

Global offsetting of the outsourced biodiversity footprint of consumption

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ABSTRACT

1 International trade outsources environmental impacts of consumption through complex value
2 chains causing biodiversity loss across Earth. There is a need to examine the negative
3 biodiversity impacts and the opportunities to mitigate and offset the impacts, as a global
4 systemic phenomenon. Traditionally biodiversity offsetting is used to offset local land use
5 impacts but no means to offset the outsourced biodiversity impacts exist. Here we explore
6 location-independent global offsetting based on an idea of a global biodiversity equivalent. We
7 scrutinize the assumptions behind the suggestion by comparing the operationally important
8 planning decisions of traditional biodiversity offsets to global offsetting. We find global
9 offsetting to be operationalizable but emphasize that it should not replace, but rather
10 complement, the traditional offsetting. We conclude that until a global degrader pays -principle
11 has been worked out and adopted, global offsetting is a viable option to offset at least some of
12 the outsourced biodiversity impacts of consumption.

13 INTRODUCTION

14 In the global economy, international trade causes ecosystem degradation and biodiversity loss
15 typically far removed from the place of consumption (Lenzen et al. 2012; Hoekstra & Wiedmann
16 2014). Indeed, unsustainable land use (Winkler et al. 2021; Jaureguiberry et al. 2022) and
17 overexploitation of natural resources (Maxwell et al. 2016) to produce the commodities
18 necessary to satisfy the needs and desires of consumers cause threats to ecosystem integrity
19 to a degree that in many places ecosystems are in risk of losing their ability to support the
20 diversity of life (Cardinale et al. 2012; Willemen et al. 2020; Kortetmäki et al. 2021; Qu et al.
21 2024). In addition to land and sea use change and direct exploitation of species, climate
22 change, pollution and spread of invasive alien species are the main anthropogenic drivers of
23 biodiversity loss (Bellard 2012; Maxwell et al. 2016; Díaz et al. 2019; Roy et al. 2024). The
24 environmental changes such as biodiversity loss resulting from these drivers are called
25 footprints (Hoekstra & Wiedmann 2014).

26 International trade outsources the environmental impacts of consumption through complex
27 value chains and causes biodiversity loss in many places of the world. Therefore, there is a clear
28 need to examine the negative biodiversity impacts, but also the opportunities to mitigate the
29 impacts, as a global systemic phenomenon. Moreover, while local land use change has been
30 the dominant driver of biodiversity loss (Jaureguiberry et al. 2022), the weight of global climate
31 change as a driver of biodiversity loss is increasing (Pigot et al. 2023; Urban 2024). Thus, we
32 must start thinking biodiversity offsetting more broadly than in the local land use planning
33 context only.

34 Biodiversity offsetting is one impact mitigation instrument with which the negative impacts of
35 development and other land use are compensated by generating equivalent gains for nature
36 elsewhere (Moilanen & Kotiaho 2018; zu Ermgassen et al. 2019; Maron et al. 2025). Biodiversity
37 offsetting is commonly framed as being the last step of mitigation hierarchy (Arlidge et al. 2018)

and it has become a globally popular, albeit controversial (Maron et al. 2016; Damiens et al. 2021) instrument with over 100 countries applying it in thousands of cases (Bull & Strange 2018). Biodiversity offsetting is traditionally applied to compensate for the local project-level impacts only, but the need to extend the logic to addressing all impacts associated with economic activity, including throughout value chains, has sometimes been touched upon (Arlidge et al. 2018; Bull et al. 2020; Milner-Gulland et al. 2021; Balmford et al. 2025; Maron et al. 2025). The shift from targeting no net loss of biodiversity towards targeting net positive impacts for biodiversity (Bull et al. 2020; Moilanen & Kotiaho 2021) can be seen to have evolved the biodiversity offsetting from an impact mitigation instrument to a biodiversity conservation and adaptation instrument (Barral et al. 2025).

A challenge for the traditional biodiversity offsetting in a global value chain setting is that it requires comprehensive and relatively detailed knowledge on the biodiversity values lost on the development site and gained on the offset site (Marshall et al. 2020). In practice, it would be very complicated to do biodiversity offsetting in all the locations around the world the value chains outsource the biodiversity impacts. Thus, when we are interested in mitigating the biodiversity footprint of consumption, we need to consider alternative approaches. One possibility is to focus on life cycle assessments (Hellweg and Milà i Canals 2014; Verones et al 2020), which aim to consider the environmental impacts of products throughout their entire life cycle. A few different biodiversity indicators have been utilized in life cycle assessment (Damiani et al. 2023; Marques et al. 2017; Sanyé-Mengual et al. 2023), and there is a need for one that is able to quantify biodiversity comparably at the global level. In this article, we will focus on such an indicator called the biodiversity equivalent (El Geneidy et al. 2026). The biodiversity equivalent is derived from the potentially disappeared fraction of species (PDF), which accounts for the share of species that are potentially lost due to different drivers of biodiversity footprints, and which is customarily calculated separately for the species in terrestrial, freshwater and marine realms (Verones et al. 2017, 2020; Crenna et al. 2020). To

arrive at the biodiversity equivalent, the PDFs in the different realms are combined by taking a number-of-species weighted average of biodiversity loss across the realms (El Geneidy et al. 2026). In essence, the biodiversity equivalent indicates the share of all species on the planet that are likely to go extinct due to human activities, and its utility for biodiversity is to some extent similar to what carbon dioxide equivalent is for climate (El Geneidy et al. 2026). Hence, El Geneidy et al. (2026) suggested that biodiversity equivalent might be used as an indicator for globally offsetting biodiversity footprints anywhere on the planet independent from the location of the biodiversity loss. Furthermore, Bull et al. (2025) have recently estimated the biodiversity footprint of Dutch dairy sector and discussed the need to address biodiversity impacts not only from direct economic activities but also those embedded in global supply chains. They developed a safeguards approach for impact compensation but did not specifically include offsetting in their model despite noting that biodiversity offsets are likely needed in achieving net positive outcomes. Thus, there is a clear need for thorough exploration of how such a global system of offsetting the biodiversity footprint could work.

In this article, our focus is in developing the conceptual understanding of the characteristics underpinning potential global offsetting. We do this by scrutinizing the assumptions of global offsetting with the biodiversity equivalent by comparing it with traditional biodiversity offsetting in the context of operationally important decisions in the planning of biodiversity offsets (Moilanen & Kotiaho 2018; see also Gardner et al. 2013). Furthermore, we explore the consequences of adopting the biodiversity equivalent to offset the global consumption-based biodiversity footprint outsourced through the international value chains.

ASSESSING BIODIVERSITY FOOTPRINT OF CONSUMPTION

While we have been able to quantify and communicate impacts of local land use on biodiversity loss, assessing the impacts of the consumption of individuals and organizations has, until relatively recently, remained more elusive. After the first examinations of the biodiversity

impacts of consumption (Lenzen et al. 2012; Wilting et al. 2017), an increasing number of studies are being published concentrating on biodiversity footprint of individual products (Asselin et al. 2020), citizens (El Geneidy et al. 2025) organizations (El Geneidy et al. 2021; Bull et al. 2022), regions (Crenna et al. 2020), and global consumption (Bjelle et al. 2021).

To assess the biodiversity footprint of consumption four key pieces of information are needed (El Geneidy & Kotiaho 2023; El Geneidy et al. 2026): We need to know i) what was consumed and how much, ii) the type and amount of environmental impact caused by the consumption, iii) the geographic location of the environmental impact caused by the consumption and iv) the biodiversity loss in each of the geographic locations due to the environmental impact caused by the consumption. These four components are embedded in the Biodiversity Equivalent Impact Assessment (BIOVALENT) methodology (El Geneidy et al. 2026). Currently there are few emerging tools and databases allowing the assessment of biodiversity loss due to the environmental impact in certain locations. One such database is the LC-IMPACT database (Verones et al. 2020), another is the ReCiPe framework (Huijbregts et al. 2017) and a third the IMPACTWorld+ (Bulle et al. 2019).

Biodiversity equivalent

Potentially disappeared fraction of species (PDF) metric accounts for a fraction of species that are potentially lost due to environmental impact (Goedkoop et al. 1999; Verones et al. 2020). PDF indicates the biodiversity impacts relative to a counterfactual natural state without any human impact. PDF ranges from 0 to 1, where 1 means that all estimated species are at risk of extinction and 0 means that no species is at risk of extinction. The metric is based on species area relationship models, geographic ranges of species, the vulnerability of species to different human impacts, and the extinction risk classification of species. Currently the PDF indicator is derived from data covering vascular plants, mammals, reptiles, birds and fish and it is calculated separately for terrestrial, freshwater and marine realms. Global PDF indicates risk of

extinction of species in each of the realms globally while regional PDF indicates the potential biodiversity loss in each of the realms at the regional scale. Openly available characterization factors (also known as impact factors) (e.g., PDF/m² or PDF/kg) exist currently e.g. for several different forms of land use, water stress, several pollutants and climate change (Verones et al. 2020). The PDF can currently be calculated for all 804 terrestrial ecoregions and 200 countries/geographical regions.

The biodiversity equivalent is derived from the potentially disappeared fraction of species (PDF). To arrive at the biodiversity equivalent, the PDFs in the different realms are combined by taking a number-of-species weighted average of biodiversity loss across the realms (El Geneidy et al. 2026). This makes biodiversity equivalent a location-independent common currency accounting for all the species in all impacted ecosystem types as a single global value.

In essence, biodiversity equivalent tells what fraction of the species of the world are at risk of going extinct globally if for example 1 km² of land is continuously exploited by a specific driver of biodiversity loss, such as land use for intensive forestry (Verones et al. 2020), in any given country. A feature of the biodiversity equivalent is that the same amount of area occupied by the same driver causes less global biodiversity loss in relatively species poor areas than what it causes in relatively species rich areas. On the other hand, if both areas experienced a loss of the same amount of biodiversity equivalent, this would indicate that the global biodiversity loss is the same. Different species would be lost in different parts of the world, but the fraction of globally potentially lost species would be the same. With global offsetting therefore, it would be possible to offset impacts at any place, but offsetting in a species-poor country would require larger areas for conservation and restoration than in tropics or other species-rich regions.

GLOBAL OFFSETTING WITH THE BIODIVERSITY EQUIVALENT

As the starting point we take the framework that allows systematic and transparent examination of the main biodiversity offsetting design decisions that significantly impact the meaning of, and

outcome expected from the traditional biodiversity offsetting plan (Fig. 1) (Moilanen & Kotiaho 2018). We build the analysis by comparing local i.e. traditional biodiversity offsetting with the global biodiversity offsetting in a framework that is built around the three main dimensions of ecological reality: what biodiversity you lose and gain, where does the loss and gain happen (space), and when does the loss and gain realize (time) (Wissel and Wätzold 2010). In addition, we examine the decisions around objectives i.e. around what do you aim at, and considerations around offset actions that are more practical implementation decisions.

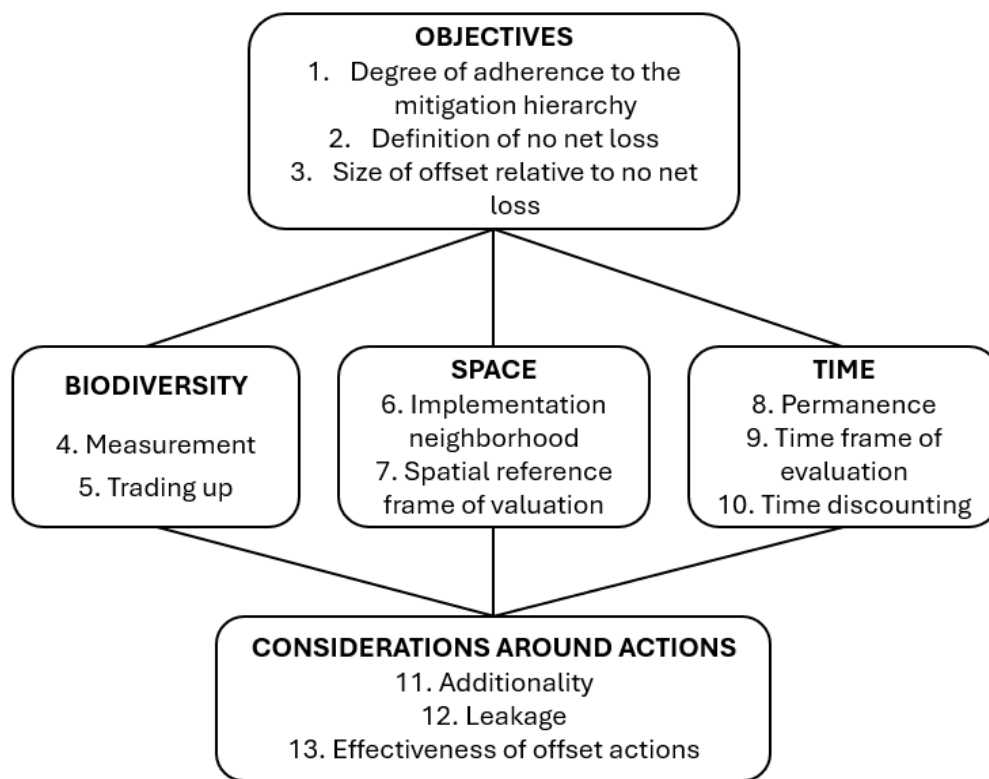


Fig. 1. Important operational design decisions in traditional biodiversity offsetting focusing on biodiversity objectives (what do you aim at), what do we lose and gain (biodiversity), where (space) and when (time). There are also a few important general considerations when implementing the offsetting actions (adapted from Moilanen & Kotiaho 2018).

Degree of adherence to the mitigation hierarchy

Mitigation hierarchy is designed to address local impacts on biodiversity through first seeking to avoid impacts wherever possible, then minimizing impacts and finally repairing the damages by means of restoration either locally or elsewhere (Arlidge et al. 2018; Moilanen & Kotiaho 2021). Policies requiring mitigation hierarchy are now well established in many countries (Bull & Strange 2018), but in practice the implementation of even the first step, to avoid the impacts, is often not considered or implemented in development projects (Phalan et al. 2018; Jones et al. 2022).

To apply mitigation hierarchy successfully, one needs relatively detailed spatial information about the biodiversity values or the location of the priority areas for biodiversity conservation at the minimum. The data on the environmental drivers caused by consumption and their impacts on biodiversity behind the biodiversity equivalent are spatially explicit. However, the resolution of the data is currently too coarse to allow detailed spatial planning of impact avoidance. Moreover, consumers of products manufactured across complex supply chains generally have little if any power to influence production decisions in other parts of the world. Nevertheless, we can think of three ways of employing the mitigation hierarchy as part of global offsetting. The first is to reduce consumption overall, then replace high impact products with low impact products, and finally to avoid products originating from globally biodiverse regions.

Definition of no net loss

At first, it might seem that the meaning of no net loss is clear, but it is not. Operationally, fully measuring all components of biodiversity in any given area over any period of time is virtually impossible (Moilanen & Kotiaho 2018). In practice, no net loss cannot mean for example that every species impacted would be fully compensated for. A critical task, therefore, is to determine how biodiversity can best be described and measured to adequately assess the losses and gains of biodiversity (Gardner et al. 2013; Maron et al. 2018). Once the adequate

representation of biodiversity is determined, no net loss is simple enough to define as the situation where losses are balanced with equivalent gains.

The logic is similar in global offsets: if we assume that the biodiversity equivalent provides an adequate representation of the global biodiversity, then in a situation where the biodiversity equivalents lost correspond to the biodiversity equivalents gained, the share of species under risk of extinction globally has not changed and therefore there is no net loss of biodiversity.

Size of compensation required relative to no net loss

Biodiversity offsetting is commonly framed such that the offset should deliver no net loss or net positive outcomes for biodiversity (Bull et al. 2020). Despite this convention, where there is no obligation to offset damages, even a partial offset is likely to be better than no offset at all. Whatever the argument for the size of the offset relative to the loss, be it no net loss, net positive or partial, we find the arguments likely to be equally applicable to both the traditional and global offsetting.

Biodiversity measurement

Traditional biodiversity offsetting requires biodiversity assessment at the development and offset sites. The assessment of biodiversity in traditional offsetting is commonly based on habitat attributes reflecting the habitat condition (Marshall et al. 2020; Jalkanen et al. 2025), which is determined relative to the same habitat type in its natural or undisturbed condition (Parkes et al. 2003). As it is impossible to measure all aspects of biodiversity in any focal area at any great detail, the most important design decision in biodiversity measurement is how much simplification is allowed (Moilanen & Kotiaho 2018).

In traditional biodiversity offsetting ecological equivalency i.e. the identity of the lost and gained biodiversity values is often expected to be the same (Bull et al. 2015). For instance, in Finland the Nature Conservation Act (9/2023) requests that the losses and gains are assessed on a

biotope type or species habitat level, and losses of condition in each must be offset with gains of condition in the same biotope type or species habitat. Knowing the identity of biotopes and habitats of species allows identifying irreplaceable biodiversity values the degradation of which should not be allowed.

Global offsetting with the biodiversity equivalent operates on a different logic. Biodiversity equivalent tracks but is not concerned about the identity of biodiversity as it operates on the share of the global biodiversity under risk of extinction. Hence, although technically potentially possible, in its' current form the biodiversity equivalent does not allow operating at the species-level but it can identify irreplaceable biodiversity values by giving more weight to threatened and endemic species. Generally, the logic of global offsetting aiming for no net loss relies on keeping the extinction risk of species on the planet constant whereas traditional offsetting aiming for no net loss relies on keeping the condition of each local biotope or species habitat condition constant.

As the risk of extinction globally is generally not zero because of non-anthropogenic reasons, keeping it constant with global offsetting means we are likely to lose some species in the future. Similarly, as the local habitat condition is generally degraded already before development, keeping it constant with traditional offsetting means the areas may lose biodiversity locally due to delayed extinctions known as extinction debt (Tilman et al. 1994). Thus, even if the mechanisms are different, both global and traditional offsetting may achieve no net loss only relative to the pre-development baseline.

Trading up

Trading up in traditional biodiversity offsetting refers to a situation where flexibility in ecological equivalence is allowed such that less threatened biotope types or species habitats can be offset with those that are more threatened (Bull et al. 2015). It is worth noting that in this case

219 the value of biotopes and habitats of species are based on human valuation and often on
220 national assessments of the risk of extinction of biotopes and species.

221 Trading up is possible in traditional offsetting as the lost and gained biodiversity values are
222 identified. Even though some offset policies are strictly like-for-like. In global offsetting trading
223 up is not operational as the biodiversity equivalent is not concerned about the identity of
224 biodiversity. Nevertheless, the biodiversity equivalent does track species distributions and is
225 affected by human valuation of species through the global vulnerability scoring based on the
226 IUCN threat levels. Occurrence of anthropogenic biodiversity loss drivers in an area that has
227 threatened species cause greater loss measured in biodiversity equivalents than the
228 occurrence of the same driver in an area that has the same number but less threatened
229 species. Thus, targeting global offsets to areas with threatened species translates into smaller
230 total area needed for the offsets, but it cannot be considered trading up.

231 **Implementation neighborhood**

232 Implementation neighborhood refers to the distance allowed between the impact and offset
233 area. In traditional offsetting, offsets are advised to be located as close as possible to the
234 impacts to guarantee ecological equivalency (BBOP 2012). As explained above, global offsetting
235 with the biodiversity equivalent operates on a different logic and is not concerned about the
236 identity and thus ecological equivalency of biodiversity. As its name implies, global offsetting
237 expands the implementation area of offset from the local scale to the global scale. When the
238 implementation neighborhood is global, options for offset implementation are increased and
239 consequently the per-unit offset costs are likely to be reduced (Moilanen & Kotiaho 2018).

240 **Spatial reference frame**

241 Spatial reference frame refers to the spatial context where biodiversity is valued. A species can
242 be considered endangered if a national reference frame is adopted even when the same species

243 might be of least concern at the global reference frame. Choice of the spatial reference frame
244 can impact trading up in traditional offsetting, but for global offsetting the choice is not
245 applicable as the reference frame is always global.

246 **Permanence of offsets**

247 Development projects often cause permanent or at least long-lasting local biodiversity loss.
248 Therefore, traditional offsets are often also expected to be permanent or last at least as long as
249 the biodiversity loss drivers remain (BBOP 2012). As the biodiversity footprint of consumption
250 that is outsourced through the value chains translates into local land use and other drivers
251 somewhere around the planet, there is no reason to believe such impacts would be any less
252 permanent. Moreover, as consumption cannot ever be completely ended, some permanent
253 pressure on biodiversity will remain. Therefore, it seems reasonable to consider most losses as
254 permanent and require global offsets to be permanent as well.

255 **Time delays and time discounting**

256 Delayed financial payment is routinely not considered equally valuable to immediate payment
257 and the same logic can be applied to delayed biodiversity gains (Moilanen & Kotiaho 2018).
258 Damage or biodiversity loss is typically relatively fast while ecosystem recovery is slow. In
259 traditional offsetting the timing of the damage is usually known, and the value of delayed gains
260 can be easily adjusted based on a yearly time discounting percentage (Laitila et al. 2014).
261 Additionally, knowing the time of damage can enable offsetting the losses before they occur,
262 which would be ideal for biodiversity. However, the timing of biodiversity impacts of the
263 production of consumables across the value chain is typically unknown. The time lag between
264 the impact and consumption can be especially long in long lasting products. As there are
265 definite time delays, time discounting of the gains could be considered in both traditional and
266 global offsets. In practice this means adding a multiplier or a ratio to discount the gains.

It is worth noting that when we consider the different drivers of biodiversity loss, all losses may not be immediate either. For example, the biodiversity impacts caused by climate change can realize decades after the greenhouse gases were emitted (Pigot et al. 2023; Urban 2024).

Time frame of evaluation

Time frame of evaluation refers to the time frame over which losses should be balanced with offset gains. As the recovery of biodiversity is slow, a shorter time frame implies less gains per area and thus on average larger offset areas and higher offsetting costs. However, very long timeframes decrease the credibility of offsets (Moilanen & Kotiaho 2018). For example, in the Finnish Nature Protection Act (9/2023) an evaluation time frame of 30 years is requested for no net loss to be reached.

In global offsetting, the difficulty is again the international value chain and the uncertainties regarding the timing of the biodiversity impacts. For simplicity, it could be reasonable to assume that the losses occur, and the time frame of evaluation begins at the point of purchasing of the products either by the consumer or the retailer.

Additionality

Additionality means that offsetting actions must deliver biodiversity benefits that would not have been gained without offsetting. For example, double counting of the ecological gains is not allowed (van Oosterzee et al., 2012). Furthermore, landowners who offer their land for offset purposes might have been motivated to protect the land anyway and hence this would not be considered additional. Ensuring additionality is essential in both traditional and global offsetting. Additionality may be tricky to assess in traditional offsetting because of the many national and international obligations to restore and protect nature. In global offsetting we can offset biodiversity losses across many different jurisdictions, which can make assessment of the additionality even more complicated.

291 **Leakage**

292 Leakage happens when instead of canceling the pressures, offsetting actions delivering
293 permanent biodiversity gains cause the pressures to shift elsewhere (van Oosterzee et al. 2012;
294 Moilanen and Laitila 2015; Balmford et al. 2025). If land use pressures are not cancelled, but
295 shifted fully or in part to another location, then gains through offsetting will be overestimated.
296 Assessing and accounting for leakage is critical in both traditional and global offsetting. In
297 traditional offsetting the risk of leakage can be assessed for example from historical trends in
298 land use such as forest harvesting data, trade flows and data on farm yields (Balmford et al.
299 2025). In principle the same approach can be used in global offsetting. However, if global
300 offsetting is conducted across many different geographical locations assessing leakage is likely
301 to be more challenging.

302 **Effectiveness of offset actions**

303 Offsetting actions in both traditional and global offsetting are predominantly restoration and
304 protection. Traditional offsetting does not typically consider biodiversity loss drivers other than
305 land use change and sometimes direct exploitation of natural resources, such as timber
306 harvesting. It is relatively easy to see that in traditional offsetting for example the land use
307 change needs to be offset once to meet the no net loss requirement.

308 When we adopt the biodiversity equivalent to offset the global consumption-based biodiversity
309 footprint outsourced through the international value chains, the biodiversity loss drivers
310 considered are generally much more numerous. We have land use change, water stress,
311 climate change and pollution to name but a few (Verones et al. 2020; Damiani et al. 2023).

312 Moreover, unlike most development projects on a site that are once off, consumption continues
313 year after year. In terms of land use change and water stress drivers the impact generally occurs
314 once and there are usually no great additional losses to be expected provided the consumption
315 causing the drivers stays the same. However, climate change and pollution drivers are

316 cumulative, and the negative impacts increase even if the consumption stays the same. Thus, in
 317 global offsetting the offsetting actions need to be considered separately for different sets of
 318 biodiversity loss drivers. For drivers like land use change and water stress offsetting once may
 319 be adequate but for the climate change and pollution drivers the offsetting must be continued
 320 as long as the emissions continue.

Table 1. Comparison of the operationally important decisions in planning of traditional and global biodiversity offsetting grouped under objectives, the three main dimensions of ecological reality (biodiversity, space, time), and actions.

Decisions	Traditional offsetting	Global offsetting
Objectives		
Degree of adherence to the mitigation hierarchy	Seldomly legislated and difficult to track whether hierarchy is implemented	Hierarchy is based on consumption decisions that may be traceable but not necessarily easy to implement
Definition of no net loss	Losses are balanced with gains in the unit that is decided to be an adequate representation of biodiversity	Same as in traditional offsetting but the unit is different
Size of compensation required relative to no net loss	Depends on what is agreed. Often no net loss or net positive impact	Depends on what is agreed. Similar to traditional offsetting
Biodiversity		
Biodiversity measurement	Based on habitat attributes reflecting the habitat condition, e.g. habitat hectare	Based on biodiversity equivalent reflecting the share of species on the planet that potentially go extinct due to human activities
	Ecological equivalency often requested	Ecological equivalency not applicable
	Allows identifying irreplaceable biodiversity values the degradation of which should not be allowed	Although technically potentially possible, in its' current form the biodiversity equivalent does not allow identifying irreplaceable biodiversity values
Trading up	Possible	Not possible
Space		
Implementation neighborhood	Local, regional	Global
Spatial reference frame	Local, regional	Global
Time		
Permanence of offsets	Permanence required	Permanence required

Time delays and discounting	Time delay known and offsets possible to be established before or after impacts	Time delay difficult to track and offsets established more likely after impacts
	Discounting delayed gains possible	Discounting delayed gains possible
Time frame of evaluation	Timing of losses known, time frame easily defined, e.g. 30 years	Timing of losses often unknown, time frame could be defined as 30 years from purchase
Actions		
Additionality	Complicated because of many restoration and protection obligations	Even more complicated if done across different jurisdictions
Leakage	Can be relatively easily assessed e.g. from historical land use trends	Can be assessed from historical land use trends but is more complex with many geographical regions
Effectiveness of offset actions	Generally considers only land use change driver requiring one-time offsets	Considers various drivers and the required offsets vary from once off to yearly depending on the driver and the impact duration

DISCUSSION

Reducing consumption in the Global North can be argued to be of utmost importance if we are seriously aiming to stop the global biodiversity loss. Indeed, most of the value chains are global, and international trade has resulted in high-income countries outsourcing their negative biodiversity impacts to low-income countries (Bjelle et al. 2021; Koslowski et al. 2020; Marques et al., 2019; Wood et al. 2018). These outsourced impacts are only rarely accounted for never mind offset in any way.

While we agree it to be desirable that the traditional offsetting is done where the negative impact has been caused, offsetting the biodiversity footprint of consumption needs other means and global offsetting as imagined here could provide one option. Even if global offsetting would be adopted, it is important to emphasize that global offsetting should not replace the traditional offsetting but be adopted in addition to it (see e.g. Maron et al. 2025). It may also be worthwhile considering the impact compensation safeguards of spatial, temporal and habitat type based considerations (Bull et al. 2025) that could be, to some extent, adopted in the global

335 offsetting system as imagined here. However, compared to having spatial and habitat-based
336 safeguards, global offsetting would enable offsetting of multiple impacts at one place, which
337 could be an advantage in cases where impacts are divided to dozens of countries. Very recently
338 there was also a suggestion that only actions achieving ecological equivalence with low
339 uncertainty should be considered actual offsetting (Bang et al. 2025). As global offsetting
340 described here does not follow the like-for-like principle, based on this suggestion we should
341 not be talking about offsetting but rather compensating for the negative impacts. While it is
342 good to discuss and scrutinize the definition of various concepts, we point out that ecological
343 equivalence is dependent on the accuracy of measurement. No biological community is ever
344 absolutely similar to another, and thus no offset site can ever be absolutely similar to the one
345 impacted.

346 Considering and comparing the allocation of responsibility in traditional and in global offsetting
347 reveals a hidden paradox: in traditional offsetting it is the developer that is held responsible for
348 the damages, while the perspective of analysis in consumption-based biodiversity footprint
349 assessment, and hence global offsetting, is that of the consumer. The paradox in allocation of
350 responsibility appears when we recognize that all local land use anywhere on the planet is
351 locally caused by some form of development. Should it thus always be the degrader after all, i.e.
352 the producer or the developer, that is held responsible for the damage rather than the
353 consumer? Allocating responsibility between producers and consumers has been considered
354 not to be that straightforward because while the producers exert the impacts and control
355 production methods, consumer choice and demand may nevertheless drive production (Lenzen
356 et al. 2007, 2012). Lenzen et al. (2007) concluded that responsibility may lie with both camps
357 and may have to be shared between them.

358 There remains a lot of work to describe how global offsetting could work in practice, including
359 additionality and spatial considerations. Global offsetting might, for example, encourage

360 restoring and protecting nature in species-rich countries and places with endemic species over
361 other areas. This could happen especially in species-rich tropical countries where land
362 acquisition is relatively cheap. However, tropics are also globally important considering
363 biodiversity and climate regulation. Biodiversity equivalent also works in a way that there would
364 be no further extinctions based on human actions which also directs offsetting to places of
365 highest importance for conservation. Maron et al. (2024) advise that offsetting should be
366 targeted to biodiversity that is hard to replace instead of habitats that are easy to restore.
367 Establishing comprehensive offset registers to avoid potential misuse and ensure additionality
368 would be crucial for this system to work as intended. Furthermore, biodiversity equivalent and
369 the PDF it is based on also include uncertainties such as inadequate representation of species
370 whereas LCA has uncertainties for example due to different human-based decisions and data
371 limitations (see e.g. Bromwich et al. 2024; Goedkoop et al. 2023). Nevertheless, before solving
372 the practical issues on implementing global offsetting while improving the underlying
373 indicators, we first need to conceptualize the global offset system.

374 To conclude, we suggest that perhaps a global adoption of a degrader pays -principle, an
375 analogue of the polluter pays -principle, would operationalize the allocation of responsibility
376 between the producers and the consumers. If all producers push the cost of traditional
377 biodiversity offsetting downstream to their value-chain, then the responsibility would be
378 automatically shared between all parties in the value chain. It is worth noting that, at the same
379 time, global offsetting would become redundant. Until a global degrader pays -principle has
380 been worked out and adopted, it is better that at least some of the outsourced biodiversity
381 footprints of consumption are offset, and global offsetting as explained here might be a viable
382 option.

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