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Trends in Ecology & Evolution

Science & Society

A way forward for biodiversity conservation: high-quality landscapes

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We are losing biodiversity quickly, not simply because of development but due to poor spatial planning. Recent findings propose thoughtful configurations and management of human-modified landscapes to protect biodiversity while allowing food production. This opens up a range of feasible actions in the conservation agenda, which overlap with food sovereignty initiatives.

The main challenge for biodiversity conservation: food production

In preparation for the post-2020 global biodiversity framework, the fifteenth meeting of the Conference of the Parties to the Convention of Biological Diversity will be held in Kunming, China, in 2021 (https://www.cbd.int). The conference will build from the Strategic Plan for Biodiversity 2011–2020 and move toward the 2050 vision of 'Living in harmony with nature', which states that 'By 2050, biodiversity is valued, conserved, restored and wisely used, maintaining ecosystem services, sustaining a healthy planet and delivering benefits essential for all people.' This vision recognizes that the main challenge for protecting biological diversity is to find ways in which human activities, in particular food production, can coexist with and benefit from biodiversity.

Although the interconnected challenge of protecting biodiversity and securing food production was widely recognized more than 30 years ago [1], the reality on the ground continues to be a separation of these two goals with disastrous consequences for both biodiversity conservation and food security. The past few decades have experienced dwindling population sizes and range shrinkages of vertebrates [2], sharp biomass declines of insects [3], and general loss of biodiversity due to habitat loss and agricultural intensification [4]. Likewise, targets for the reduction of food insecurity have been disappointing. Almost 690 million people went hungry around the world in 2019; severe food insecurity rose 70% from 2015 to 2019, and the COVID-19 pandemic exacerbated that trend: food insecurity increased in West and Central Africa by 135% and in southern Africa by 90%, and there was a threefold increase in the number of people seeking food assistance in Latin America [5].

Optimal design of human-modified landscapes to meet this challenge

The question of how best to conserve biodiversity in modern societies spurred much ecological research over the past decades. Recent reviews of these empirical studies [6–8] distilled common principles to guide the design of human-modified landscapes so that they can meet biodiversity requirements. The clever design of human-modified landscapes is meant to achieve a dual purpose, protect most forest species while allowing for food production. This proposal comes at the pinnacle of historically important discussions in relation to the design of protected areas and agricultural activities surrounding these (Box 1). These discussions added support to the general idea of linking **agroecological** (see Glossary) practices with **food sovereignty** and conservation initiatives to create agricultural matrices that produce food, habitat for biodiversity, and connectivity among forest fragments [9].

Recently, Arroyo-Rodríguez and colleagues [6] provided a spatial representation of such landscapes, giving tangible meaning to the otherwise abstract concept of 'sustainable development'. Such a focus could promote conservation efforts worldwide. Whether it is a standing tree, a living fence, or more integrated agroforestry systems, if placed in the appropriate context, their effects on biodiversity could be substantial and could foster collaboration between different conservation projects. For example, native or endangered trees of desirable timber quality can be planted with shade-tolerant crops to provide resources or dispersal opportunities to several animal species [6,7], creating synergy between projects focused on different species or at different scales (micro versus macro). Likewise, increasing the protection of riparian ecosystems not only benefits agricultural income in the long run (e.g., by regulating water flow to prevent landslides or providing habitats for pest-controlling species) but also protects biodiversity directly [9]. These and other strips of vegetation hold an intrinsic value as biodiversity reservoirs within the matrix and should not be visualized as mere

Glossary

Agroecology: a practice based primarily on diversification and the use of ecological principles to design and manage agroecosystems.
Alpha diversity: the number of species within a particular area or ecosystem.
Beta diversity: the change in species composition across habitats or over distance.
Food sovereignty: as defined by the Food Sovereignty Alliance, food sovereignty is the right of people to healthy and culturally appropriate food produced through ecologically sound and sustainable methods and their right to define their own food and agricultural systems.
High-quality matrix: a matrix dominated by heterogeneous and diverse agroecological farming systems (sometimes also referred to as agroecological matrix) that bare structural similarity to natural habitats and lack intensive use of agrochemicals. These systems provide habitats for biodiversity and promote connectivity among fragments of natural habitat. These ideas form part of UNESCO's Biosphere reserves.
Umbrella species: usually large animals that are targeted for conservation initiatives because they require vast expansions of terrain so that their conservation usually entails the protection of large areas that are expected to harbor healthy populations of smaller species.

Box 1. Historical benchmarks on how to protect terrestrial ecosystems

(i) Single large or several small (SLOSS)? This debate was concerned with the size and distribution of protected areas [6,10]. In a world in which natural areas are converted to human landscapes, what is the best way to protect biodiversity? Create a single, large reserve or several small ones embedded within human landscapes?

(ii) Land sparing versus land sharing? This debate centered on the idea that food production and biodiversity conservation could be achieved through smaller-scaled, lower-impact, and lower-yielding agricultural activities (land sharing) or through the intensification of agricultural production that released pressure on natural habitats (land sparing). However, this discussion relied on unsubstantiated premises about the agricultural productivity in both systems, ignored dynamic extinction/migration processes of species, and naively assumed that land would be spared once the demand for agricultural goods was satisfied [7].

(iii) Biological corridors or habitat patches? Small forest patches were once deemed unimportant for wildlife conservation because their small size could not hold stable populations of most species. Later, some forest patches, particularly those in a longitudinal arrangement, received attention because they could facilitate wildlife movement between protected areas (i.e., biological corridors). More than mere runways for wildlife, these small patches are now considered important components of high-quality matrices that, together with large forest patches, can sustain biodiversity [6–9].

runways for wildlife (Box 1). The landscape-level approach to conservation emended the reputation of small forest patches and secondary forests, which have essential roles for conserving **beta** and **alpha diversity** within the agricultural landscape [6,9], particularly in tropical regions where species turnover is high at even small spatial scales [10]. These habitats have often been excluded from conservation initiatives, despite the fact that they are often easier to protect. Biodiversity conservation depends on dynamical processes of migration and extinction, and, therefore, patches of forests, whether large or small, primary or secondary, should be embedded within a **high-quality agroecological matrix** that allows organisms to migrate between habitat patches [9]. This has become increasingly important in the context of climate change, for example, when distant wetter areas comprise a moist refuge for hundreds of species that experience severe droughts seasonally in part of their distributional range [3].

Planning for high-quality matrices

Such high-quality agroecological matrices will also be able to produce ample quantities and diversity of food and other ecosystem services as well as enhance the livelihoods of rural populations [11], who represent 70% of the world's extremely poor [12]. The goals of **food sovereignty** initiatives (but not those of food production *per se*) can be integrated with those of biological conservation so that a shared agenda can foster collaboration between different sectors, including government and private or community-oriented initiatives. The structure of landscapes emerges from the decisions of multiple stakeholders (e.g., farmers, local and national governments, and non-governmental organizations) so that a participatory approach is needed [13]. It is of tantamount importance to design or articulate local projects so that isolated efforts can be scaled-up to impact the regional level (e.g., through farmer's co-operatives that allow for individuals to access sustainable certifications).

Several examples of landscape approaches are beginning to yield fruits that can be measured in terms of biodiversity conservation, food security, equity outcomes, and other improvements in social conditions [14]. High-quality matrices are charismatic because they are agrodiverse, produce food, maintain biodiversity, and can thus move forward conservation initiatives that require public support. Societal backing rests on the attitudes generated at the individual level, which are more likely to emerge when feasible, non-fatalistic scenarios are presented. It is important for the general public to free itself from the misconception that the only way to feed the actual human population is to clear forest cover or forsake biodiversity [4]. The unmasking of this false dichotomy may spark genuine interest to create 'partnerships' between wild ecosystems and the societies in which they occur [3].

Bolstering protected areas with high-quality matrices

The main objective of conservation initiatives should still be to maintain as much forest cover as possible in remaining natural areas [6]. However, failure to visualize protected areas within a high-quality matrix has hindered their full conservation potential. For example, La Selva Biological Station in the Caribbean side of Costa Rica is one of the most extensively studied forests in the Americas, and within the past decades, independent research has documented sharp declines of birds, frogs, reptiles, and insects [15]. These declines contrast with the apparent 'pristine' condition of La Selva, but make sense if visualized from the landscape perspective (Figure 1). La Selva, although small in extension, connects with huge pristine areas at higher altitudes, and this apparently works well for protecting several large mammals and altitudinal migrants. However, local declines and extinctions appear to be the product of a harsh agricultural matrix in nearby lowlands (e.g., few forest patches and agricultural intensification that promotes monocultures and the use of pesticides) [15]. Insufficient matrix conditions pull La Selva away from an optimal landscape scenario that can balance food production with the protection of biological diversity [6,9]. The effects of 'local' insufficient conditions on the Caribbean lowlands may have even spread to affect insects farther away in the seasonally dry (and now drier) Pacific side of Costa Rica [3]. La Selva illustrates how previous conservation models (e.g., protection of '**umbrella**' species or land sparing) have proven themselves insufficient for conserving biodiversity and

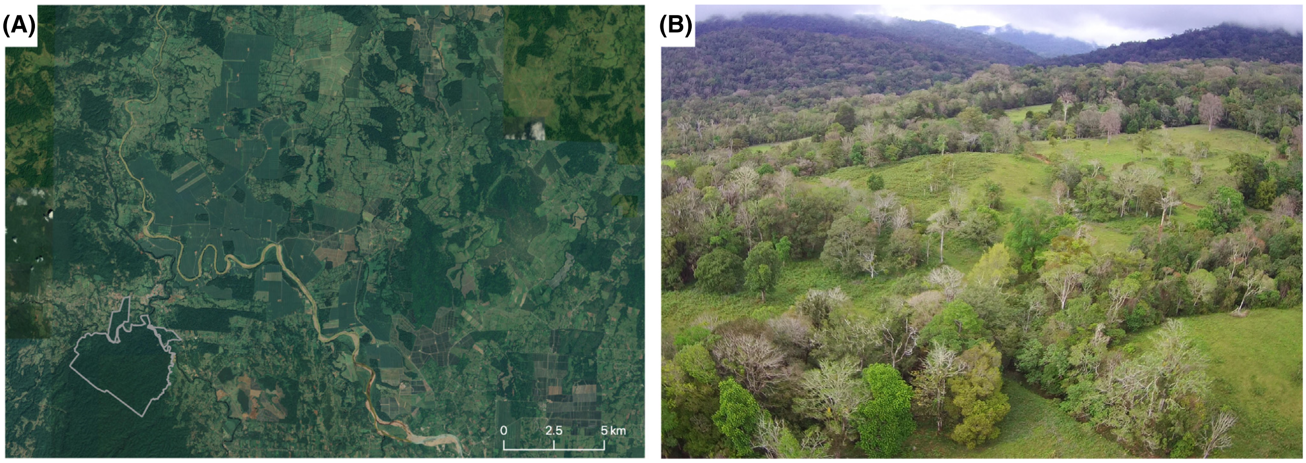

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Figure 1. The quality of the agricultural matrix surrounding protected areas can boost or hinder biodiversity conservation. (A) La Selva Biological Station (gray border), Costa Rica, protects approximately 1600 hectares of lowland tropical rainforest. La Selva connects with Braulio Carrillo National Park (bottom left) and together form a patch of approximately 52 000 hectares of uninterrupted forest throughout an altitudinal gradient (30–2906 m). Still, La Selva has suffered from severe population reductions and local extinctions in several animal groups, including birds, frogs, and lizards [15]. The harsh agricultural matrix in lowlands nearby [15] pulls La Selva away from required conditions that can better balance food production with the protection of biological diversity [6]. Note severely deforested Caribbean lowlands in the rest of the image and large areas devoted to pastures and banana or pineapple monocultures (bluish-green or brown). Source: Map data 2020 Google. (B) A higher-quality matrix surrounds La Amistad International Peace Park (mountains at the back) near Las Alturas de Cotón, Puntarenas, Costa Rica, where cattle-grazing pastures are intermingled with small forest patches and live fences that can protect targeted plant species and provide resources or dispersal opportunities to several animal species. Photo courtesy of Víctor Arroyo-Rodríguez. The smart design of human-modified landscapes that can provide goods and services to people while allowing for biodiversity conservation is possible [6]. This is a common goal of conservation and food sovereignty initiatives.

suggests that we must pay attention to the conservation of whole landscapes, especially in species-rich, tropical ecosystems [7]. It remains to be seen whether biodiversity in the La Selva region can bounce back after the documented recent declines. Efforts in the right direction should include working alongside local farmers and rural movements that emphasize agroecological production and food sovereignty. Long-term datasets and biological stations that facilitate producing these data at a landscape scale will be essential in monitoring how effectively human-modified landscapes are protecting biodiversity and providing goods and services to locals and people in general. This can help evaluate whether such cleverly designed landscapes [6] can sustain biodiversity in the long run.

An important step in the right direction would be to integrate a dual program for landscape-level planning, including incentives for food sovereignty and biodiversity conservation on the agenda of the 2021 Kunming meeting. A focus on the quality of the matrix in which natural areas are situated, and the farmers that construct it, bottom-up, should head the agenda. If the rhetoric of valuing, conserving, and wisely using biodiversity is to be more than platitude, this landscape and food sovereignty approach needs to be a central part of biodiversity conservation.

Acknowledgments

John Vandermeer provided valuable comments to the manuscript. Iria Chacón-Salas and Wagner López-Vargas helped produce the satellite image. F.G.S. is grateful to Víctor Arroyo-Rodríguez for his continuing sharing of ideas on human-modified landscapes in the Tropical Ecology and Conservation courses from the Organization for Tropical Studies.

Declaration of interests

No interests are declared.

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https://doi.org/10.1016/j.tree.2021.04.012

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