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Strong sustainability and the environmental dimension of the Sustainable Development Goals

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Research Article

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Abstract

Non-technical summary. The Sustainable Development Goals (SDG) are at the core of the development agenda. Despite their wide adoption, it is still unclear the extent to which they can provide insights on environmental sustainability. The paper presents an assessment of the potential of the indicators used in the SDGs to track environmental sustainability. The results show that only a few SDG indicators describe the state of the environment, and those that do so, do not, generally, have science-based targets that describe whether environmental sustainability conditions are met. The latter aspect should be reinforced in framework that will replace the SDGs after 2030.

Technical summary. The Sustainable Development Goals (SDG) are at the core of the development agenda. Despite their wide adoption, it is still unclear whether they can be used to monitor environmental sustainability, if this is to be understood from a strong sustainability perspective. The paper presents an assessment of the adequacy of the indicator sets used by United Nations, Eurostat, OECD, and the Sustainable Development Solutions Network for strong sustainability monitoring. The results show that most environmental indicators do not have science-based environmental standards that reflect whether natural capital meets environmental sustainability conditions, thereby preventing their use as strong sustainability indicators. While meeting the SDGs would likely contribute to improving environmental performance, on their own they are not adequate to monitor progress toward it. Complementary scientifically grounded metrics are needed to track the underlying state of natural capital that provides non-substitutable functions. The strong sustainability dimension within the SDGs will need to be strengthened in post-2030 sustainable development monitoring framework.

Social media summary. The Sustainable Development Goals are insufficient to monitor environmental sustainability.

1. Introduction

The Agenda 2030 for Sustainable Development seeks to improve the economy, society, and the environment. The Sustainable Development Goals (SDGs) are at the core of that agenda and are intended to spur action in relevant areas of critical importance for humanity and the planet (UN, 2015). The SDGs are divided into 17 goals, which are complemented by 169 targets and 232 unique indicators (UN, 2023).

Given the prominent role the SDGs play in the international development agenda, their overall suitability and consistency has been subject of extensive research (Dawes, 2020; ICSU & ISSC, 2015; McGowan et al., 2019; Nilsson et al., 2018; Spaiser et al., 2017). The SDGs generally provide a coherent policy framework (Hák et al., 2016; Janoušková et al., 2018), but have relevant shortcomings at target and indicator levels. For example, there are trade-offs between some targets, while other targets are problematic because they cannot be quantified, which makes it difficult to determine whether they are met (ICSU & ISSC, 2015). The conceptual relevance of some indicators has also been criticized (Hák et al., 2016; Janoušková et al., 2018; Mair et al., 2018).

The extent to which the environmental component of sustainable development is adequately represented in the SDGs has also been scrutinized, since this was one of the main weaknesses of the preceding Millennium Development Goals (Ekins & Usubiaga, 2019; Elder & Olsen, 2019; ICSU & ISSC, 2015). Some argue that the environmental dimension is still underrepresented compared to the economic and social dimensions of the SDGs (Eisenmenger et al., 2020; Neumann et al., 2017). In practice, the environmental dimension is integrated differently at the different levels of the structure of the SDGs. Thus, the goals generally resemble the three-dimensions around which the concept of sustainable development is organized, with most goals belonging to one of the dimensions (namely, economy, society, and environment), although there are also a few goals that overlap with various dimensions. In this

context, the wording of goals 13 (climate action), 14 (life below water), and 15 (life on land) places them within the environmental dimension of sustainable development. On the other hand, goals 6 (clean water and sanitation), 7 (affordable and clean energy), 11 (sustainable cities and communities), and 12 (responsible consumption and production) have a more transversal focus, and therefore align not only with the environmental dimension, but also with the social and/or economic dimensions (Elder & Olsen, 2019). Under most goals, the targets become multidimensional. As a result, goals (including those considered purely environmental) can have environmental, social, or economic targets, and a combination thereof (Elder & Olsen, 2019). Nevertheless, this does not prevent several targets from being non-quantifiable or from lacking specificity as argued before (ICSU & ISSC, 2015).

Beyond the goals and targets, the indicators are the most relevant component of the SDGs when it comes to monitoring sustainable development. After all, goals and targets are used to provide a sound structure to the phenomena that is being measured, while the indicators are the actual measurement tools. In this context, several SDG assessments have used different indicator sets to monitor the SDGs (while keeping the 17-goal structure). Unsurprisingly, the results led sometimes to different findings and policy conclusions, thereby raising a flag around the potential effects of having diverging indicator selection processes (Dickens et al., 2020; Janoušková et al., 2018; Lafortune et al., 2020; Miola & Schiltz, 2019). Selection of indicators needs to find a balance between the number of indicators and the cost and feasibility of compiling them. In the SDGs, these concerns had an impact on the environmental component, thereby affecting the consistency between some targets and the underlying indicators (Elder & Olsen, 2019). Ultimately, prioritizing other factors over conceptual coherence when selecting indicator sets can switch the focus between what needs to be measured toward what can be measured at a lower cost, and effect that can also impact priority-setting when informing decision making. According to Campbell et al. (2020, p. 448), '[w]e use existing data to identify priorities, but priorities for data collection are identified on the basis of which topics are priorities'.

Arguably, there are two conflicting views about how environmental sustainability should be measured. Weak sustainability assumes that the functions of natural capital can be replaced by other forms of capitals (Neumayer, 2003). In practice this has led to the monetization of natural capital and the use of these values to adjust macroeconomic aggregates (Dietz & Neumayer, 2007; Lindmark et al., 2018). However, Ekins (2011) has questioned the validity of this practice when the adjustments involve non-marginal changes, which, if implemented, would completely change the price structure of the economy. At the same time, under the weak sustainability proposition, environmental indicators can be aggregated into composite indices using fully compensatory aggregation functions, which in turn allows for the linear compensation of poor performances in environmental indicators for good performances in social and economic indicators (Wilson & Wu, 2017). The opposite view is represented by strong sustainability. Under strong sustainability, there is limited substitution capacity between the functions of different types of capital (Neumayer, 2003). This has different implications on what it should be measured and how it should be aggregated into composite indices as it will be shown in Section 2. Hereinafter, the term environmental sustainability is used as understood from a strong sustainability perspective.

Previous research has provided some insights around the suitability of the set of SDG indicators that are related to the environment to monitor environmental sustainability. Campbell et al. (2020) showed that out of the 90 indicators with an environmental focus that could be found in the official SDG indicators set, only a dozen represented environmental states and trends. The others represented other issues such as environmental policies and interventions, changes in behavior, consumption and production patterns, and interactions between people and the environment. Dickens et al. (2020) also pointed out that environmental state indicators need to be reinforced, especially those that cover ecosystem health and biodiversity, given that these do not suffice to represent the breath of ecosystem types and key dimensions of biodiversity. The link between biodiversity performance and the environmental SDG indicators has also been called into question. In this line, the work by Zeng et al. (2020) showed that biophysical indicators of biodiversity conservation had limited correlation with environmental SDG indicators. Put together, these insights call into question the link between the SDG indicators and environmental sustainability.

As shown in the paragraph above, previous research has shown some of the limitations the SDG indicators have to monitor environmental sustainability. Nonetheless, previous analyses only provide a partial perspective around environmental sustainability without any connection to its conceptual underpinnings. In this line, existing assessments of the SDGs have not been structured around the notions of weak and strong sustainability, and generally do not consider related concepts such as environmental limits or science-based targets. This would provide new insights and integrate concepts that are gaining traction in policy discussions, especially if this were done developing a consistent and intuitive set of criteria to be fulfilled by indicators. The identification of core criteria that some of the environmental indicators should meet to monitor environmental sustainability would also facilitate the future revision of the SDG indicators in the post-2030 SDG agenda. Furthermore, previous studies have focused only on the official set of SDG indicators, which takes no account of the fact that well-known international institutions such as Eurostat or the OECD, as well as many countries around the world, have adopted their own sets of SDG indicators based on their own contexts.

Against this background, this paper examines various sets of SDG indicators from the strong sustainability standpoint. These sets include the official set of SDG indicators (UN, 2023) and those used by the OECD (2022) and Eurostat (2023). In addition, the analysis also includes the indicator set used in the SDG Index (Sachs et al., 2023), given its large audience. The analysis follows a two-stage approach. In the first stage, SDG indicators related to the environment are identified building on the work of Campbell et al. (2020). In the second stage, those indicators are interrogated against a set of relevant criteria that determines their suitability as environmental sustainability indicators from a strong sustainability standpoint. To the knowledge of the authors, only partial and anecdotical evidence of the adequacy of the SDG indicators to characterize environmental sustainability exists. To overcome this limitation and provide stronger evidence on the matter, several strong sustainability criteria are proposed to interrogate the SDG indicators. The results provide a more comprehensive and analytical view on whether SDG indicators could be used to monitor environmental sustainability, while bringing forward policy-relevant concepts such as science-based targets.

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2. Criteria for environmental sustainability indicators

According to strong sustainability, there are relevant limitations to the substitutability of the functions provided by natural capital and those resulting from manufactured, social, and human capital. In this context, natural capital should be understood as 'the elements of nature that directly and indirectly produce value or benefits to people, including ecosystems, species, freshwater, land, minerals, the air and oceans, as well as natural processes and functions' (NCC, 2014, p. 21). These limits also apply to natural capital itself, in that the functions associated with some elements of natural capital can rarely be substituted for those provided by other elements. For these reasons, under strong sustainability, the unique functions associated with natural capital need to be maintained indefinitely (Ekins et al., 2003).

Criteria to capture strong sustainability have been proposed previously in the context of the SDGs. The following paragraphs describe these criteria, which often conflict with each other. The criteria apply to two elements.

- Structure of an index or an indicator set: This refers to how the indicators and dimensions are organized within a set or an index and how poor performance in one indicator or dimension is compensated in others. This aspect is associated with the assumed substitution capacity between different capital types and between the environmental functions derived from natural capital.
- Nature of the indicators: This relates to the actual content of the indicator. It checks if the indicators truly represent the environmental roles played by nature or if they depict unrelated topics.

Regarding the structure of a hypothetical index, it has been argued that for the SDGs to capture strong sustainability, all the underlying indicators would need to maintain their current level or improve over time (Rickels et al., 2016). Thus, under this criterion, having a single indicator with a worsening performance over time would mean that strong sustainability conditions would not be met. Unless instructions to address trade-offs between indicators were provided, this statement would fall under the 'very strong' sustainability conditions originally described by Turner (1993), which other have referred to as 'absurdly strong sustainability' (Daly, 1995). Similarly, Neumann et al. (2017) stated that natural capital should be constant or increase under strong sustainability conditions. If less stringent conditions were to be set to compute an index based on the SDG indicators, the weighting of the dimensions, or the aggregation function used (and by extension, the degree of substitution assumed between indicators, targets, and goals) would determine where the index would feature in the weak–strong sustainability continuum (Rickels et al., 2016). In this context, some have opted to isolate the environmental dimension of strong sustainability in an index (Usubiaga-Liaño & Ekins, 2021a).

As for the nature of indicators, different authors have argued that the suitability to monitor strong sustainability depends on what is actually being measured, independent from the degree of substitution assumed between the indicators. Some have argued that only biophysical indicators can capture environmental sustainability (Giannetti et al., 2015), while others have claimed that biophysical indicators should be able to quantify if specific reference values are transgressed (Eisenmenger et al., 2020).

While the previous arguments hint at some of the characteristics that strong sustainability indicators need to have, there are relevant caveats to be acknowledged. When focusing on the structure of an index or an indicator set, the functions used to normalize, weight, and aggregate indicators determine where the index features in terms of weak and strong sustainability (Usubiaga-Liaño & Ekins, 2024). The maintenance of natural capital at a given level is considered a precondition for environmental sustainability, but limited research on what that level might be exists (Steffen et al., 2015; Usubiaga-Liaño & Ekins, 2021b; Vea et al., 2020). If, as argued before, environmental sustainability requires maintaining environmental functions over time, environmental sustainability indicators should meet the following criteria:

- The indicators need to be conceptually related to the functions provided by natural capital. Natural capital can act as a source of resources, as a sink that assimilates waste and regulates biogeochemical cycles, as a life support system, and as a provider of human health and other welfare functions (Ekins et al., 2003). Of course, other function groupings exist (e.g. de Groot et al., 2002), but they tend to overlap partially. Indicators that meet this criterion commonly take the form of environmental pressures, states, or impacts (EEA, 2003). For human health and welfare, social state indicators are more common.
- Indicators need to reflect whether environmental sustainability conditions are met. To that end, an adequate reference value is needed. Here we refer to these reference values as science-based environmental standards (SBES) following the typology described by Usubiaga-Liaño and Ekins (2021b).

3. Methodology

This paper presents an analysis that seeks to shed some light on whether the SDG indicators that are related to the environment can be used to characterize environmental sustainability. The SDGs have been subject to related analysis where Lafortune and Schmidt-Traub (2019) compared the methodological soundness of different approaches used to monitor the SDGs in Europe. This paper employs criteria proposed specifically in a context of strong sustainability.

Our analysis considers the official SDG indicators (UN, 2023), as well as other SDG indicator sets employed by international institutions such as Eurostat, OECD, and the Sustainable Development Solutions Network (Eurostat, 2023; OECD, 2022; Sachs et al., 2023). There are other relevant SDG reporting initiatives such as those led by the UN Economic Commission for Africa or that of the Economic and Social Commission for Asian and the Pacific that could have been included. Nonetheless, the former only reports progress on specific SDG goals (UNECA et al., 2022, 2023), which would strongly bias the results of the analysis, while the indicator set used by the latter heavily builds on the official UN set (ESCAP, 2024), and would therefore not provide additional insights. For this reason, beyond the official UN set, supranational institutions that have adapted the SDG indicator framework to their own context have been chosen. As a result of the variety of indicators adopted, these sources are considered to be representative of the many SDG indicators in use by different users. Nevertheless, more SDG indicator sets exist, since countries adopt the indicators that are more suited to their context (Dickens et al., 2019; Lafortune et al., 2020). The methodology employed here comprises three steps (Figure 1). The detailed results are documented in the supplementary Excel file.

First, the SDG indicator sets assessed were filtered to identify which indicators had an environmental focus. In doing so, we

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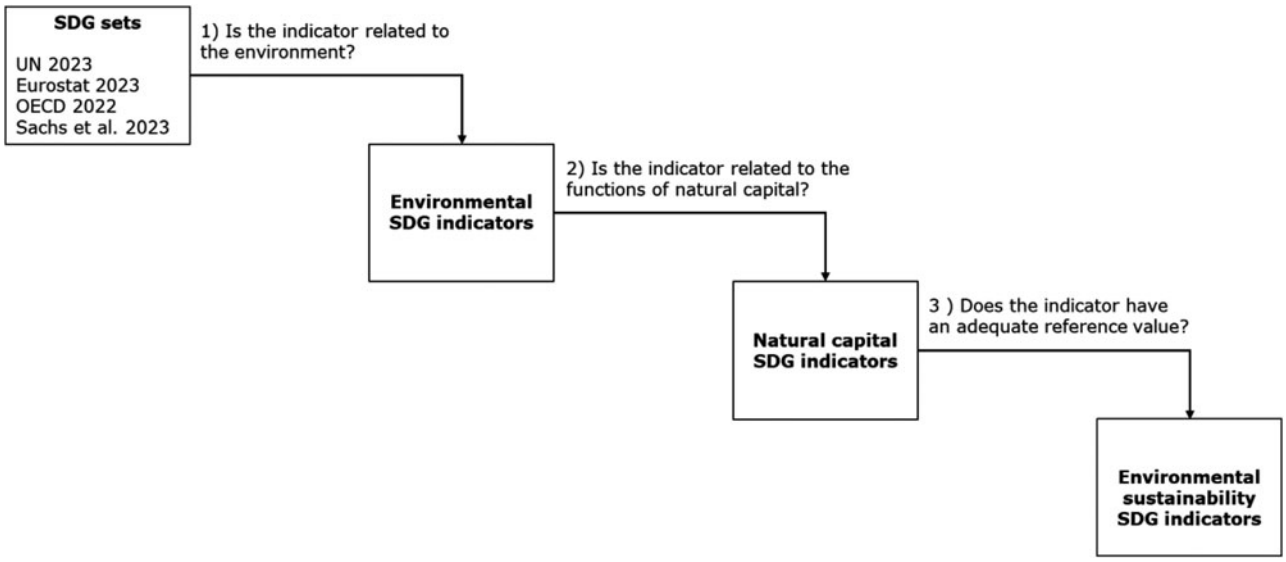

Figure 1. Decision tree used to identify environmental sustainability indicators from a strong sustainability perspective.

assessed every indicator on its merit, independent from the focus of the goal it belonged to. To that end, we followed the approach previously developed by Campbell et al. (2020). In this step, indicators that only had a social and economic focus were discarded. Indicators that combine socio-economic and environmental aspects are considered to fall within environmental SDG indicators.

After selecting the environmental SDG indicators, those related to natural capital functions were identified. Through this process, environmental indicators that do not provide relevant information in the context of environmental sustainability were discarded. At the same time, the selection of natural capital indicators showed the extent to which natural capital is represented in the different SDG indicator sets.

In the last step, the existence of adequate sustainability reference values, SBES as referred to above, was checked. In the context of strong sustainability, reference values need to describe the conditions for environmental sustainability, which requires them to be science-based (Usubiaga-Liaño & Ekins, 2021b). Building on Andersen et al. (2020), we consider that SBES need to meet two criteria: be quantitative and to be based on a clear, analytical rationale. Nonetheless, unequivocally determining this is not easy and rests to a large extent on the user's judgement. While the former ensures that the reference value can be used to measure performance, the latter considers the scientific basis to set such reference value. In this regard, reference values commonly describe a sustainable level, a value that is more lenient than a sustainable level or a change from a baseline. Only the former is regarded as being adequate to monitor environmental sustainability in absolute terms.

To carry out the third step, we first identified potential reference values and then assessed their suitability as SBES. Thus, the reference values of the UN set were identified either from the wording of the individual targets of the corresponding indicator metadata files. The OECD and the SDG Index use a step-wise approach to set reference values, where they prioritize the existence of quantitative SDG targets (OECD, 2022; Sachs et al., 2023). In the absence of SDG targets, they set reference values based on internationally agreed targets and shared aspirations, or based on best performers. Eurostat, on the other hand, sets quantitative reference values based on existing EU targets (Eurostat, 2023). In this regard, a reference value can be explicit if it is represented through a predetermined value that is proposed by the producer of the indicator. This value can have different meanings in that it can represent a scientific understanding of environmental sustainability conditions, a policy target, etc. Likewise, reference values can be implicit if they are based on the sample distribution (e.g. the score of 100 is assigned to the best performer).

The identification of environmental and natural capital indicators was undertaken independently by the first two authors of the paper. Disagreements were then identified and sorted out jointly.

4. Results

We identified 74 unique environmental indicators in the official SDG indicator set (out of 232 unique indicators). Other sets had fewer environmental indicators, but the percentage over the total was similar (Figure 2). Overall, environmental indicators represented 32–42% of total indicators. A look at natural capital indicators within the assessed SDG indicator sets shows a smaller percentage (9–16%), with the Eurostat set (20%) appearing as an outlier. The difference between environmental and natural capital indicators refers to other indicators that cover other environmental topics such as the existence of relevant policies or links between society/economy and the environment.

As shown in Figure 3, by SDG goal, environmental SDG indicators are commonly found under SDG 6 (clean water and sanitation), 12 (responsible consumption and production), 13 (climate action), 14 (life below water), and 15 (life on land) with SDG 1 (no poverty), 2 (zero hunger), 7 (clean and affordable energy), and 11 (sustainable cities and communities) showing up at the top in particular indicator sets. Natural capital indicators are mostly found under SDG 6 and 15, with SDG 12 and 14 also showing in the top in a few sets. In this context, the absolute numbers vary widely given that the assessed indicator set features between 100 and 232 unique indicators.

Beyond being related to natural capital, environmental sustainability indicators need to have an SBES to measure performance. As shown in Figure 4, the percentage of environmental indicators with an SBES varies from 0 to 34% depending on the set. Thus,

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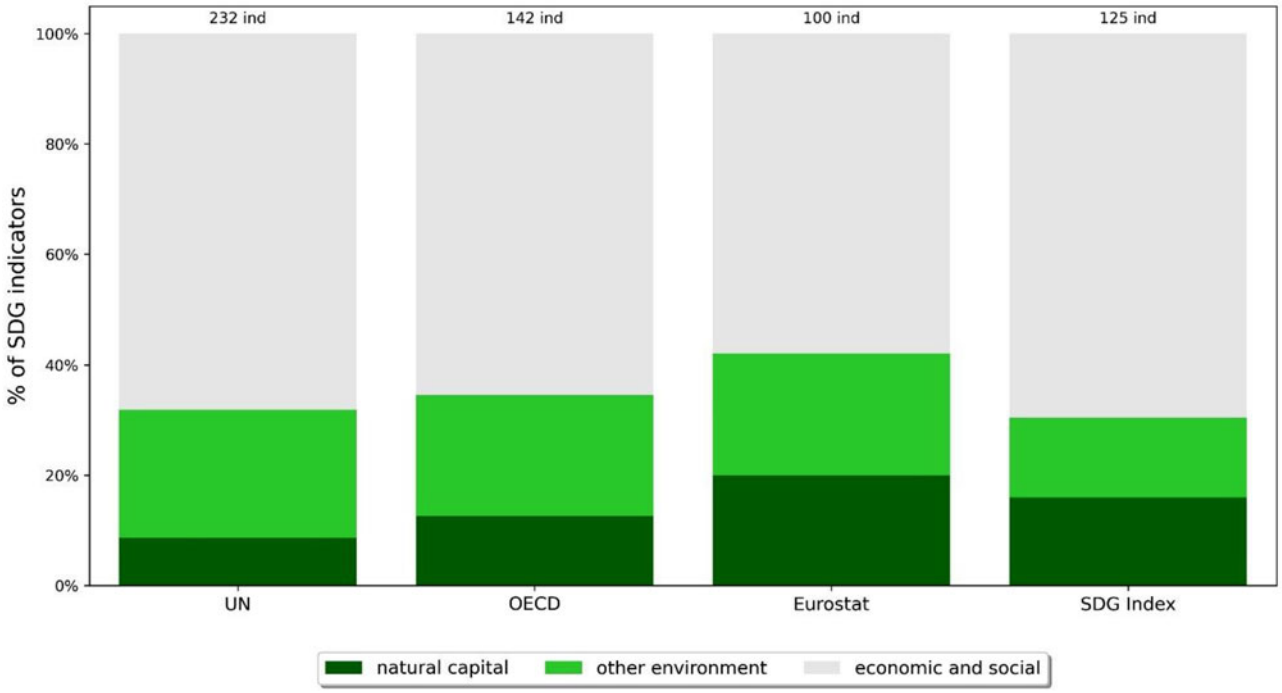

Figure 2. Environmental and natural capital indicators in the different SDG sets.
Note: the number at the top of each bar shows the number of unique SDG indicators in each set.

Eurostat indicators seem to be more oriented toward policy processes than to environmental sustainability monitoring. On the other end, 34% of the SDG Index indicator had an adequate SBES.

The information about individual indicators is shown in the supplementary Excel file.

4.1 UN indicator set

The official SDG indicator set does not provide a set of reference values that can be used to determine whether they can be considered SBES (i.e. to be quantitative and to have a clear analytical basis). Instead, this condition has been assessed based on the formulation of the SDG targets and on the metadata files of each indicator. The analysis revealed that most of the natural capital indicators in this set had directional targets that could not be quantified or that lacked specificity to establish a quantitative reference value, let alone an SBES. Thus, only three of the 20 indicators related to natural capital had quantifiable targets. Out of those four, three have a clear, analytical rationale, and can therefore be considered adequate in the context of strong sustainability. These can be found under SDG goals 6 (clean water and sanitation) and 14 (life under water).

4.2 OECD indicator set

The OECD uses the indicators to measure the distance to a reference value. To select those reference values, it gives priority to the target levels adopted as part of the SDGs, if these can be quantified. In the absence of official quantitative targets, it uses other targets available in international agreements or defines a target level based on expert opinion. Lastly, if the previous two conditions are not met, the target level is defined based on frontrunners. When targets cannot be set based on the options above, an indicator is discarded and not considered in the analysis.

The OECD set contains 18 indicators related to natural capital. All 18 have reference values: four based on the SDG targets, 11 based on other references (second condition above), and three are based on the performance of frontrunners. While all of them meet the criterion of being quantitative, only ten can be considered to meet the second criterion on the adequacy of the rationale. All in all, 20% of the environmental indicators have an SBES in the OECD set, which also equates to 56% of the natural capital indicators. The indicators with SBES are mostly found under SDG 2 (zero hunger), 3 (good health and wellbeing), 6 (clean water and sanitation), and 15 (life on land).

4.3 Eurostat indicator set

As opposed to the previous sets, the Eurostat indicator set is not used to measure SDG performance in a single year. Instead, Eurostat measures progress toward the SDGs over time. When possible, it uses quantitative reference values extracted from European policy documents. In the remaining cases, it uses directional targets. Eurostat comprises 100 indicators, 20 of which relate to natural capital functions. Out of these 20, only three have a quantitative reference value. In this line, none of the three represent SBES, since they describe an intermediate step (and therefore more lenient) toward what could be considered the environmental sustainability conditions represented by SBES.

4.4 SDG Index indicator set

The SDG Index provides a snapshot perspective of the performance of the SDGs in one year. As in the OECD set, reference values are selected by prioritizing different options. The first option is also based on the existence of reference values in the SDG targets. In the context of this paper, the second condition

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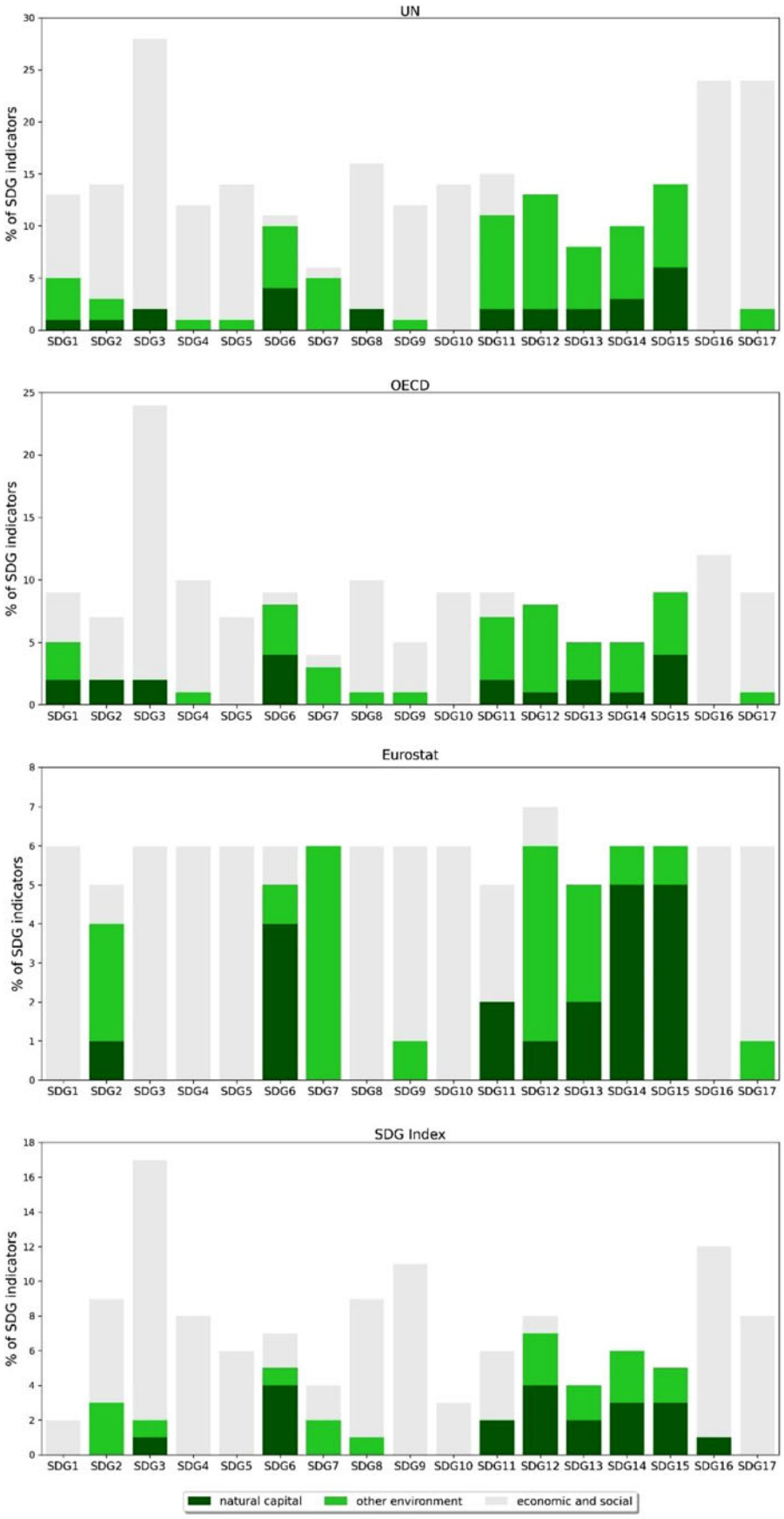

Figure 3. Environmental and natural capital indicators by goal in the different SDG sets.
Note: the number of indicators in the UN and OECD sets differs from those in Figure 2 because this figure considers an indicator that is allocated to various SDGs one for each appearance.

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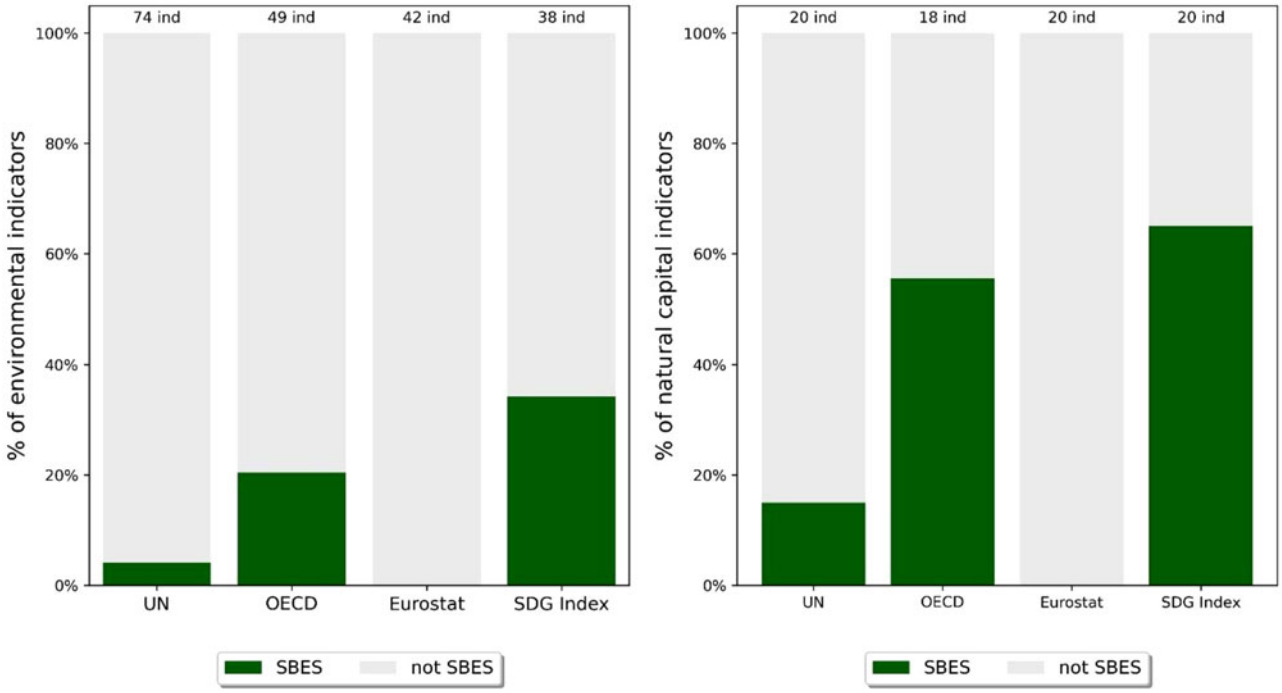

Figure 4. Environmental sustainability indicators in the different SDG sets.
Note: the number at the top of each bar shows the number of indicators in each set. In the left-side figure, it refers to the number of environmental indicators, while in the right-side figure it refers to the number of natural capital indicators.

applies to environmental indicators with a social component whereby the 'leave no one behind' principle is used. This translates as setting a reference value that represents universal access to a natural capital element or zero deprivation. After these two options, the authors of the SDG Index set science-based targets when these are available and finally, they set a reference value based on the performance of frontrunners.

There are 20 indicators in the SDG Index set that are associated with natural capital. Out of these, one uses an SDG target, one applies the 'leave no one behind' principle, 11 use the maximum possible score (e.g. zero pollution or 100% performance), two use the best performers, and four use reference values based on the frontrunners. While all the reference values are quantitative, not all of them meet the second criterion. By definition, the technical optimum has a sound and clear analytical rationale, although performance below the technical optimum could also meet this criterion. When using best performers, their soundness depends on whether the performance of frontrunners is aligned with what could be construed as an SBES. In this case, two out of four reference values meet this criterion. All in all, 13 out of 20 indicators have suitable reference values to monitor environmental sustainability. These are concentrated in SDG 6 (clean water and sanitation), 12 (responsible consumption and production), 13 (climate action), 14 (life under water), and 15 (life on land).

5. Discussion

5.1 The environmental sustainability dimension of the SDGs

The SDGs address the economic, social, and environmental dimensions of sustainable development at the different levels of their structure. While most goals can be allocated to one of these dimensions, some apply to two or even the three. The targets and indicators are more heterogeneous in that it is more common to find overlaps between those three pillars. There are different SDG indicator sets available given that these are adapted to the contexts of the institutions and countries using them. Our results show that the SDG indicator sets considered contain between 32 and 42% of environmental indicators. Although most of these indicators are found under the environmental goals (13: climate action, 14: life under water, and 15: life on land), other goals such as 6 (clean water and sanitation) are also relevant in this context. While at first sight the relatively high percentage of environmental indicators contrasts with previous claims on the underrepresentation of the environmental component of the SDGs (Eisenmenger et al., 2020; Neumann et al., 2017), a closer look reveals that many of these indicators do not represent the state of the environment or natural capital. Instead, most environmental indicators represent policy interventions, production, and consumption patterns, and other type of interlinkages between the environment and society. In total, the percentage of natural capital indicators ranges between 9 and 20% depending on the indicator set.

To monitor environmental sustainability, the focus on natural capital does not suffice. Indicators do not only have to be descriptive, but also reflect whether environmental conditions are met. This can only be done through SBES, which represent quantitative reference values with a clear analytical rationale.

Natural capital indicators fail to comply with the second criterion for three reasons. First, many indicators do not have quantitative reference values. This is very common in the official SDG indicator set, where many targets only provide information on the desired direction of evolution or do not provide sufficient details to establish a quantitative target. In those cases, progress toward the SDGs is monitored on directionality (Huan et al., 2019). Second, when quantitative values exist, these might lack a rationale in relation to whether it represents environmental sustainability conditions. This can be the case when national or

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international policy targets that are laxer than SBES are adopted (Doherty et al., 2018; Rounsevell et al., 2020). Lastly, some reference values are based on the performance of frontrunners, which can also be problematic in cases in which these countries are still far from reaching sustainable levels.

Confronting the different SDG indicators with the criterion of having SBES results in a substantial decrease in the number of indicators that can characterize environmental sustainability. The range varies between 0 and 34% of the environmental indicators depending on the set used. Hence, our results suggest that, overall, the SDG indicators cannot be used to monitor environmental sustainability from the lenses of strong sustainability.

Although the SDG indicators generally lack SBES, related concepts played a role in the process that led to the adoption of the SDGs and the underlying targets. For instance, the Planetary Boundaries framework and the Doughnut Economics framework were part of the original discussion, but there was a disconnect between the narrative that led to the higher-level structure of the SDGs and the indicator selection process (Elder & Olsen, 2019). The selection followed a technocratic approach led by statisticians where the intention to limit the number of indicators, and issues related to data compilation were prioritized (Elder & Olsen, 2019). This partial disconnect between the SDGs and the indicators used to characterize them has also affected the results of the assessment and lead to ambiguous or biased insights (Hák et al., 2016). Under the strong sustainability perspective, environmental functions need to be maintained over time, and therefore indicators used in this context should clearly reflect this.

Given the widespread political agreement around the SDGs and that around two-thirds of the Agenda 2030 period are almost over, the insights provided in this paper should inform the revision of the post-2030 sustainable development agenda, rather than the current indicator framework. In this line, previous research has provided relevant recommendations such as the need to adopt quantifiable targets that help monitor progress (ICSU & ISSC, 2015), the need to consider trade-offs in the definition of targets (Nerini et al., 2018), the need to reinforce some environmental areas (Dickens et al., 2020), and the need to more prominently represent environmental state and natural capital indicators (Campbell et al., 2020). With regard to this last point, a sustainable development monitoring system should be able to convey the main key messages of global environmental assessments such as those produced in the Global Environmental Outlook (UNEP, 2019a), the Global Assessment Report on Biodiversity and Ecosystem Services (IPBES, 2019), or in the global climate change assessment reports by the Intergovernmental Panel on Climate Change (IPCC, 2018). Beyond this, this paper shows the value of introducing SBES as targets so that the state of natural capital can be assessed against environmental sustainability conditions. While the conceptual relevance of doing so is evident, there are some difficulties that need to be considered. For instance, the knowledge base on SBES has evolved in an isolated manner and varies widely across environmental areas, biodiversity being particularly challenging (Usubiaga-Liaño & Ekins, 2021b). Thus, except for a few examples (Steffen et al., 2015; Usubiaga-Liaño & Ekins, 2021b; Vea et al., 2020), a systematic compilation of SBES is missing. International organizations are best placed to integrate SBES in their assessments in a systematic way. This would not only promote further research on the topic, but would also pave the way to reinforce the environmental pillar of sustainable development reporting in the post-2030 agenda.

5.2 The contribution of the SDGs to environmental sustainability

While the SDG indicators generally do not meet the criteria for strong sustainability indicators outlined earlier, progress on the environmental SDGs and their underlying targets can still contribute positively to environmental sustainability. In this context, even if some environmental targets are not quantifiable or if they are more lenient than SBES, they were chosen because progress toward them was considered to benefit the environment. For example, reducing pollution levels, restoring degraded ecosystems, expanding protected areas, and improving resource efficiency all align with maintaining the functions of natural capital over time.

However, some caveats need to be acknowledged. In their first Measuring Progress report, UNEP (2019b) showed that most of the environmental SDG indicators that had a positive trend represented policy interventions, improved reporting, and increased funding efforts. Meanwhile, many SDG indicators that reflected the state of the environment showed negative trends. This does not only show that the environmental SDG indicators represent varied phenomena, but also that the indicators more closely aligned with environmental sustainability evolve in a different direction. In this line, Fairbrass et al. (2024) provided initial evidence that supports the idea that the SDGs put a lot of emphasis on environmental policies that so far are not being sufficient to halt environmental degradation.

The few environmental sustainability indicators present within the broader SDG framework also risk being overshadowed or diluted by the more extensive set of indicators tracking other dimensions of sustainable development. Trade-offs likely exist between environmental sustainability and indicators tracking social or economic priorities (Ament et al., 2020; Nerini et al., 2018). For instance, increasing material living standards could drive further resource extraction and ecosystem degradation even if some economic SDG indicators improve.

In summary, while the environmental SDGs seek to steer societies toward environmental sustainability and signify political commitment, they are currently insufficient as environmental sustainability monitoring tool. The SDG indicator sets contain a few suitable indicators, but these are part of a much bigger set, which makes it difficult to deliver relevant insights from a strong sustainability perspective.

6. Conclusions

The SDGs have relevant limitations to monitor environmental sustainability from a strong sustainability perspective. Even when natural capital indicators exist in the SDG indicator sets, our results show that SBES are generally lacking. The availability of SBES that represent environmental sustainability conditions is a must in this context of strong sustainability, since the maintenance of the functions provided by natural capital is non-negotiable under this proposition. Without a set of metrics that can complement the SDG indicators, the use of the latter to provide insights on environmental sustainability can mislead messages that conflict with the scientific evidence on the degradation of the natural environment, and ultimately result in delayed action.

We have shown that the SDG indicators are not strong sustainability indicators and they were never intended to be explicitly. Nonetheless, the Planetary Boundaries framework, which builds on strong sustainability indicators, framed the underlying narrative. Had those indicators be incorporated into the global

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indicator framework, the SDGs could have been used to represent environmental sustainability as part of the wider sustainable development narrative. Given the proximity to the 2030 deadline, there is no point in adapting the SDGs to strong sustainability, but understanding their limitations in that context is relevant to make sure that the messages derived from relevant assessments are adequately interpreted and contextualized in a context of widespread environmental degradation. For this reason, complementary scientifically grounded metrics are needed to track the underlying state of critical natural capital that provides non-substitutable functions. International institutions are best placed to lead the work on this area.

The environmental sustainability indicators within the international sustainable development agenda will need to be strengthened in the indicator framework that replaces the SDGs after 2030 in order to give more robust insights into whether environmental sustainability is being achieved. This will create additional challenges, both in terms of additional knowledge needs around SBES as well as in terms of additional data demands. The last point is particularly relevant in lower-income countries where environmental data tend to be scarcer and more difficult to obtain than social and economic data. Thus, capacity building and exploiting the potential of Earth Observation or Artificial Intelligence should be at the core of this process. Nonetheless, this should not prevent the reinforcement of the environmental pillar in the revision of the post-2030 Agenda.

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