

Article

Not peer-reviewed version

Supporting the Global Biodiversity Framework Monitoring with LUI, the Land Use Intensity Indicator

[Joachim H. Spangenberg](#) *

Posted Date: 12 January 2023

doi: 10.20944/preprints202301.0226.v1

Keywords: Biodiversity loss, driving forces, land use intensity, fragmentation, Land Use Intensity index LUI



Preprints.org is a free multidiscipline platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This is an open access article distributed under the Creative Commons Attribution License which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Disclaimer/Publisher's Note: The statements, opinions, and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions, or products referred to in the content.

Article

Supporting the Global Biodiversity Framework monitoring with LUI, the Land Use Intensity indicator

Joachim H. Spangenberg

Sustainable Europe Research Institute SERI Germany; Joachim.Spangenberg@seri.de; Tel.: +49-221-2168-95

Abstract: Biodiversity loss has been identified as the environmental impact where humankind has been trespassing planetary boundaries most ruthlessly. Going beyond the pressures causing damages and analysing their underlying driving forces, ipbes identified a series of drivers. The Montreal-Kunming Global Biodiversity Framework GBF is intended to and claims to be a policy response to such analyses. To enhance the resilience of ecological systems, to allow for their recovery and enable the restoration efforts foreseen in the GBF to be successful, the pressures/direct drivers have to be reduced and the drivers/indirect drivers of biodiversity loss have to be redirected. However, often the necessary (semi-)quantitative information needed to politically address the drivers is absent or patchy. The data collected under the United Nations System of Environmental-Economic Accounting—Ecosystem Accounting, to which the GBF is affiliated, monitors the state of ecosystems, with no priority for pressure/direct driver analysis. Hence we suggest LUI, a deliberately simple index designed for two purposes, as a tool for communicating where sophisticated statistics are available, and as an information collection tool elsewhere Its simple and intuitively understandable structure makes it suitable for citizens' science applications, and thus for participative monitoring when extensive statistical data gathering is not feasible.

Keywords: Biodiversity loss; driving forces; land use intensity; fragmentation; Land Use Intensity index LUI

1. Introduction

The Kunming-Montreal Global Biodiversity Framework (GBF), adopted on December 18th, 2022, is a major step forward for biodiversity conservation and restoration (although, like any policy compromise, being far from perfect)[1]. Most prominent in the media was its demand to have, by 2030, 30% of the Earth's ecosystems under protection. However, there is more to it, and the ambition is very broad as the GBF "seeks to respond to the Global Assessment Report of Biodiversity and Ecosystem Services issued by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2019" and the 5th CBD Biodiversity Outlook [1] (p. 4) [2,3]. However, it does not mention the UNEP International Resource Panel, which found that 90% of biodiversity loss and water stress are caused by resource extraction and processing, the same activities which also contribute to about half of global greenhouse gas emissions [4]. The GBF demands reduction of pollution from all sources, by 2030, to levels that are not harmful (target 7), but does not spell out the responsibility of industrial producers.

In target 2 it demands to ensure "that by 2030 at least 30 per cent of areas of degraded terrestrial, inland water, and coastal and marine ecosystems are under effective restoration, in order to enhance biodiversity and ecosystem functions and services, ecological integrity and connectivity", but leaves terms and means to member states. The experience of climate policy and the Paris targets gives reason for scepticism about this approach. To monitor their efforts, indices are required which are applicable across the wide variety of countries and their ecosystems, to get at least an impression of how much progress is made in halting the increase and reducing the level of biodiversity pressures.

From the Kunming-Montreal Global Biodiversity Framework

In section E, § 27, the GBF calls for “urgent policy action [...] so that the drivers of undesirable change that have exacerbated biodiversity loss will be reduced and/or reversed”. For this behalf, section in H (§ 31, 2030 Targets. 1. Reducing threats to biodiversity), it specifically points to eliminating, minimising, reducing and/or mitigating the impacts of invasive alien species (target 6), but makes no reference to the indirect drivers behind the spread of invasive species, i.e. global trade and insufficient controls. It demands reduction of pollution from all sources, by 2030, to levels that are not harmful (target 7), but does not spell out the responsibility of industrial producers. As opposed to this, it is much clearer regarding consumption, demanding that, a. o., governments establish supportive policy, legislative or regulatory frameworks to ensure that consumers significantly reduce overconsumption and substantially reduce waste generation, including through halving global food waste (target 16). It appears that the CBD and its parties, and in result the GBF, shy away from admitting the need for a deep structural change of our economic systems. The necessity of such a systemic change has been shown in chapter 6 of the IPBES report the GBF claims to respond to, and a multitude of subsequent publications, with frequent participation of the IPBES authors [5–7]. The size of the challenge has been clearly shown as well in the European Environment Agency’s 2019 report [8], the recent IPCC reports and a plethora of other research reviews.

2. Methodological Background

Two main conditions for realising the GBF’s ambitions are to identify the direct and indirect pressures that caused the deterioration of the state, and reduce or eliminate them, and the regular monitoring of progress, for which a separate document has been adopted at the CBD COP [9]. It comprises a set of headline, component and complementary indicators, with the deliberately small set of headline indicators constituting the standard reporting framework to allow for easier data collection and result communication. The component and complementary indicators are optional, to be used as appropriate. To mainstream biodiversity in national statistical systems and to strengthen national monitoring systems and reporting, the set is aligned with existing intergovernmental processes under the United Nations Statistical Commission, in particular with the System of Environmental-Economic Accounting SEEA and its extension for ecosystem accounting, SEEA EA [10].

Unfortunately, all headline indicators and almost all component indicators focus on the state of the factor they describe; few – mostly complementary indicators – indicate trends, and none refers to the past development, identifying the pressures that brought about the current state. In this, they are similar to the SEEA EA system, which records the extent and the quality status of ecosystems – the extent monitoring also covers land fragmentation.

Trends then result from time series but are not indicators in themselves. Area is an easily understood and measured indicator and of crucial importance, as the abundance of a species is approximately halved when half of its habitat is lost [11], leaving the quality and its change as the

main reporting challenge. However, even that would not provide information on the courses which have led to the status quo.

This is of course no argument against monitoring the current state – such information, and the implications for impacts on biodiversity and ecosystems are crucial to define the restoration and adaptation measures foreseen in the GBF. However, they fall short of identifying the direct and indirect drivers, which is necessary to identify suitable mitigation and prevention measures to safeguard the lasting success of restoration measures taken (see Figure 1).

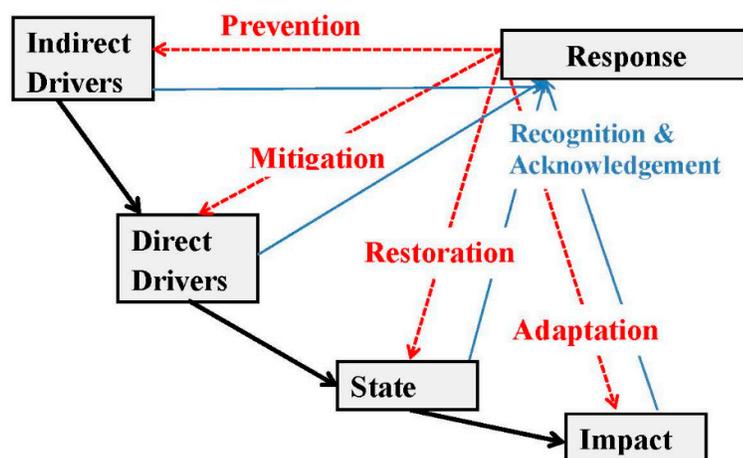


Figure 1. Different kinds of interventions require monitoring different factors and developments, with direct and indirect drivers currently not covered despite their importance for planning effective mitigation and adaptation measures. Source: Author.

While recognising the primary drivers (called “pressures” in part of the literature) is still relatively straight forward, the situation for the indirect drivers is extremely challenging. Depending on culture and other institutional settings, different indirect drivers can contribute to the same direct ones, and hence the same interventions causing biophysical disruptions can be caused, supported or triggered by different decision making processes in politics, business and civil society. However, the role of social innovation for biodiversity protection is so far grossly under-researched, as a recent literature survey has shown [12]. For instance, allocating responsibility for biodiversity loss to producers and consumers can only be done in very general terms, still requiring significant simplifications in the assessment [13]. On an even higher level, habits, routines and ideologies directing and legitimising decisions play a crucial role [14]. This is the field of political science and institutional analysis, essential to identify the most effective action to redirect indirect drivers, but no a focus in this paper.

History matters as well: external stresses act as selection forces on the gene pool, reducing the biological diversity from genes to habitats. For instance, under the environmental conditions in Europe over the past decades, plants have been better off e.g. if they could stand soil acidification, were tolerant to higher levels of UV-B radiation and higher top speeds of storms. Each of such selection conditions narrows the gene pool, and limits the adaptability for future stresses like those anthropogenically caused by changing temperature and precipitation conditions [15]. So the new pattern of short but intensive rainfalls plus arid summers with extended periods of no precipitation at all, and with more frequent and higher floods is nothing nature has been prepared for (human societies have a similar lack of preparation), as the impacts of the most recent summers have shown

[16]. Reduced root development following soil acidification [17] might even have enhanced the vulnerability to other threats such as storms.

Another of the reasons for the complexity is that biodiversity loss, unlike climate change, is not a *global* phenomenon, with the same factors (equivalent to greenhouse gases) acting everywhere. Instead, biodiversity degradation is a *ubiquitous local phenomenon* – while occurring globally, the reasons and mechanisms are to a significant degree locally based. What is adequate use in one place (grazing, mowing, water lagging,...) can be too much pressure in another – it is the combination of ecosystem characteristics and use patterns which must be in a balance. While not explicitly mentioning pressures, the GBF addresses this challenge indirectly, by defining targets for two aspects of intensive agriculture: it demands to reduce both excess nutrients loss to the environment and the overall risk from pesticides and highly hazardous chemicals, by at least half until 2030 (target 7). The demand to work towards eliminating plastic pollution by the same year affects intensive agriculture as well, since plastic films covering land and degrading into micro plastic after use are often part of the system. Addressing these transgressions of planetary boundaries is of course welcome from a biodiversity and environment point of view [18,19], but picks out only a few of the defining elements of land use change instead of providing criteria for distinguishing use intensity levels.

3. The Land Use Intensity Index LUI

Land use intensity is suggested here as a proxy for the pressures related to land use. The largest difference is between unused – often pristine or human-influenced, but little degraded areas – and land intensively used by humans for different purposes. Once humans permanently use land, the intensity of land use is then the major measure for impacts, not only for the area directly used but also for surrounding natural lands impacted by relief, nitrogen cycle, water cycle, and virtually all dynamics connecting different areas [20]. For instance, while soil sealed off from the surface by infrastructure construction is deprived of oxygen supply and sunlight, and thus only capable of hosting a limited number of subsoil species, intensively managed, large scale and high input areas are exposed to chemical and mechanical stress, deliberately suppressing biodiversity to favour a few privileged species of economic interest. As opposed to this, traditional agriculture has provided a high diversity of mostly small scale ecosystems and thus of biodiversity, often with a higher species diversity (but a different composition) than protected or otherwise unmanaged areas.

Consequently, land use intensity measures provide valuable information regarding the pressures on biodiversity, and they open the opportunity to integrate such land use into broader quantitative measurement frameworks for environmental pressures and thus to mainstream this crucial element of biodiversity preservation into environmental, but also economic, development and other policies. In order to develop a simple and logical classification scheme suitable for ‘quick and dirty’ measurement, while at the same time offering a systematic linkage to the more sophisticated statistical information necessary for later, spatially disaggregated implementation strategies of the overall policy design, we build on the SEEA approach, as suggested by the GBF. For a simple communication, but in particular for data gathering in areas where no sophisticated, long term statistical data on land use exist, or the existing one are unreliable, the approach suggested is structured to allow the transformation of narrative information gathered locally into an ordinal scale of four classes, for ranking use intensities and combine it with available data. We have named the four classes *human made, intensively used or human controlled, extensively used or cultivated* and *semi-natural or human protected area*; similar delineations have been suggested in the literature for some decades now (see Figure 2, [21]). The distance between the four classes is not measurable, but for simplicity of the calculation they are assumed to be equidistant.

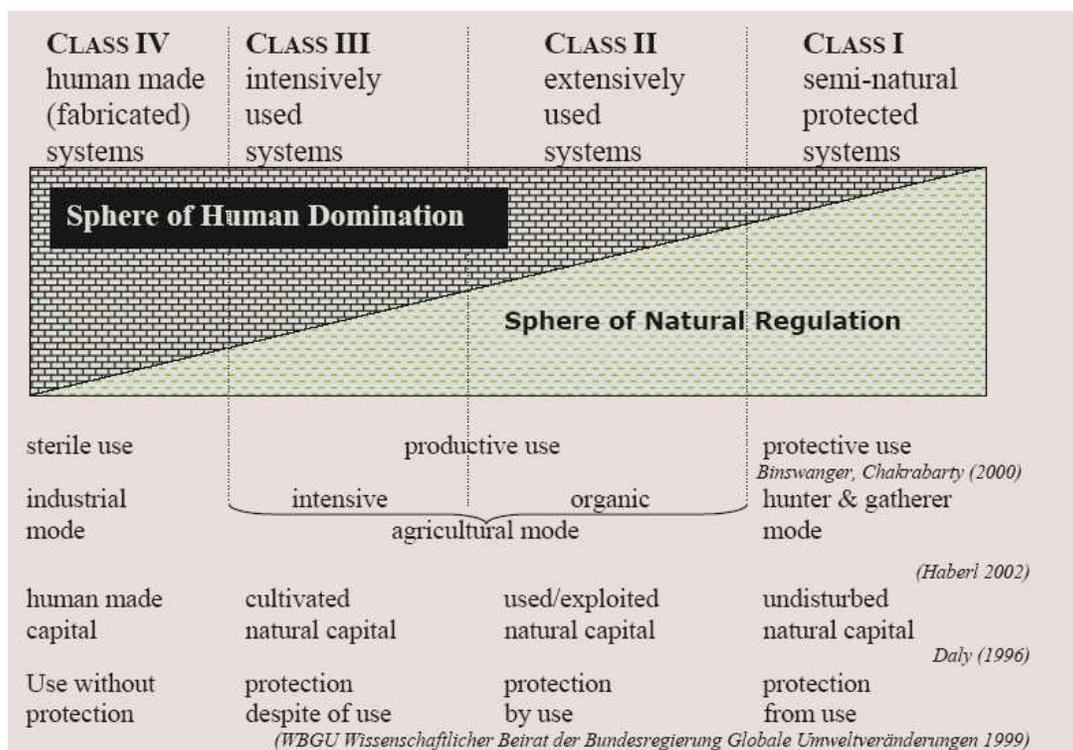


Figure 2. The overlapping of natural and anthropogenic regulation systems. *Semi-natural and protected:* In such areas, humans harvest a share of the yield from natural regulation, like small scale forest dwellers or regulatory hunters (game only) and careful gatherers do. *Extensively used:* eco-systems with low external inputs. Extensive use sets some framework conditions and uses the natural regulation mechanisms to produce the harvest. *Intensively used:* eco-systems with high input levels. They are dependent on hands-on steering of the system dynamics, humans dominating natural regulation processes. *Human made/fabricated:* area, i.e. built environment, characterised by humans suppressing and replacing natural regulation processes. Source: [21], modified.

When attempting to link these broad classes to available statistical categories, the alignment of the GBF with the SEEA is of limited support, as the SEEA itself provides no systematique of ecosystems (as earlier SEEA versions did), but refers to the IUCN classification of ecosystems [10] (p.71). This is a pity, as the IUCN system, not surprising for a system developed by a nature conservation organisation, mainly refers to ecosystem types without mentioning the level of human influence almost all ecosystems globally are exposed to (for terrestrial ecosystems, T1 to T6). Only the last category, T 7, is dedicated to human-managed ecosystems. Based upon this system we suggest the following definitions:

- Human made or fabricated area comprises built-up land (sealed soil), IUCN category T7.4, the land underlying buildings and structures. It refers to building and adjacent open land, commercial/industrial land (including mining land), traffic areas, i.e. built environment, characterised by humans replacing natural regulation processes.
- Intensively used, anthropogenically controlled ecosystems with high input levels, IUCN categories T7.3 (plantations including intensive forestry areas), T7.2 (sown pastures and fields, for instance for beef and dairy farming) and annual croplands (T7.1 referring to intensive agriculture, gardens, vineyards). They are dependent on hands-on steering of the system dynamics, humans dominating natural regulation processes.
- Extensively used, anthropogenically cultivated ecosystems with low external inputs, IUCN category T7.5 (derived semi-natural pastures and old fields, which should also include peatlands, heaths, orchards, cemeteries, fallow land and areas of sustainable forestry, fishing and grazing). Cultivation sets some framework conditions and uses the natural regulation

- mechanisms to produce the harvest. Other land uses (for example)
- semi-natural or human protected ecosystems, like protected or unused areas, IUCN categories T1 to T6, including non-cultivated wooded land and major water bodies. In such areas, humans harvest a share of the yield from natural regulation, like small scale forest dwellers or indigenous peoples do.

While the classes of urban and industrial ecosystems (T7.4) and those controlled by humans like plantations (T7.3), annual croplands (T7.1) and sown pastures and fields (T7.2) fit quite nicely with the IUCN categories, the case is more difficult for human cultivated systems. The IUCN systematique has one category for it, T7.5, named “derived semi-natural pastures and old fields”. For monitoring purposes, and reflecting the biodiversity impacts, it would be more adequate to limit the human controlled category to systems with high mechanical and chemical impacts, while chemicals-free, organic, agro-ecological and comparable traditional and indigenous land management systems would be part of category T7.5 – cultivated meaning human influenced but not controlled. This is relevant as – as highlighted in the GBF – indigenous land management has so far been the most biodiversity-friendly land use globally; indigenous peoples tend to be more guardians than exploiters of the land. The scheme is defined here for terrestrial ecosystems, limnic, coastal, marine and oceanic systems have not been taken into account and deserve separate treatment along similar lines of thought. IUCN offers classifications for these systems as well, although with limited regard to the pressure intensity they are exposed to.

Table 1 illustrates both the applicability of the existing classification system to land use intensity characterisation, but also points to some gaps to be filled. Better data presentation is desirable regarding the management forms, in particular for agricultural land and sustainable forestry. However, these data are available from national agricultural and land use statistics in most countries. Additional information can be found in the private sector, for instance at the Forest Stewardship Council FSC and at IFOAM Organics International which are running forestry and organic agriculture certification systems (although many small scale farmers do invest in certification although – often for reasons of tradition – their land management is essentially organic and sustainable. Consequently, the IUCN categorisation can be applied to characterise changes in the intensity of land use on an annual basis as essential information for biodiversity pressures, in particular if amended as suggested. Such an approach must complement and can simplify traditional, quality-focussed environmental policy and small scale measurements, but neither substitute for it nor be substituted by it.

Table 1. A matrix of land use types and intensities, description of key characteristics, name of statistical category for data mining.

Use	<u>Controlled</u>	<u>Cultivated</u>	<u>Protected</u>
intensity			
Land type			
Forest	monocultures, age classes, clear cutting IUCN category T7.3	age mixed age and natural rejuvenation; certified forestry is no IUCN category	indigenous and primary forests, selective extraction IUCN category T1 – T3
Pasture land	grazing cattle and goats IUCN category T7.2	low impact grazing, e.g. sheep or deer IUCN category T7.5	game only, regulatory hunting, IUCN category T4

Agricultural intensive land	agriculture IUCN category T7.1	Organic agroforestry, (as mentioned in the GBF) IUCN category T7.5	agriculture, agroecology	cautious gathering, IUCN category yet	no land
--------------------------------	-----------------------------------	---	-----------------------------	---	------------

Source: own compilation.

Given these land use intensity classification, we can now define the Land Use Intensity Index LUI. It distinguishes the four classes defined, with class 1 the lowest intensity level, and depicts the transition between them, offering a glimpse at the history of land use intensity development trends. Figure 3 illustrates the gradual difference of the categories and the extreme character of categories 1 and 4. Assuming equidistance of the classes, on the most simplified level, intensification and renaturalisation (i.e. the upwards and downwards movements in Figure 3) can be aggregated into one figure reflecting the net balance, with the class distances from Figure 3 as weighing factor (so that it does not matter if a piece of land is modified in one or more steps). The resulting index can be used to communicate whether the overall land use intensity has been increasing.

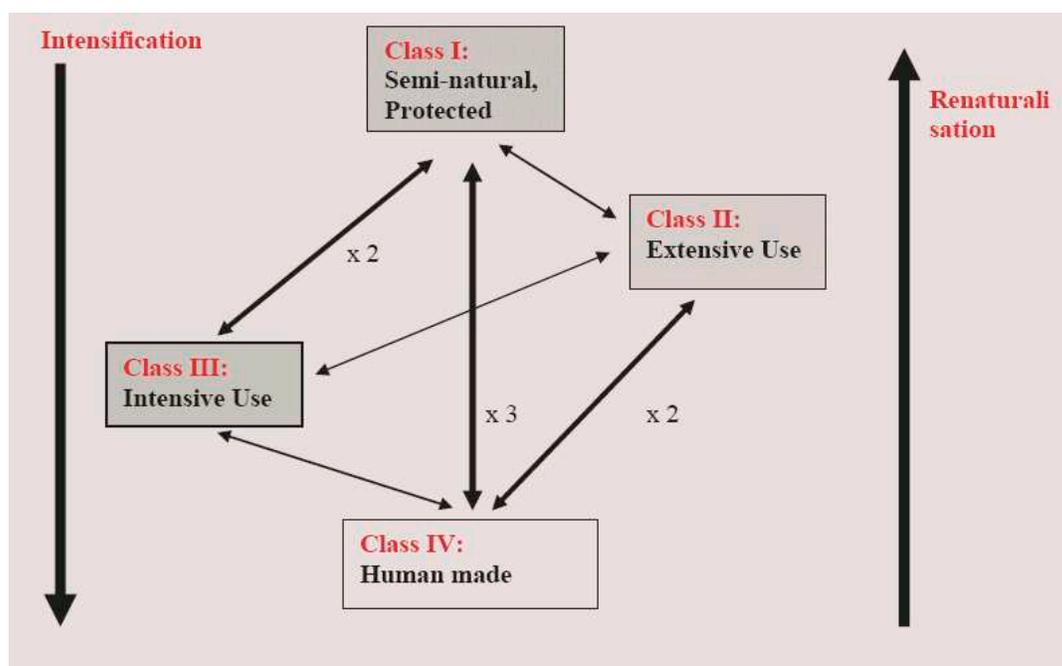


Figure 3. Dynamic land use change assessment.

However, even for setting overall policy targets it is of limited value, as it provides no obvious indication for priority setting. This can be achieved by not aggregating all data into one index, but by reporting the six transitions in Figure 3 separately. This is of high relevance for conservation and restoration as for instance if an area has only recently shifted from a lower to a higher intensity class, the resulting loss of biodiversity may not have fully materialised, offering opportunities for ecosystem recovery if the intensity is reduced again. On the other hand, if the system has been under even higher intensity in the past, it is plausible that significant efforts will be needed in restoring as good environmental state of the respective system. Hence not only the aggregate intensity development figure is of relevance, but also the order of the stages a system went through. As mentioned earlier, this is information not only available from official statistics, but also accessible by stakeholder interviews, making use of local community knowledge.

The dynamic description of shifts from one category to the other, for instance on an annual basis, can also serve to alert decision makers and focus their action on the most worrying trends. The policy

objective would then be to minimise the downward and maximise the upward transitions between the classes of the ordinal scale. In this sense, the proposed system goes beyond static state indicators and even comparative static time series, offering a conceptual tool for monitoring the large scale trends of land use dynamics and for presenting the results in an aggregated but easily digestible way.

If figures for both directions of transition are given (which can be comprehensively illustrated by just putting the data into the scheme provided by Figure 3), the necessary policy priorities are rather obvious for the respective level of monitoring and reporting (more detailed analysis is obviously essential when it comes to concrete local implementation).

4. Discussion and conclusions

As the IPBES 2019 report, to which the GBF seeks to respond, has highlighted, the most important driver of biodiversity loss is land use change, in particular land use intensification [2]. Assessing the state of species numbers, dominance structures, cover levels, spatial distributions and the like are standard procedures in scientific ecosystem analysis. They serve to characterise ecosystems, compare the composition of fauna and flora to the potential natural vegetation or the undisturbed regional state, and thus to analyse the interaction of different internal elements and external impacts, including human interference with the system. However, they are mostly focussed on certain aspects, elements and characteristics of the respective system and the influences affecting them, and do not focus on the overall pressure intensity. Pressure analysis can guide preservation policies without being dependent on such cost- and labour-intensive quantitative measurements of the state of biodiversity. They would still be desirable to monitor how effective the many policies in place now to conserve biodiversity have been, thus justifying additional efforts to develop effective ways of monitoring as demanded by the COP.

Changing management types are a comparably fast and sensitive indicator as compared to ecosystem species composition, and thus suitable as an early warning tool if conservation and restoration, as envisaged by the GBF, are on track.

Monitoring and communicating such land use intensity change poses a serious challenge, as the GBF indicators do not cover it (or at best indirectly via fertiliser and pesticide use trends), and the plethora of data being available for instance from agricultural and forestry statistics in some countries (but often using diverging definitions, resulting in incomparable data) is not communicable. In other countries, a lacking track record of past land use intensity alterations makes orally transmitted information, collected by stakeholder interviews, the best available data source, but one not easily transformed into (semi-)quantitative assessments. In particular in countries with relatively weak statistical systems, oral information transfer often plays a high role and is of surprising quality. However, as stakeholders observe rather than measure change, classifying observations requires an ordinal scale approach, with classes wide enough to accommodate the observations but still suitable to characterise land use history.

The value of such information has been highlighted by recent research showing a high level of concordance between local knowledge and remote sensing results in places where such technologies could be applied [22]. The proposal in this paper provides the opportunity to monitor changes in land use intensity based on widely available statistical data from official land use statistics in a simplified fashion, and to integrate them with qualitative oral information in semi-quantitative classification.

Funding: This research was funded by the European Commission, DG RES, under grant number GOCE-CT-2003-506675.

Data Availability Statement: Data sharing is not applicable as no new data were created or analyzed in this study. Data sharing is not applicable to this article.

Acknowledgments: The author is indebted to the entire ALARM project consortium for inspiring discussions.

Conflicts of Interest: The author declares no conflict of interest.

References

1. CBD Conference of the Parties to the Convention on Biological Diversity 2022a. Fifteenth meeting, Part II, Montreal, Canada, 7-19 December 2022. Agenda item 9A, Document CBD/COP/15/L.25: Kunming-Montreal Global biodiversity framework. Convention on Biological Diversity, COP Decisions, Decision 15/4. Available online: <https://www.cbd.int/decisions/cop/?m=cop-15> (accessed on 27 December 2022).
2. IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services [Bronzizio, E. S., Diaz, S., Settele, J.]. The IPBES Global Assessment on Biodiversity and Ecosystem Services, Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Bonn, Germany, 2019; 1148 pp.
3. CBD Convention on Biological Diversity. Global Biodiversity Outlook 5., CBD Secretariat: Montreal, Canada 2020.
4. UNEP IRP United Nations Environment Programme International Resource Panel [Oberle, B., Bringezu, S., Hatfeld-Dodds, S., Hellweg, S., Schandl, H., Clement, J., Cabernard, L., et al.]. Global Resources Outlook 2019: Natural Resources for the Future We Want. Summary for Policy Makers. UNEP: Nairobi, Kenya, 2019.
5. McElwee, P., Turnhout, E., Chiroleu-Assouline, M., Clapp, J., Isenhour, C., Jackson, T., Kelemen, E., et al.. Ensuring a Post-COVID Economic Agenda Tackles Global Biodiversity Loss. *One Earth* 2020, 3(4), 448-461. <https://doi.org/10.1016/j.oneear.2020.09.011>.
6. Turnhout, E., McElwee, P., Chiroleu-Assouline, M., Clapp, J., Isenhour, C., Kelemen, E., Jackson, T., et al. Enabling transformative economic change in the post-2020 biodiversity agenda. *Conservation Letters* 2021, 14(4), e12805. <https://doi.org/10.1111/conl.12805>.
7. Visseren-Hamakers, I. J., Razaque, J., McElwee, P., Turnhout, E., Kelemen, E., Rusch, G. M., Fernández-Llamazares, Á., et al.. Transformative governance of biodiversity: insights for sustainable development. *Current Opinion in Environmental Sustainability* 2021, 53, 20-28. <https://doi.org/10.1016/j.cosust.2021.06.002>.
8. EEA European Environment Agency. The European Environment – State and Outlook 2020: Knowledge for transition to a sustainable Europe, Publications Office of the European Union: Luxembourg, Luxembourg, 2019.
9. CBD Conference of the Parties to the Convention on Biological Diversity 2022b. Fifteenth meeting, Part II, Montreal, Canada, 7-19 December 2022. Agenda item 9B. Document CBD/COP/15/L.26: Monitoring framework for the Kunming-Montreal global biodiversity framework. Convention on Biological Diversity, COP Decisions, Decision 15/5. Available online: <https://www.cbd.int/decisions/cop/?m=cop-15> (accessed on 27 December 2022).
10. United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, Version: 29 September 2021, pre-edited text subject to official editing. Available online: <https://seea.un.org/ecosystem-accounting> (accessed on 27 December 2022).
11. Thomas, C. D., Cameron, A., Green, R. E., Bakkenes, M., Beaumont, L. J., Collingham, Y. C., Erasmus, B. F., et al. Extinction risk from climate change. *Nature* 2004, 427, 145-148. <https://doi.org/10.1038/nature02121>
12. Ziegler, R., Balzac-Arroyo, J., Hölsgens, R., Holzgreve, S., Lyon, F., Spangenberg, J. H., Thapa, P. P. Social innovation for biodiversity: A literature review and research challenges. *Ecological Economics* 2022, 193, 107336. <https://doi.org/10.1016/j.ecolecon.2021.107336>
13. Sun, Z., Behrens, P., Tukker, A., Bruckner, M., Scherer, L. Shared and environmentally just responsibility for global biodiversity loss. *Ecological Economics* 2022, 194, 107339. <https://doi.org/10.1016/j.ecolecon.2022.107339>.
14. Spangenberg, J. H. Inside the Anthro-Populo-Consumo-Capitalocene. *Anthropocene Science* 2022, 1(3), 358-374. <https://doi.org/10.1007/s44177-022-00031-3>.
15. Spangenberg, J.H., Zimmermann, R. So lasst uns denn ein Pinienwäldchen pflanzen.... FIF Forum für interdisziplinäre Forschung 1990, 3, 23-26.
16. Gazol, A., Camarero, J. J. Compound climate events increase tree drought mortality across European forests. *Science of The Total Environment* 2022, 816, 151604. <https://doi.org/10.1016/j.scitotenv.2021.151604>.
17. Wieler, A. Ein Beitrag zum Verständnis des Wesens der Bodenazidität und ihres Einflusses auf das Wurzelwachstum. In *Jahrbücher für wissenschaftliche Botanik*, Germany, 1932, Volume 76, pp. 333-406
18. Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., et al. Planetary boundaries: Guiding human development on a changing planet. *Science* 2015, 347(6223), 736; 1259855. <https://doi.org/10.1126/science.1259855>.
19. Persson, L., Carney Almroth, B. M., Collins, C. D., Cornell, S., de Wit, C. A., Diamond, M. L., Fantke, P., et al. Outside the Safe Operating Space of the Planetary Boundary for Novel Entities. *Environmental Science & Technology* 2022, 56(3), 1510–1521. <https://doi.org/10.1021/acs.est.1c04158>.
20. Hammen, V. C., Settele, J. Biodiversity and the loss of biodiversity affecting human health. In *Encyclopedia of Environmental Health*. Nriagu, J. O., Ed. in chief; Elsevier Science BV: Amsterdam, Netherlands, 2011, pp. 353–362. 1

21. Spangenberg, J. H. Environmental space and the prism of sustainability: frameworks for indicators measuring sustainable development. *Ecological Indicators* 2002, 2(3), 295-309. [https://doi.org/10.1016/S1470-160X\(02\)00065-1](https://doi.org/10.1016/S1470-160X(02)00065-1).
22. Takasaki, Y., Coomes, O. T., Abizaid, C., Kalacska, M. Landscape-scale concordance between local ecological knowledge for tropical wild species and remote sensing of land cover. *Proceedings of the National Academy of Sciences* 2022, 119(40), e2116446119. <https://doi.org/10.1073/pnas.2116446119>.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.