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

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Abstract: Biodiversity loss has been identified as one of the environmental impacts where humankind has been trespassing over planetary boundaries most significantly. Going beyond the pressures causing damages (calling them 'direct drivers') and analysing their underlying driving forces, IPBES, the Intergovernmental Science–Policy Platform for Biodiversity and Ecosystem Services, also identified a series of indirect drivers. The Montreal–Kunming Global Biodiversity Framework, GBF, including its suggested monitoring approach, is intended to and claims to be a policy response to such analyses. However, to assess the human impact on ecosystems as a basis for planning conservation and restoration, as foreseen in the GBF, monitoring ecosystem typologies (in the GBF with reference to the UN statistical standard SEEA ES, which, in turn, refers to the IUCN ecosystem classification) is not enough. It needs to be complemented with data on the severity of human impacts and on the history of places, i.e., how and when the current ecosystem status was brought about. In this conceptual paper, we suggest LUI, a deliberately simple ordinal scale index for land use intensity changes, to address these two gaps. It is based on the hemeroby concept, measuring the human impact as deviation from naturalness. This makes it an information collection and presentation tool for those working in landscape planning and management. LUI's simple and intuitively understandable structure makes it suitable for citizen science applications, and, thus, for participative monitoring when extensive statistical data gathering is not feasible and past data are not available. Of course, it can also be used as a simple tool for communicating when detailed statistical data series are available. While the aggregate index is expected to communicate well, its components are more relevant to motivate and help policy makers to prioritise their decisions according to the severity of recent anthropogenic ecosystem disturbances.

Keywords: biodiversity loss; driving forces; land use intensity; fragmentation; land use intensity index LUI

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1. Introduction

The Kunming–Montreal Global Biodiversity Framework (GBF), adopted on 18 December 2022, is a major step forward for biodiversity conservation and restoration [1]. 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] [1]. In target 2, it seeks 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 [4] (the experience of climate policy and the Paris targets are reasons for scepticism about this approach). Some further demands are summarised in Box 1.

To monitor the efforts, indices are required, which are applicable across the wide variety of countries and their ecosystems, to obtain at least an impression of how much progress is made in halting the increase and reducing the level of biodiversity pressures.

Box 1. 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 the 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—The Role of LUI

Two main conditions for realising the GBF's ambitions are identifying the direct and indirect drivers that caused the deterioration of the state, and reducing or eliminating 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 a 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 its System of Environmental–Economic Accounting SEEA and its extension for ecosystem accounting, SEEA EA [10]. The CBD headline indicators and almost all component indicators focus on the state of the factor they describe; few—mostly complementary indicators—indicate trends, and none refer to past developments, identifying the pressures that brought about the current state. Trends can be derived from time series, but are not indicators in themselves. The monitoring system uses area as an easily understood and measured indicator of crucial importance, as the abundance of a species is approximately halved when half of its habitat is lost, leaving the prevailing quality (and, over time, its change) as the main reporting challenge. As monitoring does not include backcasting, no information on the causes that have led to the status quo is provided. In this, the monitoring system endorsed at CBD COP [9] is similar to the SEEA EA system [10], which records the extent and the quality status of ecosystems, with the extent monitoring also covering the state of land fragmentation, but not past trends.

Backcasting is also lacking in the Unified Classifications of Threats and Actions [11]. It initially called the direct drivers 'direct threats', comprising sources of stress and proximate pressures, i.e., the proximate human activities or processes that have caused, are causing, or may cause the destruction, degradation, and/or impairment of biodiversity targets; a later version referred to them as 'pressures' [12,13]. It classified the indirect drivers, comprising the ultimate underlying factors and root causes, usually social, economic, political, institutional, or cultural, that enable or otherwise add to the occurrence or persistence of proximate direct drivers, as 'contributing factors'. In a 2016 updated version, it referred to them as 'driving forces' [13]. In this paper, we follow the IPBES terminology of direct and indirect drivers, aware of earlier research describing the same phenomena using different terms.

A lack of past data is, of course, no argument against monitoring the current state—such information, and the implications for impacts on biodiversity and ecosystems, is 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 the restoration measures taken (see Figure 1).

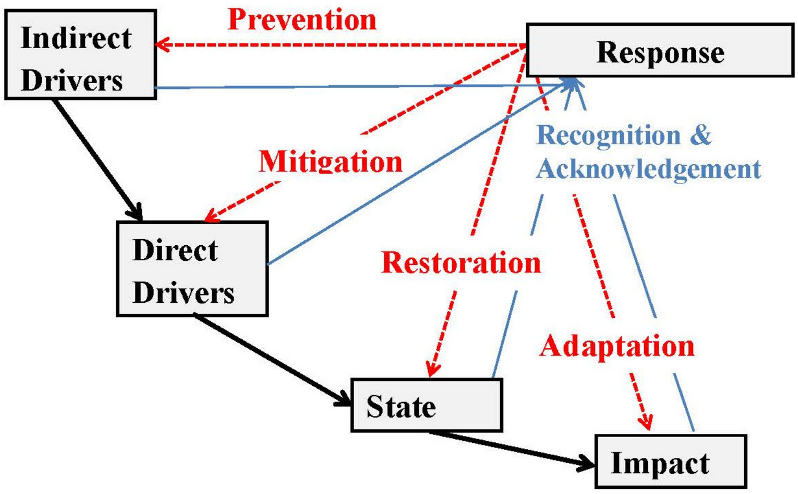

Figure 1. Different kinds of interventions require monitoring different factors and developments, with direct and indirect drivers currently not covered despite their importance for planning effective mitigation and adaptation measures. Source: Author [14].

While recognising the direct drivers (or pressures) is relatively straight forward, the situation for the indirect drivers is more challenging. Depending on culture and other institutional settings, different indirect drivers can contribute to the same direct ones, and, hence, the same interventions, in which biophysical disruptions can be caused, supported, or triggered by different decision making processes in politics, business, and civil society. 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 could withstand higher top speeds of storms. Each of such selection conditions narrows the gene pool and limits the adaptability for future stresses, such as anthropogenically caused changing temperatures and precipitation conditions [15]. 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 logging, . . .) can be too much pressure in another—it is the combination of ecosystem characteristics and use patterns, which must be in a balance against the backdrop of the prevailing natural disturbance regimes. These are usually not considered as direct or indirect pressures [11] except when they are modified by human influence. Then they turn into indirect drivers, causing significant biodiversity loss. Examples include the introduction of invasive species [18], eutrophication from transforming the Amazon for agricultural use, leading to Saragossum blooms [19], or anthropogenic climate change [11] intensifying wildfires in recent years in Siberia, Canada, Australia, and even the UK. Through multiple temporal and spatial feedbacks between human and natural disturbance regimes, entire landscapes are shifted into, and then maintained (trapped) in, a highly compromised structural and functional state, a process which has been described as the "landscape trap" [20].

While not explicitly mentioning direct drivers/pressures, the GBF addresses this challenge indirectly, by defining goals for two aspects of intensive agriculture: it demands the reduction of both excess nutrient loss to the environment and the overall risk from pesticides and highly hazardous chemicals by at least half by 2030 (target 7). The demand to work towards eliminating plastic pollution by the same year affects intensive agriculture as well, since plastic films covering the land and degrading into microplastic after use are often part of the system. Addressing these transgressions of planetary boundaries is welcome from a biodiversity and environmental point of view, but picks out only a few of the defining elements of land use change instead of providing criteria for distinguishing use intensity levels [21,22]. Hence, one gap in the suggested monitoring programs is the exclusive focus on the current state, with no information on how it came into being. A frequent second one is the lack of a reference point indicating the severity of impacts (as measured, for instance, by the hemeroby index [11]). A third challenge is constituted by the use of cardinal measures for indices, which require intensive data collection, can go beyond the capabilities of citizen science data collectors, and do not lend themselves to retrospective analysis. LUI has been designed to address these problems.

3. Hemeroby and the Land Use Intensity Index LUI

Policy-relevant landscape indices need to measure the human impact on the landscape, and, hence, assessment tools play a key role in land management and territorial planning. Transparent and inclusive assessment procedures enable informed and participative decision making, based on solid, but not necessarily sophisticated, scientific observations and monitoring, and are suitable for citizens to use in order to participate in their application. In this way, by using a shared approach, a common cognitive framework can emerge, allowing for an enhanced role of citizens in information collection (citizen science) and decision making [23].

In this conceptual paper, we use land use intensity as a proxy for the direct drivers related to land use. This appears justified, as land use can be considered the interface between the natural conditions of the landscape and the anthropogenic influence. Land use intensity not only modifies the composition of the plant cover and the associated fauna [24,25], but also soil aggregates composition and stability [26], carbon pool dynamics, and soil microbial respiration [27] in ecosystems as different as Alpine highland meadows and humid subtropical lowlands. 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 [28].

In order to develop a simple and logical classification scheme suitable for 'quick and dirty' measurement, we define the four LUI classes aligned to those hemeroby levels describing reversible human interventions [29]. The terminology of hemeroby was coined by Jalas [30] and refined by Sukopp [31], and is now regularly used in landscape planning and management, in particular in German speaking countries and regions. According to Sukopp [32], the degree of hemeroby is an integrative measure for the impacts of all human interventions on ecosystems, whether they are intended or not. It is the result of the impact on a particular area and the organisms which inhabit it, and increases with growing human influence. The degree of hemeroby is given by a cardinal index, based on simple indicators such as the share of neophytic species, morphological and chemical soil features, and land use types (for an illustration of indication levels, see Figure 2).

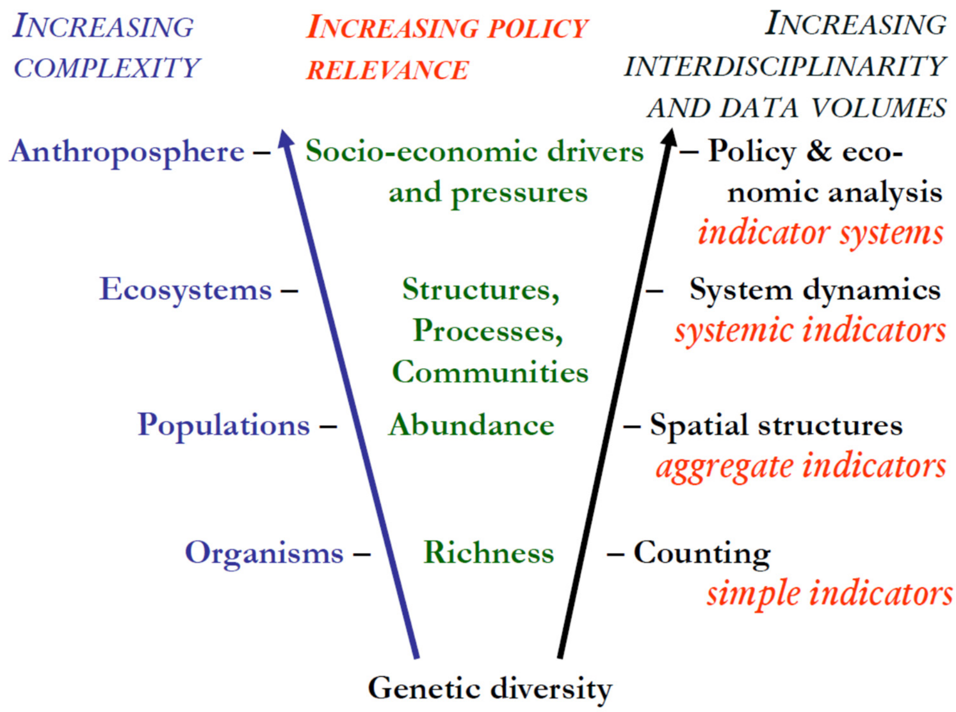

Figure 2. Indicators and indices on different complexity levels measure different characteristics of ecosystems and their respective biocenoses. The hemeroby index and LUI are on the level of systemic indicators; the former is calculated mainly from simple indicators.

Eurostat defines hemeroby, in a more simple way, as the magnitude of the deviation from the potential natural vegetation caused by human activities (https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Hemeroby_index, accessed on 30 March 2023). More specifically, Kowarik distinguishes 'closeness to nature' from hemeroby [33]. The former takes the original, culturally still-uninfluenced, state as its reference point, although it can only be reconstructed by making a variety of (sometimes heroic) assumptions. The latter, hemeroby, takes the potential vegetation and fauna of the site that would develop when human influence ceases and self-regulation takes place as its reference point. Both can be considered to be interpretations of the term 'naturalness'. Hence, hemeroby can be understood as an inverse measure of naturalness if anthropogenic interventions are reversible [29]. In plant ecology, the hemeroby index is widely used to characterise the anthropogenic disturbance level of a habitat, but is also applicable, e.g., to the bird populations nesting or feeding in the disturbed areas [24]. However, it does not address the anthropospheric complexity, providing no policy and economic analysis, which has motivated authors such as Erb et al. to suggest even more complex measurement systems, including input, output, and system structure [34,35]. On the other hand, when Hill et al. analysed biodiversity in urban England, they found the hemeroby index possible to calculate, but too complicated for their purpose [36]. They suggested to use a set of simple indicators, such as share of neophytes, which can be an appropriate solution if a strong correlation with the higher level index can be demonstrated.

3.1. Hemeroby

The four classes of LUI are aligned to a subset of the hemeroby levels as defined by Sukopp [31]. Pristine nature, free from human influence (which today exists hardly anywhere), is excluded, as well as fabricated systems where nothing of the initial biocenosis is left and the soil and aquifer conditions have been altered so much that, if human pressure abated, a different potential natural vegetation would emerge. However, LUI is defined as an ordinal (hemeroby-aligned) scale measurement system of four classes, which reduces the data demand as compared to a cardinal index of hemeroby, without going back to the level of simple indicators. The distance between the four classes is not measurable, but, for simplicity of the calculation, they are assumed to be equidistant. We have named the four classes *human made*, *intensively used*, *extensively used*, and *semi-natural and human protected area*; similar delineations have been suggested in the literature for some decades now (see Table 1). LUI will be defined as an aggregate measurement of the shifts which have occurred to a landscape over time.

Table 1. The classes of LUI in the gradient of anthropogenic interventions.

Nature-Free	Class IV	Class III	Class II	Class I	Nature
Fabricated systems Metahemerobe Biocenoses destruction irreversible	Human made systems Polyhemerobe Partial reversibility, support dependent	Intensively used systems Euhemerobe Partial reversibility, time consuming	Extensively used systems Mesohemerobe Almost full reversibility, natural process	Semi-natural and protected systems Oligohemerobe Full reversibility, natural process	Uninfluenced systems Ahemerobe No reversibility required
Examples					
Mining, quarrying, sealed soil under infrastructure	Settlement areas with green and blue elements (patchwork)	Intensive agriculture, tree plantations, high yielding monocultures	Organic agriculture, sustainable forestry, agroforestry	Protected and abandoned systems indigenous land use	Does not exist due to long-distance impacts
Selected references					
(WBGU 1999)	Use without protection	Protection despite use	Protection by use	Protection from use	
(Haberl 2002)	Industrial mode	Intensive agricultural mode	Organic agricultural mode	Hunter and gatherer mode	
Human made capital *(Daly 1996)*	Cultivated natural capital		Used/exploited natural capital		Undisturbed natural capital
sterile use *(Binswanger, Chakrabarty 2000)*	Productive use		Protective use		

The deliberately simple basic measurement structure is intended to make data gathering easier, for example, in UK cities, but, in particular, in areas where no systematic, detailed, long-term statistical data on land use exist, or where the existing ones are unreliable. Obviously, it can also be used as a simple, intuitively understandable way of presenting information from more data-rich sources, presenting developments over time in a rather coarse manner. In particular, the simple structure allows to transform narrative- or interview-based information gathered locally into an ordinal, hemeroby-related scale and combine it with other available data.

Table 1, while not intended to cover drivers and impacts exhaustively, provides some illustrative examples. For instance, 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, which, together with the changed soil structure and water regimes, will make a recovery of the initial system impossible. Intensively managed, large scale, and high input agricultural areas are exposed to chemical and mechanical stress, deliberately suppressing biodiversity to favour a few privileged species of economic interest, and, given the partly long residual time of chemicals in the soil, will take an extended period to recover.

Semi-natural and protected: In such areas, humans harvest a share of the yield from natural regulation, such as small scale forest dwellers, 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, with humans dominating natural regulation processes. *Human made:* An area, i.e., a built environment, that is characterised by humans suppressing and replacing natural regulation processes. The hemeroby classification is following that of Steinhardt et al. [37], who refer to Sukopp [32]. Following Kowarik [29], we understand hemeroby as an inverse measure of naturalness if anthropogenic interventions are reversible. Hence, unimpacted nature and irreversibly damaged systems are excluded from LUI. Reversibility estimates come from past experience. Source: author.

In opposition 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 with a different composition) than protected or otherwise unmanaged areas.

3.2. Calculating LUI

Given these land use intensity classifications, we can now define the Land Use Intensity Index, or LUI. It is based on the four classes defined, and depicts the transition between them, offering a glimpse at the history of land use intensity development trends. Figure 3 illustrates the differences in the categories, the potential moves between them, and the quality states not part of LUI: the pristine state of nature which can easily be left but can hardly be reached again, and the no-nature situation of fabricated systems, which can be rather easily reached, but are extremely hard to leave again. As LUI monitors reversible transitions, both states are not part of the index. Assuming equidistance of the classes, intensification and re-naturalisation (i.e., the upwards and downwards movements in Figure 3 indicating decreasing and increasing hemeroby) can be aggregated into one figure reflecting the net balance, with the class distances from Figure 3 as weighing factors. In this calculation, it does not matter if a piece of land is modified in one or more steps, nor does the order of subsequent steps matter—an admittedly simplifying assumption, given the possibility of path dependent developments. The resulting index can be used to communicate whether, and, if so, how significantly, the overall land use intensity has been increasing.

However, while possibly good for communication, the aggregate figure is of limited value for setting policy targets as it provides no obvious indication for priority setting. This can be achieved by not aggregating all of the data into one index, but by reporting the six transitions in Figure 3 separately. This is of high relevance for conservation and restoration—for instance, if an area has only recently shifted from a lower to a higher intensity class (hemeroby increase), the resulting loss of biodiversity may not have fully materialised. This would offer opportunities for ecosystem recovery if the intensity is reduced again quickly enough. 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 the good environmental state of the respective system. Hence, not only is the aggregate intensity development figure of relevance, but also the order of the stages that a system went through, and the time that has passed since the transition. As mentioned earlier, this is information not only available from official statistics but also accessible by stakeholder interviews, making use of local community knowledge. In a test involving over 900 communities and nearly 4000 households, Takasaki et al. found that the knowledge regarding the presence of local species, often underestimated regarding its comprehensiveness and reliability, was in 'strong concordance' with the land cover information gathered by regional remote sensing as a proxy for species habitat [38].

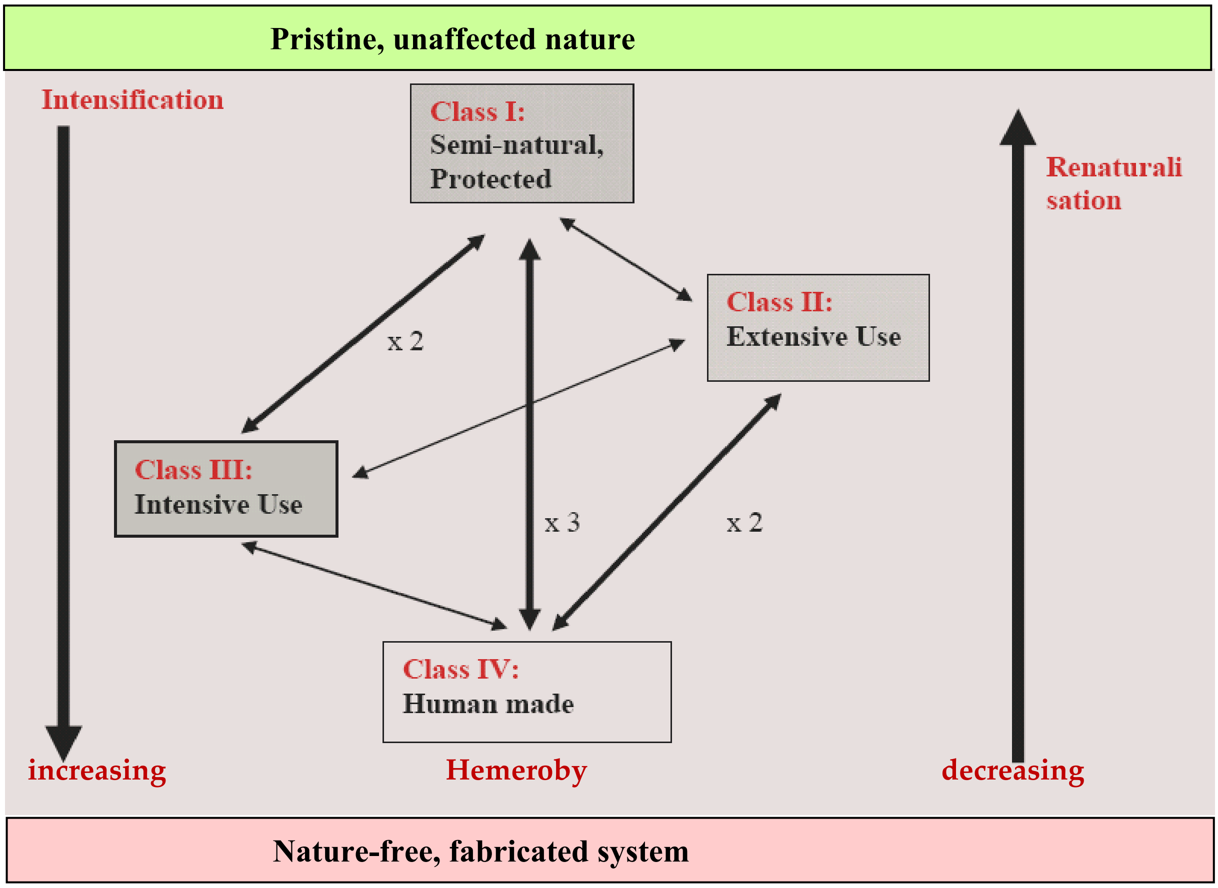

Figure 3. Dynamic land use change assessment—moving between four classes, with no movement into the state above or out of the state below considered possible.

Local knowledge can fill gaps in cases where remote sensing is difficult due to rather permanent cloud covers, provide additional information in the case of multi-storey agriculture (e.g., ground vegetables, bushes, bananas, palm trees) which remote sensing has difficulty penetrating, and can inform if the habitat suitable for certain species is, indeed, populated by them. Furthermore, in these regions with long and detailed time series of observations, the narratives can give a good impression of past land use changes, and the four simple classes of LUI have been designed to accommodate local narratives reaching back a generation or more. The historical perspective can be extended significantly when stimulated by using appropriate tools; Goussios and Faraslis, using 3D Geovisualisation for participatory retrospection to mobilise the collective memory, managed to generate a reconstruction of spatial of land use and exploitation in the early 19th century [39]. Deep structural changes made even longer ago may be indicated by street and area names referring, e.g., to shores, rivers, or harbours long relocated, or to swamp areas long drained [40].

3.3. Linking LUI Back to GBF and IUCN

Mapping the LUI classes on the GBF monitoring scheme is necessary to unlock the potential of local and indigenous knowledge on local biodiversity and to mobilise it for GBF monitoring, as well as to introduce information about change dynamics into the assessments. As mentioned, the GBF monitoring system offers no categories and indicators of its own.

When attempting to find a systematic linkage of the broad hemeroby-based classes of LUI to the more detailed statistical information necessary for later, spatially disaggregated implementation strategies of the overall policy design, we looked at two IUCN categorisation systems.

The first option we considered is establishing a systematic link to the SEEA approach, as suggested by the GBF. However, this solution—preferable due to the GBF recommendation—is not without problems, as the SEEA itself provides no system of ecosystems (as earlier SEEA versions did), but refers to the classification of ecosystems developed by IUCN CEM [10] (p.71). However, 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 that almost all ecosystems globally are exposed to. Hence, the terrestrial ecosystems, T1 to T6, are classified as if undisturbed by human impact; only the last category, T7, classifies human-managed ecosystems. The second option we checked is establishing a link to the threat/direct driver categories of the IUCN CMP system [12,13]. Unfortunately, as this system's categories are based on land use purposes, regardless of the impacts caused, the correspondence between ecosystem type and impact levels, to the hemeoroby based LUI classes, is even weaker than for the IUCN CEM ecosystem types, which at least indirectly reflect impacts as far as they are caused by specific land use forms. Based upon these considerations, we suggest the following 'translation' into IUCN categories:

- Human made systems (LUI class IV) can be related to 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 environments characterised by humans replacing natural regulation processes. In the IUCN CMP classification of threats to biodiversity, this corresponds to residential and commercial development, in addition to the transportation category, roads, and railroads. While, in LUI, mining areas and soil under infrastructure are considered "nature-free" and not covered, the reminder of IUCN category T7.4 falls under the definition of LUI class IV.
- Intensively used systems (LUI class III) covers anthropogenically controlled ecosystems with high input levels, corresponding to several IUCN categories. Category T7.3 comprises plantations, including intensive forestry areas. Category T7.2 includes sown pastures and fields, plus intensive lifestock farming, such as, for instance, beef and dairy farming and annual croplands. Category T7.1 refers to special forms of intensive agriculture, such as gardens and vineyards, but should be extended to include land use such as liquid manure dumps. They are dependent on hands-on steering of the system dynamics where humans dominate the natural regulation processes. The IUCN CMP classification of threats to biodiversity is worse—the category covers agriculture, but orchards and agroforestry are closer to LUI class II than class III.
- Extensively used systems (LUI class II) are anthropogenically cultivated ecosystems with low external inputs (cultivation meaning to use rather than to suppress the natural regulation mechanisms to produce the harvest). It corresponds to IUCN category T7.5 comprising derived semi-natural pastures and old fields (the IUCN CMP categorisation as 'partly biological resource use' is even less helpful). Based on its use intensity, it should be understood to also include peatlands, heaths, orchards, cemeteries, fallow land and areas of sustainable forestry, hunting, plant gathering, fishing, bee-keeping, and grazing.
- Semi-natural or protected systems (LUI class I) comprise protected or unused areas, including abandoned land. This corresponds to IUCN categories T1 to T6, including non-cultivated wooded land and major water bodies. For CMP, this falls under land/water protection with elements of biological resource use. In such areas, humans harvest a share of the yield from natural regulation, such as small scale forest dwellers or indigenous peoples do.

While the classes of urban and industrial ecosystems (T7.4) and those controlled by humans, such as 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 system has one category for it: T7.5, named "derived semi-natural pastures and old fields". For monitoring purposes, and for purposes of reflecting the biodiversity impacts, we prefer to limit the 'human controlled' category (LUI class III) 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, corresponding to LUI class II. This is relevant since—as highlighted in the GBF and by IPBES [2]—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.

As a result of the mapping exercise, we see that IUCN ecosystem types, suggested by the GBF as the basis of biodiversity monitoring, comprise different land use forms of varying inherent intensity, and, hence, offer a chance to link them to policy-relevant information regarding the level of human-made system deformation, as provided by LUI. While there is some correspondence between the categorisations, as ecosystem types are, to some degree, aligned with land use types, this is not the case unequivocally. Hence, whenever a GBF-initiated and IUCN-category-based monitoring happens, the overlaps shown above can help to bridge the gap to the information about the hemeroby state of the systems, with LUI being used as a simple and transparent approach. Together, a more relevant set of information would emerge as the basis for land use monitoring and planning decisions.

Table 2 illustrates both the overlaps of categories discussed, and 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.

Table 2. A matrix of land use types and intensities, description of key characteristics, and names of statistical categories for data mining.

Use Intensity	Intensively Used	Extensively Used	Semi-Natural Protected
Land Type			
Forest	Monocultures, age classes, clear cutting, high yielding varieties IUCN category T7.3	Mixed age and species, natural rejuvenation, some neophyte species; certified forestry has no IUCN category	Indigenous and primary forests, local species, 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 land	Intensive agriculture IUCN category T7.1	Organic agriculture, agroforestry, agroecology (as mentioned in the GBF) IUCN category T7.5	Cautious gathering, no IUCN category yet

Source: own compilation.

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]. Consequently, land use intensity measures such as the hemeroby-based LUI provide valuable information regarding the pressures on biodiversity, and they open the opportunity to integrate land use and its change into broader quantitative measurement frameworks for environmental pressures. Thus, it seeks to mainstream this crucial element of biodiversity preservation into environmental, but also economic, development and other policies. 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 current potential natural vegetation, or to the undisturbed regional state (two measures of naturalness), 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 (or direct driver, or threat) analysis can guide biodiversity conservation and recovery policies without being dependent on cost- and labour-intensive field work to generate quantitative assessments 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 CBD COP. Hence, monitoring and communicating land use intensity change poses a serious challenge. Moreover, the GBF indicators do not cover the future (or, at best, indirectly cover it via fertiliser and pesticide use trends), and the plethora of data available, for instance, from agricultural and forestry statistics in some countries (too 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 it is of surprising quality. The value of such information has been highlighted by recent research showing a high level of concordance with remote sensing data. 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. This is why we have designed the LUI as an ordinal system, forgoing the higher level of precision provided by a cardinal hemeroby index but offering more intuitive understanding and easier handling, as well as the probability to offer meaningful results based on a limited amount of data.

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 actions on the most worrying trends. The policy objective would then be to minimise the downward transitions 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).

As a coarse but dynamic system, LUI could also feed into more recent methodological developments, such as the spatio-temporal land use pattern analysis as pursued by modelling and assessment projects such as STEPLand [41].

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 a semi-quantitative classification.

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Note

1 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].

References

1. CBD Conference of the Parties to the Convention on Biological Diversity 2022a. In Proceedings of the Fifteenth Meeting, Part II, Montreal, QC, 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. Brondizio, E.S.; Díaz, S.; Settele, J.; IPBES Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. *The IPBES Global Assessment on Biodiversity and Ecosystem Services*; Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services: Bonn, Germany, 2019; p. 1148.
3. CBD Convention on Biological Diversity. *Global Biodiversity Outlook 5*; CBD Secretariat: Montreal, QC, Canada, 2020.
4. UNEP IRP United Nations Environment Programme International Resource Panel. *Global Resources Outlook 2019: Natural Resources for the Future We Want. Summary for Policy Makers*; Oberle, B., Bringezu, S., Hatfeld-Dodds, S., Hellweg, S., Schandl, H., Clement, J., Cabernard, L., Che, N., Chen, D., Droz-Georget, H., et al., Eds.; UNEP: Nairobi, Kenya, 2019.
5. McElwee, P.; Turnout, E.; Chiroleu-Assouline, M.; Clapp, J.; Isenhour, C.; Jackson, T.; Kelemen, E.; Miller, D.C.; Rusch, G.; Spangenberg, J.H.; et al. Ensuring a Post-COVID Economic Agenda Tackles Global Biodiversity Loss. *One Earth* **2020**, *3*, 448–461. [CrossRef] [PubMed]
6. Turnhout, E.; McElwee, P.; Chiroleu-Assouline, M.; Clapp, J.; Isenhour, C.; Kelemen, E.; Jackson, T.; Miller, D.C.; Rusch, G.M.; Spangenberg, J.H.; et al. Enabling transformative economic change in the post-2020 biodiversity agenda. *Conserv. Lett.* **2021**, *14*, e12805. [CrossRef]
7. Visseren-Hamakers, I.J.; Razzaque, J.; McElwee, P.; Turnhout, E.; Kelemen, E.; Rusch, G.M.; Fernández-Llamazares, Á.; Chan, I.; Lim, M.; Islar, M.; et al. Transformative governance of biodiversity: Insights for sustainable development. *Curr. Opin. Environ. Sustain.* **2021**, *53*, 20–28. [CrossRef]
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, 2019.
9. CBD Conference of the Parties to the Convention on Biological Diversity 2022b. In Proceedings of the Fifteenth Meeting, Part II, Montreal, QC, 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. System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White Cover Publication, Version: 29 September 2021, Pre-Edited Text Subject to Official Editing. 2021. Available online: https://seea.un.org/ecosystem-accounting (accessed on 27 December 2022).
11. Salafsky, N.; Salzer, D.; Stattersfield, A.J.; Hilton-Taylor, C.; Neugarten, R.; Butchart, S.H.M.; Collen, B.; Cox, N.; Master, L.L.; O'Connor, S.; et al. A Standard Lexicon for Biodiversity Conservation: Unified Classifications of Threats and Actions. *Conserv. Biol.* **2008**, *22*, 897–911. [CrossRef] [PubMed]
12. CMP Conservation Measures Partnership 2020. Open Standards for the Practice of Conservation Version 4.0. Available online: https://conservationstandards.org/wp-content/uploads/sites/3/2020/10/CMP-Open-Standards-for-the-Practice-of-Conservation-v4.0.pdf (accessed on 18 March 2023).
13. CMP Conservation Measures Partnership 2016. Direct Threats Classification 2.0. Available online: https://docs.google.com/spreadsheets/d/1rJSNz1LG_KOqoudVFglodx47HZ9LR-M6iVlRYMvn9Wk/edit#gid=310830663 (accessed on 18 March 2023).
14. Spangenberg, J.H. Hot Air or Comprehensive Progress? A Critical Assessment of the SDGs. *Sustain. Dev.* **2016**, *25*, 311–321. [CrossRef]
15. Spangenberg, J.H.; Zimmermann, R. So lasst uns denn ein Pinienwäldchen pflanzen. *FIF Forum Interdiszip. Forsch.* **1990**, *3*, 23–26.
16. Gazol, A.; Camarero, J.J. Compound climate events increase tree drought mortality across European forests. *Sci. Total. Environ.* **2021**, *816*, 151604. [CrossRef] [PubMed]
17. Wieler, A. Ein Beitrag zum Verständnis des Wesens der Bodenazidität und Ihres Einflusses auf das Wurzelwachstum. *Jahrbücher Wiss. Bot.* **1932**, *76*, 333–406.
18. Mack, M.C.; D'Antonio, C.M. Impacts of biological invasions on disturbance regimes. *Trends Ecol. Evol.* **1998**, *13*, 195–198. [CrossRef]
19. University of South Florida Optical Oceanography Lab 2023. Outlook of 2023 Saragassum Blooms in the Caribbean Sea and Gulf of Mexico. Available online: https://optics.marine.usf.edu/projects/SaWS/pdf/Sargassum_outlook_2023_bulletin2_USF.pdf (accessed on 18 March 2023).
20. Lindenmayer, D.B.; Hobbs, R.J.; Likens, G.E.; Krebs, C.J.; Banks, S.C. Newly discovered landscape traps produce regime shifts in wet forests. *Proc. Natl. Acad. Sci. USA* **2011**, *108*, 15887–15891. [CrossRef]
21. Rockström, J.; Steffen, W.; Noone, K.; Persson, Å.; Chapin, F.S.I.; Lambin, E.F.; Lenton, T.M.; Scheffer, M.; Folke, C.; Schellnhuber, H.J.; et al. Planetary boundaries: Exploring the safe operating space for humanity. *Ecol. Soc.* **2009**, *14*, 1–32. [CrossRef]

22. Steffen, W.; Richardson, K.; Rockström, J.; Cornell, S.E.; Fetzer, I.; Bennett, E.M.; Biggs, R.; Carpenter, S.R.; De Vries, W.; De Wit, C.A.; et al. Planetary boundaries: Guiding human development on a changing planet. *Science* **2015**, *347*, 1259855. [CrossRef] [PubMed]
23. Battisti, F.; Campo, O.; Manganelli, B. Land Management in Territorial Planning: Analysis, Appraisal, Strategies for Sustainability—A Review of Studies and Research. *Land* **2022**, *11*, 1007. [CrossRef]
24. Battisti, C.; Fanelli, G. Applying indicators of disturbance from plant ecology to vertebrates: The hemeroby of bird species. *Ecol. Indic.* **2016**, *61*, 799–805. [CrossRef]
25. Fanelli, G.; Battisti, C. Comparing disturbance-sensitivity between plants and birds: A fine-grained analysis in a suburban remnant wetland. *Isr. J. Ecol. Evol.* **2014**, *60*, 11–17. [CrossRef]
26. Li, Y.; Ma, Z.; Liu, Y.; Cui, Z.; Mo, Q.; Zhang, C.; Sheng, H.; Wang, W.; Zhang, Y. Variation in Soil Aggregate Stability Due to Land Use Changes from Alpine Grassland in a High-Altitude Watershed. *Land* **2023**, *12*, 393. [CrossRef]
27. Ghorbani, M.; Amirahmadi, E.; Konvalina, P.; Moudrý, J.; Kopecký, M.; Hoang, T.N. Carbon Pool Dynamic and Soil Microbial Respiration Affected by Land Use Alteration: A Case Study in Humid Subtropical Area. *Land* **2023**, *12*, 459. [CrossRef]
28. Hammen, V.C.; Settele, J. Biodiversity and the loss of biodiversity affecting human health. In *Encyclopedia of Environmental Health*; Nriagu, J.O., Ed.; Elsevier Science BV: Amsterdam, The Netherlands, 2011; pp. 353–362.
29. Kowarik, I. Natürlichkeit, Naturnähe und Hemerobie als Bewertungskriterien. In *Handbuch der Umweltwissenschaften: Grundlagen und Anwendungen der Ökosystemforschung*; Schröder, W., Müller, F., Eds.; VCH Verlag: Landsberg, Germany, 2006; Section VI-3.12. [CrossRef]
30. Jalas, J. Hemerobe und hemerochore Pflanzenarten—Ein terminologischer Reformversuch. *Acta Soc. Fauna Flora Fenn.* **1955**, *72*, 1–15.
31. Sukopp, H. Wandel von Flora und Vegetation in Mitteleuropa unter dem Einfluβ des Menschen. *Ber. Landwirtsch.* **1972**, *50*, 112–139.
32. Sukopp, H. Dynamik und Konstanz in der Flora der Bundesrepublik Deutschland: Dynamics and constancy in the flora of the 1972, Federal Republic of Germany. *Schr. Veg.* **1976**, *1976*, 9–27.
33. Kowarik, I. Natürlichkeit, Naturnähe und Hemerobie als Bewertungskriterien. In *Handbuch Naturschutz und Landschaftspflege*; Konold, W., Böcker, R., Hampicke, U., Eds.; Wiley-VCH: Verlag Hoboken, NJ, USA, 2014; pp. 1–18.
34. Erb, K.-H.; Haberl, H.; Jepsen, M.R.; Kuemmerle, T.; Lindner, M.; Müller, D.; Verburg, P.H.; Reenberg, A. A conceptual framework for analysing and measuring land-use intensity. *Curr. Opin. Environ. Sustain.* **2013**, *5*, 464–470. [CrossRef]
35. Erb, K.-H.; Fetzel, T.; Haberl, H.; Kastner, T.; Kroisleitner, C.; Lauk, C.; Niedertscheider, M.; Plutzar, C. Beyond Inputs and Outputs: Opening the Black-Box of Land-Use Intensity. In *Social Ecology: Society-Nature Relations across Time and Space*; Haberl, H., Fischer-Kowalski, M., Krausmann, F., Winiwarter, V., Eds.; Springer International Publishing: Cham, Switzerland, 2016; pp. 93–124.
36. Hill, M.O.; Roy, D.B.; Thompson, K. Hemeroby, urbanity and ruderality: Bioindicators of disturbance and human impact. *J. Appl. Ecol.* **2002**, *39*, 708–720. [CrossRef]
37. Steinhardt, U.; Herzog, F.; Lausch, A.; Müller, E.; Lehmann, S. Hemeroby index for landscape monitoring and evaluation. In *Environmental Indices—System Analysis Approach*; Pykh, Y.A., Hyatt, D.E., Lenz, R.J., Eds.; EOLSS Publ.: Oxford, UK, 1999; pp. 237–254.
38. 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. *Proc. Natl. Acad. Sci. USA* **2022**, *119*, e2116446119. [CrossRef] [PubMed]
39. Goussios, D.; Faraslis, I. The Driving Role of 3D Geovisualization in the Reanimation of Local Collective Memory and Historical Sources for the Reconstitution of Rural Landscapes. *Land* **2023**, *12*, 364. [CrossRef]
40. Sousa, A.; García-Murillo, P. Can place names be used as indicators of landscape changes? Application to the Doñana Natural Park (Spain). *Landsc. Ecol.* **2001**, *16*, 391–406. [CrossRef]
41. Serra, P.; Salvati, L. Land Change Science and the STEPLand Framework: An Assessment of Its Progress. *Land* **2022**, *11*, 1065. [CrossRef]