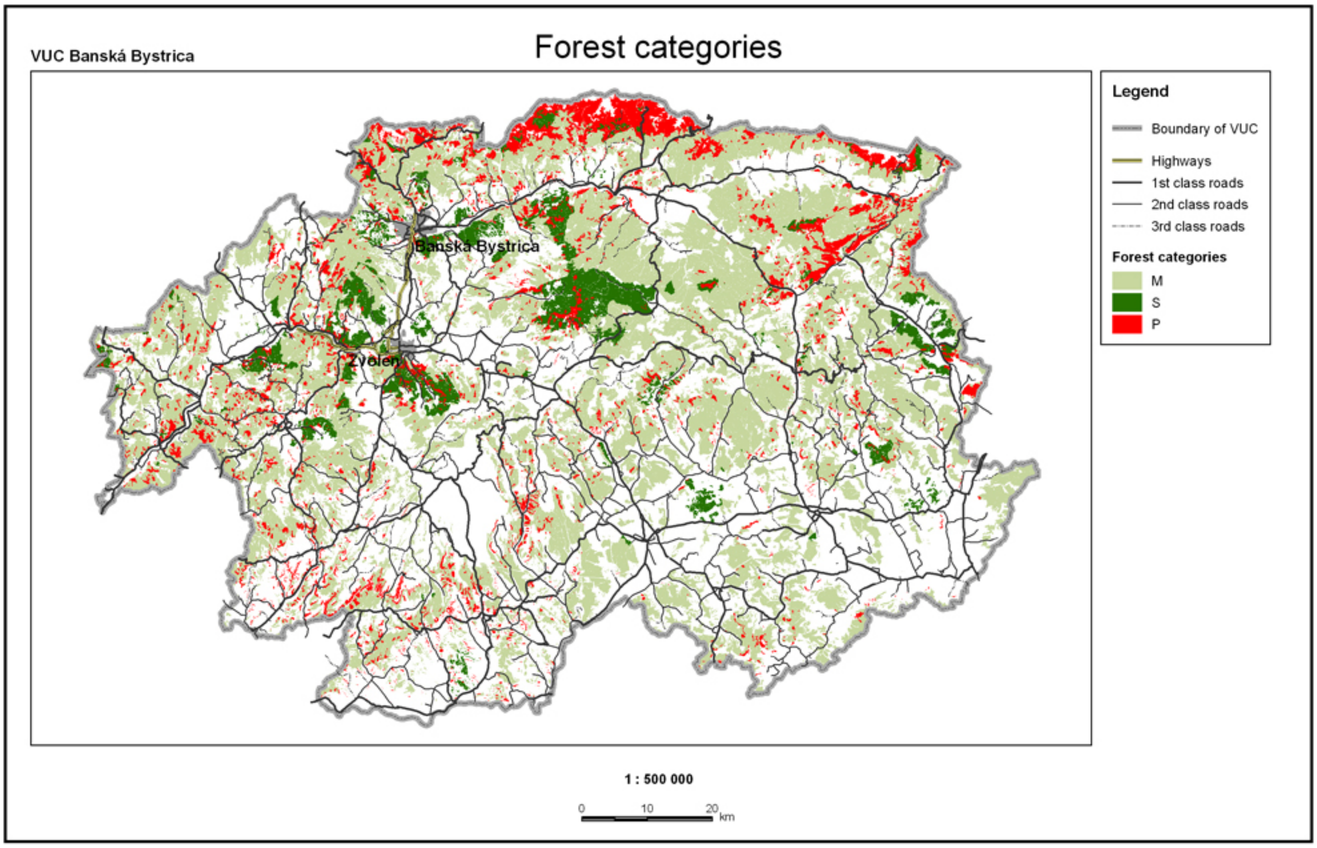
Map 8


VUC Banská Bystrica
Average road transportation distances of forest stands
Banská Bystrica
Zvolen
Legend
Heating plant
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Distances (km)
0 - 20
20 - 40
40 - 60
60 - 80
80 - 100
100 - 120
120 - 140
1 : 500 000
0 10 20 km

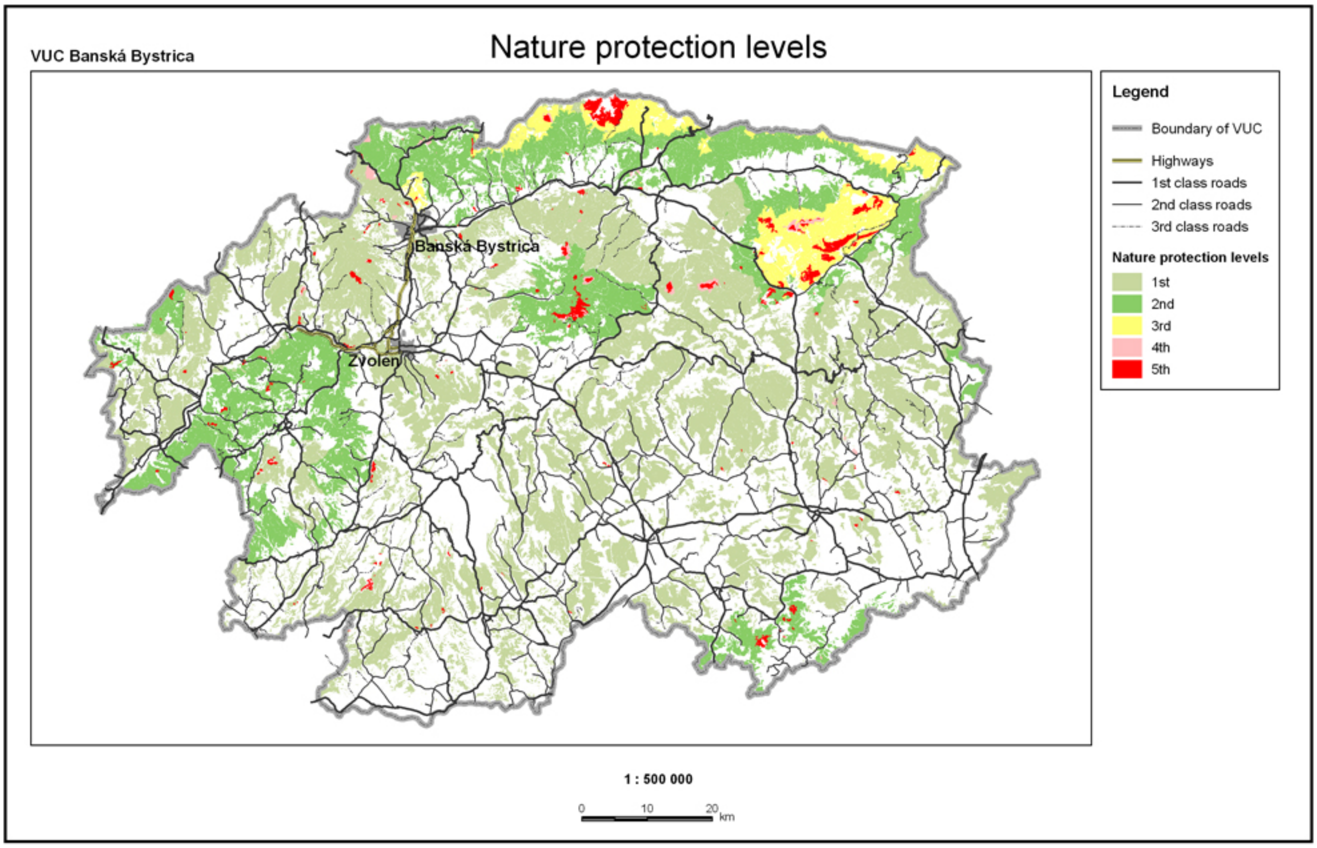
Map 9


VUC Banská Bystrica
Accessibility of forest stands in accordance with slope categories
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Slope (%)
< 50
> 50
1 : 500 000
0
10
20
km

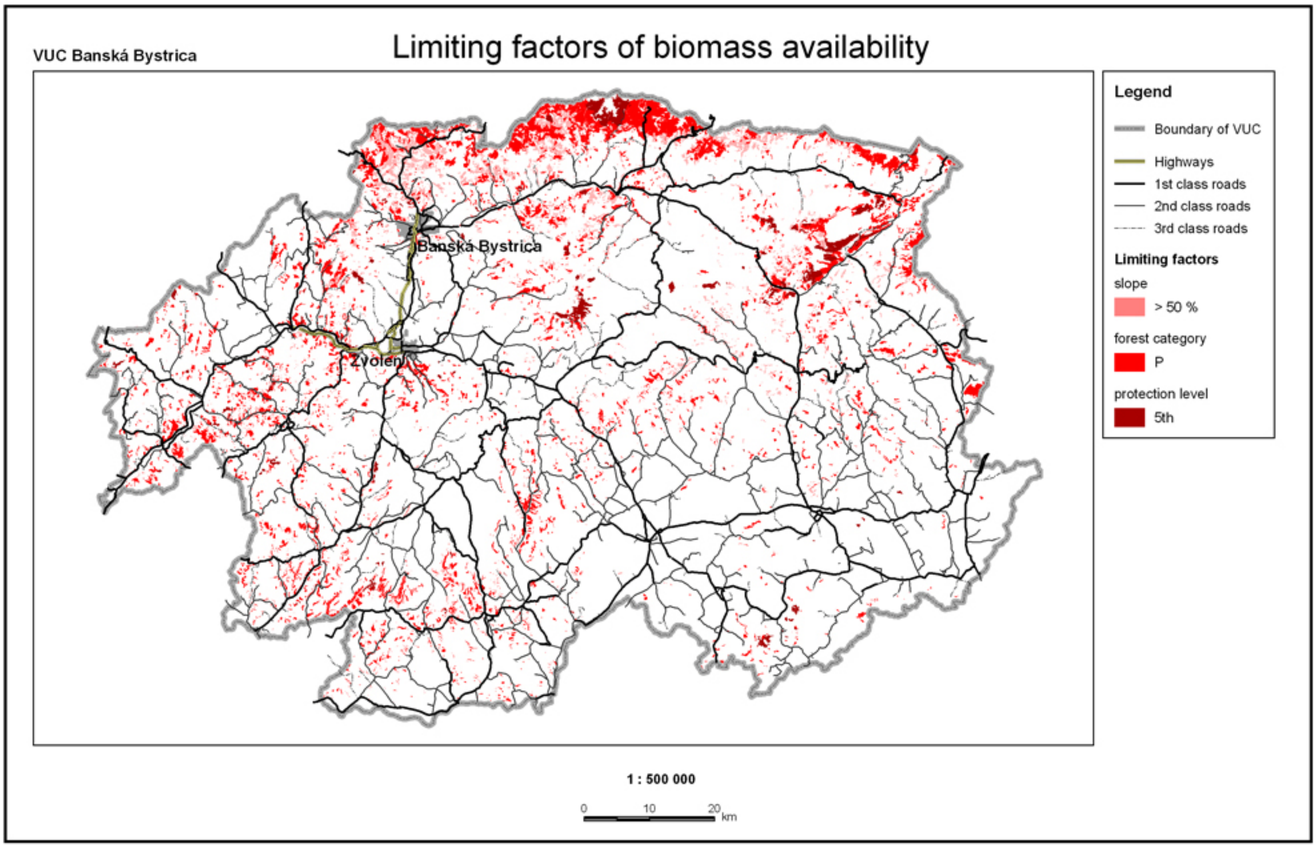
Map 10


VUC Banská Bystrica
Forest categories
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Forest categories
M
S
P
1 : 500 000
0
10
20
km

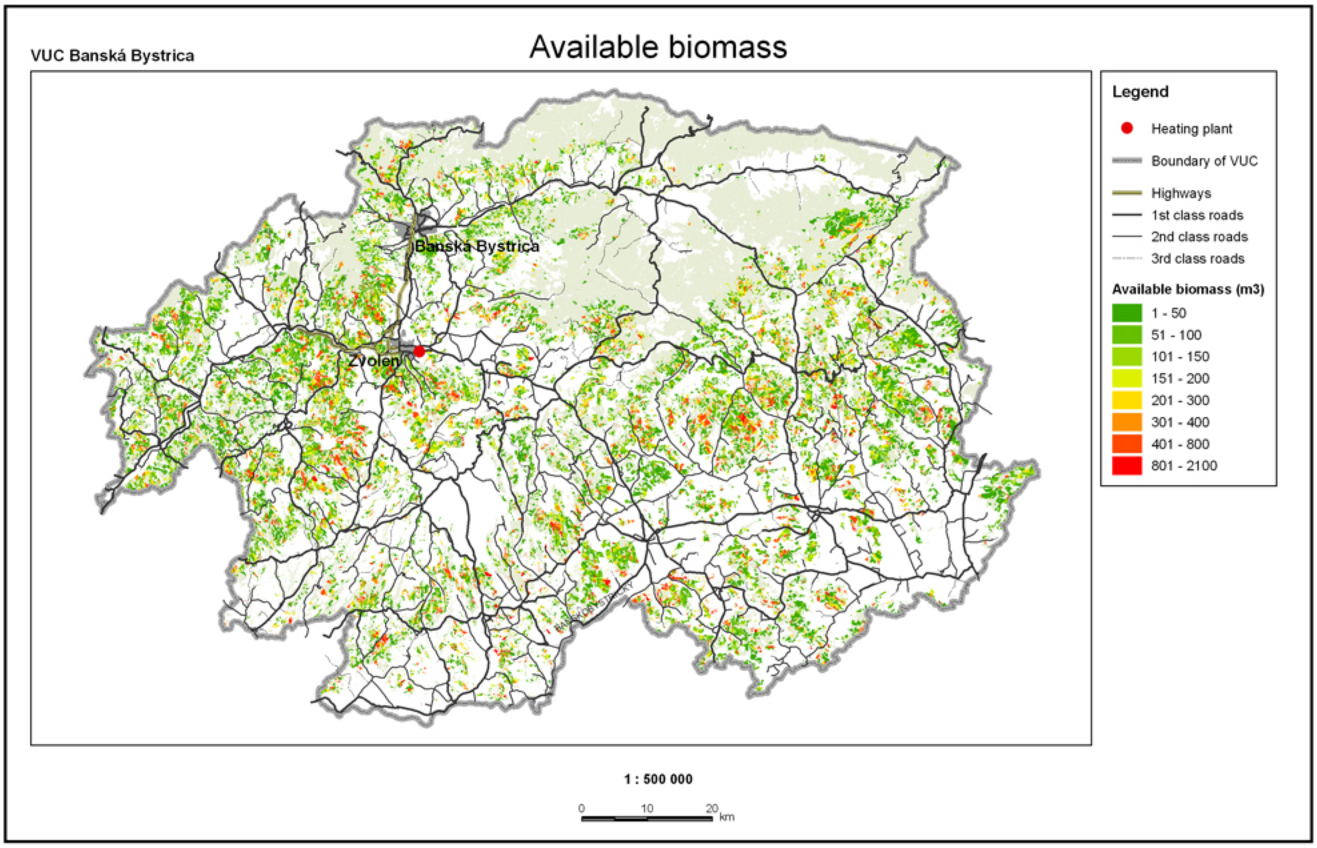
Map 11


VUC Banská Bystrica
Nature protection levels
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Nature protection levels
1st
2nd
3rd
4th
5th
1 : 500 000
0
10
20
km

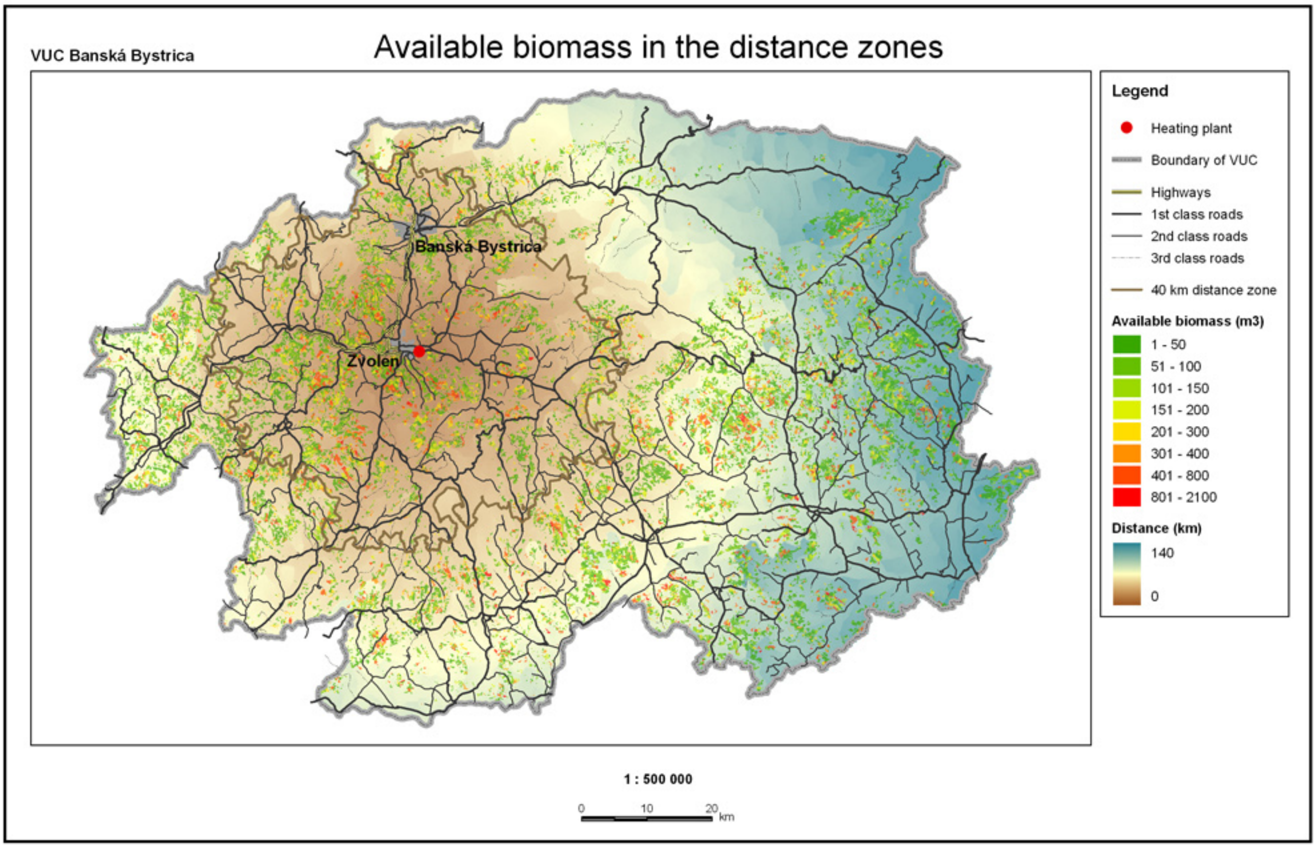
Map 12


VUC Banská Bystrica
Limiting factors of biomass availability
Banská Bystrica
Zvolen
Legend
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Limiting factors
slope
> 50 %
forest category
P
protection level
5th
1 : 500 000
0
10
20
km

Map 13


VUC Banská Bystrica
Available biomass
Banská Bystrica
Zvolen
Legend
Heating plant
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
Available biomass (m3)
1 - 50
51 - 100
101 - 150
151 - 200
201 - 300
301 - 400
401 - 800
801 - 2100
1 : 500 000
0
10
20
km

Map 14


VUC Banská Bystrica
Available biomass in the distance zones
Banská Bystrica
Zvolen
Legend
Heating plant
Boundary of VUC
Highways
1st class roads
2nd class roads
3rd class roads
40 km distance zone
Available biomass (m3)
1 - 50
51 - 100
101 - 150
151 - 200
201 - 300
301 - 400
401 - 800
801 - 2100
Distance (km)
140
0
1 : 500 000
0
10
20
km