PNAS COMMENTARY

Agriculture, urbanization, climate, and forest change drive bird declines

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The current biodiversity crisis is characterized by a major loss of unique species as well as their interactions with their biotic and abiotic environment. This is a global tragedy in terms of the impoverishment of our life, but also for the damage to ecosystem functioning, which can severely affect major ecosystem services. In PNAS, Rigal et al. (1) address with a comprehensive analysis the current biodiversity losses of birds, a popular and well-studied group. Their analysis across European countries quantified the relative importance of four widespread anthropogenic drivers: agricultural intensification, urbanization, changes in forest cover, and climate change. They identified agricultural intensification as the major cause for the decline of most bird populations, especially invertebrate feeders, which are known to be of major importance for biological pest control (2). Urbanization also affected birds' population dynamics negatively, while forest cover had no overall effect, and effects of temperature change depended on the species' thermal preference. Land-use change does not impair all species equally, and particular life-history traits indicate higher vulnerability (1, 3). Insectivorous birds and nectar and fruit feeders suffer most from land-use change, while granivores and omnivores often benefit (1, 4). Further, long-distance migrants suffer as well as woodland birds, although much less than farmland birds. The results of the analyses of Rigal et al. (1) provide convincing arguments for urgently needed changes in the European agricultural policy (5, 6), with more emphasis on biodiversity-friendly and sustainable measures when balancing socioeconomic and ecological goods (Fig. 1).

The dramatic declines in bird diversity are on par with a decline in overall biodiversity, including insects, which account for two orders of magnitude more species than birds (10). The predominant role of agriculture for biodiversity losses found by Rigal et al. (1) is in line with most studies on this topic (11). Agricultural intensification and expansion is still the most important driver of biodiversity decline, even beyond the detrimental effects of climate change, which not only leads to phenological changes (e.g., earlier arrival of migrants and earlier breeding), but reorganizes community compositions and associated ecosystem functioning at regional to global scales (9) and creates particularly strong threats to the biodiversity at high altitudes (12).

Nevertheless, the relative role of each agricultural practice is unclear. Local overfertilization and excessive pesticide use are often seen as main causes (1), but drivers such as eradication of natural habitat in agricultural landscapes, farmers' specialization on few crops grown in monocultures, enlarging field sizes, and the loss of landscape-wide heterogeneity are among the most fundamental factors of current biodiversity decline (13). Rigal et al. (1) report that they had difficulties acquiring long-term fertilization and pesticide use data, so analyses of large datasets that disentangle local and landscape-scale effects of agrochemical use would be an important next step. The insight that landscape structure, not single local conservation measures, plays a dominant role in maintaining and restoring biodiversity has still not found its way into the agri-environmental policy of the EU (6, 14). Successful agricultural measures to enhance biodiversity include landscape-level management to diversify cropland (15) and to reduce field size (best down to <1 ha) (16), which can multiply biodiversity without sacrificing productive land while sustaining high yields (17). Further, there is a need to keep or restore natural habitat (best >20%) (18). Achieving such a landscape-level mosaic of natural habitat patches and fine-grained cropland diversification in both conventional and organic agriculture is key for promoting large-scale biodiversity, which needs to be urgently acknowledged for an agricultural paradigm shift (6).

Notwithstanding the above, the last areas of Europe's wilderness (2.2% of the land) and of traditional agroecosystems, supporting a wealth of synanthropic species with a long history of human land use, have to be preserved (13). In the European Union, the Central and Eastern European new member states (Poland, Hungary, Czech Republic, Slovakia, Slovenia, Estonia, Latvia, and Lithuania joined the EU in 2004 and Romania and Bulgaria joined the EU in 2007) need particular attention, as they still support large areas of species-rich farmland (especially grasslands), but keeping this traditional, low-intensity land use and landscape mosaic is little acknowledged or supported by the EU Common Agricultural Policy. The map of Rigal et al. (1) shows that farmland birds suffered less harmful declines in these regions. The accession to the EU shortly increased the populations of many farmland birds due to large-scale abandonment, showing how quick bird populations can respond (19), although they collapsed soon due to agricultural intensification (20). Targeting policy, research, and monitoring for conserving these diversified regions is urgently needed (21). In comparison with bird communities of cropland, those of grassland (representing three-quarters of agricultural land globally) are

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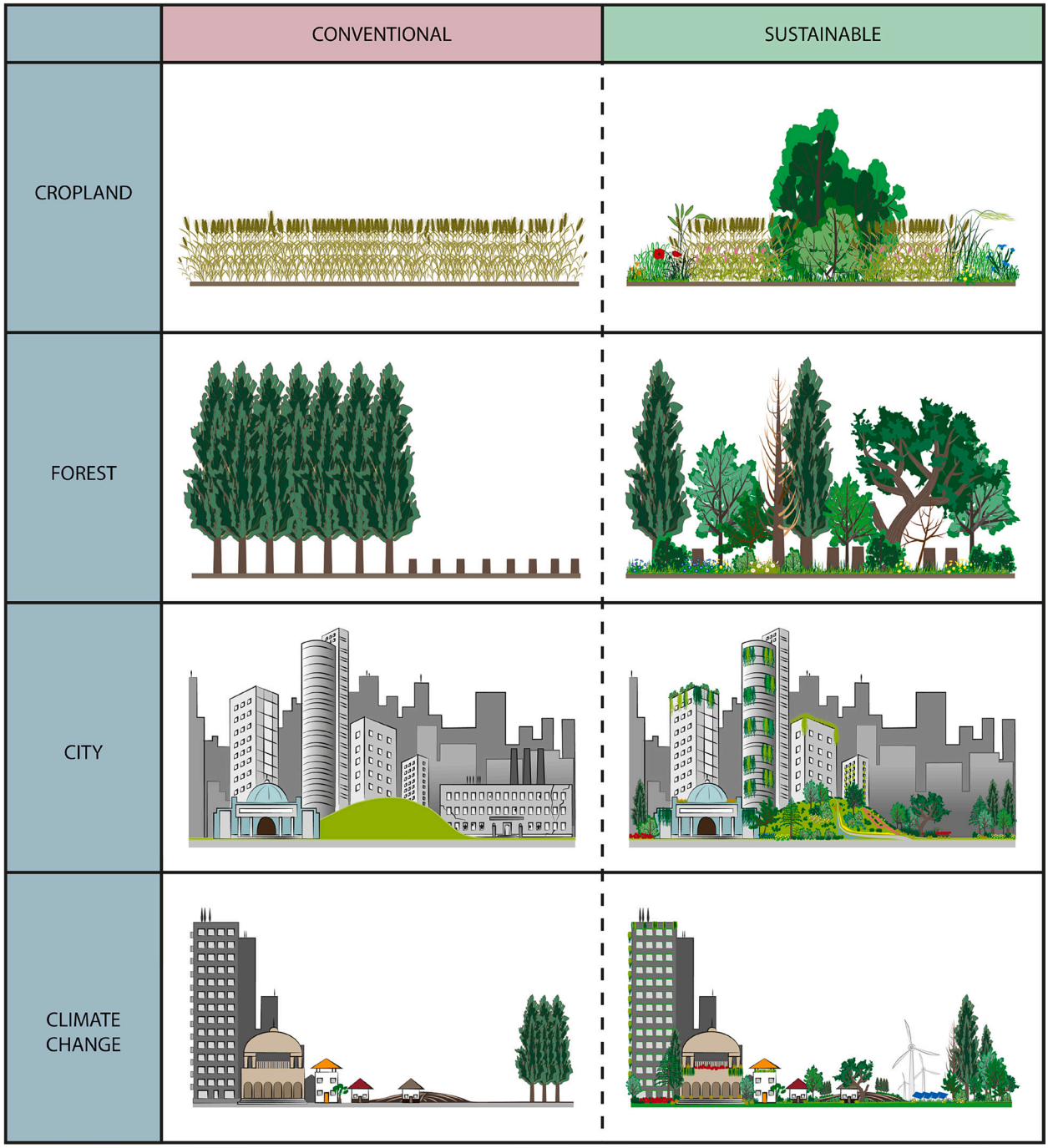

Fig. 1. Conceptual illustration of the roadmap from conventional toward sustainable land use supporting high biodiversity. Cropland: From monocultures to diversified cropland, integrating crop mixtures, semi-natural field margin strips and hedges, as well as small field size (6). Forest: From monodominant stands and clearings to diversified tree stands, herbaceous and shrub vegetation, as well as remains of old trees and deadwood (7). City: From densified, gray cities to green cities with planted roofs and buildings as well as diversified gardens, parks, and other green spaces (8). Climate change: From land use allowing heat accumulation and greenhouse gas production to diversified greening with effective CO_2 sequestration and green energy (9).

much richer, especially with low-intensity grazing or mowing. Semi-natural grasslands, e.g., as part of low-intensity mixed farming, are of major importance for farmland biodiversity in agricultural landscapes (22). Interestingly, hedges and other woody structures can also greatly enhance bird richness, but not most ground-nesting birds, which avoid hedges (23).

In terms of the management of forests (providing 37% of habitable land globally), structural complexity, diversified measures such as harvesting, keeping old trees with deadwood, and a large-scale landscape perspective appear to be the best overall management strategy to maintain or restore biodiversity, in particular under climate change (7). Destruction of natural forests is an extreme threat in biodiversity hotspots, particularly in the tropics. In addition to forest degradation and loss, the spread of nonnative plantation forests is a major threat, as they miss complex and diverse vegetation, which is needed for a rich native bird community (24).

Urbanization is the most extreme form of environmental degradation, causing substantial declines in bird species richness (1), mainly in comparison to rural or near-natural

areas (8). Hence, species losses occur mainly at the interface between the green rural landscapes with their relatively high richness and the gray urban areas. Even though urbanized areas cover only <3% of the globe (compared to 50% agriculture), a strong increase in urbanization can be observed, to which only a limited number of synanthropic species can adapt well. Not only urban densification, but also urban sprawl, especially in countries where land is limited or in metropolis regions, poses a major threat to bird fauna. Well-connected urban green (and blue) infrastructures, including parks and gardens, as well as the greening of buildings, greatly help mitigating bird losses.

The results of the analyses of Rigal et al. provide convincing arguments for urgently needed changes in the European agricultural policy, with more emphasis on biodiversity-friendly and sustainable measures when balancing socioeconomic and ecological goods.

There are winners and losers for all pressures of land use, depending on the species' traits (1). Diet is an important filter, and agricultural intensification causes strong negative effects on invertebrates feeders (4) and urbanization disadvantages farmland birds and granivorous species, while increasing forest cover helps long-distance migrants (1). In future large-scale analyses, further important traits may be considered, such as nesting place (e.g., ground, shrub, tree, or cavity) and foraging stratum (e.g., ground, understory, bark, canopy feeders), which are known to be influenced by the amount of tree, shrub, and grassy areas in all the three major land-use types studied here.

In conclusion, Rigal et al. (1) convincingly report the dramatic decline in bird diversity loss across Europe. There are winners and losers of land-use change, depending on traits such as diet preferences. For agriculture, the most important driver of species losses, the negative effects of agricultural intensification on insect feeders are particularly annoying, as this indicates a strong reduction in biological pest control (2). Agricultural intensification goes far beyond agrochemical use, and future research should consider a landscape perspective considering the beneficial role of small and diversified fields as well as a minimum of semi-natural habitat (6). Similarly, climate change is not restricted to the increase in temperature, and future research may analyze how changing patterns of precipitation are endangering biodiversity by uncommon dryness or wetness, and overall, by an increasing number of weather extremes (9). Further, biodiversity suffers from multiple pressures, interacting in an additive or even synergistic way, which is little explored so far (25). Last but not the least, any success in overcoming the current biodiversity crisis needs to broaden the view toward socioecological approaches (26), meeting global sustainability goals.

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