

1 **When defining boundaries for nexus analysis, let the data speak**

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8 A policy and research agenda has emerged in recent years to understand the interconnected risks
9 natural resource systems face and drive. The so-called 'Food-Energy-Water' (FEW) nexus has
10 served as a focal point for the conceptual, theoretical and empirical development of this agenda.
11 This special issue provides an opportunity to reflect on whether natural resource use, as viewed
12 through the FEW-nexus lens, provides a useful basis for guiding integrated environmental
13 management.

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15 Within this piece, we describe how the partiality of FEW-nexus overlooks major pathways of
16 resource use (i) within the food system and (ii) across the wider burden of human activity. As a
17 result, we argue FEW-centric analysis is more likely to disguise rather than reveal key
18 opportunities for integrated environmental management.

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20 **Rethinking critical pathways**

21 FEW nexus analysis assigns primary importance to interdependent pathways of resource use
22 within the food system: food-energy, energy-water, food-water. Although this adds a new vantage
23 point to assess the environmental impact of food systems, these feedbacks often do not constitute
24 major pathways of resource use (Bijl, et al. 2018; Vivanco, et al. 2018; White, 2018). In China and
25 the United States Vivanco and colleagues found major water and energy footprints within the food-
26 related sectors to arise from direct and indirect (i.e. embodied) consumption, not feedbacks
27 between water extraction and energy use (Vivanco, et al. 2018). Indeed, these feedbacks
28 contribute to less than 1% of total water and energy resource use across all economic output in
29 these nations. Consequently, analysis of FEW nexus linkages alone may provide an insufficiently
30 complete picture for managing resource-related risks within the food system. As a recent editorial
31 in Nature notes:

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33 *"...the risk is that containing this territory, however loosely, constrains it instead — and that*
34 *the nexus becomes the focus of the analysis, rather than a natural consequence of*
35 *studying the supporting problems.¹"*

1 A whole systems approach to environmental management must examine the totality of resource
2 use within the food system. Such an approach can help to identify less complex, but more
3 significant pathways leading to absolute resource use (Vivanco, et al. 2018).

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5 **Rethinking critical boundaries**

6 By definition, FEW-centric analysis overlooks competition for water, energy, and land resources for
7 other services (e.g. construction, electronic, and clothing) and priorities (e.g. environmental
8 conservation and urban development). In some cases, non-food resource use poses a more acute
9 environmental burden than food consumption and production (Vivanco, et al. 2018). The
10 construction or renewal of manufactured capital (buildings, infrastructure, machinery, and
11 equipment) is responsible for half of annual global material extraction, underlining the need to
12 extend nexus analysis beyond the food sector (Krausmann, et al. 2017).

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14 A more comprehensive multi-sectoral analysis of 'the nexus' can help inform integrated natural
15 resource management in several ways. First, it can help to identify countries, sectors, and supply
16 chains critical to the promotion of integrated management of water, energy, land, and climate.
17 Despite a growing number of studies on the FEW nexus, we still lack a foundational understanding
18 of these priority areas. Second, multi-sectoral analysis can help identify and evaluate possible
19 rebound effects induced by sustainability measures where income savings or moral licensing shift
20 consumption, and its associated environmental impacts, from target sectors to other production
21 systems (Wood, et al. 2017). Third, nexus analysis undertaken across all aspects of human activity
22 can help to inform more coherent, comprehensive, and transformative pathways for living well
23 within planetary boundaries. The speed, scale, and severity of resource depletion and
24 environmental change requires no less than a systemic approach; it is not clear FEW-nexus
25 analysis provides this.

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27 **Where next for the nexus?**

28 If we accept the need to redraw the boundaries of nexus analysis, to encompass multiple pathways
29 of resource use within coupled human and environmental systems, what is the application of
30 existing FEW-based modelling within this context? The topical focus of nexus-based assessment
31 on FEW interactions undoubtedly limits the application of existing tools and methods of analysis to
32 this end. Most models focus on the manual construction of resource accounts for specific pathways
33 of resource which make their flexible application across multiple sectors, supply chains, and spatial
34 scales impractical. Within this context, national and global resource accounting methods, such as
35 material flow accounting and environmental input-output analysis, offer a promising avenue for
36 broadening the scope and policy utility of nexus-based analysis (Bijl, et al. 2018; Vivanco, et al.
37 2018; White, et al. 2018). Such methods of analysis offer a more comprehensive account of

1 resource use across all aspects of human activity, enabling identification of important sectoral and
2 spatial scales of nexus management. This allows for a global view of the network of human activity
3 and the way in which interlinkages and trade flows between nations redistribute the environmental
4 burdens of production and consumption. Such a re-configuration of nexus analysis does not
5 demand the development of entirely new areas of scholarship, but simply better linkage of existing
6 data, models and insights within natural resource accounting research.

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8 In contrast to other commentators, we do not question the principle need for nexus-style
9 assessment. As development begins to outstrip the limited capacities of multiple environmental
10 systems (water, land, climate, ecosystems and beyond), integrated appraisal of policy measures
11 appears increasingly necessary; agendas such as the UN Sustainable Development Goals
12 demand this. Instead, we argue FEW-centric analysis fails to capture fully the many drivers of
13 resource use within production and consumption systems. While effective management of the
14 FEW linkages might promote sustainable allocation of natural resources, it does not necessarily
15 guarantee it. As a rule of thumb, boundaries of nexus analysis and governance should be informed
16 by a comprehensive understanding of the total environmental burden of human activity as it
17 emerges from analysis of the data. By contrast current FEW analysis tries to set these boundaries
18 a priori. Only when we zoom out from the FEW nexus can we begin to identify the opportunities for
19 joined-up thinking in our complex and changing world.

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