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PRACTITIONER'S PERSPECTIVE

How to design multifunctional landscapes?

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Abstract

1. The expansion of homogeneous landscapes has been a major driver of biodiversity loss, climate change and land degradation. There is an urgent need for a transition to multifunctional landscapes that provide abundant and nutritious food while also delivering several other contributions essential for a good quality of life. However, implementing this process, especially in large-scale agriculture without economic subsidies, remains unclear.
2. We discuss guidelines for a transition to multifunctional landscapes based on science and our experience as practitioners. In this transition, practitioners manage crop fields, natural habitats and field edges.
3. We propose an iterative process for designing multifunctional landscapes. Initially, at a fine-scale resolution, we identify and classify areas with low opportunity costs (e.g. low crop productivity) or a high appreciation for nature (e.g. near housing areas). These areas are categorized into either 'wide' patches or 'narrow' corridors (i.e. edges <100 m wide). Subsequently, wide patches (including those with remnants of native species regardless of size) are allocated for natural habitat restoration (covering at least 20% of the farmland), while narrow zones are designated as biological corridors (making up at least 10% of the farmland and designed to be 50–100 m wide). Also, field size and configuration are redesigned to enhance the efficiency of agricultural practices and edge density. This entails creating smaller fields with strip cropping that follows environmental heterogeneity, instead of relying on large, squared monocultures. Ultimately, this design is continually refined through engagement with stakeholders, incorporating cost–benefit analyses, as well as a process of ongoing monitoring, evaluation and mutual learning.
4. *Synthesis and applications*. We describe an iterative process by which large-scale agriculture can support biodiversity and leverage nature's contributions to people while providing more nutritious food and stabilizing crop yields and profits. Multifunctional landscapes will be critical in achieving the targets of the Kunming-Montreal Global Biodiversity Framework by 2030 and moving the world towards net-zero emissions by 2050.

KEYWORDS
agroecology, habitat restoration, land use change, landscape design, nature-based solutions, nature's contributions to people, precision agriculture

1 | INTRODUCTION

Landscapes hosting farming, ranching and/or forestry activities are expanding and becoming increasingly homogeneous (Kremen & Merenlender, 2018; Tscharntke et al., 2021). The homogenization of landscapes, in terms of both landscape composition and configuration, stands as one of the main drivers of biodiversity loss and is responsible for the degradation of many of nature's contributions to people (Brauman et al., 2020; Kremen & Merenlender, 2018; Tscharntke et al., 2021). There is an urgent need to transform these homogeneous landscapes into multifunctional ones, capable of providing not only nutritious food in large quantities but also several other essential contributions to human life. Multifunctional landscapes play a crucial role in maintaining a good quality of life by ensuring soil protection and regeneration, water and air purification, pollination, pest control, ocean acidification dampening and climate change mitigation, while also mitigating the impacts of natural hazards such as hurricanes, landslides and floods (Brauman et al., 2020; Kremen & Merenlender, 2018; Tscharntke et al., 2021). Additionally, multifunctional landscapes contribute to the provision of food, feed, energy, medicines, genetic resources and support non-material aspects of a good quality of life, including learning, inspiration, physical and psychological experiences and cultural identities (Brauman et al., 2020). However, the process of transforming homogeneous landscapes into multifunctional ones remains unclear, particularly in large-scale farming settings in countries where economic subsidies to agriculture are non-existent. Moreover, perceived trade-offs between nature conservation and agricultural profits exist in regions like many grain-exporting farming belts in the global south (Tittonell et al., 2020).

Based on scientific evidence and our own experience as practitioners, we present here a six-step process for designing and implementing multifunctional landscapes, with a focus on large-scale agriculture (Figure 1). Additionally, we provide a series of concrete actions and their potential benefits to consider during this process (Table 1). While there are many practices to increase multifunctionality within the crop field (e.g. service crops, crop rotations), these have been discussed elsewhere (Kremen & Merenlender, 2018; Tscharntke et al., 2021). In this article, our focus lies on the design of the size and configuration of different habitat types, such as natural habitats, field edges and crop fields.

2 | STEP ONE: IDENTIFY AREAS WITH LOW OPPORTUNITY COST OR HIGH APPRECIATION OF NATURE AND CLASSIFY THEM INTO WIDE PATCHES AND NARROW CORRIDORS

Areas with low opportunity costs are typically associated with low crop yield potential. These can be identified through precision agricultural machinery, which not only commonly monitors crop yield but also topography. Remote sensing tools can complement this process. Phenological analysis based on vegetation indices helps to identify the less productive areas within crop fields. Remotely sensed agricultural applications involving time-series data have become more accessible with the emergence of cloud computing platforms like Google Earth Engine. Our experience on many farms indicates that certain areas are consistently sown as part of a larger management unit but yield negative profitability every year (refer to step five below). In fact, the extent of highly unprofitable land was determined to be 27% of row-crop land in Iowa during 2015 (Brandes et al., 2016). Such areas with low crop yield potential present a significant opportunity for biodiversity restoration and often hold high value in providing nature's contributions to people, such as wetland protection and corridors for valuable mammal species. Other areas to be considered in this step are those highly susceptible to erosion, such as steep slopes, or those that play critical roles in the drainage system. Therefore, the inclusion of topographic and surface drainage system maps is essential (Lovell & Johnston, 2009), including those illustrating surface water coverage under normal and extreme climatic conditions (Nosetto et al., 2015).

These areas can be classified into two categories, each allowing for different management regimes (see the next two sections). The first category includes areas with larger surface ('wide patches') suitable for natural habitat restoration, such as waterlogged lowlands and spots with subsurface soil limitations. The second category comprises areas with elongated shapes ('narrow corridors') that follow rivers, channels, dune crests and areas of heavy machinery and livestock transit. The latter are typically less than 100 m wide and are suitable for the development of biological corridors.

The same process of classifying wide patches and narrow corridors should also be applied to housing areas within the farm. Housing areas present a significant opportunity for restoration because they need to be protected from agrochemical drift; thus, they should not be located directly adjacent to conventional cropland. Additionally, in these areas, the non-material contributions of nature are highly valued. These contributions include physically and psychologically beneficial activities, healing, relaxation, recreation and aesthetic enjoyment based on contact with nature.

Areas still covered by native vegetation should be designated for natural habitat restoration, regardless of size. Restoration priorities should be directed towards natural habitat remnants, as they frequently support native species at the reproductive stage, including late successional ones that may require decades to establish in cleared areas. These areas can serve as stepping stones across the agricultural landscape, facilitating the emigration and immigration of species (Grass et al., 2019). Both residential areas and remnant native vegetation, especially woody patches, can be easily distinguished from the agricultural matrix through the use of remote sensing.

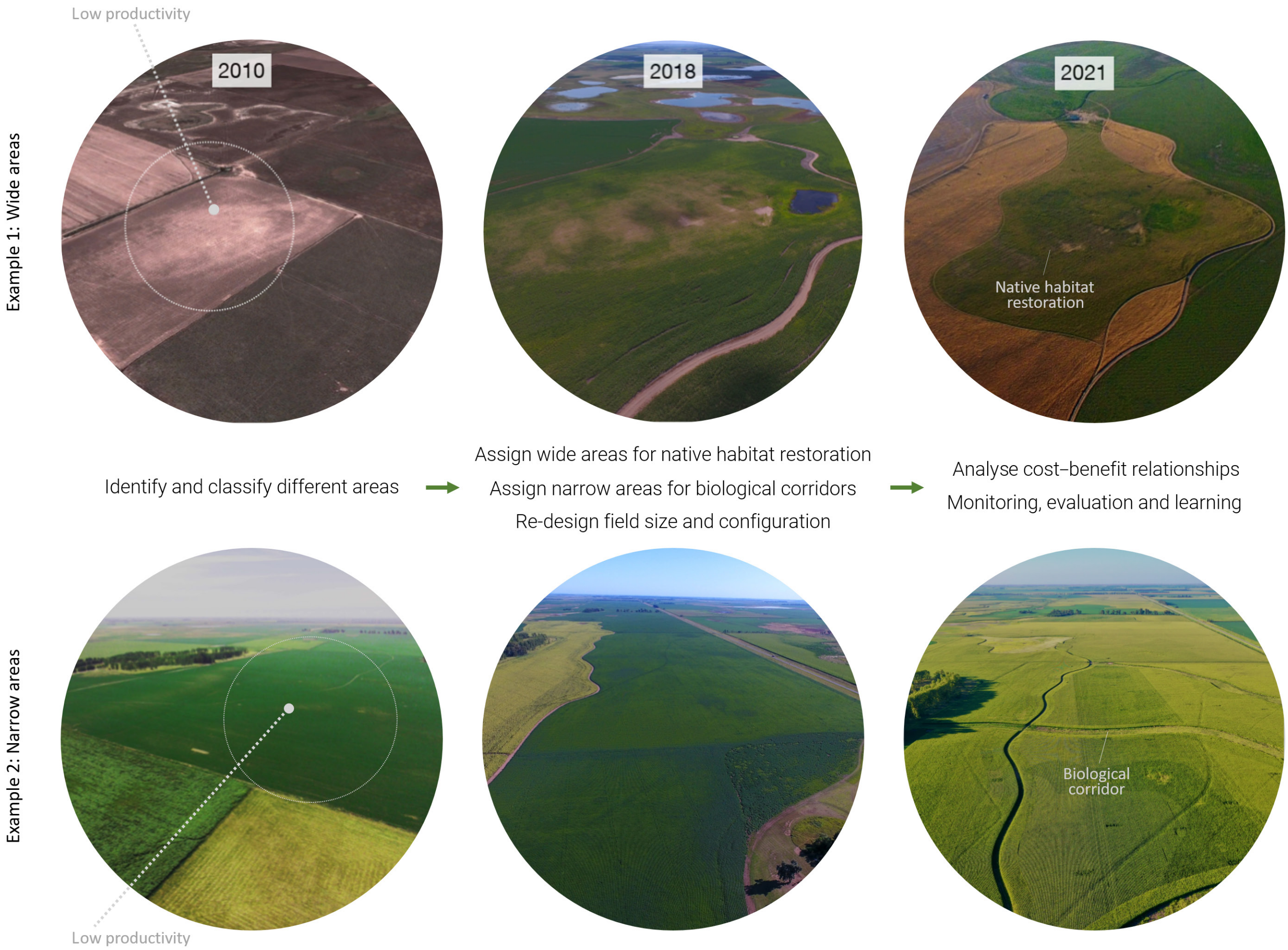

FIGURE 1 Transition to multifunctional landscapes in large-scale agriculture. We propose an iterative six-step process for designing and implementing multifunctional landscapes in areas dominated by large-scale monocultures, in which farmers manage not only crop fields but also natural habitats and field edges. The process is exemplified in a farm growing annual crops in La Pampa, Argentina. A progressive process allows for an effective transformation through monitoring, evaluation and learning. Transition is shown from left (initial condition) to right. Areas with low productivity were identified and turned into restored natural areas (wide patches, Example 1, top row) or biological corridors (narrow areas, Example 2, bottom row). In the process, field size is reduced, crop diversity increased and landscape connectivity enhanced.

By now, it should be clear that the multiple criteria for selecting areas for restoration are not mutually exclusive. For instance, a waterlogged lowland can represent an area with low crop yield potential, play a critical role in the drainage system, retain native vegetation and even be situated close to a housing area. Once the areas have been identified and classified, they are stored within a GIS-like geospatial environment to support subsequent steps.

3 | STEP TWO: ASSIGN WIDE PATCHES FOR NATURAL HABITAT RESTORATION

Our focus is to restore natural habitats within farming landscapes where little natural habitat remains. Such an approach complements, but does not replace, the need for protected areas (Grass et al., 2019; Kremen & Merenlender, 2018; Tscharntke et al., 2021). Natural habitats are those dominated by native species and are substantially similar in composition and structure to habitats that would have been present in the absence of intensive human activities. Keeping natural habitat does not mean that such areas are to be left untouched, as they can be grazed, mowed, harvested or burned where that is consistent with continued biodiversity conservation.

A recent review of scientific evidence suggests that at least 20% of natural habitat is needed within farming landscapes to support the provision of many of nature's contributions to people simultaneously (Garibaldi et al., 2021). This percentage arises as a minimum, rather than an optimum, and is a simple guide to detect the many landscapes worldwide that do not comply with such criteria (Garibaldi et al., 2021). Under conditions of spatial heterogeneity and/or where there are direct contributions from nature to crop productivity (e.g. crop pollination, biological pest control, minimization of soil erosion), this target can be achieved with little or no trade-offs with

TABLE 1 Characteristics of the approach to design and implement multifunctional landscapes, and recommendations on suggested actions and their benefits.

Characteristic	Actions	Benefits
Science-based	• Gather and analyse various types of geospatial information (topographic, edaphic, biological, hydric, productive etc.). • Involve researchers and technical staff as stakeholders. • Partner with recognized scientific institutions or consultants.	• Gain new and innovative insights. • Increase trust of stakeholders. • Reduce risks from unanticipated problems.
	• Select appropriate indicators to monitor, including nature and agronomic elements. • Combine the use of mapping and modelling approaches with field testing.	• Monitor effectively and efficiently.
	• Use available technology responsibly. • Explore new technologies including those from other disciplines.	• Lower the barriers to the transition by reducing time and overall cost (increase efficiency).
Participative	• Engage relevant stakeholders early in the process and keep them actively participating. • Consider current activities but also future activities that could be developed in the different habitats. • Keep in mind that the new design must be functional and practical to the dynamics of all stakeholders in the farm (e.g. machinery circulation, nature appreciation etc.).	• Increase trust of stakeholders • Facilitate the transition by leveraging synergistic interactions. • Improve acceptance and enjoyment of stakeholders • Reduce costs and increase income through new business opportunities.
Iterative	• Set achievable and measurable goals for the short and mid-term. • Depending on resources available, risk assessment and global impact of intervention, prioritize areas to target in the short, mid- and long term. • Set a clear monitoring and evaluation agenda and plan, including timing and monetary resources needed.	• Allow for adjustments reducing the risks. • Feed the learning process. • Increase trust of stakeholders.

crop productivity (see step five below; Garibaldi et al., 2021). However, variation exists in the land area needed for nature's distinct contributions to people, and the 20% minimum needs to be adapted to different socio-ecological contexts. Indeed, in forest ecosystems, and when prioritizing the conservation of both forest specialist and generalist species, it is suggested that landscapes should contain ≥40% forest cover (Arroyo-Rodríguez et al., 2020).

Restoration should take a 'fractal perspective', in which the >20% target is applied at all spatial scales, from single fields to whole landscapes (Garibaldi et al., 2021). At the smallest scale, enhancing regulating contributions, such as those provided by pollinators, is likely to require >20% within each 1×1 km area ($1\,km^2 = 100\,ha$). Natural habitats should be kept in place to allow the development of several generations of native species and for the persistence (or re-establishment) of native communities over time. The time frame should allow for recovery of soil fertility and establishment of a healthy soil seed bank. Distinct habitats with different levels of degradation will require different recovery times, which may also vary depending on the management strategy adopted.

4 | STEP THREE: ASSIGN NARROW AREAS (EDGES) FOR BIOLOGICAL CORRIDORS

Although many of the above recommendations for natural habitats also apply to the management of edges as biological corridors, we present the discussion in a different section, as edges can relate more to linear components of the landscape and might be planted with exotic species to increase multifunctionality (i.e. while the main focus of natural habitats is to restore native communities, this is not necessarily the case for edges). Many studies have shown the benefits of flowering plants at the edge of crop fields for pollinator conservation (Zamorano et al., 2020) and biological pest control (Albrecht et al., 2020). However, there is no clear recommendation of how large and wide these edges should be. Based on our experience with large-scale monocultures, edges should be at least 50 m wide, considering the influence of nearby machinery and agrochemical drift.

At early restoration stages, edges are commonly sown with a multispecies mix of herbaceous seeds, which can be grazed or maintained through regular cuts. Planting woody species (e.g. fruit or ornamental trees) is an interesting practice to increase structural complexity and species diversity. Trees should be planted at the centre of the 50 m to reduce the potential effects from light, nutrient or water competition with the crops. It is expected that trees will allow the establishment of a more diverse community of birds and, in turn, the arrival of a more diverse community of seeds. When available, native species should be preferred for both herbaceous and woody plants, while invasive species should always be avoided. Exotic but not invasive species can also enhance nature's contributions to people, such as many fruit trees outside their native habitat.

As practitioners, we commonly aim for more than 10% of farmland area covered with 50–100 m wide edges. If we add the 20% area of natural habitats discussed before, our guidelines for multifunctional landscapes are essential to achieve the 30% area restoration target by 2030 of the Kunming-Montreal Global Biodiversity

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Framework. Connectivity between narrow areas and between narrow and wide areas is desirable, as it can facilitate the re-establishment of native species that have been reduced or eliminated, and which can re-colonize from patches of native vegetation that remain in the landscape (Grass et al., 2019). Additionally, it can mitigate the risks associated with random events occurring on any particular site.

5 | STEP FOUR: RE-DESIGN FIELD SIZE AND CONFIGURATION

The scientific literature demonstrates numerous benefits associated with reducing field sizes, including increased crop yield (Magrach et al., 2022) and improved weed control (Garibaldi et al., 2023). However, there is still no definitive recommendation for the optimal size. Field configuration is even less clear, although it is generally anticipated that field shapes leading to a higher perimeter to area ratio, thus enhancing edge density (e.g. strips instead of squares), can enhance nature's contributions to people (Garibaldi et al., 2023).

Considering the positive impact of edge density on arthropod communities, which provide essential biological pest control and pollination services (Martin et al., 2019), a potential approach to counteract the adverse effects of large fields is to design them in strips. This strategy increases edge density without compromising the effective cropped area (Ditzler et al., 2021). Moreover, these strips can be tailored to account for environmental heterogeneity, such as varying soil conditions or water availability for crops. Conventional square designs in agricultural landscapes overlook this environmental diversity, but its consideration can streamline management while simultaneously boosting crop yield and nature's contributions to people. In summary, by decreasing field sizes and increasing edge density, the complexity and diversity of the landscape also increase. This shift promises associated benefits for both crop yield and nature's contributions to people (Magrach et al., 2022).

6 | STEP FIVE: ANALYSE COST–BENEFIT RELATIONSHIPS IN AN ITERATIVE PROCESS WITH STAKEHOLDERS

In the absence of subsidies or other governmental incentives, any strategy oriented towards supporting a transition to multifunctional landscapes in large-scale agriculture needs to ensure profits from the very beginning of the transition. Therefore, performing regular cost–benefit analysis is critical. Indeed, it might be perceived that multifunctional landscapes achieve lower crop yields and farmer profits than homogeneous landscapes. However, multifunctional landscapes can increase crop yields (and thus income) by enhancing pollination services for pollinator-dependent crops, which are increasingly in demand globally (Garibaldi et al., 2016); reducing erosion and improving soil biological activity and nutrient availability; slowing the rapid evolution of pests and weeds (Garibaldi et al., 2023; Gould et al., 2018); and/or preventing floods and regulating climate. Multifunctional landscapes can also be designed to reduce costs, as the above-described contributions to crop yield and yield stability can reduce the amount of inputs that farmers need to buy (e.g. herbicides, Garibaldi et al., 2023).

In our experience, reducing field sizes and strip cropping (see step 4 above) also respond to farmers' need to work more efficiently by adapting to landscape complexity (e.g. edaphic, topographic) that is being rediscovered thanks to high-precision technologies and data processing. Indeed, it has been shown that strip cropping can achieve higher and more stable profits than larger monocultures (Exner et al., 1999). Furthermore, during the last decades, precision agriculture has helped to identify many areas within agricultural fields that achieve negative profitability (Table 1), showing that farmers can save money leaving these areas out of production. Therefore, in general, the long-term economic and environmental benefits from a transition to multifunctional landscapes are likely to outweigh the initial costs of landscape transformation.

Importantly, profitability analyses need to be performed regularly as market conditions show great variability. There are also longer term tendencies in income opportunities. For example, the farm area that is affordable to leave out of crop production can increase over time if markets incorporate mechanisms for payments for ecosystem services. In this way, the design of multifunctional landscapes is a dynamic process.

Profitability, though important, is not the sole dimension guiding decision-making. An iterative process involving stakeholders is essential, where different versions of a landscape 'master plan' (Figure S1) and their consequences in terms of synergies and trade-offs across multiple dimensions are discussed (Lovell & Johnston, 2009). At this step, multicriteria and other decision-making tools can be implemented to consider trade-offs across nature's contributions to people. Participatory approaches are also critical to understand and account for potential trade-offs in stakeholders' needs (refer to Table 1 and also Doran, 1981; Tittonell et al., 2020).

7 | STEP SIX: IMPLEMENT MONITORING, EVALUATION AND LEARNING

Based on our experience, for transitions to multifunctional landscapes to be effective, they should be progressive and rely on monitoring the landscape's evolution, evaluating the results and continuous learning (see also Lovell & Johnston, 2009). Progressive transitions mean that innovations are implemented in steps or in small fractions of the farm initially. This ensures that mistakes or failures do not significantly impact the profitability of the entire farm. Once these innovations are tested, learned and successfully applied, their use is expanded across the farm, creating room for more innovations to enter the evaluation–implementation loop.

Effective monitoring involves measuring specific indicators, which need to be agreed upon beforehand (Doran, 1981) and should encompass both production and biodiversity aspects. Good indicators possess the following characteristics:

1. Practical: They are easy to measure using available resources.
2. Precise: They are operationally defined in clear terms and unambiguous.
3. Reliable: They can be consistently measured over time and are repeatable.
4. Timely: They can be measured at intervals relevant and appropriate to the goals.
5. Integrative: They combine several correlated variables into a single measure.

Evaluation entails quantitative analyses of the indicators, their variability and potential trade-offs or synergies among the processes or values they represent. Both monitoring and evaluation benefit significantly from involving specialized agents, such as scientists and technical staff. Finally, learning emerges from the integration of the above aspects, leading to a more holistic, qualitative analysis and conclusions, and the development of new narratives and proposals for further innovations (Figure 1).

8 | CONCLUSIONS

Today, technology (e.g. GIS, precision agriculture, remote sensing, artificial intelligence) provides immensely powerful tools that can offer extremely precise information and help implement innovative designs that were previously discarded as impractical for large-scale agriculture. We trust that the guidelines presented here can serve as a motivation to accelerate the transition to multifunctional landscapes in large-scale farming systems, especially where there are no external policy incentives and such changes must be stimulated by endogenous forces. We also expect to generate further discussions and incentive for research to account for the many knowledge gaps we have described (e.g. optimal size and shape of edges). In any case, we see that the transition to multifunctional landscapes has already begun in many places around the world (Lovell & Johnston, 2009), and that it is a process with enormous potential to enhance biodiversity and nature's contributions to people while providing more nutritious food and stabilizing crop yields and profits.

AUTHOR CONTRIBUTIONS

Lucas A. Garibaldi led the writing of the manuscript. Paula F. Zermoglio, Esteban G. Jobbágy, Lucas Andreoni, Alejo Ortiz de Urbina, Ingo Grass and Facundo J. Oddi contributed critically to the drafts and gave final approval for publication.

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CONFLICT OF INTEREST STATEMENT

None of the authors have a conflict of interest to declare.

DATA AVAILABILITY STATEMENT

This manuscript has no data.

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REFERENCES

Albrecht, M., Kleijn, D., Williams, N. M., Tschumi, M., Blaauw, B. R., Bommarco, R., Campbell, A. J., Dainese, M., Drummond, F. A., Entling, M. H., Ganser, D., Arjen de Groot, G., Goulson, D., Grab, H., Hamilton, H., Herzog, F., Isaacs, R., Jacot, K., Jeanneret, P., … Sutter, L. (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: A quantitative synthesis. *Ecology Letters*, *23*(10), 1488–1498. https://doi.org/10.1111/ele.13576

Arroyo-Rodríguez, V., Fahrig, L., Tabarelli, M., Watling, J. I., Tischendorf, L., Benchimol, M., Cazetta, E., Faria, D., Leal, I. R., Melo, F. P. L., Morante-Filho, J. C., Santos, B. A., Arasa-Gisbert, R., Arce-Peña, N., Cervantes-López, M. J., Cudney-Valenzuela, S., Galán-Acedo, C., San-José, M., Vieira, I. C. G., … Tscharntke, T. (2020). Designing optimal human-modified landscapes for forest biodiversity conservation. *Ecology Letters*, *23*(9), 1404–1420. https://doi.org/10.1111/ele.13535

Brandes, E., McNunn, G. S., Schulte, L. A., Bonner, I. J., Muth, D. J., Babcock, B. A., Sharma, B., & Heaton, E. A. (2016). Subfield profitability analysis reveals an economic case for cropland diversification. *Environmental Research Letters*, *11*(1), 014009. https://doi.org/10.1088/1748-9326/11/1/014009

Brauman, K. A., Garibaldi, L. A., Polasky, S., Aumeeruddy-Thomas, Y., Brancalion, P. H. S., DeClerck, F., Jacob, U., Mastrangelo, M. E., Nkongolo, N. V., Palang, H., Perez-Mendez, N., Shannon, L. J., Shrestha, U. B., Strombom, E., & Verma, M. (2020). Global trends in nature's contributions to people. *Proceedings of the National Academy of Sciences of the United States of America*, *117*(51), 32799–32805. https://doi.org/10.1073/pnas.2010473117

Ditzler, L., Apeldoorn, D. F. V., Schulte, R. P. O., Tittonell, P., & Rossing, W. A. H. (2021). Redefining the field to mobilize three-dimensional diversity and ecosystem services on the arable farm. *European Journal of Agronomy*, *122*, 126197. https://doi.org/10.1016/j.eja.2020.126197

Doran, G. T. (1981). There's a S.M.A.R.T. way to write management's goals and objectives. *Management Review* (*AMA Forum*), *70*, 35–36.

Exner, D. N., Davidson, D. G., Ghaffarzadeh, M., & Cruse, R. M. (1999). Yields and returns from strip intercropping on six Iowa farms. *American Journal of Alternative Agriculture*, *14*(2), 69–77. https://doi.org/10.1017/s0889189300008092

Garibaldi, L. A., Carvalheiro, L. G., Vaissiere, B. E., Gemmill-Herren, B., Hipolito, J., Freitas, B. M., Ngo, H. T., Azzu, N., Saez, A., Astrom, J., An, J., Blochtein, B., Buchori, D., Garcia, F. J. C., Oliveira da Silva, F., Devkota, K., Ribeiro, M. D. F., Freitas, L., Gaglianone, M. C., … Zhang, H. (2016). Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms. *Science (New York, N.Y.)*, *351*(6271), 388–391. https://doi.org/10.1126/science.aac7287

Garibaldi, L. A., Goldenberg, M. G., Burian, A., Santibañez, F., Satorre, E. H., Martini, G. D., & Seppelt, R. (2023). Smaller agricultural fields, more edges, and natural habitats reduce herbicide-resistant weeds. *Agriculture, Ecosystems and Environment*, *342*(November 2022), 108260. https://doi.org/10.1016/j.agee.2022.108260

Garibaldi, L. A., Oddi, F. J., Miguez, F. E., Bartomeus, I., Orr, M. C., Jobbágy, E. G., Kremen, C., Schulte, L. A., Hughes, A. C., Bagnato, C., Abramson, G., Bridgewater, P., Carella, D. G., Díaz, S., Dicks, L. V., Ellis, E. C., Goldenberg, M., Huaylla, C. A., Kuperman, M., … Zhu, C.-D. (2021). Working landscapes need at least 20% native habitat. *Conservation Letters*, *14*, e12773. https://doi.org/10.1111/conl.12773

Gould, F., Brown, Z. S., & Kuzma, J. (2018). Wicked evolution: Can we address the sociobiological dilemma of pesticide resistance? *Science*, *360*(6390), 728–732. https://doi.org/10.1126/science.aar3780

Grass, I., Loos, J., Baensch, S., Batáry, P., Librán-Embid, F., Ficiciyan, A., Klaus, F., Riechers, M., Rosa, J., Tiede, J., Udy, K., Westphal, C., Wurz, A., & Tscharntke, T. (2019). Land-sharing/-sparing connectivity landscapes for ecosystem services and biodiversity conservation. *People and Nature*, *1*(2), 262–272. https://doi.org/10.1002/pan3.21

Kremen, C., & Merenlender, A. M. (2018). Landscapes that work for biodiversity and people. *Science*, *362*, eaau6020. https://doi.org/10.1126/science.aau6020

Lovell, S. T., & Johnston, D. M. (2009). Creating multifunctional landscapes: How can the field of ecology inform the design of the landscape? *Frontiers in Ecology and the Environment*, *7*(4), 212–220. https://doi.org/10.1890/070178

Magrach, A., Giménez-García, A., Allen-Perkins, A., Garibaldi, L. A., & Bartomeus, I. (2022). Increasing crop richness and reducing field sizes provide higher yields to pollinator-dependent crops. *Journal of Applied Ecology*, *60*(January), 1–14. https://doi.org/10.1111/1365-2664.14305

Martin, E. A., Dainese, M., Clough, Y., Báldi, A., Bommarco, R., Gagic, V., Garratt, M. P. D., Holzschuh, A., Kleijn, D., Kovács-Hostyánszki, A., Marini, L., Potts, S. G., Smith, H. G., Al Hassan, D., Albrecht, M., Andersson, G. K. S., Asís, J. D., Aviron, S., Balzan, M. V., … Jeanneret, P. (2019). The interplay of landscape composition and configuration: New pathways to manage functional biodiversity and agroecosystem services across Europe. *Ecology Letters*, *22*, 1083–1094. https://doi.org/10.1111/ele.13265

Nosetto, M. D., Paez, R. A., Ballesteros, S. I., & Jobbágy, E. G. (2015). Higher water-table levels and flooding risk under grain vs. livestock production systems in the subhumid plains of the Pampas. *Agriculture, Ecosystems and Environment*, *206*, 60–70. https://doi.org/10.1016/j.agee.2015.03.009

Tittonell, P., Piñeiro, G., Garibaldi, L. A., Dogliotti, S., Olff, H., & Jobbagy, E. G. (2020). Agroecology in large scale farming—A research agenda. *Frontiers in Sustainable Food Systems*, *4*, 584605. https://doi.org/10.3389/fsufs.2020.584605

Tscharntke, T., Grass, I., Wanger, T. C., Westphal, C., & Batáry, P. (2021). Beyond organic farming—Harnessing biodiversity-friendly landscapes. *Trends in Ecology & Evolution*, *36*(10), 919–930. https://doi.org/10.1016/j.tree.2021.06.010

Zamorano, J., Bartomeus, I., Grez, A. A., & Garibaldi, L. A. (2020). Field margin floral enhancements increase pollinator diversity at the field edge but show no consistent spillover into the crop field: A meta-analysis. *Insect Conservation and Diversity.*, *13*, 519–531. https://doi.org/10.1111/icad.12454

BIOSKETCHES

Lucas A. Garibaldi is an agronomist motivated by research to promote sustainable farming transitions, with an emphasis on biodiversity, healthy food production and physical and mental well-being.

Paula F. Zermoglio is a biologist who carries out research in insect diversity and ecology, particularly associated with human productive activities.

Esteban G. Jobbágy is an agronomist dedicated to understand managed ecosystems and the interplay of human decisions and natural processes at multiple scales, with a particular focus on water and nutrient cycling.

Lucas Andreoni is an agricultural consultant of extensive farms in Argentina that motivate and support farmers to manage their farms towards a sustainable agroecosystem, focusing on regenerative practices regarding soils and biodiversity. To achieve this goal, he is also involved in designing public policies at regional level.

Alejo Ortiz de Urbina is an artist and an entrepreneur searching for a more sustainable way of managing large-scale croplands and innovates landscape design solutions through the combination of his farming experience and landscaping designs along the Argentinean pampas countryside.

Ingo Grass is an ecologist whose research aims to find solutions to reconcile biodiversity conservation and agricultural production.

Facundo J. Oddi is a forester with training in GIS and remote sensing technology, which he uses to study problems related to land use.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Figure S1. Example of a master plan developed for Terregal farm, La Pampa, Argentina.

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