Matters Arising

Cross-scale translation of Earth system boundaries should use methods that are more science-based

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The review paper by Bai et al. "Translating Earth system boundaries for cities and businesses" elucidates "the steps and choices involved in a scientifically rigorous translation of Earth System Boundaries (ESB) for businesses and cities".[1] It is hoped that such purportedly scientifically rigorous approaches will enable translation of global frameworks, such as planetary boundaries and carbon budgets to smaller scales for local decisions. Ten principles for translating ESBs to businesses and cities are proposed to establish a fully coherent and transparent procedure. Similar approaches have also been used by others in recent publications [2,3]

We agree with the need for methods to translate ESBs across scales in a scientifically rigorous manner, but argue that, 1) the methods in this review are overly subjective: more scientifically rigorous methods for this translation are available, but not included in this review, 2) the approaches discussed in this review may violate the "incentivizing" principle proposed in Fig. 3 by discouraging the protection and restoration of ecosystems, thus undermining the core tenets of environmental sustainability and the motivation underlying the planetary boundaries framework [4] and the goals of this paper. Details in support of these arguments are in our published work [5,6] and summarized below.

Most existing methods for translating ESBs, including those reviewed in Bai et al. rely on downscaling of ESBs based on normative judgments. However, regardless of the scientific rigor of the sharing approach and whether the methods are top-down or bottom-up, reliance on direct downscaling even when scientific data about regional ecological budgets are available leads to inherent shortcomings. These shortcomings stem from the subjectiveness of direct downscaling of ESBs, coarse geographical resolution of ecological data in ESBs, and implicit assumptions regarding rights to ecosystem services, which may inadvertently deter environmental sustainability efforts. For the methods described in Bai et al, the stakeholder's boundary is quantified by downscaling global or sub-global ESBs to smaller systems which implicitly assumes spatial heterogeneity in proportion to the selected sharing principle. Such an assumption is likely to be incorrect for most systems. For example, the actual ecological carbon sequestration capacity in the U.S., Russia and Saudi Arabia are 7.6E8, 1.8E9 and 1.6E5 ton/year, respectively. [7] Downscaling the global sequestration capacity in proportion to a sharing principle such as economic activity or others can assign a share to regions that is very different from its actual boundary. For instance, downscaling based on the economic sharing principle of gross value added

(GVA), will assign sequestration capacities of 8.4E8 ton/year to the U.S., 6.2E7 ton/year to Russia and 3.2E7 ton/year to Saudi Arabia. Effectively, Russia's ecological capacity is redistributed to Saudi Arabia due to the latter's larger GVA per mass of carbon. This is also demonstrated for selected U.S. states in the Great Lakes region, where Illinois with the lowest carbon sequestration capacity gets the highest downscaled ecological budget which covers up the severity of its regional environmental issues. [6]

In general, downscaling of ESBs causes the ecological budget to be distributed across the entire region based on the selected sharing principle. Therefore, regions with a higher ESB but smaller relative economic activity (or another sharing principle) have to "give away" their capacity to regions with higher economic activity. Such an approach risks disincentivizing regions from protecting and restoring their ecosystems since in the current global economic system, they will bear the cost of protection but based on methods from Bai et al., others may enjoy the benefits. Such challenges have been identified in Box 1 of Bai et al., but literature that addresses these issues [5,6] has been overlooked in the review.

To further convey the flaws in using downscaling even when scientific knowledge is available, we consider an analogous situation that is commonly encountered in life cycle assessment (LCA). Here, downscaling (allocation) is often used to distribute emissions between multiple co-products. LCA best practices recommend this subjective approach as a last resort only when scientific data is not available. Consider a case where total emissions from power generation are available for a selected region. To determine the emissions from individual technologies such as coal, natural gas, solar and wind that are used in this region, LCA practitioners will not just downscale the total emissions by a subjective partitioning metric like gross value added, population served, or other criteria like those in Table 1 of Bai et al. A sound and credible LCA would utilize scientific knowledge about the actual emissions intensity of each technology to determine its contribution to the total emissions. We argue that just as in LCA, allocating ESBs to individual cities and businesses should also utilize scientific knowledge about local and regional ecosystems, and use downscaling only when absolutely necessary. Using subjective approaches even when scientific data are available makes the approach more vulnerable to greenwashing, thus reducing its credibility, and violating the principles in Figure 3 of Bai et al. Furthermore, scientific knowledge about ecosystems is increasingly available for most regions.

The approach in our previous work [5,6] uses scientific data and models to determine ESBs at multiple spatial scales based on relevant ecosystem services. For example, for translating the climate change ESB to a city, our approach quantifies the sequestration capacity available within city limits from its own urban ecosystems. This capacity is considered to belong to the city and cannot be given away to other regions by downscaling. This creates incentives for the city to protect and restore its own ecosystems. The region (state or nation) in which the city lies can also have its own ESB. The portion of this ESB that lies on public land is distributed between residents by a downscaling approach like those in Figure 3. Following a similar approach at the global scale, the global ESB that is publicly owned such as from the oceans is also downscaled to the city scale. This multiscale approach for translating ESBs uses scientific knowledge when available and subjective downscaling only when there is no other option due to lack of scientific knowledge. Another advantage of such a more science-based approach is that the resulting metrics are much more robust than the metrics from approaches that rely only on downscaling. This issue of regional variation can be worse for impacts like water use that have smaller servicesheds.[5]

This makes our science-based approach less vulnerable to greenwashing by cherry-picking the sharing principle.

Direct downscaling of ESBs has become popular perhaps because of its ease of use due to its mathematical simplicity and low data requirements. However, due to the shortcomings described above and in our previous work, results from this approach and its suggested actions can be misleading and result in perverse outcomes. Instead of relying on direct downscaling, we recommend the use of more science-based metrics and methods. Subjective downscaling should be used only when it is truly unavoidable. Such approaches have been available for many years and are better at accounting for the actual regional boundaries for selected actors such as cities and businesses [5,6]. They encourage ecosystem restoration and protection for ensuring environmental sustainability and are better at meeting the goals articulated in Bai et al.'s review. Such methods are more likely to guide us towards a future within Earth system boundaries and meet the vision articulated in this review [1] and should be included in it.

References

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