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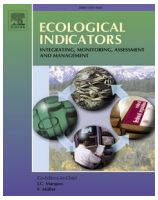

Necessary or oversimplification? On the strengths and limitations of current assessments to integrate social dimensions in planetary boundaries

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ABSTRACT

With the Earth system being about to leave Holocene conditions and thus the known safe operating space for humanity, frameworks such as the Planetary Boundaries (PBs) and the Sustainable Development Goals (SDGs) provide quantitative metrics to guide sustainability transformations. In order to strive, not only for compliance with the PBs but also for societal well-being, some approaches attempt to combine both PBs and SDGs within a single assessment.

We focus on two prominent examples, the "Doughnut" by Kate Raworth and the #SDGinPB project of the 2018 report to the Club of Rome, which are not only aimed at public outreach, but also at guiding policy-making. To meet these objectives, the approaches should possess a certain accuracy in determining the progress in achieving the SDGs and in complying with the PBs. We evaluate, by using a multi-indicator approach for comparison, whether both approaches' limited set of indicators can still represent the SDGs' complexity. This comparative approach estimates the progress in achieving SDGs, especially in the Global North, to be significantly lower.

Based on these results and against the approaches' purposes, we discuss their simplifications and at which point the results are no longer reliable. We conclude that global assessments can be an important factor in initiating transformative processes by stimulating public discourse, but that the actual implementation of these would require approaches with greater recognition of local particularities.

1. Introduction

In recent years, since the publication of "Limits to growth" (Meadows et al., 1972), the idea of limiting human expansion on the planet has been of great urgency and has gained renewed societal and political momentum with the concept of "Planetary Boundaries (PB)" (Rockström et al., 2009b; Rockström et al., 2009a; Steffen et al., 2015). The use of limited global resources has been historically and still remains unequally distributed among and within countries (Kahiluoto et al., 2015; Häyhä et al., 2016; O'Neill et al., 2018). The imperative of limiting human activities on the planet is, therefore, also linked to the obligations of taking responsibility for past activities and a fair distribution of the remaining resources among nations, as well as among different social groups; this, along with the question of how to integrate societal well-being in the PB concept, is considered to be crucial (Downing et al., 2019). In attempting to answer this question, an increasing number of scholars refer to another globally important concept, the "Sustainable Development Goals (SDGs)" (Griggs et al., 2013; Keppner et al., 2017; Heck et al., 2018; Downing et al., 2019). Although efforts to link PBs and social dimensions are scarce, they still may reveal synergies and "may constitute a necessary […] condition for achieving global sustainability" (Steffen and Stafford Smith, 2013).

Two notable examples of such efforts are the "Doughnut of social and planetary boundaries" (Raworth, 2012; 2017) and the #SDGinPB project (Randers et al., 2018; Randers et al., 2019). The former ties in with the representation of the planetary boundaries and offers a substantive extension of this concept. The latter was first published in 2018 as a report to the Club of Rome (Randers et al., 2018); its goal is to model different future scenarios to "achieve the SDGs within planetary boundaries […] by 2050" (Randers et al., 2019). Since both approaches do not only have scientific implications, but also explicitly aim at guiding policy making, they should be closely examined before decisions are taken.

We examine both concepts, paying particular attention to how the

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SDGs are reflected by the indicators used. Furthermore, we discuss the concepts' purposes, rationalities and forms of representation. It is striking in both concepts that the original, very comprehensive SDGs (Hák et al., 2016) are represented by only one (partly two) indicators. In order to reassess, if these concepts are able to represent the SDGs' rationale, we apply an alternative, comparative calculation of the current status quo of SDG achievement based on the "SDG Index and Dashboard Report" (Sachs et al., 2017). Of course, every model is a simplification. Our comparison can help to assess which simplifications are tolerable or where they may lead to unreliable results. When looking at the different approaches and results, we see significant differences in the assessments of achieving SDGs. Based on these comparisons, we discuss the number and choice of indicators, together with methods for aggregating them. In consideration of differing aims, purposes and strengths of the approaches, we conclude by sketching out the schemes of combining different approaches working at different scales, to serve in working towards social-ecological transformations. By reflecting on the different scales considered in the approaches, we take up the current conception of PBs that also combines global and regional scales (Steffen et al., 2015).

2. Background: Social dimensions within planetary boundaries

In the following we look at two prominent approaches to combine the Earth system science perspective of the PB concept with the multi-disciplinary perspective of SDGs (Brand, 2016).

2.1. The "Doughnut of social and planetary boundaries"

A promising step in promoting the importance of social dimensions within the PB discourse is the 'Doughnut" (in short) approach (Raworth, 2012). By stating, "[h]umanity is currently living far beyond the planet's means […], [while] many millions of people live in appalling deprivation" (Raworth, 2012), Raworth outlines not only the challenge for humanity but also the scientific challenge of integrating social and environmental goals into a common framework. The "Doughnut" comprises the nine environmental dimensions of the PBs and includes an analogous second radar chart that encompasses the social dimensions (11 in its initial 2012 version and 12 in its updated version from 2017 (Raworth, 2017)); these dimensions build upon the SDGs, although not all goals are accounted for (see Table 1 and Supplementary Material). The boundaries defined for these social dimensions represent the lower limits of developments, which need to be surpassed, rather than undercut, in order to avoid critical human deprivation (Raworth, 2012; 2017).

To date, none of the boundaries of the so-called "social foundation" have been surpassed on a global scale (Raworth, 2017). Among the dimensions considered, 'health', 'peace and justice' (corruption in particular), 'political voice', 'gender equality' and (socio-technical) 'networks' appear to be the most pressing problems, with indicators showing the greatest gap to the social foundation. On the other hand, much seems to have been achieved in terms of undernourishment and access to improved drinking water, whilst access to improved sanitation remains a major problem and illustrates the ambivalent assessment of the 'water' dimension in the "Doughnut" concept (Raworth, 2017).

2.1.1. Societal well-being versus environmental stewardship?

Raworth sees the main purpose of the "Doughnut", in its function, as "a compass for humanity's 21st century progress" (Raworth, 2017). Typically, the function of a compass is to help in determining the relative position to a reference point and to give a concrete direction before and during the journey. Even beyond the level of individual SDGs and PBs, the "Doughnut's" vivid illustration sets a social foundation against the ecological ceiling. This raises the question as to whether societal well-being and environmental stewardship are contradictory goals (or reference points). By illustrating both, the progress in reaching the social foundation and the development towards overshooting the ecological ceiling, with an increasing distance from the centre of the "Doughnut", the concept conveys the impression that improvements in human well-being may lead to an overshoot of the ecological ceiling. Or – in the opposite direction – also that the use of nature's resources and life supporting systems could drop to a certain level that also leads to a shortfall below the social foundation. On the one hand, this can be true in some respects, especially in those cases where human well-being depends directly on the use of finite resources, as in the connection between the availability of and access to water and food, freshwater withdrawal and land conversion (O'Neill et al., 2018; Hickel, 2019). On the other hand, resource scarcities are arguably often a result of inequality and not an issue of availability (Leach, 2016). In addition, some of the twelve dimensions for human well-being may not affect the nine dimensions of the planetary boundaries at all, or advances in the former may even mean progress in the latter (e.g. advancements in 'social equity' and 'peace and justice' may foster climate change mitigation and vice versa). This also points to the question of whether the image of approaching the social foundation is one of economic growth or, rather, is one of increasing societal well-being. Raworth's answer to this question is that the "Doughnut" is not intended to impose limits on human well-being (Raworth, 2012), but to allow for the path of decoupling human well-being from economic growth to remain open.

Several scholars (Daly, 2017; Mouysset et al., 2018) and international organisations recognise the idea of the "Doughnut" for its success in raising awareness of the importance of considering social equity and well-being in the PB debate (Keppner et al., 2017). Whilst we share this view, we fear that the memorable image of the "Doughnut" could

Table 1
Number of indicators per SDG used by different frameworks.

	SDG	Global indicator framework	SDG Index and Dashboard Report	Doughnut	#SDGinPB
1	No poverty	14	3	2	1
2	Zero hunger	13	6	1	1
3	Good health and well-being	27	14	2	1
4	Quality education	11	5	2	1
5	Gender equality	14	5	2	1
6	Clean water and sanitation	11	4	2	1
7	Affordable and clean energy	6	4	2	1
8	Decent work and economic growth	17	6	1	1
9	Industry, innovation and infrastructure	12	9	1	1
10	Reduced inequalities	11	3	1	1
11	Sustainable cities and communities	15	3	1	1
12	Responsible consumption and production	13	8	–	1
13	Climate action	8	4	–	1
14	Life below water	10	5	–	1
15	Life on land	14	5	–	1
16	Peace, justice and strong institutions	23	9	3	1
17	Partnership for the goals	25	5	–	1
	Total	244	98	20	17
	Mean	14.4	5.8	1.7	1.0

propagate the misleading idea that social developments are inevitably in conflict with, or at least decoupled from, preserving the environment. Other approaches, probably including some that are based less on Western world views, would argue for more inclusive attempts at social and ecological justice; such approaches, for instance the idea of "relational values" (Chan et al., 2016), emphasise the notion that steps towards environmental protection support social equity and vice versa.

2.2. The "#SDGinPB" project

A further attempt to take social dimensions into account has first been published in the current report to the Club of Rome, whose authors try to identify pathways "to attain the SDGs within planetary boundaries: […] #SDGinPB" (Randers et al., 2018). The declared goal of the #SDGinPB project is to quantify humankind's current progress and possible ways of achieving "an inclusive and prosperous world development within a stable and resilient Earth system" (Randers et al., 2018). Therefore, Randers and colleagues "want a very simple model to allow [them] to transparently explore the contextual assumptions of SDG policies and implementation." (Randers et al., 2019). Randers et al. take a critical view of their results and argue that the model "is not a sustainability forecaster, but a 'what-if' calculator" (Randers et al., 2019).

Methodologically, they proceed as follows: in the assessment of the developments in seven world regions, all achieved SDGs are given a score of 1 and SDGs that are at least 50% achieved are given a score of 0.5 and added up to produce an SDG success score per world region. The main idea is to combine this SDG success score with a score for the number of PBs that have not been transgressed. Based on the observations of developments between 1970 and 2015, different scenarios are run as model simulations up until 2050. The modelling basis is formed by two system dynamic models: the long-established Earth3-core (spreadsheet) model (Goluke et al., 2018) and the Earth System Climate Interpretable Model (ESCIMO) (Randers et al., 2016; Randers et al., 2019), both complemented by a module to compute the indicators for SDGs and PBs, respectively (Collste et al., 2018).

With few exceptions (SDGs 10 and 17), Randers et al. assess the SDGs by using historical data of the chosen SDG indicators to identify a statistical relationship between their performance in the seven world regions and gross domestic product per person (GDPpp). These relations are then used to forecast the respective regional performances regarding the SDG indicators in various scenarios. For those SDGs that are more closely related to environmental concerns (SDGs 13–15), the future trends of their indicators are outcomes of the ESCIMO model. As for the planetary boundaries, the underlying processes are also outcomes of the combination of the Earth3 and ESCIMO models. Nonetheless, apart from PBs 1, 3 and 4, the indicators of all remaining PBs are, again, functions of GDPpp (Collste et al., 2018).

The four scenarios in the report to the Club of Rome differ in terms of assumed GDP growth as well as efforts to reduce poverty, unemployment and inequality, to increase renewable energies, food and water supply, to improve levels of education and to bring about gender equality (Randers et al. 2018). The model results for the scenarios "same" (business as usual), "faster" (higher annual GDP growth) and "harder" (same GDP growth as business as usual, but 30% more effort in all of the policy fields mentioned above) show few differences by 2050, with global SDG success scores of between 11 and 12 (out of 17) and 3 to 5 PBs (out of 9) that are not transgressed. By contrast, the fourth scenario, called "smarter", is described as an "extraordinary transformation" with an average GDP growth as high as in the "same" scenario but having higher growth rates in poor countries. This is accompanied by rapid shifts towards more sustainable paths in the policy fields mentioned above, including active financial redistribution. As a result of these efforts, the global SDG success score would appear to reach 13.5 by 2050 which is comparable to the status quo the authors estimated for the *United States* and *other rich countries*, while seven out of nine PBs are likely to remain in, or return to, a safe operating space (Randers et al., 2018). However, this does not take into account how strongly the current economic wealth of the Global North is linked to the poverty of the Global South (Arvanitakis and Hornsby, 2017; Galanis et al., 2019) and how the latter should achieve similar prosperity without exploiting other countries (Felipe et al., 2014). The updated 2019 publication concentrates on the 'business as usual' scenario, supplemented by a sensitivity analysis focussing on changes in GDPpp (Randers et al., 2019). Randers and colleagues find that increasing or decreasing economic growth rates by one percent do affect the results regarding the SDG success score, as well as the compliance with planetary boundaries, but (macro-)economic changes alone do not help in achieving SDGs within PBs.

2.2.1. GDP and the paradigm of economic growth

As mentioned, the #SDGinPB project ties most projections for the future developments of its indicators to functions of GDPpp. While this seems a reasonable choice, given the ample evidence for a positive correlation between economic growth and certain aspects of human life, such as literacy, life expectancy and reduced child mortality (van den Bergh, 2009; Singh et al., 2012), GDPpp as an indicator for the overall development of a country has long been questioned (van den Bergh, 2009; Costanza et al., 2014). There are numerous examples of countries where various aspects of societal well-being have stagnated or decreased despite GDP growth (van den Bergh, 2009). Other shortcomings include the failure to take account of informal work, which, in many cases, devalues activities that are mainly carried out by women (Saunders and Dalziel, 2017), the externalisation of negative social and environmental effects and the lack of representation of income distribution within the economy of a nation (van den Bergh, 2009). All these issues in the discussion of GDP amount to the question of whether the scientific and political focus on GDP should be overcome (Hickel, 2019). It is worth noting that this question is also considered by the developer of the "Doughnut" as a core implication of her concept (Raworth, 2017).

2.3. In search of comprehensive indicators

The official indicators used by the United Nations to monitor developments towards achieving the SDGs encompass 1–5 indicators per target, of which 5–13 have been defined per SDG. This adds up to 244 indicators in total (United Nations Statistical Commission, 2017). An assessment based on these indicators would call for a multi-criteria assessment that is able to integrate (on average) 14 indicators per goal. Obviously, such an assessment would become even more difficult in a scenario projection. Consequently, Randers et al. (2019) reduce their assessment for the #SDGinPB project to one indicator per goal (see Table 1 and Supplementary Material). The authors critically reflect on the drawbacks and they argue plausibly for a simple and comprehensible model, which they also make transparently available. Nevertheless, the applied simplifications raise questions as to whether this approach can produce a result that represents the actual status in achieving the SDGs and whether the idea behind each individual goal can be adequately represented by a single indicator.

In comparison, eight out of twelve dimensions of the "Doughnut" for the social foundation are split into two indicators, while four dimensions are also represented by a single indicator (note that not all dimensions used for the "Doughnut" match the SDGs). As the "Doughnut's" indicators are not used for scenario projections, it is technically much easier to add further indicators to the concept which is, in fact, what has been done in the updated version of the "Doughnut" (Raworth, 2017).

If we look at the official targets per SDG, it quickly becomes clear that both concepts cannot cover this thematic range with their choice of indicators. Nevertheless, it is possible that the indicators were chosen in such a way that they represent the status of target achievement. To test this, we use a multi-indicator approach as an alternative approximation of the SDG achievements to compare it with the status quo calculations

(SDG success score for 2015) of the #SDGinPB project and the "Doughnut".

3. Methods: Setting the stage for a multi-indicator approach

The indicators of the "Global indicator framework for the Sustainable Development Goals" (United Nations Statistical Commission, 2017) are not normalised to a common scale, nor is a status of target achievement defined for all of them, nor is there a global data coverage (Sachs et al., 2017). Therefore, this comprehensive global indicator framework cannot easily be translated into a uniform value for each SDG, or even a composite value for all SDGs. Against this background, Sachs and colleagues regularly publish the "SDG Index and Dashboard Report" that provides a quantitative snapshot of a large variety of measurable SDG indicators (Sachs et al., 2017). We use this report to compare the current global status for achieving the SDGs with the #SDGinPB project and the "Doughnut" (see Table 1 for a comparison of the number of indicators used). Up to the present time, the annual "SDG Index and Dashboard Report" has been published in five versions (2016–2020). Since the scenarios of the #SDGinPB project are derived from baseline data for 2015, we chose the "SDG Index and Dashboard Report 2017" which is also used in the #SDGinPB assessment and whose data base corresponds well to the 2015 baseline (Collste et al., 2018).

The SDG success score, used in #SDGinPB, has a maximum value of 17 which is obtained if a world region achieves all 17 goals (Randers et al., 2018; Randers et al., 2019). For each indicator the "SDG Index and Dashboard Report" possesses a lower (worst performance of a country) and upper boundary (either absolute targets, such as zero hunger or full gender equality, or the average of the five top-performing countries). Between these two boundaries, four thresholds are defined: red, orange, yellow and green. The green threshold is equivalent to the achievement of a goal (Sachs et al., 2017). This classification allows countries to reach levels that are above the achievement of a goal.

In order to bring this classification in line with the #SDGinPB classification, we normalised the indicator values, with the lower boundary (worst performance) serving as the lower limit and the green threshold serving as the absolute upper limit. In doing so, we avoid extreme performances for one indicator (such as cereal yield, which in many countries is 3–9 times above the green threshold of 2.5 t/ha) that would bias the SDG score, otherwise, this could result in an SDG perceived as being achieved, although other indicators for this goal would be still far below the green target. In other words, we argue that surpassing a certain target of SDG does not compensate for missing another target. By calculating the arithmetic mean of all indicators per SDG we obtained a score of between 0 and 100 for each country. Afterwards, we grouped the countries according to the seven world regions in the #SDGinPB project. In order to calculate the SDG success score, a country would be assigned 1 score point for a score of 100 and 0.5 for scores > 50. Since these are still national scores, they have to be aggregated to a score for the corresponding world region. If this were carried out with the countries' normalised values and the success scores subsequently calculated, the world regions would scarcely reach a success score of 1. As a consequence, a world region would have a success score of either 0 or 0.5 per goal, depending on the score being higher or lower than 50, thus, we decided to calculate success scores per country. Subsequently, these success scores were averaged for the seven world regions and weighted by the respective national share of the overall population, taking into account only those countries that were assigned a score for the respective SDG. Whilst we only obtained a success score of 1 in exceptional cases, but when compared to the simple distinction between 0 and 0.5, more distinct nuances between 0 and 1 could be observed.

For comparison with the "Doughnut", we omit the calculation of a success score and, instead, use the arithmetic mean of the SDG indicators as values from 0 to 100 per country. By analogy with the percentage deficits in the "Doughnut" illustration, we finally use the difference to 100 of the values weighted according to the country's share of the global population.

4. Results: Contrasting approaches

The comparison of the SDG success scores of our calculation with the #SDGinPB project reveals marked differences (Fig. 1); most apparent are the total SDG scores for the regions *USA*, *other rich countries, China* and *emerging economies* which are 2.5 to 5 points lower in our assessment than in the single indicator assessment of the #SDGinPB approach. The scores for the regions *Indian subcontinent*, *Africa south of Sahara* and *rest of the World* differ by 0.7 to 1.5 points; interestingly, these three regions score higher with a multi-indicator SDG success score than in the #SDGinPB approach.

Figure 2 provides a hint that some of the differences observed are partly methodology-related; we calculated the SDG scores by country and combined them into a common score per region. As mentioned above, such an approach levels off the extremes, as shown by the fact that we have scores of neither 0 nor 1 for any SDG, except for the two vast countries of *China* and the *USA* and the *Indian subcontinent* (India, Pakistan and Bangladesh).

At first glance, it might seem surprising that not even the *USA* and *other rich countries* achieve SDGs such as "Zero hunger" (SDG 2) or "Clean water and sanitation" (SDG 6). Nevertheless, if we consider indicators such as obesity (for SDG 2) and telecoupling effects, where consumption in the Global North has negative effects on the Global South (e.g. groundwater extraction for SDG 6), the results of our calculations show that even these rich countries are still not on a sustainable level. Further noticeable results are the mismatches in SDG 8 "Decent work and economic growth" and SDG 5 "Gender equality". Based on the indicator 'job market growth', Randers and colleagues assessed SDG 8 as being achieved by all world regions apart from the *USA* and *other rich countries*, which is certainly a surprising result for the rephrased SDG "Decent jobs". In contrast to this, our assessment also considers, amongst others, the indicators 'child labour' and 'unemployment rate', which results in a more differentiated picture regarding the success score for this SDG. A similar picture emerges for "Gender equality", which, when focussing on 'gender parity in schooling' alone (as carried out in #SDGinPB), leads to a result that shows SDG 5 to have been achieved within all world regions except *Africa south of Sahara* and *rest of the world*. In comparison to this, our assessment based on the indicators of 'unmet demand for contraceptives', 'female years of schooling', 'female labour force participation', 'women in national parliaments' and 'gender wage gap', resulted in significantly lower scores across all world regions (see Supplementary Material for a complete list of indicators used in both approaches).

Aggregating the SDG indicators of the SDG Index and Dashboard Report on the global level led to an alternative illustration of the "Doughnut" (Fig. 3). In this "Doughnut" variant, SDGs 13–15 ("Climate action", "Life below water" and "Life on land") have been omitted as they mainly describe natural states that in the logic of the "Doughnut" are placed in the outer circle, the planetary boundaries. Since the dimensions of the original "Doughnut" do not match the SDGs, we reassigned its indicators to the SDGs (see Table 1 and Supplementary Material). Table 2 provides a comparison between the "Doughnut" indicators (0–3 per goal) and the multi-indicator approach that we used. Compared to the "Doughnut's" twelve social dimensions, our multi-indicator approach includes two additional SDGs, namely SDG 12 "Responsible consumption and production" and SDG 17 "Partnership for the goals".

Taking a closer look at the levels of shortfall (cf. Table 2), in the case of the original "Doughnut", there are some instances in which the two indicators for one SDG show contradicting results. Striking examples are SDGs 5 ("Gender equality"), 6 ("Clean water and sanitation"), 7 ("Affordable and clean energy") and 16 ("Peace, justice and strong institutions"). In these cases, the multi-indicator lies somewhere between the indicators of the original "Doughnut", although it does not tend to lie

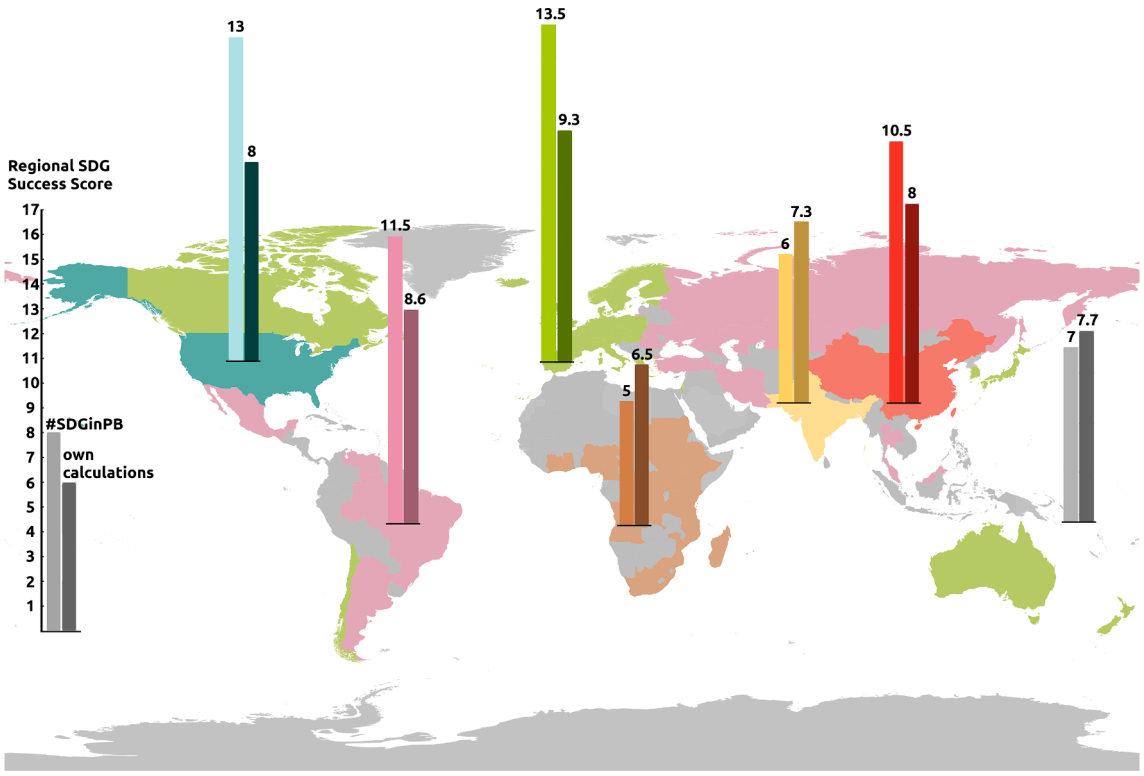

Fig. 1. Total SDG success scores of the seven world regions in 2015, showing the #SDGinPB project scores (left-hand bars in light colours) in comparison to our calculation (right-hand bars in dark colours).

close to their mean. Further shortfall values of the multi-indicator approach show an inconclusive picture compared to the "Doughnut" indicators; this starts with smaller shortfalls (SDGs 1, 3 and 9), continues with similar values (SDGs 8 and 10) and also contains values that indicate much greater shortcomings in the global achievement of the SDGs (2, 4, 11). These differences appear to be independent of whether one or two indicators are the basis of comparison for the multi-indicator approach.

5. Discussion: Which simplifications are tolerable?

5.1. What type and number of indicators are appropriate?

The fact that the #SDGinPB project can model 12 out of 17 SDGs (and 6 out of 9 PBs) based simply on GDPpp obviously has a remarkable strength with regard to transparency, traceability and the calculation of scenarios. Integrating more targets and indicators per SDG would not make this task any easier. Anyway, the question remains, which inaccuracies should we tolerate in favour of modellability and at which point are modelling results no longer reliable?

The inevitable problem of failing to express comprehensive goals through single indicators was exemplified by the comparative assessments of SDG2 ("Zero hunger"). In this example, both #SDGinPB and the "Doughnut" do not account for important partial aspects such as obesity, stunted development or wasting among small children (see Supplementary Material). Since the thematic scope of many SDGs is partly already reflected in their bipartite title (e.g. "Good health and well-being" or "Decent work and economic growth"), two indicators, as used for some dimensions of the "Doughnut", may be a good choice to reflect better this scope. One of these examples is the representation of SDG 6 "Clean water and sanitation" in the "Doughnut"; both indicators represent aspects of the SDG 6 title while exhibiting very distinct states. In the SDG Index and Dashboard Report, two further indicators complement the assessment: "Freshwater withdrawal" and "Imported groundwater depletion". While the multi-indicator approach leads to the loss of discriminability among the states of the individual indicators shown by the "Doughnut", the latter lacks the consideration of other important factors, such as spill-over effects that take into account the linkages among different countries and world regions (e.g. imported groundwater depletion).

Apart from the pure number of indicators per goal, the type of indicators is, of course, also of great importance for the assessment. The comparison of the multi-indicator approach with #SDGinPB has demonstrated the influence that the choice of indicators has on the assessment. Our analyses has revealed a general tendency of the #SDGinPB project to overestimate the performance of the Global North, while underestimating the performance of the Global South. If we use SDG indicators that correlate positively with GDPpp, it is not surprising that wealthy regions outperform the poorer ones. Moreover, it is not surprising that the overall picture would become blurred if we include indicators that show no, or even a negative, correlation with GDPpp (e.g. diseases of affluence and spill-over effects). However, if the aim of capturing the scope and the essence of the SDGs are not to be abandoned, we have to accept or (given the ambiguity of reality) even expect and welcome that this will be reflected in the indicators. In relation to GDP, SDG 8 provides an interesting example. Amongst others, the official UN indicators for SDG 8 include 'GDPpp growth rates', 'informal employment', 'equal pay for men and women', 'unemployment rates', 'child labour' and 'occupational injuries'. Interestingly, in this case, the choice of using the indicator of 'job market growth' within #SDGinPB led to positive results for all world regions except for the *USA* and *other rich countries*. However, if choosing other indicators such as 'child labour' and 'occupational injuries', this would probably have shown the opposite picture. This points to another important aspect that strongly influences the choice of indicators: Data availability. 'Child labour' and 'occupational injuries' are two examples of indicators that are certainly recorded much less frequently than data on labour market and GDP. This is especially important when comparable data in terms of quality,

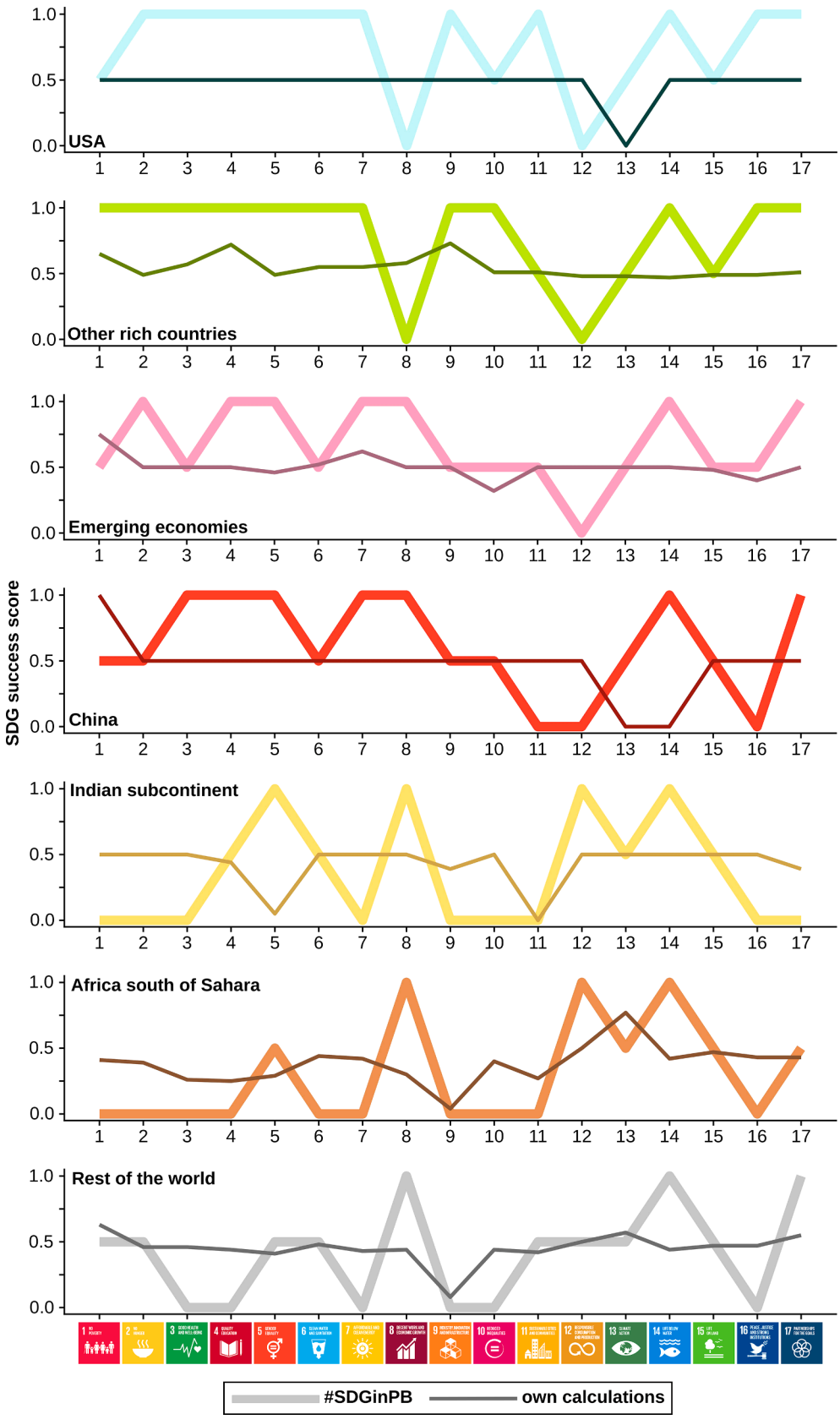

Fig. 2. SDG success scores for the seven world regions in 2015, based on single indicators as calculated in #SDGinPB (thick lines in light colours) and our calculations based on multiple indicators (thin lines in dark colours).

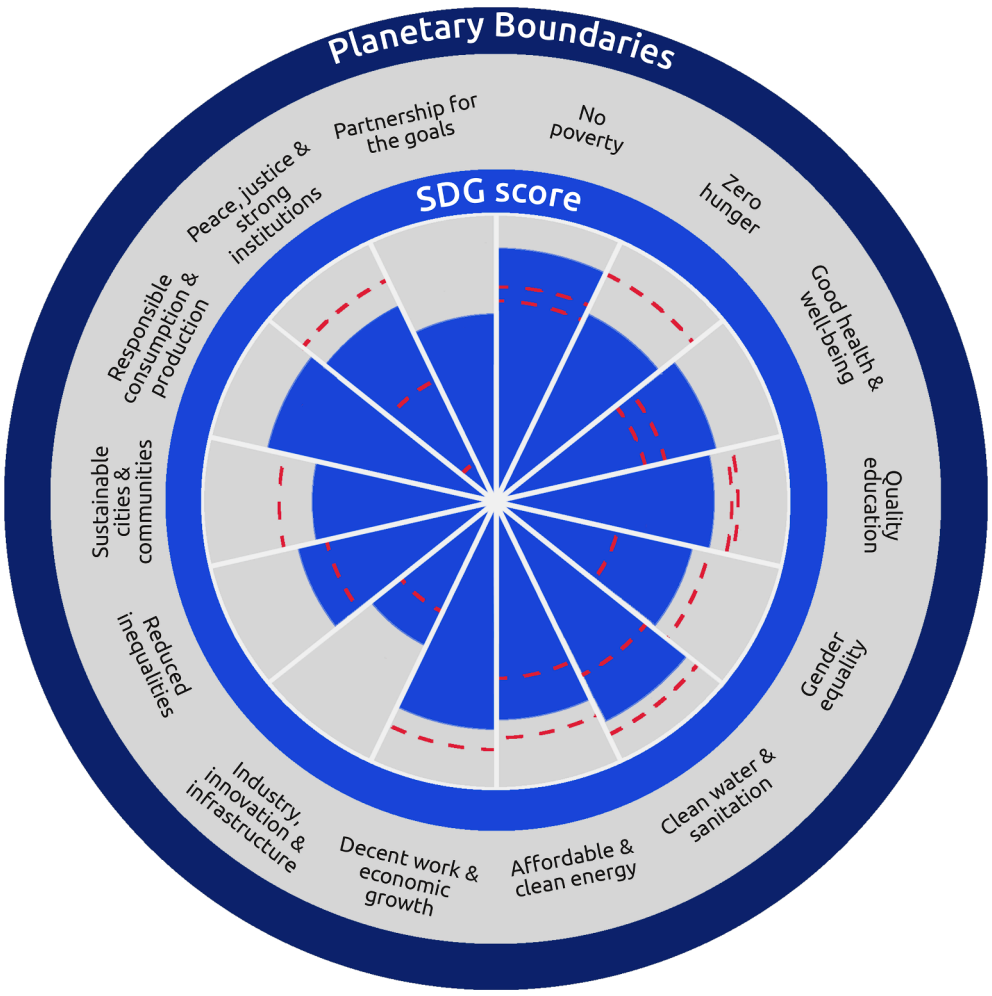

Fig. 3. Results of using the SDG success scores as an alternative approach to the inner circle of the "Doughnut" represented as blue slices. The dotted red lines mark the position of the corresponding indicators of the original "Doughnut". As the original dimensions do not match the SDGs, the indicators have been reassigned. SDGs 1–12, 16 and 17 are arranged clockwise. SDGs 13–15 were excluded as they overlap with the PBs. The "Doughnut's" outer circle, representing the PBs is not shown for better legibility and because the PBs have not been recalculated.

Table 2
Comparison of the calculated shortfalls for achieving the SDGs between the indicators used for the "Doughnut" and our multi-indicator assessment based on the SDG Index and Dashboard Report. The "Doughnut's" original 12 dimensions build upon but do not match the SDGs. Therefore, the 1–2 indicators per dimension have been reassigned to match the SDGs, resulting in 1–3 indicators per SDG.

SDG	1	2	3	4	5	6	7	8	9	10	11	12	16	17
Multi-indicator: shortfall (%)	11	28	25	31	31	15	24	20	44	30	37	19	25	35
Doughnut: short-fall below social foundation (%)	29/24	11	46/39	15/17	56/23	9/32	17/38	13	57	39	24	–	52/85/13	–

completeness and duration of the observation period are needed for different countries and regions.

If, in addition, it is to be assessed how far a certain region has progressed in terms of achieving one or even all SDGs, it stands to reason not only to list the individual indicators side by side, but also to aggregate them into one value. For our multi-indicator approach, we relied on a simple and robust additive aggregation of equally weighted indicators (Gan et al., 2017). In order to ensure a high comparability, we aimed at calculating the multi-indicator success score similar to the success score used in the #SDGinPB project. Of course, some differences remain, mainly due to the necessary aggregation to one indicator per goal. In principle, the impact of the methods for weighting and aggregating indicators should not be underestimated. For many weighting methods, such as those based on statistical correlations or public opinion, there is a risk of overstating the change in one indicator for the overall assessment (Gan et al., 2017). With regard to SDG 2, a possible (extreme) example would be that if obesity is overweighted, a decrease in obesity could mask a simultaneous increase in hunger and thus a negative development would be interpreted positively. This and further issues are discussed extensively in a number of informative reviews (Böhringer and Jochem, 2007; Mori and Christodoulou, 2012; Huang et al., 2015; Gan et al., 2017).

Obviously, individual indicators are easier to understand and to model, but do not do justice to the SDGs; several individual indicators per SDG provide a certain analytical depth, but do not permit the determination of the current status and, finally, aggregated multi-indicators take better account of the scope of SDGs, but render it difficult to interpret the results. Interestingly, Randers and colleagues (2019) also address similar issues in searching for a more meaningful well-being index and have developed the "average Wellbeing Index". It is based on five components, all of which are represented by a single indicator, but whose forecasts are still functions of GDPpp (Randers et al., 2019).

All in all, the choice of the methods for integrating indicators should be a case-specific choice, depending on the objective of the assessment. Moreover, since the number of targets and indicators per goal within the official SDG indicator framework also differs (United Nations Statistical Commission, 2017), it seems reasonable that the choice of the type and number of indicators should be made individually for each goal.

5.2. Between necessary and oversimplification

Evidently, all possible approaches have their weaknesses, but also their specific strengths and therefore, we need to evaluate the simplifications made in light of the purposes and aims of the assessments. On the one hand, complicated models are "more likely to be useful in terms of prediction capacity, scenario analysis and decision making support" (Sun et al., 2016). Simpler models, on the other hand, possess higher degrees of transparency and traceability, which make them the preferred tool for education, transferability and communication (Sun et al., 2016).

Starting with the key implications stated by Raworth (2017), we will look at the "Doughnut's" purposes and aims. The first three implications refer to (i) "the dependence of human wellbeing on planetary health", (ii) the reflection of "deep inequalities – of income and wealth, of exposure to risk, of gender and race, and of political power – both within and between countries", and (iii) the need for "political prioritisation of gross domestic product growth [to be] replaced by an economic vision that seeks to transform economies" (Raworth, 2017). The third key implication is particularly striking in this context, as it also addresses the need to abandon GDP as a leading indicator. Although 7 out of 20 indicators of the "Doughnut" are similarly reflected in the #SDGinPB, the concept as a whole clearly expresses a general critique of economic growth that is found neither in the SDGs nor in #SDGinPB. All of these three implications relate mainly to the concept's purpose as a communication tool to raise awareness and stimulate public discourse. The great recognition the concept is receiving from NGOs, academia and politics is proof of its usefulness and success in this regard, although the global perspective alone cannot provide much detail in showing the inequalities among and within countries.

The final key implication is clearly formulated, not least in the title of the 2017 publication, as a further intended purpose: The "Doughnut" shall serve as "humanity's compass in the 21st century" (Raworth, 2017). In order to serve as a compass, first and foremost, a reference point is needed to determine a relative position to achieving the SDGs. As shown above, the accuracy in determining this position using the "Doughnut" is anything but clear. Secondly, we need a pre-defined direction, which in principle can be given by the SDGs and PBs. However, since among and within these dimensions target conflicts can always arise (Alcamo et al., 2020) and the prioritisation among them remains unsolved, the compass needle may spin quickly.

The mentioned purpose of the #SDGinPB project is to use the model as a 'what-if' calculator to investigate the possible effects of policies to achieve SDGs and to be a useful tool to inform politicians and the general public. This requires a certain degree of transparency and traceability as well as the capacity to make predictions and support decision-making. Consequently, the #SDGinPB project must combine the advantages of model types at both ends of the scale defined by Sun et al. (2016). However, in order to be able to make reliable statements about future scenarios, firstly, the basic assumptions of the model must be correct and, secondly, the initial situation on which the scenarios are based must be described appropriately. As discussed above, the assumption of predominantly positive correlations between the GDPpp and SDG results seems too simple to derive recommendations for development paths. Furthermore, the deviating results of our comparative calculations for the status quo call into question whether the starting point of the calculated scenarios is set correctly and, consequently, also leaves doubts about their calculations for the future. Since the model "should be seen as a starting point – a proof of concept – for further elaboration" (Randers et al., 2019), #SDGinPB definitely is an inspiring starting point, although especially for the indicators' close linkage to GDP, alternatives should be sought. In this context, the models transparency and flexibility is of great advantage, as it allows to revise the model "[w]hen reality differs from the assumptions made" (Randers et al., 2019).

Clearly, a model that can cover the range of all SDGs and PBs would impose high demands on the quality and quantity of data and would be extremely complex. Therefore, this remains at best a vision for the future and instead of waiting for such a model, a first estimation may be the better decision. However, its uncertainties must be clearly communicated and its results must not be misleading, such as overestimating the Global North's achievements and underestimating its planetary responsibility. Provided a critical view is maintained, both assessments discussed can be useful attempts for obtaining such an initial estimate. More importantly, approaches such as #SDGinPB, the "Doughnut' and also the PB concept itself have clear merits when it comes to public outreach and the raising of political and societal awareness. Indications of this strength are the memorable illustrations, the reduction to simple and easily comparable numbers and, not least, the choice of memorable names ("Doughnut") and terms that are compatible with public outreach, for example, via social media (#SDGinPB).

5.3. Working across scales and concepts

All in all, the challenges humanity faces in the 21st century are too manifold, too interlinked and too intricate to be presented and quantified satisfactorily in one conceptual picture. Scientific assessments of sustainable development, whether used to evaluate the status quo or future projections should still aim to address this complexity (Mitchell, 1996). In this case, this would mean not to fall behind the (shared) understanding of sustainable development expressed in the SDGs. The UN global indicator framework (United Nations Statistical Commission, 2017) and the process of its development (Hák et al., 2016) can provide some orientation here. This does not mean, of course, that the indicators listed in the framework have to be integrated one-to-one, but rather that the scope expressed in the targets and indicators should be reflected in the best possible way. In this context, it might be worthwhile to focus on positive images of targets and goals rather than boundaries (Downing et al., 2019). This would not only help to evoke a positive attitude towards necessary changes, but would also take into account current results that indicate that global thresholds can scarcely be quantified at all, let alone be predicted as too many factors, interactions and case-specific variabilities influence their occurrence (Hillebrand et al., 2020).

As long as assessments take place on a global level, this is also the logical first level at which action can be derived from them. Although Randers and colleagues certainly do not try to trivialise the problem situation, they do try to identify five general measures to realise transformative change (Randers et al., 2018). In this context, it is important to be aware of the difficulties that exist in agreeing on global policy strategies (not to mention their implementation). If we also take into account the many local particularities in terms of political, economic, cultural and ecological conditions (Pahl-Wostl, 2015), it is merely impossible to find one universal transformation path for all regions of the world (Jahn et al., 2020). Therefore, we argue to leave the global scale for a moment and work instead on realising different locally-adapted social-ecological transformations at the sub-global scale (Heck et al., 2018; Martín-López et al., 2020). In so doing, we can obtain a better understanding of the case-specific particularities (DeFries et al., 2012), a fair and equal participation of the stakeholders and, finally, react to the obstacles to the effective implementation of transformative measures (Lam et al., 2020). By including and communicating the manifold worldviews and perspectives, the different local attempts will not only learn from each other, but will also allow us to consider the connections among them (Martín-López et al., 2020). This is an important prerequisite for social-ecological transformations (Pichler et al., 2017), although this does not mean to leave out global assessments entirely, but instead to work across scales (Heck et al., 2018) and to integrate the local experiences on the global scale. Conversely, global valuations help to estimate the locally effective drivers that can be attributed to globally accumulated effects and not to lose sight of the contexts (Kok et al., 2017; Renn et al., 2020). In doing so, we may not only account for conflicts and trade-offs, but also for synergies between regions and scales (Heck et al., 2018).

The case of PBs shows that the importance of regional and global scales can be taken into account, but also that they cannot easily be integrated in one conceptual figure or index (Steffen et al., 2015). This becomes even more complex if, in addition to the scale transitions, we also try to consider linkages within as well as among the nine PBs and 17 SDGs, even though some targets of SDGs refer to similar processes as the PBs (e.g. SDG 6 and PB "Freshwater use" or SDG 13 and PB "Climate change"). Given this complexity, we suggest not to attempt to conceptually integrate all dimensions and scale levels, but to consider concepts of different thematic and scale foci side by side, starting from the local challenges.

6. Outlook: Towards adapted, power-conscious and inclusive transformations

With this study, we highlight two pivotal points. First, we emphasise the limited depth of focus of global models that aim to map complex states with a small number of indicators. Second, we draw attention to the shortcomings and blind spots that arise in assessments of all kinds, not least due to the choice of indicators. Meanwhile, the great strength that global concepts and models, such as #SDGinPB and the "Doughnut", possess in public outreach helps to reveal global challenges and interdependencies. Although the simplifications made raise some doubts about the accuracy of the assessments, if they are based on critical reflection and re-examined at the local level, they can still provide a helpful orientation at the science-policy interface. However, even if we could precisely identify the current status in achieving SDGs or complying with PBs, we do not necessarily know the reasons for the shortcomings (Renn et al., 2020). This is certainly a question that deserves, at least, as much attention as the search for accurate assessments.

Moving on from the determination of positions and the search for causes to the exploration of possible actions, "issue-specific, tailor-made solutions appear in general more promising" (Biermann, 2012) as local conditions, particularities, stakeholder- and power constellations are so different around the globe that "one-size-fits-all" solutions are likely to fail. Therefore, global assessments and agreements can only serve as (1) guidelines that still allow sufficient creative leeway and (2) as clarifications of methods and procedures for finding transformative pathways. The central importance of global relations and balances among the world regions, depending on their historical responsibility, influence and social and environmental impacts, is beyond question. In this sense, the concepts discussed here play an important role.

In order to find effective measures for transformative processes, a global assessment alone is definitely not sufficient; rather, it is necessary "to develop locally shared visions of sustainable development" (Schleicher et al., 2018). If sustainability science aims to foster this development, it surely faces a challenging task in integrating the required disciplinary knowledge, but, in addition, should not forget about people's non-scientific and everyday knowledge. The existing diversity of ideas, disciplines and research foci are a promising foundation that "can be improved by a critical, inter- and transdisciplinary approach to social-ecological transformations" (Görg et al., 2017).

CRediT authorship contribution statement

Lukas Drees: Conceptualization, Methodology, Investigation, Data curation, Writing – original draft, Writing - review & editing, Visualization. **Robert Luetkemeier:** Conceptualization, Writing – original draft, Writing - review & editing. **Heide Kerber:** Conceptualization, Writing – original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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