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Sustainable high-yield farming is essential for bending the curve of biodiversity loss

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Food production does more damage to wild species than any other sector of human activity, yet how best to limit its growing impact is greatly contested. Reviewing progress to date in interventions that encourage less damaging diets or cut food loss and waste, we conclude that both are essential but far from sufficient. In terms of production, field studies from five continents quantifying the population-level impacts of land sharing, land sparing, intermediate and mixed approaches for almost 2000 individually assessed species show that implementing high-yield farming to spare natural habitats consistently outperforms land sharing, particularly for species of highest conservation concern. Sparing also offers considerable potential for mitigating climate change. Delivering land sparing nevertheless raises several important challenges—in particular, identifying and promoting higher yielding farm systems that are less environmentally harmful than current industrial agriculture, and devising mechanisms to limit rebound effects and instead tie yield gains to habitat conservation. Progress will depend on conservationists forging novel collaborations with the agriculture sector. While this may be challenging, we suggest that without it there is no realistic prospect of slowing biodiversity loss.

This article is part of the discussion meeting issue 'Bending the curve towards nature recovery: building on Georgina Mace's legacy for a biodiverse future'.

1. Introduction

The scale and speed of the extinction crisis demand innovative thinking and bold responses. More than 50 years after recognizing the problem, and despite dozens of international agreements, near-daily calls to action and billions of dollars invested in conservation interventions, we are still collectively failing to bend the curve of biodiversity's decline [1,2]. Continued business-as-usual conservation will not turn things around, and we are fast running out of time to change how we do things. Humanity has altered over 70% of the Earth's land surface [3], halved the biomass stored in terrestrial vegetation [4], and impacted our fellow species so heavily that over one-quarter of those assessed are now threatened with extinction [5]. New work on the areas of habitat that individual species can occupy indicates that people have already reduced these by an average of almost 40% for the six in every seven terrestrial vertebrate species that have declined under human land uses [6], while well-monitored vertebrate populations have typically shrunk by almost 70% since 1970 [7]. All available indications are that these impacts will increase markedly this century [2,8].

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Beyond yields: a systems approach is essential for reconciling agriculture and biodiversity

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1. Introduction

Balmford *et al*. [1] advocate land sparing and high yields as the primary strategy to address biodiversity loss and ensure food security. We challenge the notion that managing agricultural land solely to optimize yields can halt or reverse the decline of biodiversity [2]. Decades of yield-centric agriculture, divorced from ecological and social concerns, have proven inadequate.

2. Rethinking agricultural productivity beyond yields

Despite acknowledging agriculture's profound negative impacts on biodiversity and ecosystem function, the authors advocate 'sustainable high-yield agriculture' primarily through '*sustained access to fertilizer, improved varieties* [*including genetically modified*], *markets and sound agronomic advice*'. These practices are similar to those promoted under the Green Revolution's tech-driven strategies [3, p. 8], raising concerns about how their sustainable model truly differs from the current high-input agricultural intensification paradigm. This approach risks perpetuating biodiversity decline [4], agriculture's contribution to a quarter of global greenhouse gas emissions [5], inadequate remuneration of farmers [6], and malnutrition affecting at least 735 million people [7]. Agrochemical dispersal degrades ecosystem functions at regional and global scales [8]. Intensive agriculture perturbs hydrological cycles, exacerbating water scarcity and driving planetary boundary transgressions related to freshwater and land-system change [9]. Moreover, atmospheric nitrogen deposition, a result of fertilizer use, alters distant ecosystems, impacting global biodiversity and biogeochemical flows [10]. A singular focus on maximizing yields, ignoring environmental and social externalities—inadequately addressed in their text—risks exacerbating the hidden costs of food systems, estimated at $10 trillion in purchasing power parity in 2020 [11]. Notably, 70% of those costs concern human health, followed by environmental degradation. From a policy perspective, high-yield farming is economically questionable, since many associated costs are partially covered through highly distortive, environmentally and socially detrimental public agriculture support mechanisms [12]. These direct subsidies, input-based subsidies and export subsidies deplete public funding that could support education, healthcare and biodiversity conservation. By ignoring high-yield

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industrial systems' structural limitations, technocratic approaches could limit solutions to partial fixes and overlook alternatives rooted in sustainability, equity and resilience.

We argue sustainable agriculture should be defined by its proven ability to deliver and ensure access for everyone to healthy foods, while maintaining/improving natural resources and ensuring the wellbeing of all farmers. Context-specific adaptation and continuous scientific evaluation beyond high yield or organic practices are essential, as advocated in the agroecology literature [13]. For example, agroecology prioritizes optimizing whole-farm and landscape socio-ecological principles contributing to soil health, biodiversity, resource circularity, justice, equity and access to affordable, locally sourced and nutritious food [14]. Balmford *et al.* exhibit a paradoxical stance, acknowledging briefly the potential of '*less capital-intensive approaches—including integrated pest management, push–pull methods of controlling pests, co-culture techniques, silvopasture and drip irrigation—to achieve marked increases in yields, often with lower inputs of water or potentially harmful chemicals*' [1, p. 8], yet later implying an inherent trade-off between yield and environmental integrity within agroecological systems (see '*The chief challenge to land sharing is that most actions ... typically tend to reduce farm yields*' [1, p. 5]). This assumption is challenged by empirical evidence suggesting that such trade-offs are not inevitable [15], and that agroecological practices, including agroforestry and cover cropping, can simultaneously enhance agricultural productivity and profitability, improve ecosystem services and contribute to food security [16–22] in a changing climate [23].

3. The need for on-farm biodiversity conservation to achieve the world's biodiversity goals

Rather than improving the state of the world's biodiversity, we argue that relying solely on high-yield intensive agriculture for food production will compromise achieving Global Biodiversity Framework (GBF) targets 1, 4 and 10 [24] and multiple Sustainable Development Goals [25]. Balmford *et al.*'s advocacy for land sparing is undermined by three critical oversights: a flawed assumption of effective 'spared' land protection, an underestimation of leakage effects, and a neglect of agrobiodiversity's crucial role.

First, Balmford *et al.*'s land-sparing paradigm, reliant on assumed effective protection, is frequently contradicted by empirical evidence. Effective 'spared' land protection necessitates more than spatial designation; it requires legally binding protection, local community engagement and ensuring that 'spared' areas form part of a functional ecological network. Without these, spared lands are susceptible to fragmentation [26], disturbance and conversion, including from distant but powerful drivers of land use change such as illegal logging, urbanization, and infrastructure development [27]. While protected areas have successfully contributed to reducing deforestation and improving livelihoods, their effectiveness in achieving broader conservation goals is contested in certain contexts [28,29].

Second, Balmford *et al.*'s analysis of the Jevons paradox potentially underestimates the substantial impacts involved (cf. 'Jevons effects are rare' [1, p. 9]) [30,31], while the discussion on leakage is incomplete. The authors acknowledge spatial displacement of agricultural production, but neglect the equally critical phenomenon of consumption leakage, i.e. efficiency gains leading to increased consumption. Increased agricultural productivity, even when spatially confined, can precipitate lower food prices, thereby stimulating heightened demand and consumption, ultimately driving further land conversion beyond initially spared areas [32]. Balmford *et al.* link agriculture's ecological footprint to consumption, trade, and supply chains [33]. They suggest that the European Union (EU)'s Biodiversity and Forest Strategies for 2030 requirement to spare old-growth forests and reduce yields in other forests is undesirable, on the basis that sparing tropical forests is more important for biodiversity. Yet, biodiversity needs conserving in every biome [34]. They also overlook the EU Regulation on Deforestation-free Products which is designed to mitigate leakage effects by requiring uniform forest protection rules.

Finally, the authors overlook the risks posed by genetic erosion, an inherent consequence of intensive high-yield farming systems [24,35]. This erosion represents a systemic loss of adaptive capacity, reducing the potential for future agricultural innovation and therefore threatening long-term food security. GBF targets 4 and 10 highlight the need to include agrobiodiversity—such as underutilized varieties and breeds and species like pollinators and soil organisms—in conservation to protect them from extinction while supporting agriculture [24]. Safeguarding this biodiversity requires consuming neglected foods and restoring ecosystem functioning through integrated spatial planning (GBF target 1) [36], efforts at risk from a narrow focus on maximizing yields.

4. Ensuring a socially just approach

The authors' advocacy for land sparing overlooks critical socio-ecological complexities of non-integrated land-use planning, farmer decision-making and agricultural transitions.

First, promoting large-scale intensification of agricultural land could reinforce agribusiness dominance of land and food systems, while marginalizing smallholder farmers and Indigenous peoples [30], and increasing local inequalities [37]. Technology-based intensification is capital-intensive, which smallholders struggle to compete with, leading to displacement or economic dependence on large agribusinesses [38]. A key example of this dynamic is the promotion of genetically modified organisms. Despite promises of higher yields, they have failed to address food security in regions with significant yield gaps, particularly in Africa [39]. The ban of Bt cotton in Burkina Faso due to performance issues [40], mixed outcomes in India [41], and loss of farmer seed sovereignty [42] highlights the limits of over-reliance on this corporate-driven approach [43]. As acknowledged in the agroecology literature [44] and beyond [45], achieving 'sustainable' agriculture requires that agricultural landscapes are recognized and managed as the multifunctional systems that they are [32].

Second, the authors over-simplify decision-making processes, ignoring evidence of the multi-criteria determinants of adoption and maintenance of ecologically friendly practices by farmers [46]. These studies show cultural values, knowledge access, social networks, land security and awareness of long-term ecological benefits shape farmers' decisions. Likewise, the authors condemn input reduction efforts by relying on a poorly planned transition example (the Sri Lanka case) while ignoring successful efforts aiming to reduce chemical use and dependency, such as the regulated markets for diversified family farming in Brazil [47], voluntary participation schemes for organic farming in Cuba [48] and government-supported natural farming in India [49] .

In conclusion, a yield-centric approach to agriculture risks reinforcing the prioritization of 'short-term, individual, and material gains' [4, p. 12] that drive biodiversity loss, climate change and pollution. Addressing climate change, habitat loss and pollution requires transformative change beyond incremental land-use efficiency gains [4]. For this, we call on science to empirically validate which farming practices, agrifood system structures and transition pathways are capable of providing the world with a socially just, biodiverse, climate-, water- and food-secure future.

Data accessibility. This article has no additional data.

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All authors gave final approval for publication and agreed to be held accountable for the work performed herein.

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Invited reply

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Why a nuanced, pragmatic focus on yields is essential

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We thank Damien Beillouin and colleagues [1] for their comments. Several of the points they make align with what we tried to say in this and many previous papers—albeit perhaps not clearly enough. So to be as direct as possible:

(1) We do not advocate a continuation of business-as-usual high-yield farming. Many current practices are damaging, environmentally, socially, or both, and need to be improved or replaced by better ones.
(2) We strongly believe that farming practices need to be evaluated based on their environmental outcomes and their impacts on animal welfare and human well-being. Indeed, we have developed and applied a quantitative framework for doing so [2–4].
(3) Although increases in farm yields usually slow rates of habitat conversion (e.g. [5–8]), we agree that (as explored in [9]) maximizing the benefits of land-sparing requires additional actions to ensure effective habitat conservation, including community engagement, habitat management and legally enforced protection.
(4) We completely agree that biodiversity needs conserving in every biome. But in the context of moves by many richer nations towards increased support for farming practices that risk lowering domestic production and increasing imports from far more biodiverse parts of the world [10,11], we take the view that their efforts to enhance farmland wildlife must be accompanied by additional measures to ensure that domestic food production is maintained [12,13].

We disagree with Beillouin *et al.* on four other substantive points. First, we contend that most actions that make farmland more accommodating for biodiversity reduce yields. Beillouin and colleagues suggest otherwise, citing Jones *et al.*'s [14] analysis of 43 papers investigating biodiversity and yield outcomes of farm system diversification. But this assessment finds evidence for yields increasing with biodiversity only when the latter is measured in terms of species richness or richness-evenness. Because richness-based metrics say very little about population viability and can mask the replacement of local specialists with widespread generalists, they often generate unhelpful and in some instances contradictory results compared with more detailed analyses of how contrasting actions impact the abundance of large numbers of individually assessed species [15–18]. The Jones *et al.* analysis also looks only at impacts on species within farmed land, without reference to their status in natural habitats or indeed to the impacts of farm practices on those species (which are usually the majority) which do not live on farmed land at all: as such it is unclear how farm diversification affects biodiversity as a whole. And of course diversification describes only some of very many land-sharing practices—and even here the authors report that the most commonly recorded outcome is an increase in biodiversity but a reduction in yield. Based on this, the literature and our own and others' analyses of the impacts of real-world practices on the abundance of approximately 2000 individually assessed species [19–27], we therefore maintain our view that practices associated with greater on-farm biodiversity are very largely associated with lower yields; and that as a result, to achieve any given level of food production they reduce the space available for natural habitats [28].

Second, we disagree that our article underestimates the problem of rebound effects, whereby increases in farm yield lower prices or raise profits and so incentivize increased production. Most local or regional studies report that rebound is indeed widespread (see above, and [29]). But Jevons effects—instances of extreme rebound where growth in total output outstrips growth in yield, resulting in the area under production increasing—appear to be rare in agriculture. Where Jevons effects are absent, yield increases are associated with reductions in natural habitat loss and so are likely to benefit biodiversity [29]. A further caution is that the magnitude of any rebound effect is likely to diminish when assessed at larger scales, because improving output efficiency in one area will, *ceteris paribus*, reduce production elsewhere. Nevertheless, reducing rebound effects in high biodiversity areas would usually be environmentally beneficial, which is why we devote space in our article and elsewhere [9,29] to exploring market and policy mechanisms that are demonstrably capable of lowering them by actively coupling yield increases with habitat protection.

A third area of disagreement concerns Beillouin and colleagues' view that high-yield farming systems will necessarily lead to the genetic erosion of crops and related agrobiodiversity. As explained, we think it is important to consider and evaluate all agricultural systems that offer the prospect of markedly increased farm yields. Several systems—such as mixed cropping, inter-cropping, crop rotation and co-culture—offer prospects of boosting yields while increasing the diversity of varieties and breeds in use or reinstating long-established agronomic practices [30–33]. But we also note the exciting suggestion from the agrobiodiversity community that higher yield production may be key to making space, without compromising overall food production, not just for natural habitats but also areas dedicated to the maintenance even of markedly lower yielding varieties and their associated agronomic practices [34].

Finally, we believe that to identify socially just as well as environmentally beneficial outcomes, we should consider all possible high-yield farming practices. Options should only be ruled out on the basis of clear evidence that they generate unacceptable environmental or social outcomes. Beillouin *et al.* raise particular concerns about genetically modified organisms (GMOs), saying these have failed to address food security in Africa, and led to mixed outcomes in India. But both points seem poorly founded. We cannot know whether GMOs would help African food production because most African countries have not approved any GM food crop. And in India, a compelling econometric analysis confirms that growing Bt rather than conventional cotton boosts long-term yields, cuts pesticide use and increases smallholder welfare [35]—which is why almost 100% of growers continue to use Bt seeds (M Qaim, 2025, personal communication). There are, of course, important concerns about GMO adoption increasing the reliance of smallholder farmers on multinational corporations. But we see that as a reason to strongly support investments by government agencies and foundations in the development and rollout of locally appropriate GM varieties—not a justification for excluding farmers from accessing potentially groundbreaking technologies [36–38].

In sum, while acknowledging its risks, we maintain that the great bulk of evidence indicates that increasing agricultural yields is much more likely to slow biodiversity loss and mitigate climate change than approaches focused on enhancing on-farm biodiversity. We consider that on an already crowded planet where the persistence of most species and the retention of carbon-dense vegetation cannot be achieved on farmed land, the area-efficiency of food production will be a central determinant of environmental outcomes. It therefore seems sensible to evaluate the environmental and social consequences of any new or existing approaches to delivering sustained high yields, and to explore mechanisms that link support for their deployment to the effective conservation of the natural habitats on which the mitigation of the extinction and climate crises inescapably depends.

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