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FOOD SYSTEMS AT RISK

NEW TRENDS AND CHALLENGES

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CHAPTER 3.2

RISKS OF IRREVERSIBLE BIODIVERSITY LOSS

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SUMMARY

Biodiversity is the driving force of ecosystem services and has been the foundation of agriculture for many, many years. The drastic evolution of agriculture over the past century in industrialised and some developing countries, based on improved varieties and synthetic inputs, greatly increased production but has led to the artificialisation of agroecosystems and great losses of specific and genetic diversity. In turn, these losses have hampered food systems in different ways: degraded ecosystem services affecting crop yields and resilience, reduced crop biodiversity, and highly specialised industrialised food processing, which has decreased the diversity of the food supply and its nutritional value.

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Biodiversity as a foundation for food systems

Biodiversity encompasses all "living organisms from all sources and the ecological complexes of which they are part, including diversity within species, between species and of ecosystems" (United Nations, 1992). It is the driving force of ecosystems and at the origin of many goods and services and, indeed, of human existence and well-being. However, biodiversity is facing major challenges: most human activities make use of biodiversity and, simultaneously, threaten its integrity directly or indirectly, for example through anthropogenic climate change.

Food systems represent a very large part of human activity, responding to very basic human needs and mobilising biodiversity at all stages. Primary food production depends on ecosystem functions and services on 40 percent of emerged land. Food processing uses many services provided by biodiversity, such as fermentation, and consumers, through their intestinal microbiotas, process food into well-being and health.

At the same time, food systems are putting real pressure on biodiversity through several drivers and pathways, the main one being the conversion of natural ecosystems to agriculture. These interactions between food systems and biodiversity, with multiple feedback loops, generate risks that might be severely aggravated by the way food systems operate and evolve. Some authors estimate that agriculture represents one of the major threats to biodiversity through land-use and ecosystem artificialisation at three embedded and interacting scales: ecosystemic, specific and genetic diversity (FAO, 2019).

How does industrialisation of food systems affect biodiversity?

For years, agriculture has comprised of harnessing biodiversity, domesticating and combining plants, animals and microbes in a very wide range of agricultural systems on all continents and shaping agricultural landscapes. Innovation was mainly rooted in biodiversity at different scales. At the beginning of the twentieth century, agriculture in the northern hemisphere went into a process where production was based on selected varieties, synthetic fertilisers and pesticides, in addition to mass mechanisation heavily reliant on fossil fuels. It has led to industrialised agriculture and food systems, and resulted in the artificialisation of agricultural fields; biodiversity is reduced to a uniform and synchronous canopy, usually consisting of a single genotype of some major species, with the rest of the living organisms being systematically eliminated as 'limiting factors'.

This transformation has affected not only most of the agricultural land in developed countries, but also some sections of agriculture in Low-Income (LI) and Lower Middle-Income (LMI) countries, the Green Revolution being based on the same rationale and principles. This has been reinforced by the globalisation of markets, which tends to lead to regional specialisation, the segregation of crop and animal production, and the industrialisation of the processing and distribution of food products (Martin *et al.*, 2019). The link between biodiversity and agriculture has somehow been broken. Because these transformations provide large increases in yields and economies of scale, they have been very attractive to developing countries as a pathway for modernisation. Although agriculture in these regions remains very diverse, in terms of production systems, farm size and intensification levels, with the cohabitation of multiple trajectories and models, this modernisation process is making progress (Bosc *et al.*, 2015).

This evolution affects biodiversity in agroecosystems and beyond in several ways:

• When the production process draws more resources than the ecosystem can sustainably provide, species populations and biodiversity are depleted. When cropping systems get simpler (i.e. mono-cropping at large scales) and regions more specialised, the diversity of species is eroded, not only for crop species but also for the other compartments of above- and below-ground biodiversity. This is particularly true for the complex soil-living communities which, for the most part, constitute a "hidden biodiversity" yet to be described (FAO, 2019). This erosion is irreversible and affects trophic chains and ecosystem services (De Clerck, 2017).

• The use of pesticides has a direct effect on biodiversity, at the plot scale and on auxiliary species, such as pollinators and soil biota. Through trophic chains, its leads to a drastic reduction of the ecosystem services that agricultural production needs (van Lexmond, 2015). Because of the multiple connections between natural and cultivated areas, this pressure reaches beyond agricultural land to natural areas, at the landscape and regional scales, decreasing the resilience of these areas.

• The impact on crop genetic diversity is the subject of concern and controversy, partly because there is no consensual tool to measure it (van de Wouw *et al.*, 2010). However, there is clearly a loss of diversity when traditional varieties or races are replaced by improved varieties (Khoury *et al.*, 2014). This can generate a genetic homogenisation at the global scale and possible weaknesses to pests, as historically illustrated by many examples in maize, banana and wheat (Bioversity International, 2017).

Most of the time these losses of biodiversity are irreversible, with many studies showing that the state of degradation of biodiversity across the planet has long passed the boundaries of sustainability (Springmann *et al.*, 2019).

What risks for food systems in LI and LMI countries?

Eroded biodiversity hampers food systems in different ways:

• The first major risk is the degradation of the capacity of ecosystems to support production, especially soils. Plateauing yields have been reported in several crops and 20 percent of the world's cultivated land has lost productive capacity (FAO, 2019). Eroded agrobiodiversity also triggers a vicious circle where more external inputs are needed to maintain yields, making farmers more dependent (Frison and IPES, 2016). Documented collapses in insect populations and diversity at a rapid rate (biomass declining at an annual rate of 2.5 percent for three decades), exemplify this fast-growing risk for agriculture and food production (Sánchez-Bayo, and Wyckhuys, 2019).

• Reduced diversity in production decreases the diversity of the food produced in a given region and it is not easy to compensate for this on markets (de Clerk, 2017; Jones, 2017). In southern countries, the industrialisation of agriculture, with its larger and more specialised farms seeking economies of scale, might degrade the nutritional value of products (Herrero, 2017). Most public policies and incentives designed to increase production accentuate the risk of poorly diversified diets, food systems and landscapes (*cf.* Box 6).

• At the processing stage, besides clear advantages (efficiency, labour productivity, cost per food unit etc.), industrialisation and a high degree of specialisation reduce food chain biodiversity, therefore decreasing nutritional quality and diversity (Remans, 2014).

• Ever-evolving and ever-adapting agrobiodiversity represents the creativity of life; its irreversible erosion means less capacity to innovate and adapt in the future, especially to climate change. Living in the 'Anthropocene' epoch, we already recognise biodiversity's finiteness in the form of impoverished landscapes and precarious ecosystems.

The market globalisation of agriculture has been a reinforcing driver in biodiversity erosion, as several researchers have shown (Khoury *et al.*, 2014). By increasing product fluxes and genetic material exchanges, it has reinforced these perturbations, either by erosion (i.e. reduced number of commodity species) or outbreak risks (i.e. invading species and exotic pests). Furthermore, the wide use of pesticides and antibiotics has generated very serious problems in antibiotic resistance (Morand and Lajaunie, 2018) and pesticide resistance (Heap, 2014).

What are the emerging solutions?

In their diversity, food systems have the resources to counter these risks, provided their actors can innovate based on new foundations:

- Production systems should reintegrate diversity at the plot, farm and landscape scales, not only to boost ecosystem services supporting crop production and protection, but also for the benefit of environmental integrity and health. Diversification is one of the best options to improve the nutritional value of production (Herrero *et al.*, 2017; Remans, 2014).

- Plant, animal and microbial agrobiodiversity, in and around the plot, above- and below-ground, must be preserved and valued as a precious capital. *In situ* conservation involving farmers would powerfully leverage their resilience and innovation capacity. This could lead to a new biotechnology based on complex specific combinations instead of an over-simplification (HLPE, 2017).

- A radically new approach of all food system actors and policy makers focused on performance at each step of the value chain, not limited to yields and productivity, but encompassing nutrition and environmental footprints (Frison and IPES, 2016).

BOX 6

DIVERSIFYING CROP SYSTEMS TO IMPROVE THE FOOD SECURITY AND NUTRITION OF SMALLHOLDERS IN MALAWI

Increasing intra- and interspecific diversity in cropping systems results in enhanced ecosystem services linked to crop nutrition (closing nutrient cycles, capture of atmospheric nitrogen, reduced leaching and run-off etc.), weed control (mulching, allopathy etc.) and pest management (breaking pest cycles, biocontrol etc.). It also improves the diversity of products available, although the way agricultural diversity translates into dietary diversity at the farm household level is not always straightforward nor easy to demonstrate.

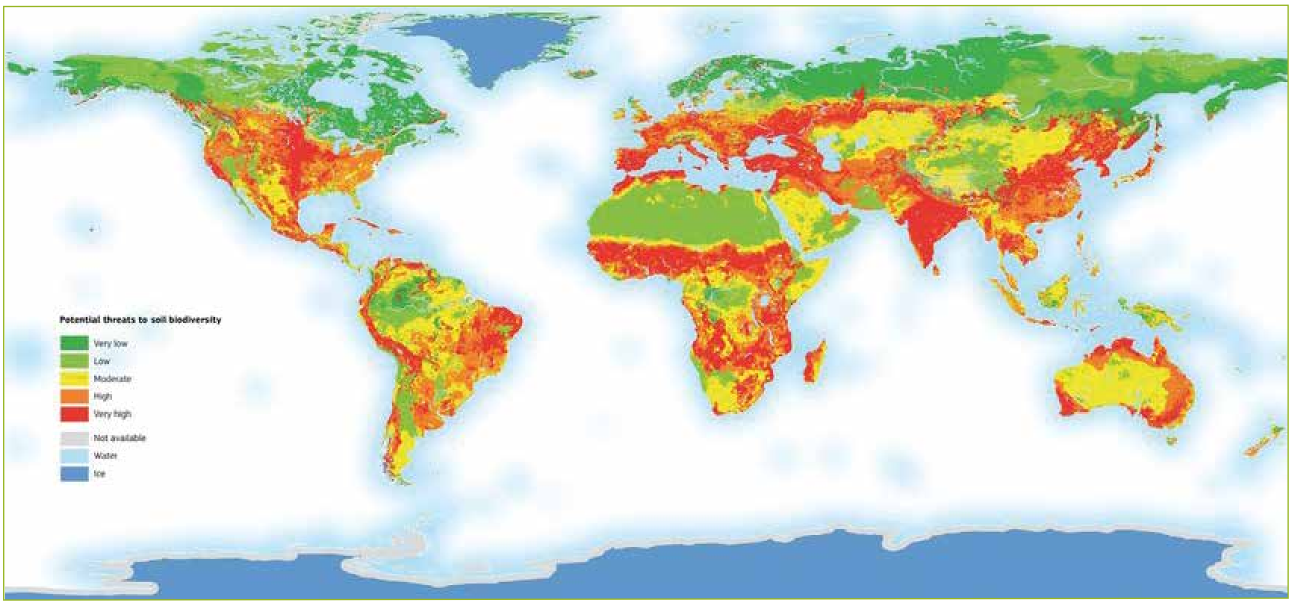
In Malawi, a country in semi-humid tropical Africa, more than 70 percent of rural people live below the poverty line, with serious food security challenges. Almost one-third of Malawian households experience severe food insecurity and calorie deficiencies, 50 percent of children under the age of five are stunted, 60 percent of pre-school age children are deficient in vitamin A and nearly three-quarters are anaemic (Nyantakyi-Frimponga *et al.*, 2017).

Through a large cross-sectional household survey (1,000 diversified smallholders with farm sizes of less than three acres) in two districts in Malawi, Nyantakyi-Frimponga *et al.* (2017), compared their health, food security and nutrition status. Household heads, spouses or another well-informed adult within the household were interviewed using a structured questionnaire specifically designed for the study, including questions on their self-perceived health and a Household Food Insecurity Access Scale (HFIAS) module to explore household food insecurity. The key independent variable was the use of agroecology (adopted by 571 households and not adopted by 429 households), understood as a set of farming practices mimicking natural systems, diversifying crops and increasing agrobiodiversity with attention paid to interactions with adjacent natural landscapes and taking particular care of soil by mulching and legume cropping.

The results showed that households which had adopted agroecology were more likely to report optimal health status and the average treatment effect showed that adopters were 12 percent more likely to be in optimal health. The paper concludes that with the adoption of agroecology in the semi-humid tropics it is possible for households to diversify their crops and diets, which has strong implications for improved food security, good nutrition and human health.

At the country level, Jones, Shrinivas and Bezner-Kerr (2014) explored plausible causal mechanisms that may operate between farm production diversity (crops and livestock) and diet diversity, based on data from a nationally representative sample of farming households in Malawi. The combination of increased farm diversity with dietary diversity was significantly greater in households lead by women compared to those headed by men, and in wealthier households. There was an especially strong link between legume, vegetable and fruit consumption with greater farm production diversity. More diverse production systems may contribute to more diverse household diets. However, this relationship is complex; it may be influenced by gender, wealth, control of household decisions, the relative market-orientation of a household's agricultural production and the specific nature of farm diversity.

Jones (2017) has also explored how agricultural biodiversity, diet quality and anthropometric outcomes are associated in LI and LMI countries. A comprehensive review of five databases revealed that agricultural biodiversity has a small but consistent link with more diverse household and individual diets, although the magnitude of this association varies with the extent of the existing diversification of farms. Greater richness in on-farm crop species is also associated with small, positive increments in linear stature in young children. Agricultural diversification may contribute to diversified diets through both subsistence and income-generating pathways and may be an important strategy for improving diets and nutrition outcomes in LI and LMI countries.



Map 8: *Map of potential threat to soil biodiversity. Source Orgiazzi* et al.*, eds. 2016. European Union, 2016.*

References

Bioversity International. 2017. *Mainstreaming agrobiodiversity in sustainable food systems: scientic foundations for an agrobiodiversity index.* Rome, Bioversity International.

Bosc, P.-M., Marzin, J., Bélières, J.-F., Sourisseau, J.-M., Bonnal, P., Losch, B., Pedelahore P. & Parrot, L. 2015. Defining, characterizing and measuring family farming models. In J.-M. Sourisseau, ed. *Family Farming and the worlds to come.* Dordrecht, Netherlands, Springer.

De Clerck, F. 2017. Agricultural biodiversity and the provision of ecosystems services. In D. Hunter, L. Guarino, C. Spillane, P.C. McKeown, eds. *Routledge handbook of agricultural biodiversity,* pp. 268–284. London, Routledge.

FAO. 2019. *The state of the world's biodiversity for food and agriculture.* J. Bélanger & D. Pilling, eds. Rome. FAO Commission on Genetic Resources for Food and Agriculture Assessments. 572 pp. (also available at www.fao.org/3/CA3129EN/CA3129EN.pdf).

Heap, I. 2014. Global perspective of herbicide-resistant weeds. *Pest Management Science,* 70: 1306–1315.

Herrero, M., Thornton, P.K., Power, B., Bogard, J.R., Remans, R. Fritz, S., Gerber, J.S., ***et al.*** 2017. Farming and the geography of nutrient production for human use: a transdisciplinary analysis. *The Lancet Planetary Health,* 1: e33–42.

HLPE. 2017. *Sustainable forestry for food security and nutrition.* Report by the High Level Panel of Experts on Food Security and Nutrition of the Committee on World Food Security. Rome.

Frison, E.A. & IPES-Food. 2016. *From uniformity to diversity: a paradigm shift from industrial agriculture to diversified agroecological systems.* Louvain-la-Neuve, Belgium, IPES.

Jones, A.D., Shrinivas, A. & Bezner-Kerr, R. 2014. Farm production diversity is associated with greater household dietary diversity in Malawi: Findings from nationally representative data. *Food Policy,* 46: 1–12.

Jones, A.D. 2017. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low-and middle-income countries. *Nutrition Reviews,* 75(10): 769–782.

Khoury, C.K., Bjorkman, A.D., Dempewolf, H., Ramirez-Villegas, J., Guarino, L., Jarvis, A, Rieseberg, L.H. & Struik P.C. 2014. Increasing homogeneity in global food supplies and the implications for food security. *Proceedings of the National Academy of Sciences,* 111(11): 4001–4006.

Martin, A.R., Cadotte, M.W., Isaac, M.E., Milla, R., Vile, D. & Violle, C. 2019. Regional and global shifts in crop diversity through the Anthropocene. *PLoS ONE,* 14(2): e0209788.

Morand, S. & Lajaunie, C. 2018. *Biodiversity and health: linking life, ecosystems and societies.* London, UK, ISTE.

Nyantakyi-Frimpong, H., Kangmennaang, J., Bezner Kerr, R., Luginaah, I., Dakishoni, L., Lupafya, E., Shumba, L. & Katundu, M. 2017. Agroecology and healthy food systems in semi-humid tropical Africa: Participatory research with vulnerable farming households in Malawi. *Acta Tropica,* 175: 42–49.

Remans, R. 2014. Measuring nutritional diversity of national food supplies. *Global Food Security,* 3(3–4): 174–182.

Sánchez-Bayo, F. & Wyckhuys, K.A.G. 2019. Worldwide decline of the entomofauna: a review of its drivers. *Biological Conservation,* 232: 8–27.

Springmann, M., Clark, M., Mason-D'Croz, D., Wiebe, K., Bodirsky, B.L., Lassaletta, L., de Wries, W., ***et al.*** 2018. Options for keeping the food system within environmental limits. *Nature,* 562: 519–525.

United Nations. 1992. *Convention on biological diversity.* Rio de Janeiro, UN [online] https://www.cbd.int/doc/legal/cbd-en.pdf.

van de Wouw, M., van Hintum, T., Kik, C., van Treuren, R. & Visser, B. 2010. Genetic diversity trends in twentieth century crop cultivars: A meta-analysis. *Theoretical and Applied Genetics,* 120: 1241–1252.

van Lexmond, M.B., Bonmatin, J.M., Goulson, D. & Noome, D.A. 2015. Worldwide integrated assessment on systemic pesticides. Global collapse of the entomofauna: Exploring the role of systemic insecticides. *Environmental Science and Pollution Research,* 22: 1–4.