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Chapter 2

Substituting intensive external input use by biodiversity-derived ecosystem functions

One of the fundamental principles of agroecology is to increase crop performance by strengthening ecosystem functions driven by available agrobiodiversity. This so-called ecological intensification process enhances biomass production by improving nutrient and water cycles and combating pests and diseases, while keeping external input use to the bare minimum. This chapter presents research summaries regarding **Gliessman's second transition** level, which aims: "to replace external input-intensive and environmentally degrading products and practices with those that are more renewable, based on natural products, and more environmentally sound [….] They employ alternative practices that include the use of nitrogen-fixing cover crops and rotations to replace synthetic nitrogen fertilizers, the use of natural controls of pests and diseases, and the use of organic composts for fertility and soil organic matter management."

At this level, the focus is essentially on the cropping system (more rarely on the production system) and the practice changes mainly concern specific production aspects: nutrient dynamics, pest protection, water efficiency, etc. Essentially six HLPE principles are applied in innovations, i.e. recycling, input reduction, soil health, animal health, biodiversity and synergy and in some cases co-creation of knowledge (when there is participatory innovation). The most important principle applied here is diversification and the overall idea is to mobilize or amplify ecosystemic functions while minimizing the use of external inputs that are widely used in intensive production systems. At this level of transformation, farmers are the main actors involved.

The external input substitution process depends greatly on the cropping system considered and the local context. The transformation pathways to apply transition step 2 could differ markedly because there are several starting points and different changes of pace. For example, in a low-input production system, the focus would be more on finding ways to intensify and increase yields, without recourse to excessive use of external inputs. However, in an intensive, high external input system, the focus would be on determining how to reduce the use of these inputs and substituting with organic and agroecological functions, without significant yield loss or reduction.

Research addressing this substitution stage could fall in three categories:

Biological pest and disease regulation: Controlling crop pests and diseases is a key factor determining the final yield. Pesticide-use is claimed to be 'convenient', i.e. a single product may be designed to kill a range of pests, pathogens, weeds, etc. In-depth knowledge on the functionalities at play in living communities is needed to be able to replace pesticides or minimize their use, e.g. through regulation provided by biodiversity uses. A few examples are outlined here. In general, increasing varietal diversity, and optimizing its pattern in the field is a low-cost strategy to reduce the impact of pests and diseases (de Santis *et al.*), as illustrated in Ethiopian Highlands, where temporal and varietal diversification were found to minimize the impact of rust epidemics in wheat crops, and of *Orobanche crenata* in temperate food legume crops (Kemal *et al.*). The use of auxiliary species to control pests and diseases can be a second step: in Réunion, increasing biodiversity—animal, plant and microbial—in the vicinity of the crop fields, and both above- and below-ground, can markedly reduce, and sometimes eliminate, pesticide use in horticulture (Deguine *et al.*); in southern Europe, the careful introduction and mass rearing of *Cotesia typhae*, a new parasitoid species that preys on corn stemborers (*Sesamia nonagrioides*), is promising (Kaiser *et al.*). However, decisions with regard to using these tools may not depend only on their efficacy, the concerned farmers might be locked into their technical practices due to external constraints (Navarrete *et al.*). These agroecological techniques are sometimes complex and require in-depth research in plant and animal physiology. In Madagascar, a combination of silica inputs and enhanced earthworm activity was found to enhance rice crop tolerance to leaf blast (*Pyricularia* sp.), which disappeared when nitrogen fertilizers were applied (Blanchart). Soil biodiversity is essential for crop health and rhizosphere microbiomes, when enhanced with growth-promoting microbes, produce multiple benefits of induced plant growth, defense against diseases and survival under stress (Gopalakrishnan *et al.*). Biocontrol through the use of plant extracts in crop fields is also an interesting avenue to be explored (Sylvie & Martin).

▼ ***Agroecology in Senegal.*** *© T. Chevallier/IRD*

Reducing dependency on external costly inputs: Soil fertility is one of the most important elements in production systems, which explains the massive use of external fertilizer inputs in conventional cropping systems. Alternative approaches, based on the agroecological principles of recycling, diversification and soil health management, allow substantial input reduction. This is illustrated here: by the fine-tuned management of manure applications on Sahelian soils (Lardy *et al.*; Masse); the so-called priming effect to enhance the mineralization of organic matter which is essential for soil health and nutrient supplies (Bernard & Maron); the optimized use of crop residues associated with legume cover crops in industrial palm plantations, where fertilizer inputs could represent up to 80% of the total cost of the crop (Bessou); or crop residue composting with manure in intensive rice cropping systems in the Mekong region (Nguyen *et al.*). Soil fertility and crop yields were shown to be markedly improved in agroforestry systems: associations with *Ziziphus mauritiana* trees in Sahelian regions improved the rainwater use efficiency, soil fertility and millet yields, while maintaining the soil organic carbon content (Bado *et al.* and chapter 3, see page 50). Although requiring innovative tenure arrangements with regard to both land and trees (Chomba *et al.*), as well as long-term investment and financial support, the introduction of trees was found to substantially boost farmers' income within a few years, thereby enhancing their family's livelihood (La *et al.*). Associations with legume crops were found to improve soil fertility, and the use of bioinoculants could boost crop yields provided that their quality is controlled (Herrmann *et al*). Diversification in climate change stricken regions could also provide gains in terms of water management (Devkota & Nangia)

Substituting environmentally disruptive inputs: Pest and disease control with pesticides is a major source of pollution and health hazards in the tropics, and replacing these dangerous chemicals is crucial goal of agroecology. This is illustrated here in the agroecological approaches implemented to control devastating fall army worms (*Spodoptera frugiperda*): in Africa, through integrated strategies (improving plant health through better soil fertility, diversifying farms and landscapes to favor natural enemies and increase their efficacy (Harrison); in India, combining different tools to control fall army worms without insecticide use seems very promising (Jaba *et al.*); as well as in Mexico with the use of pheromone traps (Fonteyne *et al.*). The current vegetable production boom in sub-Saharan Africa relies on intensive chemical control, and agroecological methods are now employed to reduce this chemical input reliance. One example concerns the use of affordable low-tech net houses that protect plants against pests and extreme climatic conditions (Deletre *et al.*). The next generation of crop pest and weed management in countries of the Global South will be scalable and based on a combination of nature-based solutions and affordable digital mobile phone-based tools tailored for use by low-literacy farmers (Tamò & Chikoye; Malézieux).

In livestock production, the sometimes massive use of chemicals to control crop pests and parasites has major impacts on health and the environment, particularly regarding the issue of antibiotic resistance development. Drastic changes in production systems are thus needed alongside the adoption of One Health approaches (Ducrot *et al.*). Two examples of alternatives are presented here: the promising use of color baited toxic screens and baits to control hematophagous flies that can transmit numerous diseases to humans and livestock (Desquesnes *et al.*); and the diversification of pasture plant species that was found to reduce outbreaks of sheep, goat, equine and bovine parasites, in turn significantly reducing prophylactic helminthicide treatments (Dumont *et al.*). Aquaculture also involves high usage of dangerous inputs, yet solutions for ecological intensification in aquaculture exist based on optimized diversification of trophic links and integration with other types of production (Caruso *et al.*).

The sections below provide some details on examples of agroecology interventions relating to the three categories of research that addresses the substitution stage and principle.

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