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Cultivated lands: blind spots in global biodiversity data

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Biodiversity loss due to agricultural expansion and intensification is well documented. Accordingly, the Global Biodiversity Framework calls for transforming agroecosystems towards sustainable management. Yet, cultivated land remains a blind spot in global, open-access biodiversity data, creating knowledge gaps and reporting biases. Overcoming this requires tailored incentives, data integration, and farmer agency.

Agriculture is a key driver of global biodiversity loss

More than 30 years ago, McIntyre *et al*. aptly stated: 'Management of agricultural landscapes will be the litmus test of our ability to conserve species' [1]. The Rio Summit of 1992 echoed this concern, calling for more sustainable agricultural practices to protect nature. Agriculture now covers nearly half of the world's habitable land, and biodiversity loss persists, driven primarily by agricultural expansion and intensification. This has severe implications for nature's contributions to people, including food security [2]. The Global Biodiversity Framework (GBF) seeks to address this issue, with 11 of its 23 targets for 2030 concerning the role of agriculture for conservation, either directly (Targets 7, 10) or indirectly (Targets 1, 2, 4, 8, 11, 14, 15, 18, 21). By 2050, the GBF aims to reduce human-induced extinction risks (Goal A) and promote the sustainable management of biodiversity, with nature's contributions to people valued, maintained, and restored (Goal B).

Species observations are key for GBF progress reporting

Open-access species observations are crucial for informing biodiversity policy and will play a key role in the GBF. Several progress indicators require such data for their calculation, calibration, and validation [3,4]. This includes headline indicators on species' population sizes (A.4) and distributions (21.1), enabling assessments of biodiversity responses to GBF-driven changes in cultivated lands (i.e., cropland and intentionally planted grassland). Platforms such as the Global Biodiversity Information Facility (GBIF) will be a key source of species observations, recognized in GBF's monitoring guidelines [4]. GBIF facilitates access to data from opportunistic sources (e.g., citizen science) and structured monitoring efforts (e.g., national surveys). Monitoring data (i.e., spatially representative, systematic, and routinely generated species observations) are essential in cultivated lands, where species' habitat use may vary markedly within and between growing seasons [5].

As global biodiversity monitoring improves, cultivated lands remain a blind spot

In the 21st century, the proportion of cultivated lands with species observations has generally increased in all continents [+11% (±3%); Figure 1A]. This reflects political, societal, and scientific actions taken, with the 2010 Aichi Biodiversity Targets prompting new national monitoring infrastructures and additional citizen science initiatives (Figure 1A, vertical dotted lines). Yet, gaps and biases in the geographic and habitat representation of species observations persist. By the end of 2024, ~30% of cultivated lands (~8% stable, ~22% contracting/expanding) lacked species observations (Figure 1B). This includes >50% of cultivated lands of Africa, Asia, and Latin America, which together account for ~62% of the global total.

The GBF (Target 21) acknowledges these data limitations and prioritizes the use of models to map biodiversity indicators [4], alongside targeted monitoring to gradually fill gaps. However, gap-filling efforts, focused on expanding the number of sampled species and the coverage of their ranges, may overlook temporal gaps and biases affecting biodiversity (change) assessments [6]. This, in turn, undermines GBF reporting in cultivated lands, where these data limitations persist. Indeed, as global data coverage improved since 2010, so did the proportion of cultivated lands without new data on species observations [Figure 1A; +1% (±3%)], largely in Africa, Asia, and Latin America [+4–14% (±2–3%)]. By the end of 2024, ~60% and ~28% of global cultivated lands lacked data for ≥1 year and ≥3 years, respectively, since the last species observations (Figure 1C), suggesting that data collection efforts are generally not sustained.

Challenges in filling biodiversity data gaps in cultivated lands

The GBF recognizes the value of citizen science and calls on governments to strengthen its use. Although citizen science could contribute to over half of the GBF's data requirements [7], it cannot resolve all challenges. We highlight three key issues that, we believe, will continue to hinder effective biodiversity monitoring on cultivated lands.

Issue 1. Access restrictions and privacy concerns

Cultivated lands are usually connected to roads and therefore generally accessible, but typically privately owned and of restricted access. Access restrictions may originate from physical boundaries (e.g., fences) and are often legally enforced to prevent crop damages during the

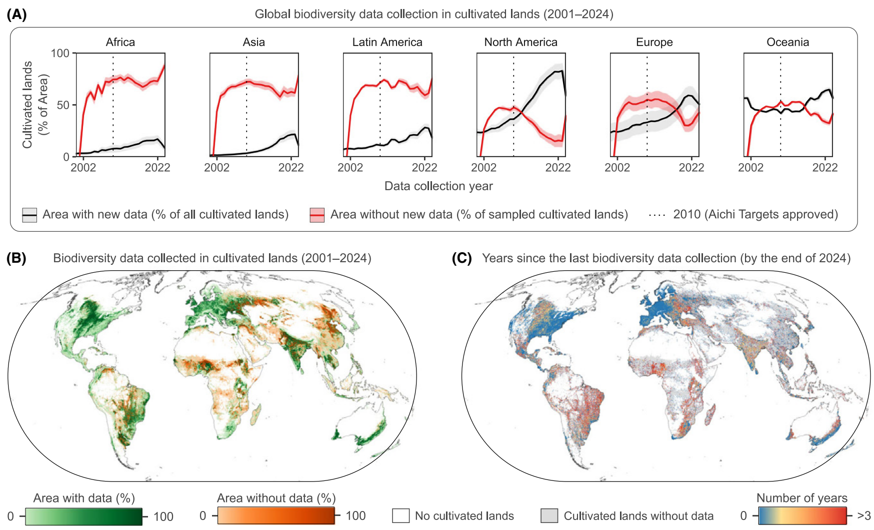

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Figure 1. Biodiversity data gaps and biases in cultivated lands. (A) Global distribution of species observations published in Global Biodiversity Information Facility (GBIF) (https://doi.org/10.15468/dl.qx5hmp) between 2001 and 2024. In each continent and year, black lines (95% confidence intervals as grey ribbons) show the mean annual proportion of all cultivated lands (combining stable and expanding/contracting) with new species observation data. Red lines (95% confidence intervals as pink ribbons) show the proportion of cultivated lands with species observations in previous years, but without new data in the respective target year. Mean values and their 95% confidence intervals were estimated from country-level estimates and weighted by the total area of cultivated lands in each country. Vertical, dotted, black lines mark the approval of the Aichi Biodiversity Targets in 2010, which led to large data gains through national monitoring schemes and citizen science. (B,C) Global distribution of cultivated lands, with and without species observations, mapped at a 10×10 km^2 resolution. (B) Per-pixel proportions of cultivated lands (based on mapped extents and changes between 2000 and 2020). Green refers to pixels with recorded species observation data, oranges and browns refer to pixels without species observations, based on GBIF data for the period 2001–2024. (C) Number of years since the last species observation data were recorded for pixels with prior species observations (i.e., those in green in B), calculated until the end of 2024. Blue represents pixels with data recorded in 2024. The colour gradient from yellow to red represents varying data gaps, from 1 to 23 years (shown in greens in B). Grey represents pixels without species observations (shown in oranges/browns in B). The displayed outputs are based on open-access datasets (for data sources see the notes in S1 in the supplemental information online).

growing period. Farmers may be reluctant to allow access to their land for biodiversity monitoring due to liability and data privacy concerns, or fears of legal consequences and economic losses arising from discoveries of threatened species [8]. These physical, socioeconomic, and legal factors often force biodiversity surveys along roads or field boundaries (Figure 2A), which may not accurately reflect within-field and whole-farm level biodiversity (Figure 2B), distorting subsequent biodiversity (change) assessments [6].

Issue 2. Societal and research priorities shaping survey asymmetries

Cultivated lands are key sources of food and income, yet comparatively less attractive for both citizen [9] and professional scientists [10] compared to habitats of (perceived) higher ecological value. With urban populations projected to reach 70% by 2050, citizen-science observations are likely to increasingly concentrate near cities, impacting agroecological monitoring programs that rely on volunteer data contributors (e.g., [11]). Simultaneously, scientific surveys, often shaped by funders' priorities, may not alleviate asymmetries in monitoring locations and surveyed species. This challenge may be amplified in agricultural frontier regions (e.g., Amazonia; Figure 2C), where larger field sizes increase distances between observer and observed species.

Issue 3. Lack of appreciation for the needs and contributions of farmers

Farmers from diverse backgrounds, including Indigenous communities, make key contributions to biodiversity knowledge [12]. They may even help 'discover' species thought to have been displaced by agriculture [13]. However, the full potential of engaging farmers as both biodiversity data contributors and users remains untapped. Challenges include motivational mismatches, misaligned incentives, and cultural barriers [12]. Farmer fatigue, that is, declining motivation or willingness to participate in agroecological experiments or biodiversity data collection over time, may arise from the time, effort, and cognitive load required, especially when tasks are repetitive, complex, or lacking direct benefits.

Solutions for improving biodiversity monitoring on cultivated lands

If left unaddressed, data gaps and biases in cultivated lands can distort our perceptions of biodiversity and its changes [6,10], with consequences for policy-relevant reporting [3,4]. We therefore propose the following solutions, aligned with specific GBF targets.

Incentivising access to cultivated lands

Incorporating privately owned cultivated lands in biodiversity monitoring requires incentives for farmers. This could imply subsidies or tax benefits for monitoring contributions, complementing existing schemes that reward farmers for agri-environmental practices or biodiversity outcomes, or social recognition for farmers' participation. GBF-related efforts to phase out biodiversity-harming

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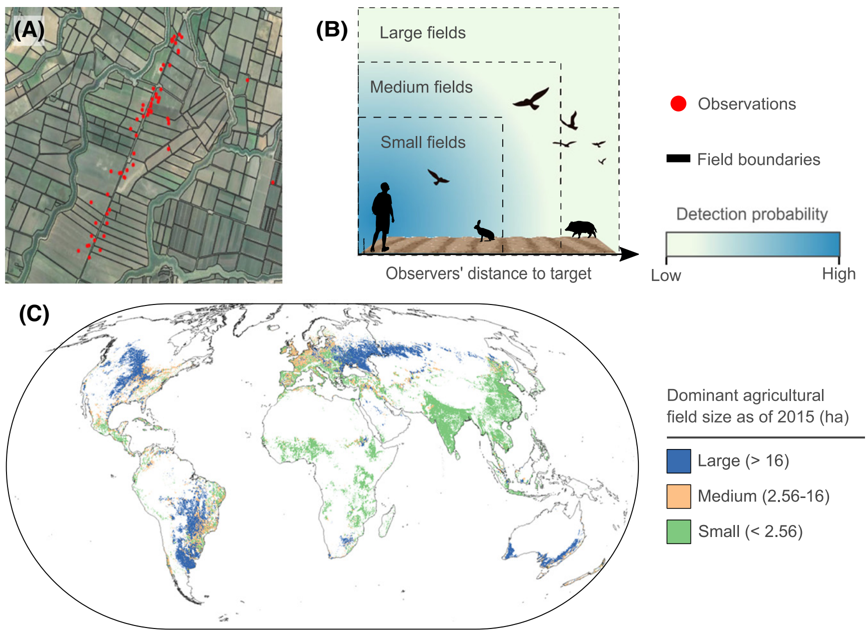

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Figure 2. Challenges of biodiversity monitoring in cultivated lands. (A) Exemplary data from California, depicting state-provided delineations of field boundaries in cultivated lands as of 2019 (black outlines). These data are overlaid with species observations published in the Global Biodiversity Information Facility (GBIF) and made in the same year (red dots). Species observations are largely aligned along a country road, likely reflecting land access limitations and observer preferences. (B) Relationship between the location of an observer and the location of within-field species occurrences. When observations are made at the edges of agricultural fields, larger field sizes increase the distance between the observer and the occurring species. Larger horizontal distances reduce species- and locality-specific detection probabilities, make species identification more difficult, and may introduce trait-related (e.g., larger body size, conspicuous vocalizations) and taxonomic biases. This challenge is especially prevalent in regions where larger fields dominate agricultural landscapes. (C) Global map of dominant agricultural field size (https://pure.iiasa.ac.at/id/eprint/15526/).

incentives (e.g., production subsidies) by US$500 billion per year (Target 18) could liberate funds to enable such compensation measures. National administrative and control frameworks for managing agricultural subsidies could incorporate biodiversity monitoring modules, enabling standardized reporting for a defined set of taxa.

Mobilising underused resources for data collection, integration, and accessibility

Farmers may already inform on species occurrences (e.g., on soil biota, insects) through existing reporting requirements for soil health, pest management or other systematic monitoring schemes (e.g., agricultural censuses). Embedding targeted biodiversity monitoring efforts in such schemes would offer a better representation of different management practices and their biodiversity effects. Not only such farmer-reported data, but also scientific databases on biodiversity and land use (e.g., PREDICTS[i]), can reduce data gaps in cultivated lands, supporting GBF commitments (Target 21). This requires data producers to prioritize open-access platforms used in global reporting (e.g., GBIF), and to commit to data integration initiatives linking agricultural data (e.g., CGIAR[ii]) and biodiversity time-series (e.g., BIOTIME[iii]). In resource-poor countries, the funding of monitoring capabilities (GBF Target 19: US$200 billion/year), if well designed, could support data needs on both food security [14] and GBF reporting.

Ensuring benefits for farmers to secure their long-term commitment

Any farmer-led biodiversity monitoring will have to be simple, flexible, clearly beneficial (e.g., providing information on pollination or pest control), and aligned with farmers' schedules and capacities. Feedback from data gathered on their land would then enable farmers to adapt land management and adopt biodiversity-promoting practices [12]. This could also be achieved through 'Digital Agriculture', as many of its technologies also enable biodiversity monitoring [15]. Such integrated, farm-level monitoring would offer tangible benefits (e.g., optimizing production costs). This solution is becoming increasingly accessible to farmers thanks to public and private investments in nearly every country [15]. If combined with rural digitalization programmes (e.g., 'smart villages'), it would grant rural and Indigenous communities the agency in biodiversity monitoring (Target 21).

Developing solutions for data sharing, privacy, and protection

Integrating biodiversity into all levels of decision-making and society lies at the core of the GBF (Targets 14, 22), with an explicit call for biodiversity knowledge to be made accessible to all (Target 21). In cultivated lands, this requires clear and transparent data-sharing agreements between governments, research institutions, rural and Indigenous communities, landowners and farmers that respect property and data rights (Targets 21, 22). Volunteer and federated data access, based on free, prior and informed consent, offers a way forward. Public agencies feeding farmer-reported data into open-access biodiversity data platforms can support GBF reporting, provided that appropriate anonymization and/or spatial aggregation safeguards privacy. Mediating data access through these institutions is critical to ensure data quality, interoperability, and protection of data providers.

Moving forward to tackle blind spots

Filling biodiversity data gaps in cultivated lands will enhance our understanding of species distributions and extinction risks, biodiversity responses to agricultural management, benefits of biodiversity for crop production, and conservation and restoration priorities. Such knowledge is highly relevant to (biodiversity) science, policy, and society, and is key to guiding sustainable transformations of food systems. Long-term, field-to-landscape-level biodiversity monitoring is required, combined with information on agricultural management. Yet, such data remain rare. National Biodiversity Strategies and Action Plans (NBSAP), which will guide progress monitoring towards the GBF agenda, must explicitly tackle blind spots in biodiversity data on cultivated lands for effective reporting.

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Resources

[i] https://doi.org/10.5519/j4sh7e0w

[ii] www.cgiar.org/

[iii] https://biotime.st-andrews.ac.uk/

Supplemental information

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