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Chapter 3

Redesigning agroecosystems on the basis of a new set of ecological processes from farm and landscape

This chapter focuses on the redesign, implementation and management of agroecosystems that differ from current systems. This redesign process is driven by a transformation commitment (less dependence on pesticides, more efficient in the use of water, decent work and improved wellbeing, adaptation to climate change, landscape quality and biodiversity preservation, etc.). It may represent a real break with the past while being geared towards long-term change. It draws on certain agroecological principles: diversifying varieties/breeds, crop rotations, fostering complementarity between livestock and crop production, reintroducing trees in farms and landscapes, and reconsidering agroforestry systems in terms of their multifunctionality. Although often having a specific focus, it soon strives to reconsider all agroecosystem functions and services, and their sustainability and resilience in response to the highly variable nature of external constraints (climate, prices, etc.). This redesign process may take place on the farm or in the landscape, within the scope of collective management (watershed, small management area), or within a broader territorial project involving non-farmer stakeholders (public authorities, environmental protection or tourism agencies). This chapter is devoted to five major themes, the first four of which approach agroecosystem redesign from a specific standpoint, while the last one calls for a review of all agroecosystem functions and services.

Enhancing biological interactions: Insight into the importance of biological diversity and biotic interactions in agroecosystems has led to the development of strategies based on the introduction of new biological diversity, the analysis of its effects and its role in disease resistance and control, and in pollination. A literature review has highlighted interactions between crop protection practices and viral zoonotic diseases, with a One Health vision (Ratnadass & Deguine). Redesign research regarding banana agroecosystems in the West Indies takes the functional traits of plants into account, with the aim of selecting these so-called service plants and combining them as multifunctional cover crops for weed control, while also optimizing nitrogen resource acquisition (Dorel *et al.*). An ecological engineering approach promotes biological control for sustainable pest management by enhancing natural enemy survival and action by increasing floral diversity in rice landscapes (Zaidi *et al.*). On a larger scale, Farming with Alternative Pollinators (FAP) strategies use marketable habitat enhancement plants consisting (in small areas) of spices, oil seeds or other vegetables that attract and sustain higher abundance and diversity of wild pollinators and natural enemies over time (Christmann).

Functions and ecosystem services of agroforestry: Agroforestry systems—combining woody species and annual crops—are very diversified. They range from traditional tree monocultures (coffee, cocoa, rubber, fruit orchards, etc.), where the challenge is to enhance diversity within and between species so as to ensure their resilience and sustainability, to multispecies agroecosystems including *bocage* systems (trees-crops-livestock), to natural agroforestry parks, which must be preserved in the light of the various pressures exerted on them. The issues and intended redesigns are dealt differently in these systems. In traditional cropping systems, research focuses on the functional traits of agroforestry systems, particularly in view of the need for better pest control, but also of the diversity of the ecosystem functions and services of these systems (Avelino *et al.*; Penot). The idea is to optimize natural resource use (a unit of agroforestry area produces more than the sum of crops grown in pure stands) and to generate functional synergies (Winowiecki *et al.*; Rodenburg *et al.*). An example regarding cocoa systems illustrates the impacts of the introduction of a mixture of fruit and forest trees chosen for their varied assets (cocoa yield, biological pest control, product diversity, etc.) (Jagoret). The contribution of these systems to climate change mitigation through carbon sequestration in wood and soil—as illustrated in the case of hedges and hedgerows—is a challenge that needs to be accurately and spatiotemporally quantified (Viaud & Thenail). Water management is also important, as demonstrated here in fruit tree-crop intercropping systems implemented in Mediterranean and dryland regions to manage scarce water resources (Wery *et al.*). Regarding nature parks, the aim is to renew interest in tree products, in line with current socioeconomic priorities, while developing forest product value chains and establishing new governance rules (Cardinael; Seghieri *et al.*).

▼ *Restoration of an agrosylvopastoral production system of the Ouled Sbaihia community located in a semiarid area in Tunisia.* © *Slim Slim*

Enhancing the complementarity of crop and livestock farming: The status of livestock is questioned in this redesign process: animals enhance the value of certain highly stressed environments (drylands, mountains, etc.) and enable biogeochemical cycles to be completed by enhancing the value of certain resources, returning nutrients to the soil and stimulating the soil biological activity (Louhaichi & Hassan; Rekik *et al.*). Livestock-crop integration can also be an adaptation option in a climate change setting (products and additional food resources), yet also a constraint, i.e. providing livestock feed resources even in drought conditions (stocks, new resources) (Novak *et al.*). Management of the water and soil moisture status is a common focal point. Some examples illustrate this introduction in agroforestry systems and agropastoral systems requiring water management. The conversion of mixed crop-livestock systems into organic farming systems can reduce farm vulnerability through more autonomous nutrient management (Martin). Mixed fish-rice production systems are also part of this loop mindset, but this time at the field level (Freed *et al.*).

Redesigning landscapes: Agroecosystem redesign initiatives often have to take the landscape scale into account, including production and interstitial areas, which can have a regulatory role (specific habitat, refuge, etc.), including a broad range of environments (diverse soils, access to water resources according to the hydrological conditions) (Petit-Michaut; Omondi *et al.*). Closer adaptation of agroecosystems to their environment, including possible synergies and complementarities between cultivated and natural biodiversity, farmers, landscape management stakeholders and the territory also sometimes have to be considered in this process (Yadav *et al.*). The territory is a socioecosystem in which environments, activities and societies coevolve—ecosystem services such as cultural, memorial and historical amenities are particularly attached to it.

These different aspects are partly illustrated with regard to the landscape level and geared towards enhancing the regulatory services of the landscape against pests and diseases. This is achieved by taking semi-natural spaces and their functions into consideration, while sometimes preserving certain spaces within the landscape (Deconchat *et al.*). The landscape dimension is particularly important in agropastoral systems, which use areas that vary according to the seasons, rainfall and soil moisture conditions (Mekuria & McCartney; Romero *et al.*; Strohmeier *et al.*).

Building resilience through ecosystem services: Redesign calls into question all agroecosystem functions and services. There are numerous examples of participatory design approaches—also known as open innovation—to identify acceptable innovative solutions, drawing on academic and field knowledge to identify agroecosystem transition scenarios (Scopel; Saj & Demenois; Sourisseau *et al.*). Conceptual frameworks have been formalized to account for ecosystem service function value chains (Rakotovao *et al.*; Lescourret *et al.*). Many examples derive from India, sub-Saharan Africa (West Africa, Madagascar), France, etc., regarding various systems, illustrating ways of accounting for GHG emissions, carbon sequestration, soil function conservation, reduction of energy or water consumption (Ruiz & Sekhar), etc., thereby mitigating the weak aspects of each system. Agroecology constitutes a lever for climate change adaptation and mitigation (Kebede *et al.*). It is vital to take agricultural work and the role of the actors, particularly women (Crossland *et al.*), into account in this innovative concept in order to address and even overturn well-established practices.

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