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TRANSITION FRAMEWORK FOR NEGLECTED AND UNDERUTILIZED CROP SPECIES

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ABSTRACT

There are thousands of neglected and underutilized species (NUS) worldwide, but only a few make it to the mainstream and spotlight. The reason for that lies probably in the dynamics of the transition from a NUS to a major crop. However, there is no transition framework that specifically addresses NUS. To bridge the gap, this paper suggests a transition framework for NUS. This work was carried out within the project SUSTLIVES (Sustaining and improving local crop patrimony in Burkina Faso and Niger for better lives and ecosystems). It draws upon a search performed on the Web of Science in July 2022. The eligible articles were analysed using the Multi-Level Perspective (MLP) on socio-technical transitions and its three elements viz. niches, socio-technical regime and socio-technical landscape: Niches refer to NUS; the socio-technical regime relates to the incumbent, dominant system of major commercial staple crops, and includes factors hindering NUS integration; and the socio-technical landscape refers to policies and macro-trends affecting both the niche and the regime. The transition dynamics and success depend not only on the characteristics of the niche NUS (cf. strengths and weaknesses), regime and landscape, but also on the type, intensity and timing of interactions among them. The interaction of elements as well as transition speed are moderated by the levers of change that lie in the areas of policy, finance and market, technology and practices, culture, and science and innovation. Further work is needed to refine and test the framework in different contexts and on various NUS.

Keywords: *niche crop, NUS, orphan crop, sustainability transitions, Multi-Level Perspective.*

INTRODUCTION

Evidence shows that tens of thousands of crop species remain relatively underutilized (Chivenge et al., 2015). Indeed, whereas more than 7,000 crop species have been used for food throughout human history (FAO, 1998; Garn & Leonard, 2009), only about 150 species are currently cultivated commercially (FAO, 1995; Prescott-Allen & Prescott-Allen, 1990). Further, FAO (2010) estimates that more than half of the global dietary energy need is met by only four crops: rice, potatoes, wheat and maize. The vast majority of edible crops are referred to, inter alia, as neglected and underutilized species (NUS) or niche and orphan crops (Li & Siddique, 2018). In this respect, Padulosi et al. (2013) suggest that "*Neglected and underutilized species (NUS) are those to which little attention is paid or which are entirely ignored by agricultural researchers, plant breeders and policymakers*" (p. 5). NUS have been claimed to contribute to sustainable development as they hold the potential to address numerous challenges facing humanity. Indeed, their promotion has been reported to contribute to food and nutrition security (Padulosi et al., 2013; Ulian et al., 2020), agro-biodiversity conservation (Padulosi et al., 2013), climate change adaptation and mitigation (Mabhaudhi et al., 2019), environmental integrity and health (Mabhaudhi et al., 2019), human health (Tadele, 2018) and rural livelihoods sustainability and resilience (Kour et al., 2018; Padulosi et al., 2013). However, many challenges and constraints hinder the mainstreaming of NUS (El Bilali et al., 2023; Mabhaudhi et al., 2019). Padulosi et al. (2013) argue that "*Neglect by agronomic researchers and policy makers, genetic erosion, loss of local knowledge, marketing and climate change are major challenges to the sustainable use of NUS*" (p. 6). Meanwhile, according to Williams and Haq (2002), the constraints to NUS development include the limited availability of germplasm, lack of interest by actors in the food chain (e.g. farmers, researchers, extension agents), and lack of technical information and tailored national policies. To promote NUS, barriers against their mainstreaming and integration in the food system have to be identified and thoroughly analysed (Baldermann et al., 2016). Therefore, research, innovation and development are highly required to unlock the NUS potential (Mabhaudhi et al., 2017), especially in developing countries (Chivenge et al., 2015). Whereas the promotion of NUS should contribute to sustainable and resilient agri-food systems, there is no framework to guide and steer such an endeavour. To bridge the gap, this paper suggests a transition framework for NUS that is based on the Multi-Level Perspective on socio-technical transitions (MLP).

MATERIAL AND METHODS

This work was carried out within the project SUSTLIVES (Sustaining and improving local crop patrimony in Burkina Faso and Niger for better lives and ecosystems) whose aim is to promote the transition towards sustainable and climate-resilient agriculture and food systems in Burkina Faso and Niger through the development of local agro-biodiversity to ensure food security and improve the livelihoods of rural communities (SUSTLIVES, 2023).

The present article draws upon a search performed on the Clarivate Analytics - Web of Science (WoS) database in July 2022, using the following search string: *(transition OR transformation OR mainstream OR integration OR scaling OR change) AND (agriculture OR food) AND ("neglected and underutilised species" OR NUS OR "neglected species" OR "neglected and underutilized crop" OR "neglected crop" OR "abandoned crop" OR "abandoned species" OR "alternative crop" OR "alternative species" OR "local crop" OR "local species" OR "lost crop" OR "lost species" OR "minor crop" OR "minor species" OR "niche crop" OR "niche species" OR "orphan crop" OR "orphan species" OR "traditional crop" OR "traditional species" OR "underdeveloped crop" OR "underdeveloped species")*. The search returned 438 documents, but 403 documents were excluded following the screening of titles and abstracts as well as, when needed, the scrutiny of full-texts; 113 documents following the screening of records based on titles, 226 documents following the analysis of abstracts, 64 documents following the analysis of articles. Therefore, 35 articles were considered in the review.

The selected, eligible documents were analysed using the MLP framework (Geels, 2002; Geels & Kemp, 2012). While the first studies utilizing MLP focused on sustainability transitions in energy and mobility sectors, MLP is nowadays also widely applied in agriculture and food systems (El Bilali, 2019). The MLP suggests that transitions are the result of the interaction among three elements; niches, sociotechnical regime and sociotechnical landscape (Markard et al., 2012). These three elements or analytical levels have different degrees of structuration (Köhler et al., 2017). In the MLP, the socio-technical *regime* refers to the shared cognitive routines, rules and practices stabilising existing incumbent, dominant systems. Meanwhile, *niches* offer safe, protected spaces, apart from the regime rules, where innovations can develop (Smith et al., 2010). The socio-technical *landscape* is the exogenous environment that cannot be changed directly by the regime and niche actors. In the MLP framework, systemic change leading to sustainability transitions is a result of multi-level interactions; niche-innovations build up internal momentum, changes in the landscape create destabilising pressure on the regime, whose destabilisation creates windows of opportunity for niche innovations (Geels, 2011; Markard & Truffer, 2008). In MLP, transition is conceptualised as a change from a regime to another. MLP stresses the importance of the alignment of processes at all levels (niche, regime and landscape) for a transition to happen and be successful (Geels, 2011).

RESULTS AND DISCUSSION

Out of the thousands NUS worldwide, only a few manage to get to the mainstream and spotlight. The reason for that lies probably in the processes of transition from a NUS to a major crop. These, in turn, are affected by the characteristics of the elements of MLP (niche, regime, landscape). NUS are considered as niches. The socio-technical regime refers to the incumbent, dominant system of major commercial, staple crops; it includes factors that hinder the integration of NUS into

the food chain. The socio-technical landscape refers to policies and macro-trends that affect both the niche and the socio-technical regime.

As per the MLP, the proposed framework (Figure 1) assumes that a transition, so the development of niche NUS, emerges through complex and multi-level interactions between the different system components. It also admits that the different elements should align to enable a transition. The landscape, which cannot be easily changed by food system actors, can create opportunities for niche NUS but also exert pressure on the dominant system (cf. conventional agriculture relying on major crops) to change. For instance, climate change is pushing many farmers to look for alternative, climate-resilient crops. Although many niche NUS can be present in an area, they do not become mainstream as long as the dominant, major crops are strong, viable and fit-to-purpose. Moreover, the success of a niche NUS depends also on its viability, opportunities created by landscape as well as attitude of the dominant system/regime and its actors. Indeed, the dynamics as well as the success of transition depend not only on the features of the niche NUS, sociotechnical regime and sociotechnical landscape but also on the interactions and relationships among the three elements.

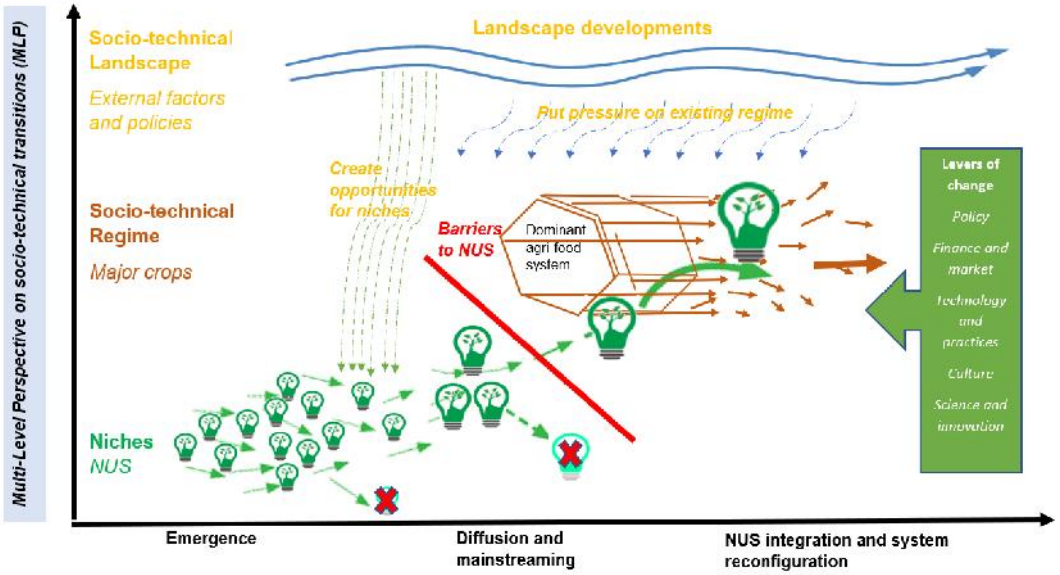

Figure 1. Transition framework for integrating NUS into agri-food systems.
Source: Authors.

Different features of the *niche* NUS determine not only their own potential but also their potential to compete with major commercial crops. These relate to the intrinsic strengths and weaknesses of NUS. The strengths of NUS include adaptability to grow in harsh environmental and climatic conditions as well as

marginal and nutrient-depleted soils/lands. Furthermore, many NUS adapt to cultivation systems with low inputs (cf. fertilisers, agrochemicals) as they are tolerant to biotic and abiotic stresses. Other strengths of NUS are their outstanding nutritional properties and benefits such as their high contents of proteins and health-promoting compounds (El Bilali et al., 2023). Bottlenecks to NUS use include planting material availability and knowledge about crops and their uses (McMullin et al., 2021). The weaknesses of NUS also relate, inter alia, to low yield and productivity, difficult access to quality seeds and propagation materials, difficult access to information by producers and value chain actors, and lack of adequate processing technologies (El Bilali et al., 2023).

The socio-technical *regime* affecting the niche NUS regards the constraints hindering NUS development, as well as the competitiveness of the major crops, which are already adapted to the regime rules and standards. In particular, the current agricultural knowledge and innovation system (AKIS), including research and development, is unfavourable for NUS (Mabhaudhi et al., 2017). This situation, in turn, determines a lack of interest in NUS from researchers. Hunter et al. (2019) argue that the key barriers to the mainstreaming of NUS are limited and fragmented data, limited capacity, low recognition of NUS values and disabling agriculture and food policies. Meanwhile, Matthews and Ghanem (2021) suggest that different perception gaps hinder NUS development. However, whereas NUS have generally low yields compared to major crops, the production and productivity are rapidly increasing and value chains and markets are improving over time (Bachewe et al., 2019), which can make them not only more appealing for value chains' actors but also more competitive compared to commercial crops. This, in turn, may speed up their integration into the local food systems and diets.

The elements of the sociotechnical *landscape* relevant to the transition of NUS are macro-level trends and processes (societal, economic, cultural and environmental) and policies that put pressure on the current agri-food system, and consequently major commercial crops, thus creating, eventually, opportunities for the niche NUS. It is clear that the multiple challenges faced by the current food system (e.g. biodiversity loss, climate change, natural resources depletion/degradation, food insecurity and malnutrition) call for its urgent transformation. The critique of the dominant agri-food system touches upon its constituting elements such as major commercial and staple crops (Rojas et al., 2009). This, in turn, creates opportunities for NUS (El Bilali et al., 2023). Indeed, nowadays, there is a wider recognition of the potential of NUS in biodiversity conservation, climate resilience and adaptation, food and nutrition security and rural livelihoods. Moreover, ongoing changes in socio-cultural preferences and perceptions favour NUS use and consumption. There is a growing demand for NUS for healthier, more diversified and more balanced diets. Interestingly, the growth in income and urbanization seem to have a positive impact on NUS consumption. The development of NUS processing, which widens the range of NUS-based products available on the market, as well as the opportunities offered by information and communication technologies for NUS promotion contribute to this positive trend. Moreover, many

policies – especially those aiming to conserve and promote biodiversity, protect natural resources and adapt to climate change in agriculture and food systems contribute to the mainstreaming and enhancement of NUS.

The grouping of the proposed actions to enhance the integration of NUS into food systems under *levers of change* was informed by the proposal made in the context of the Food Systems Summit organized by the United Nations in New York in September 2021 (FAO, 2020) as well as the conceptualization of the socio-technical system and regime in MLP (Geels, 2004). Accordingly, the following levers of change have been identified: policy, finance and market, technology and practices, culture, science and innovation (Table 1). The lack of resources for research, innovation and development on NUS is a main barrier to their development and enhancement (Hermann et al., 2013) so it comes as no surprise that a recurring recommendation is the development of research programmes on NUS to substantiate and provide evidence on their relevant attributes (Hunter et al., 2019). Such a research program should be inclusive and based on participatory approaches to allow the involvement of all concerned actors and stakeholders. Moreover, multi-disciplinary research on NUS calls for transforming traditional agronomic research (Rudebjer et al., 2013). Research is a prerequisite for the promotion and enhancement of the NUS, but there is also a need for further complementary actions such as development of NUS value chains. In this respect, Mabhaudhi et al. (2017) suggest a roadmap that includes the development of human capital/capacity, market and policy. Hermann et al. (2013) call for addressing the supply and demand constraints affecting the production and consumption of NUS. The regional strategy on "Crops for the future" in the Pacific (Taylor et al., 2011) contains actions relating to the generation and collection of knowledge and research, communication and dissemination, market development, partnerships, policy advocacy, capacity building and institutional strengthening. Meanwhile, the framework for the enhancement of NUS introduced by Padulosi et al. (2013) encompasses NUS and associated indigenous knowledge conservation, participatory selection of cultivars and quality seeds production, enhanced cultivation practices and value addition technologies development, nutritional content assessment, marketing, value chains strengthening and NUS popularization, and capacity building. Amelework et al. (2021) suggest training of farmers and producers, development of suitable business models, creating market and diversifying products, investing in processing enterprises and enhancing awareness among consumers. Furthermore, enabling policies have an important role to play in the promotion and enhancement of NUS (Notaro et al., 2017).

Table 1. Examples of proposed actions, related to the various levers of change, to mainstream NUS in agri-food systems.

Levers of change	Recommended actions - Examples	Sources
Culture	Training farmers, producers and value chain actors	Amelework et al. (2021)
Finance and market	Developing suitable business models and value chains for priority NUS	Amelework et al. (2021); Hegde (2009); Mabhaudhi et al. (2017)
Finance and market Technology and practices	Promoting NUS through improved packaging and marketing	Masao et al. (2022)
Policy	Creating a more supportive policy environment for NUS in agriculture, food and trade fields	Hermann et al. (2013); McMullin et al. (2021); Notaro et al. (2017)
Science and innovation	Screening diverse genotypes for bioactive compounds to aid breeding efforts directed at biofortification	Aditika et al. (2022)

It should be pointed out that in real-life context it is often not a question of clear-cut and distinct transition from one crop to another; rather, it is a long-term dynamic process in which rural households and farmers combine different crops to meet their various needs and/or to adapt to the changing contexts and environments (natural as well a market and socioeconomic ones). This may imply the inclusion of a new niche NUS in their crops portfolio and the new crop might become over time the most important one in terms of production and, consequently, income generation.

CONCLUSIONS

This paper suggests an integrated analytical framework for understanding the transitions of NUS. It also sheds light on the role of NUS in the transition towards sustainable and resilient agri-food systems. The Multi-Level Perspective (MLP) is used to structure the analysis and specify the analytical categories (niche, regime, landscape, levers of change). One of the obvious advantages of the proposed framework is that it allows using rich and multifaceted literature on sustainability transitions in the analysis of the integration of NUS into food systems.

The dynamics, and success of the transition, depend not only on the features and characteristics of the three elements (cf. niche NUS, sociotechnical regime and sociotechnical landscape) but also on their interactions and relationships. Different features of the niche NUS (cf. intrinsic strengths and weaknesses) determine not only their potential but also whether they can stand the rules of the dominant system and compete with the major commercial crops. The characteristics of the sociotechnical regime affecting transition dynamics regard the constraints it creates and the competitiveness of the major commercial crops. Macro-level trends and processes in the sociotechnical landscape and policies put pressure on the current

agri-food system thus creating windows of opportunities for the niche NUS. The lack of research, due to the current AKIS, is a main barrier to the development and enhancement of NUS. However, the development of research is not enough for the promotion of the integration of NUS into agri-food systems and should be complemented by actions aimed at the development of the supply chains of NUS, from production to consumption through processing and distribution. Indeed, the levers of change for triggering transitions lie in the areas of policy, finance and market, technology and practices, culture, science and innovation.

Further work is needed to refine and test the suggested transition framework on different NUS and in different contexts and settings, especially in developing countries of the Global South. The developed framework can guide and make more effective, efficient and sustainable endeavours and undertakings aiming at the promotion of NUS with consequent environmental, social and economic benefits at household, local and national levels. Indeed, the promotion of NUS can trigger the transition of agri-food systems toward more resilience and sustainability.

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