Notes Académiques
de l'Académie d'agriculture de France

Academic Notes
of the French Academy of agriculture

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Title :
Ecosystem services for a global agroecological transition / Services écosystémiques pour une transition agroécologique à l'échelle mondiale

Year :
2023. Volume 16. Number 4. pp. 1-13.

Published online:
18 October 2023.
https://doi.org/10.58630/pubac.not.a724686

Notes académiques de l'Académie d'agriculture de France
Academic Notes from the French Academy of Agriculture
(N3AF)
Point de vue

Ecosystem services for a global agroecological transition

Services écosystémiques pour une transition agroécologique à l'échelle mondiale

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Résumé

Il y a désormais des preuves scientifiques claires de l'existence de limites planétaires caractérisant l'équilibre de la planète depuis les débuts de l'agriculture et des villes, il y a 10 000 ans, et que nos modèles de consommation (en particulier alimentaire) des 50 dernières années ont contribué à largement dépasser (climat, biodiversité, eau, pollution, cycles biogéochimiques). Le concept des limites planétaires appelle un nouveau paradigme pour régénérer, selon les principes de l'agroécologie, les services écosystémiques (de support, de prélèvement, de régulation et culturels) que l'agriculture intensive a trop souvent dégradés. Un équilibre doit ainsi être trouvé entre une proportion de la planète à conserver intacte par des actions de conservation et de restauration, et une autre, où l'activité économique ne permet plus de conserver et restaurer, mais peut se transformer pour devenir régénérative et donner la priorité aux services écosystémiques locaux, y compris une part minimale d'habitats naturels dans les zones agricoles.

Abstract

There is now clear scientific evidence of the existence of planetary boundaries characterizing the equilibrium of the planet since the beginnings of agriculture and cities 10,000 years ago, and which our consumption patterns (especially food) of the last 50 years have contributed to largely exceed (climate, biodiversity, water, pollution, biogeochemical cycles). The planetary boundaries concept calls for a new paradigm to regenerate, following the principles of agroecology, the ecosystem services (support, harvesting, regulation and cultural services) that intensive agriculture has too often degraded. A balance must be found between a proportion of the planet to be kept intact through conservation and restoration actions, and another where economic activity no longer allows for conservation and restoration but can be transformed by becoming regenerative and prioritizing local ecosystem services, including a minimum share of natural habitats in agricultural areas.

Mots clés
agriculture, biodiversité, services écosystémiques, limites planétaires, agroécologie, agriculture régénérative

Keywords
agriculture, biodiversity, ecosystem services, planetary boundaries, agroecology, regenerative agriculture

Introduction

The agroecological transition still balances, in France as well as in the world, between a rather productivist vision based on a narrative aiming to "feed the world", in which global production, of which one third is lost or wasted, includes cattle feed and the supply of biofuels; and a more resolutely ecological vision, which argues that "we will not feed the world with a degraded nature".
As part of the European Green Deal (European Commission, 2021), the European Union is trying to change the paradigm of European agriculture towards a more environment-friendly and regenerative one, namely through its ''Farm to Fork'' (F2F) strategy (European Commission, 2020), that recommends a drastic reduction of pesticides and fertilizers use. However the COVID-19 pandemic disrupted many value chains at different times and places between 2020 and 2021, subsequently raising tensions on food commodities, that have been further amplified by the war in Ukraine since 2022. Voices rose arguing that the F2F Strategy would result into very significant production declines, hence adding even more tension on food supply (Bremmer *et al.*, 2021). Yet other authors, when observing the 20-year crop yield stagnation (Brisson *et al.*, 2010; Grassini *et al.*, 2013; Wiesmeier *et al.*, 2015 ; Schauberger *et al.*, 2018) questioned the value added by pesticides and fertilizers and argued that such stagnation could be mostly due to the loss of ecosystem services in monoculture systems under conventional agriculture (Poux and Aubert, 2018). Two more recent studies conducted in Germany and the US on the impact of regenerative agriculture (which has long been associated with lower yields) on winter wheat, barley, and rapeseed even showed yield increases, while avoiding yield losses under drought (Kurth *et al.*, 2023; Petry *et al.*, 2023).
The objective of this article is to review how the most recent science, founded on the concept of planetary boundaries, informs the role that ecosystem services play in agriculture, and calls for more regenerative practices that intelligently combine land sparing and land sharing.

An agricultural model with out-of-control externalities?

Besides having more than covered an increasing demand for food, feed, fiber and fuel over the past decades, our agriculture has also generated significant environmental impacts. Today conventional agriculture is indeed one of the most impactful sectors on Earth, as it:
- generates 29% (21-37%) of greenhouse gas emissions (IPCC, 2019),
- consumes 69% of freshwater resources through evapotranspiration (UNESCO, 2021),
is responsible for 73% of deforestation (Díaz *et al.*, 2019),
- threatens 24,000 of the 28,000 (or 86%) species at risk of extinction (Benton *et al.*, 2021),
- has been responsible for half of the emerging infectious diseases of the past 75 years (UNEP, 2016).

Figure 1. Comparison between the economic value of the global food system with its externalities on health, the environment and the economy, in trillions of US $ (Pharo et al.*, 2019)*

The economic value of these impacts has been evaluated in the FOLU Growing Better global report (Pharo *et al.*, 2019), which estimated that negative economic externalities of our global food system were even higher than its economic value (Figure 1), with 25% of the negative externalities being on the environment, and 50% on human health.

Hence both from the global environmental and macro-economic points of view, there is now no doubt that our agricultural model can be considered as “out-of-control” and unsustainable.

The planetary boundaries: a framework to assess the “Earth ecosystem”

The vision that “we will not feed the world with a degraded nature” is based on the scientific evidence of existing planetary boundaries (Rockström *et al.*, 2009; Steffen *et al.*, 2015 ; Persson *et al.*, 2022) characterizing the balance of the planet since the beginning of agriculture and cities 10,000 years ago, and which our consumption patterns (especially food) over the past 50 years have contributed to largely exceed (climate, biodiversity, water, pollution, biogeochemical cycles) (Figure 2).

Those boundaries, of which several remain uncertain or challenging to determine scientifically, have however become an irreplaceable planning framework for numerous public and private decision makers. The litterature has shown that, to remain below planetary boundaries by 2050 (Willett *et al.*, 2019 ; Rockström *et al.*, 2020), our global agriculture should:

(1) become a CO_2 sink (to bring CO_2 atmospheric concentration below 350 ppm),
(2) reduce its nitrogen and phosphorus release into the environment,
(3) reduce its use of pesticides and herbicides,
(4) halt by 2020 the conversion of natural lands (forests, natural grassland, wetlands),
(5) restore biodiversity and its functions,
(6) marginally increase its water consumption.

All these may look very demanding, and this is where ecosystem services can be mobilized to maintain, or *a minima* return as close as possible to, the equilibrium that planet Earth has experienced for the past 10,000 years, while feeding a growing population.The above objectives are aligned with most principles of agroecology, supporting regenerative agriculture, a set of practices and principles increasingly adopted, and of which the recent definition was given by the One Planet for Biodiversity (OP2B) coalition is as follows (Petry *et al.,* 2023):

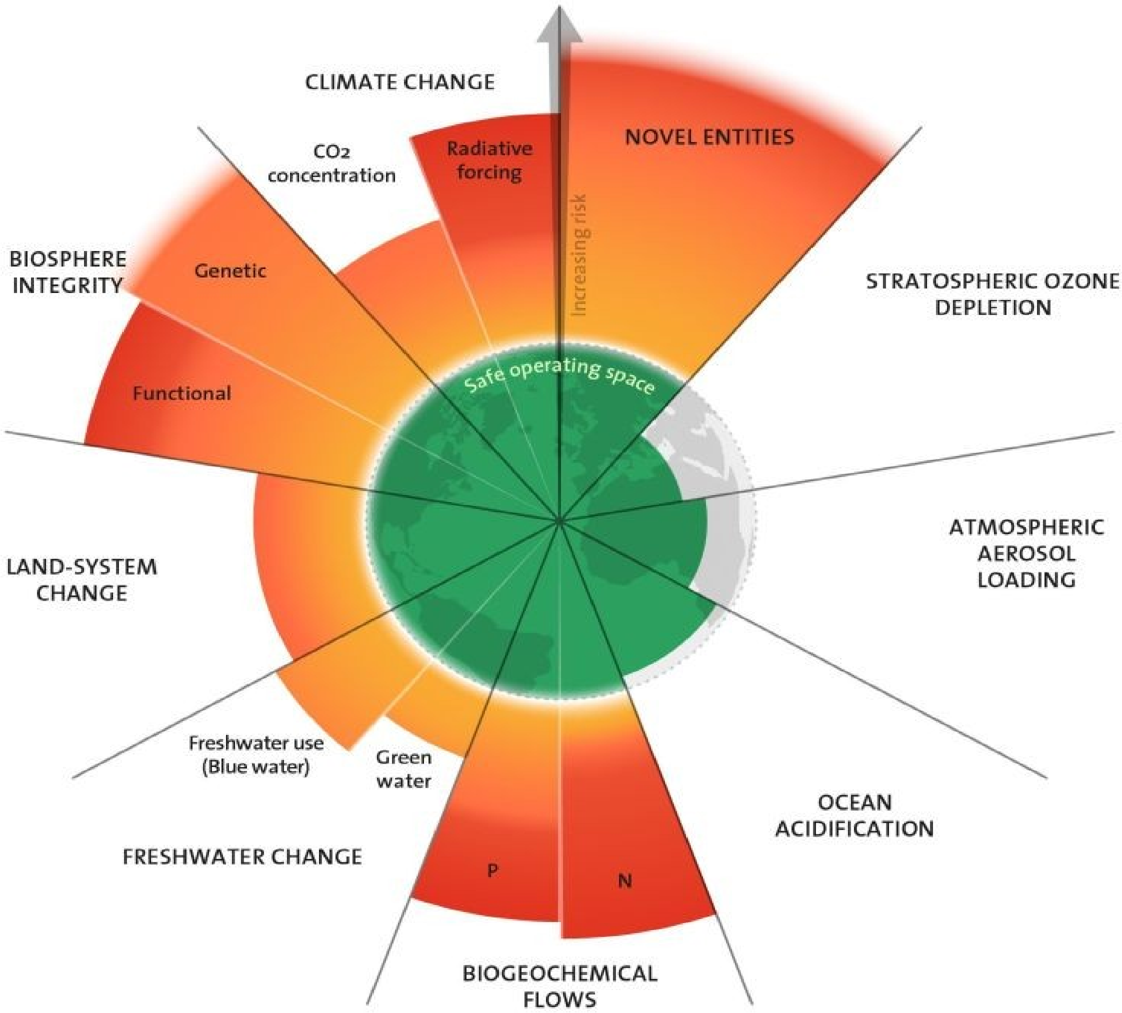

*Figure 2. The planetary boundaries: the green zone represents the "safe space for humanity", as defined by the stability of the environmental variables considered over the past 10,000 years (Holocene); the orange zone corresponds to an increasing risk for the major planetary equilibria; the planetary boundaries themselves are at the border between the green and orange zones. The variables considered have been normalized to correspond to the safe operating space. Novel entities include pollutants in general (*i.e.*, for agriculture: mostly plastics and pesticides)(Credits Azote for Stockholm Resilience Centre, based on the latest publications on the subject: Steffen* et al.*, 2015; Persson* et al.*, 2022; Richardson* et al.*, 2023).*

"Related to agroecological principles, regenerative agriculture is an outcome-based farming approach that generates agricultural products while improving soil health, biodiversity, climate, water resources, and supporting farming livelihoods.
Regenerative agriculture is a holistic approach that aims to, simultaneously, promote above- and

below-ground carbon sequestration, reduce greenhouse gas emissions, protect and enhance biodiversity in and around farms, improve water retention in the soil, reduce the use of pesticides, improve nutrient use efficiency, and support farming livelihoods."

The role of ecosystem services in agriculture

Scientists and economists usually estimate that the services provided by nature and ecosystems have an economic value that represents twice the world's Gross National Product (Costanza *et al.*, 2014). Indeed, nature provides humans with numerous services (known as ecosystem services) that are classified into four categories (Millenium Ecosystem Assessment, 2005):

(1) supporting services such as soil formation, photosynthesis, soil nutrient cycling, and species biodiversity, which support the other services below;

(2) provisioning services such as food, water, timber, fuel and fiber (paper, clothing);

(3) regulating services: climate, river regimes, diseases, waste, and water and air quality;

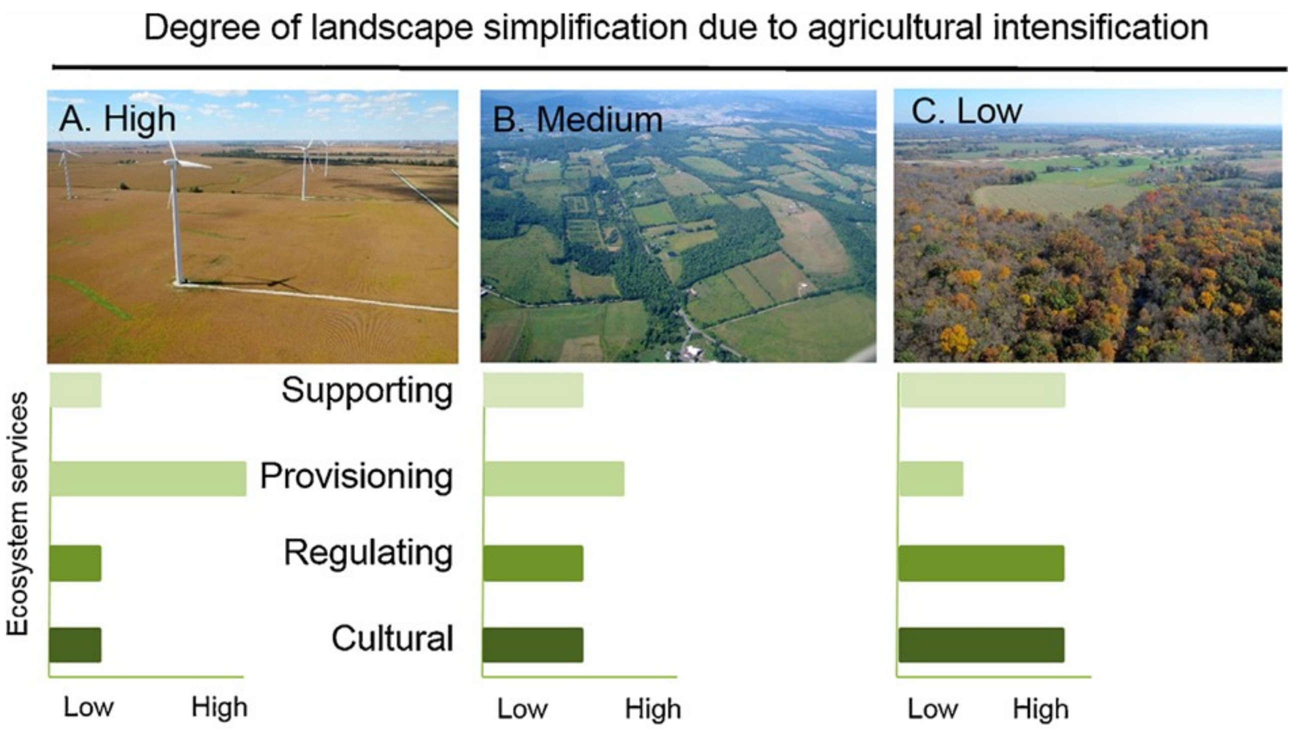

*Figure 3. Relative levels of current ecosystem services provided, and design goals for landscapes across a gradient of agricultural simplification. (A) Highly simplified landscape ranks high in productivity (*i.e.*, provisioning service) but low in supporting, regulation and cultural services. This can be a local consequence of land sparing, where "somewhere else" and not necessarily close by, land is spared for natural habitats. Among the design goals for such landscapes is to restore ecological integrity. (B) Moderately simplified landscapes may be less productive but with good supply of other services (a typical example of land sharing, with a better local balance between ecosystem services). (C) For landscapes with low levels of simplification, which can be the counterpart of (A) in a land sparing approach, goals may include increasing productivity without undue loss of other services (adapted from Landis, 2017).*

(4) cultural services that provide recreational, aesthetic, and spiritual benefits.
It seems obvious that conventional agriculture, as well as a "feed the world" narrative, tends to prioritize the provisioning services, which often results in reducing other services. On the other hand, regenerative agriculture, as well as a "we will not feed the world with a degraded nature" narrative, as they address the challenges imposed by planetary boundaries, tends to rebalance the four ecosystem services categories, especially recognizing the essential role of supporting services, without which others are at risk, including of course the provisioning ones. The prioritization of these ecosystem services at local, regional and global scales remains to a large extent the result of societal choices and trends, of which some have been mentioned in the introduction.
Ecosystem services also help unravel the limits of the land-sparing / land-sharing model, which is basically a conservation biology model, not an "ecological function" model, therefore aiming at the conservation of the greatest number of species and focusing on species biodiversity and abundance, which is only one of the many supporting ecosystem services.
In turn, taking ecosystem services into account to include agricultural functions such as pollination, pest disease control, soil carbon storage, etc., implies maximizing the greatest number of these functions, rather than the conservation of the greatest number of species (Phalan *et al.*, 2011 ; 2016 ; Kremen, 2015). Achieving an optimal balance among ecosystem services at the local scale tends to privilege land sharing, as shown on Figure 3.
A recent review of 98 meta-analyzes (Tamburini *et al.*, 2020) explored the impact of various regenerative practices fostering biodiversity in agriculture, namely crop diversification, addition

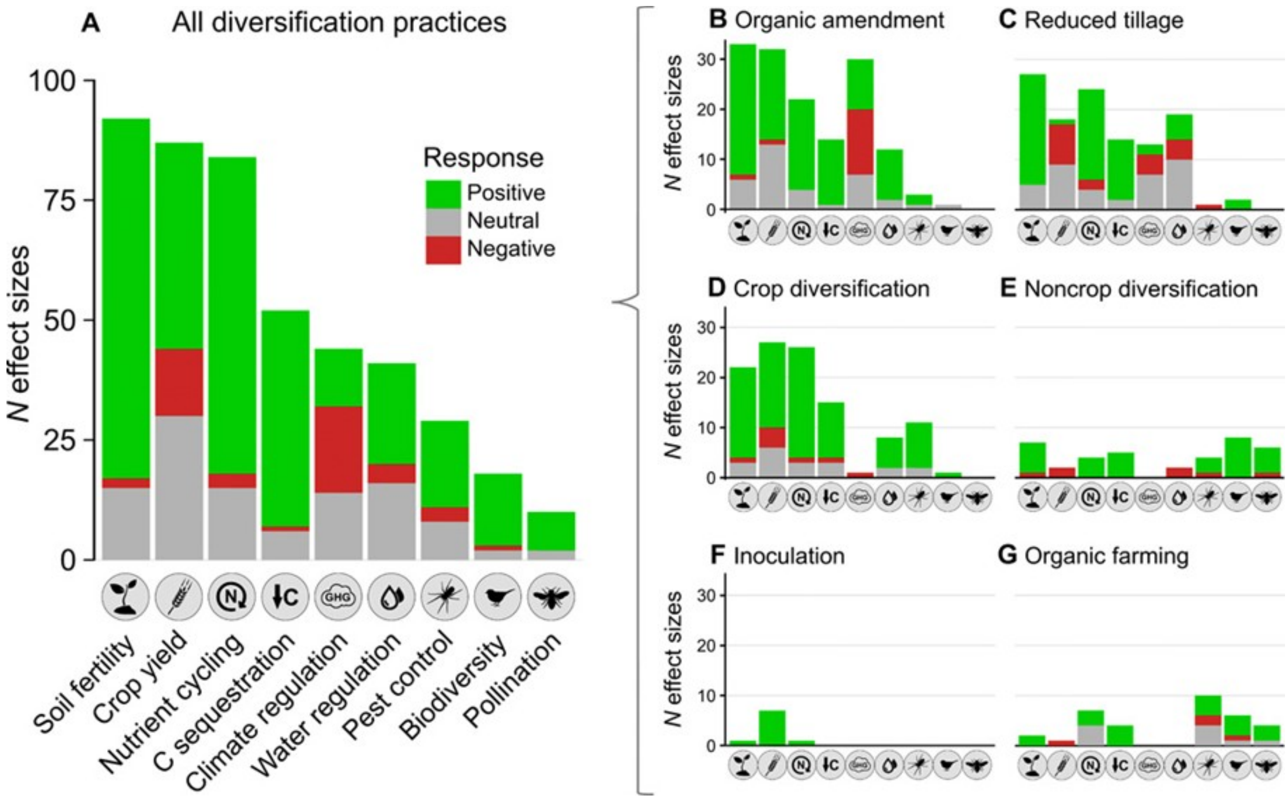

*Figure 4. Number of reported effect sizes (number of studies comparing agroecological practices with conventional high-input agriculture) with a significant positive (*green*), negative (*red*), or neutral (*gray*) response to agroecology (Tamburini* et al.*, 2020).*

of non-crop habitats within or around the field or in the surrounding landscape, organic amendment, inoculation of microorganisms into the soil, reduced tillage, and organic farming. It clearly demonstrated the multiple benefits of such practices, including on crop yields (Figure 4). It also showed that studies that considered non-crop habitats within or around the field or in the surrounding landscape (See E – Non Crop Diversification in Figure 4) overall show the positive impacts of land sharing, except on crop yield and water regulation.

Recent literature has confirmed that, locally, land sharing is a key, yet often forgotten, element of regenerative agriculture. Indeed many authors have shown the benefits of a higher density of semi-natural habitat and increased agricultural landscape complexity in providing essential ecosystem functions, in particular pollination, biological pest control and climate regulation, and in preventing soil erosion, nutrient loss and water contamination, suggesting that at least 10–20% of semi-natural habitat per km^2 was needed to ensure ecosystem functions (Tscharntke *et al.*, 2012 ; Montoya *et al.*, 2019; Garibaldi *et al.*, 2020 ; DeClerck *et al.*, 2023). A recent metareview explored the minimum quantity of semi-natural habitat (land sharing) required for provisioning of these services, confirming this 10-20% threshold as shown in Figure 5 (Mohamed *et al.*, 2022).

On the role on crop yields, a recent and broader study explored the synergies and trade-offs between biodiversity and yield from 43 studies across 18 countries around the world and observed win-win outcomes for biodiversity and

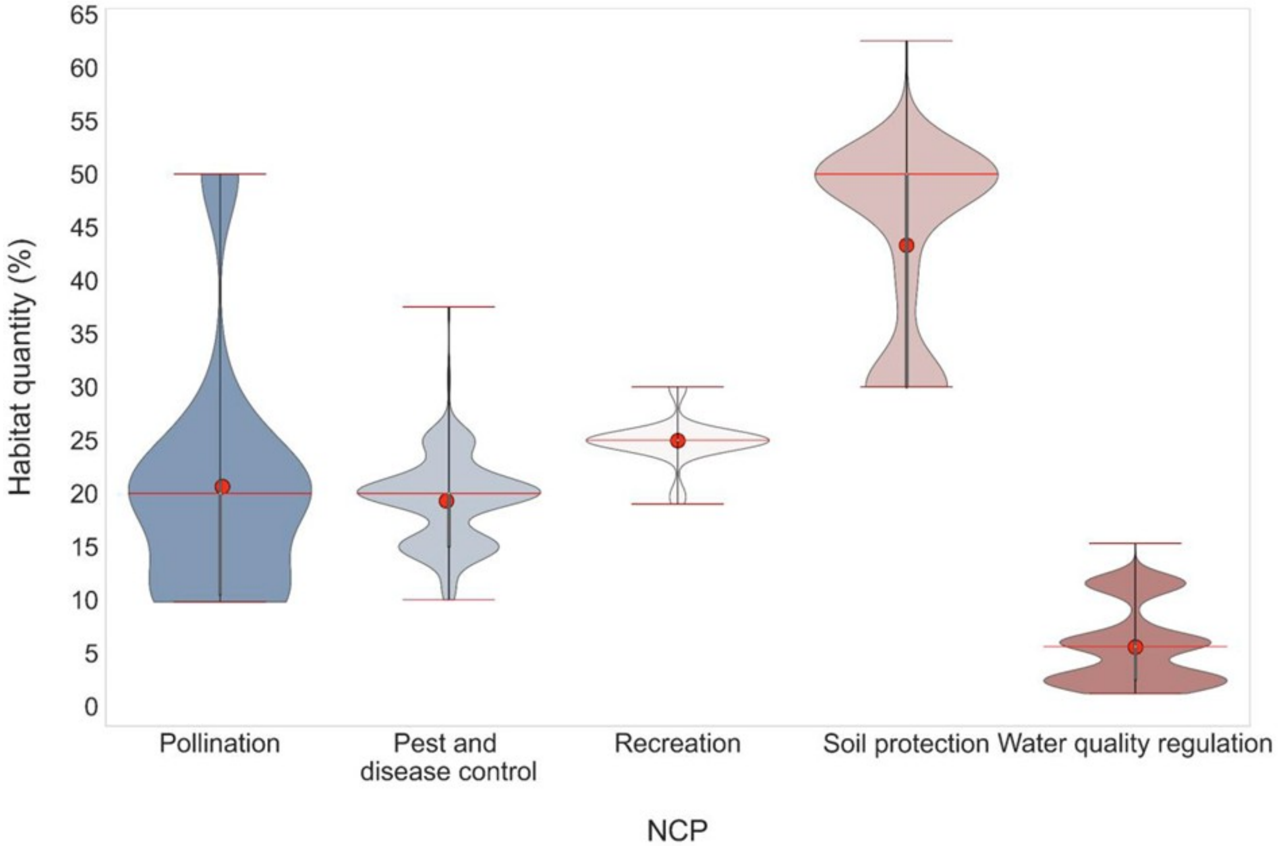

Figure 5. Threshold minimum quantity of habitat required for provisioning of ecosystem services. The lower and upper red lines correspond to the whiskers (min, max, respectively) indicating the range of the data. The middle red line represents the median, while the red dot represents the weighted mean value (Mohamed et al.*, 2022).*

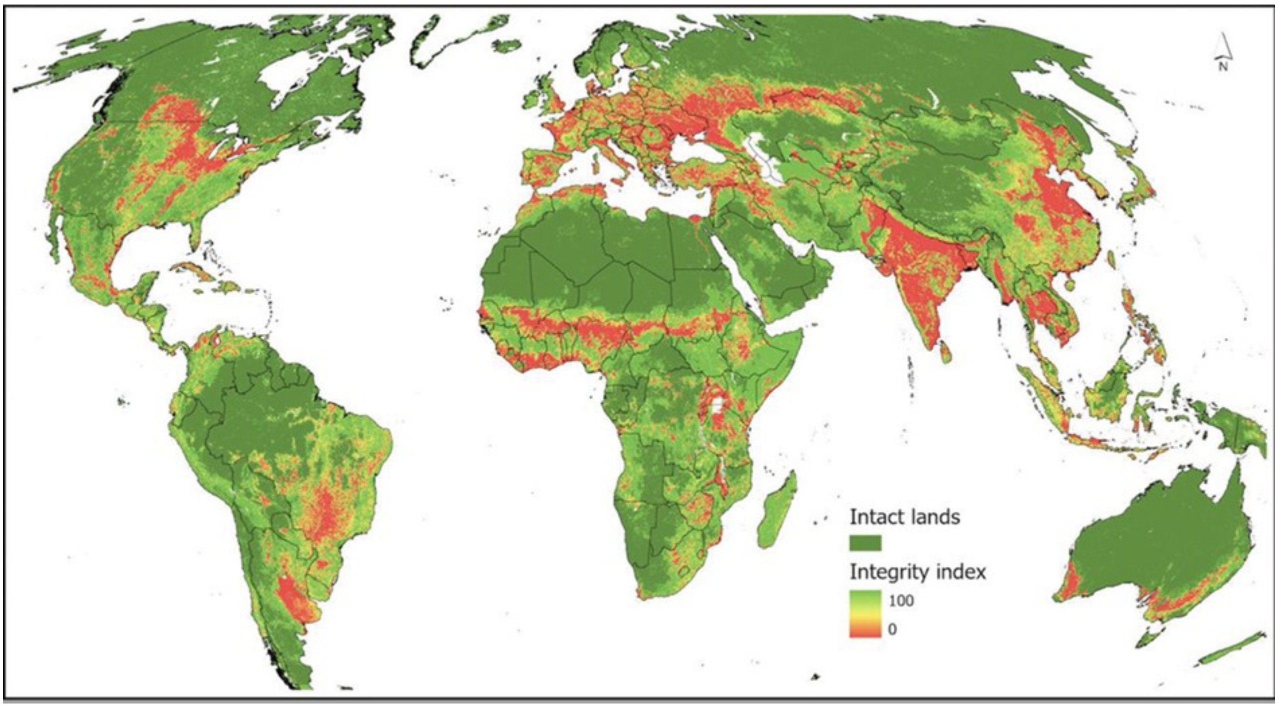

Figure 6. Global distribution of biodiversity intactness (dark green) and ecological integrity. Regions in red are below proposed thresholds for biodiversity in agriculture (DeClerck et al.*, 2023).*

yield in only 23% of cases (Jones *et al.,* 2023). Such outcomes were more likely in temperate climates when combining multiple crops and landscape diversification and using no agrochemicals

Towards a regenerative approach intelligently combining land sharing and land sparing

A recent synthesis from the scientific committee of the UN Food Systems Summit (UNFSS) (Braun *et al*., 2023), recommended to combine conservation, restoration and regeneration to ensure the world food security, as follows (DeClerck *et al.*, 2023).

(1) *"Agriculture must spare space for biodiversity to meet global environmental goals (*i.e., *land sparing):*

• *Halting the expansion of agriculture into intact ecosystems is necessary to halt the loss of biodiversity and mitigate climate change, and is likely to contribute significantly to stabilizing hydrological cycles.*

• *Restoring 15% of converted lands in priority areas could avoid 60% of expected extinctions and help provide vital ecosystem services, such as sequestering 30% of the total CO_2 increase in the atmosphere since the Industrial Revolution.*

(2) At least 10–20% of semi-natural habitat per km^2 (i.e., *land sharing) is needed to ensure ecosystem functions, notably, pollination, biological pest control and climate regulation, and to prevent soil erosion, nutrient loss and water contamination. Today, 18–33% of agricultural lands are below these respective threshold values for biological integrity."*

The first bullet point clearly concerns the global and regional scales, whereas the second one concern the local scales, as exemplified in our argument above.

The map in Figure 6 shows the areas that are below the thresholds proposed above for biodiversity in agriculture, showing that much agricultural land has lost integrity, so that the remaining quantity of natural habitat is insufficient to provide ecosystem services. Hence the call for increased local land sharing.

A balance must hence be found between a proportion of the planet to be kept intact through conservation and restoration actions (land sparing at global and regional scales) and another where economic activity no longer allows for conservation and restoration, but which can be transformed to become regenerative by including a minimum share of natural habitats in agricultural and urban areas (land sharing at local scales).

Conclusions

Reviewing the most recent science studies, including the concept of planetary boundaries, this article explores how ecosystem services and the role they play in agriculture, and aims to provide a better guidance for the agroecological transition towards increased regenerative practices in agriculture.

The evidence reviewed in this paper demonstrates that following a regenerative approach taking local ecosystem services into account to include agricultural functions (such as pollination, biological pest control, climate regulation, prevention of soil erosion, nutrient retention and reduced water contamination) implies maximizing the greatest number of these functions, rather than conserving the greatest number of species as suggested by the continually debated “land sparing *vs* land sharing” model.

To ensure our agriculture remains within the planetary boundaries, we therefore recommend combining ecosystems conservation and restoration (including land sparing at global and regional scales) and ecosystems regeneration (including land sharing at local scale). This follows the recent UN Food Systems Summit (UNFSS) recommendation to spare space for biodiversity to meet the global environmental goals of halting the expansion of agriculture into intact ecosystems and restoring 15% of converted lands in priority areas, and to share the rest of the (cultivated) space with at least 10–20% of semi-natural habitat per km^2 to ensure ecosystem functions through a more regenerative approach of agriculture such as agroecology.

Acknowledgements

The author wishes to acknowledge Denis Couvet (FRB) and Fabrice DeClerck (CGIAR) for the useful discussions that have led to this review paper.

Conflicts of interest

The author declares no conflict of interest.

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Rubrique
Cet article a été publié dans la rubrique « Points de vue » des *Notes académiques de l'Académie d'agriculture de France.*

Reçu
25 avril 2023

Accepté
7 septembre 2023

Publié
18 octobre 2023

Édité par
Anonyme

Rapporteurs
1. Anonyme
2. Anonyme

Citation

Vidal A. 2023. Ecosystem services for a global agroecological transition, *Notes académiques de l'Académie d'agriculture de France / Academic Notes from the French Academy of Agriculture (N3AF),* 16(4), 1-13.
https://doi.org/10.58630/pubac.not.a724686.

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