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Can we use indicator-based farm sustainability assessment tools for the WEFE Nexus?

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Abstract. Fair and safe allocation of natural resources for the Euro-Mediterranean area, especially for semi-arid regions, strongly relies on the adoption of WEFE (Water Energy Food Ecosystem) Nexus strategies. Transitioning to WEFE Nexus requires novel quantifiable assessment for interlinked analysis of the four WEFE sectors. Several indicator-based tools exist for agricultural sustainability at the farm scale. This contribution investigates on the application of such tools in relation for WEFE Nexus approaches. The IDEA method was selected for extending its applicability as a novel WEFE Nexus indicator toolkit and the following challenges are identified: (1) some WEFE aspects need to be reinforced in order to expand the scope beyond the actual agro-ecological focus; (2) the application at the farm scale needs to be articulated with larger scales where the WEFE Nexus displays emerging consistencies; (3) Nexus interactions, trade-offs and synergies could be further accounted for. These three challenges help identify how the IDEA indicator-based tool could be adapted to assimilate the WEFE Nexus approach, and so to allow applications in new agro-hydrological contexts.

Keywords. UPH 22; SDG; indicator; Mediterranean; IDEA; WEFE Nexus

1 Introduction

In some contexts, in particular Mediterranean and semi-arid ones (Cudennec et al., 2007; Merheb et al., 2016), sustainability issues are in strong need of avoiding compartmentalization that actually impacts fair allocation of water, energy, food and environment resources among competing social and economic sectors. Sustainable and safe resource management thus requires the adoption of WEFE (Water Energy Food Ecosystem) Nexus strategies. Hoff (2011) underlines that "*A nexus approach can support a transition to sustainability*". This was further emphasized in the FAO reports which state "*the Water-Energy-Food Nexus is framed within the broader debate on sustainable development*" (FAO, 2014a, b). More recently, Liu et al. (2017) emphasized the critical role of the WEF Nexus in "*developing strategies for sustainable development*". This has been further advocated by Cudennec et al. (2018) and Heal et al. (2021) with additional perspectives on the epistemological and the water quality dimensions. The WEFE Nexus expands the WEF Nexus with the accounting of the multiple concurring Ecosystem dimensions. It elaborates on the complexity of interactions between different elements of the natural and human systems, and the necessity of considering such complexities for the well-being of present and future generations. The Ecosystem dimension, within the WEFE Nexus paradigm, may be further extended to consider the interlinkages between the bio-physical components of the WEF Nexus with a multiple conceptualization of the eco-social setting. As a result, the second E (Ecosystem) may be considered as a multi-scalar realization of the diverse and intertwined facets of the human-nature interface. In particular, this work envisages the triple conceptualization of the E – referring to the Environmental, Economic and Engagement (Society) facets – promoted within the Nexus-Ness project (https://prima-nexus-ness.org/nexus-ness/concept/, last access: June 2022), an innovation action co-funded by the Hori-

zon 2020 and the Partnership on Research and Innovation in the Mediterranean Area (PRIMA) programs. Indeed, the WEFE Nexus is an integrated approach that focuses on the co-management of Water, Energy, Food, and Ecosystem resources and amenities co-demonstrating with citizens and stakeholders multiple benefits of Nexus strategies "*with a view to improving integrated solutions in the field that improve achievement of SDGs*" (Carmona Moreno et al., 2019).

The interlinkages (in particular trade-offs and synergies) between the various elements of the WEFE Nexus are difficult to grasp at a given scale, and so level of organization, and even more between the different scales/levels which can be concerned and nested in a particular scenario. Furthermore, beyond the diagnostic assessment of a peculiar condition, appreciating its sustainability, exploring future alternatives, innovating policies (Bazzana et al., 2023) and identifying transformation paths require a quantitative compromise between conceptualization and its feasibility towards operational implementation.

Assessing agricultural sustainability has a long history in contexts where the WEFE Nexus is less critical. Indicator-based agricultural sustainability assessment tools have been developed and already tested. This contribution seeks to verify if indicator-based farm sustainability assessment tools could be adapted to support adoption of WEFE Nexus strategies. We explore a particular method, IDEA, which is well consolidated for sustainability assessment and agro-ecological transition monitoring at the farm level.

In the following, we will present the IDEA method and discuss the challenges but also the prospects for its application for geographical, bio-physical and socio-economic scales of interest of WEFE Nexus assessment strategies.

2 The IDEA method

The IDEA method (in French "Indicateurs de Durabilité des Exploitations Agricoles", i.e. Indicators of Farms Sustainability) has been designed and circulating for more than 20 years. The first prototype was published in 1999. The method was then updated three times: IDEA1 in 2000, IDEA2 in 2002, and IDEA3 in 2008 (https://methode-idea.org/, last access: June 2022). Here we are referring to version 3 (Zahm et al., 2008) and to related applications and assessments (Binder et al., 2010; Marchand et al., 2014; De Olde et al., 2016). It includes the three dimensions (normative, systemic and procedural) of an operational sustainability assessment tool as defined by Binder et al. (2010). IDEA proved to be a robust and relatively easy-to-use method. The concepts and objectives are clear (De Olde et al., 2016), themselves rooted in the key concepts of agriculture sustainability (Zahm et al., 2008): environmental reproducibility, livability, and viability. We acknowledge that these three concepts respectively correspond to the environmental, social, and economic pillars of sustainability. In the IDEA terms, these are represented through the agro-ecological, socio-territorial and economic scales. The main concepts of the method are transcribed into 16 objectives, characterized with 41 indicators, themselves clustered into 10 components. The agro-ecological scale/level includes three components: diversity, organization of space and farming practices, assessed with 19 indicators. The socio-territorial scale/level includes three components: quality of the products and land, organization of space, and ethics and human development, assessed with 16 indicators. Finally, the economic scale/level is sub-divided into four components: economic viability, independence, transferability, and efficiency, assessed using six indicators. Table 1 summarizes the scales/levels, components and indicators of IDEA. A scale has a total score of 100. This score is calculated by summing the individual score of indicators in each component. It should be noted that a maximum score is set for each indicator and each component. Furthermore, indicators do not have the same score ranges, hence have different expert-based pre-defined weights. The overall farm sustainability score is equal to that of the scale with the lowest score. Finally, this method is based on predefined goals and set of indicators, and on a clear target group (farmers). This may reduce the stakeholders' participation in the goal settings and the elaboration of evaluation criteria. However, it allows more flexibility in comparing the system in time and space. Moreover, IDEA is flexible in its application to farms. Hundreds of French farms and various types of farms in Tunisia (M'Hamdi et al., 2009), Algeria (Bekhouche-Guendouz, 2011), Morocco (Baccar et al., 2019), Mexico (Salas-Reyes et al., 2015; Fadul-Pacheco et al., 2013), Senegal (Faye et al., 2020) and Lebanon (Srour et al., 2009) have been evaluated with the IDEA3 method.

3 Challenges and prospects for the WEFE Nexus assessment with the IDEA method

Three main challenges impact the assessing of the WEFE Nexus by means of the IDEA method, which are summarized in Table 1 as commentaries on the IDEA components and indicators. Some suggestions are also made in order to adapt IDEA for the WEFE assessment as hereafter briefly reported.

1. Some WEFE aspects need to be emphasized in order to widen the scope of IDEA beyond the agro-ecological focus. Indeed, if one looks more closely at the agro-ecological scale, IDEA emphasizes on the ecosystem in term of biodiversity, organization of space, pollution while the other Nexus aspects are under-represented. Indeed, it divides the total score of 100 unequally between the diversity and organization of space components on the one hand, and the farming practices component on the other hand. The first two relate more to the ecosystem aspect of the Nexus. Even some indicators in the farming practices can also be classified under the ecosystem aspect such as "soil protection". Hence,

Table 1. The scales/levels, components and indicators of the IDEA method (Zahm et al., 2008) along with the authors' commentaries.

Scale	Component	Indicators	Commentaries re. the WEFE Nexus
Agro-ecological	Diversity	Diversity of annual or temporary crops	These indicators relate to the ecosystem dimension of the WEFE Nexus. A single aggregated bio-diversity indicator might be considered.
		Diversity of perennial crops	
		Diversity of associated vegetation	
		Animal diversity	
		Enhancement and conservation of genetic heritage	
	Organization of space	Cropping pattern	These indicators relate to the food production aspect of the Nexus and would need to be reframed into the specific perspective.
		Dimension of fields	
		Stocking rate	
		Fodder area management	
		Organic matter management	These indicators relate to the ecosystem aspect.
		Ecological buffer zone	
		Measures to protect the natural heritage	This indicator relates to the cultural dimension.
	Farming practices	Fertilization	These indicators relate to the environmental and water quality aspects.
		Effluent processing	
		Pesticides and veterinary products	
		Animal well being	This indicator is related to food production and to ethics
		Soil resources protection	This indicator relates to the environment and to food production.
		Water resources protection	This is the only indicator that explicitly mentions water.
		Energy dependence	This is the only energy-related indicator.
Socio-Territorial	Quality of the products and lands	Quality of food stuffs produced	This indicator relates to the food production dimension.
		Enhancement of building and landscape heritage	This indicator relates to the cultural dimension.
		Processing of non-organic waste	This indicator relates to the environment dimension.
		Accessibility of space	These indicators are promising not only regarding the social dimension but also to articulate the farm scale/level with upper levels in the Nexus perspective.
		Social involvement	
	Organization of space	Short trade	
		Services, multi-activities	
		Contribution to employment	
		Collective work	
		Probable farm sustainability	
	Ethics and human development	Training	
		Labor intensity	
		Isolation	
		Reception hygiene and safety	
		Contribution to world food balance	This indicator proves how a WEFE indicator can be articulated between scales/levels.
Economic	Economic viability	Available income per worker compared with the national legal minimum wage	These indicators at the farm scale/level are entry points to articulate with the upper scales/levels.
		Economic specialization rate	
	Independence	Financial autonomy	
		Reliance on direct subsidies from CAP and indirect economic impact of milk and sugar quotas	
	Transferability	Total assets minus lands value by non-salaried worker unit	
	Efficiency	Operating expenses as a proportion of total production value	

this scale gives more values to the ecosystem over other aspects of the Nexus. Indeed, the energy aspect, and the water aspect are only explicitly represented in two indicators with a total score that cannot exceed 12 points out of 100. Therefore, there is an imbalance in the scoring of the indicators between different aspects of the WEFE Nexus.

The socio-territorial scale also includes indicators that can be well put under the WEFE components especially food quality. The indicator "processing of non-organic waste" can also be put under the ecosystem component. Yet, it appears that IDEA3 emphasizes more on the ecosystem aspect of the Nexus.

2. The application scale is the second challenge. The IDEA assesses sustainability at the farm scale/level while the Nexus is at play at various scales/levels. Therefore, the application on the farm scale needs to be articulated with larger scales where the Nexus displays emerging consistencies. Indeed, the Nexus includes interactions at various scales and there exist many externalities to a given Nexus system. These interactions are not explicitly accounted for in IDEA. However, the fact that IDEA is divided into agro-ecological, socio-territorial and economy scales, does permit to account for some interactions across scales, in particular the impact of the farm on the higher organizational scale. Indeed, while the agro-ecological scale "*analyses the propensity of the technical system to make efficient use of the environment at the lowest possible ecological cost*", the socio-territorial scale "*characterizes the integration of the farm within its landscape and in society*" (Zahm et al., 2008). Hence, the method does take into account certain interactions between the farm and its surroundings, however these are limited to very specific social, environmental and food quality aspects. Thus, if it is to be used for the WEFE Nexus assessment, the farm impact should be also assessed in terms of other aspects of the WEFE Nexus, including water and energy. Moreover, the impact of larger scales on the farm should also be accounted for. In addition, the economic scale of IDEA focuses on the farm economic viability, independence, inter-generational transferability and efficiency. While these are decisive aspects to focus on, they are limited to the farm itself and there is no assessment of the farm contribution to regional economy and vice versa. Another aspect that IDEA dismisses relates to the institutional and governance impacts. Furthermore, the method does not take into account the aggregated effect of multiple neighboring exploitations that share the same resources. The interactions of these exploitations affect the environment but also each individual farm. Moreover, the aggregated effects of multiple small scales can result in the emergence of new challenges at larger scales.

3. Third, an emerging challenge will appear if/when expanding the IDEA method to address the Nexus approach: it should be avoided to deal with different aspects of the Nexus on the one hand, and the sustainability domains on the other hand, in silos. Indeed, IDEA, like the majority of sustainability assessment tools, does not explicitly examine the synergies and trade-offs between the indicators within each scale or between scales whereas these are central in the Nexus approach.

4 Summary

The WEFE Nexus is certainly embedded in the question of sustainable development. It presents a most needed operational framework that can better account for and help understand and unravel the different interlinkages, synergies and trade-offs within but also between the natural and human systems in order to manage our resources in a sustainable manner; especially when dealing with vulnerable environments. However, for such a framework to become useful, one should be able to quantify its performance in terms of sustainability. Hence, the importance of the Nexus sustainability assessment. Yet, such an endeavor is not a simple task even if numerous tools exist for agriculture sustainability assessment. In this work, we highlighted some limitations but also prospects using the example of one particular tool: the IDEA. The main challenges relate to the under-representativeness of some aspects of the WEFE Nexus, the applicability scale, and the Nexus interactions, trade-offs and synergies (see Unsolved Problem in Hydrology (UPH) 22). Nevertheless, with some adaptation, such tools are a good avenue to explore sustainability assessment and transition design, with a focus on the Nexus as it is needed in some contexts. Their appeal relates to the fact that they cover all three dimensions of sustainability. Moreover, they are widely used with a large bibliographic record, which permits comparisons and discussions. Future research should certainly focus on enhancing these tools to better account for all WEFE aspects and to be able to capture in a more explicit way the intra-scale but also inter-scale synergies and trade-offs. The adaptation should certainly focus on adapting the list of indicators to better represent the different aspects of the WEFE. Moreover, a participatory approach in co-defining and co-weighing the indicators can certainly be beneficial when adapting such tools for different case studies. Finally, the insertion of new dynamic indicators can enhance the monitoring of the WEFE sustainability.

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References

Baccar, M., Bouaziz, A., Dugué, P., Gafsi, M., and Le Gal, P.-Y.: The determining factors of farm sustainability in a context of growing agricultural intensification, Agroecol. Sustain. Food, 43, 386–408, https://doi.org/10.1080/21683565.2018.1489934, 2019.

Bazzana, D., Comincioli, N., El Khoury, C., Nardi, F., and Vergalli, S.: WEF Nexus Policy Review of Four Mediterranean Countries, Land 2023, 12, 473, https://doi.org/10.3390/land12020473, 2023.

Bekhouche-Guendouz, N.: Evaluation de la durabilité des exploitations bovines laitières des Bassins de la Mitidja et d'Annaba, PhD Thesis, Institut National Polytechnique de Lorraine, 2011.

Binder, C. R., Feola, G., and Steinberger, J. K.: Considering the normative, systemic and procedural dimensions in indicator-based sustainability assessments in agriculture, Environ. Impact Asses., 30, 71–81, https://doi.org/10.1016/j.eiar.2009.06.002, 2010.

Carmona-Moreno, C., Dondeynaz, C., and Biedler, M.: Position paper on water, energy, food and ecosystems (WEFE) nexus and sustainable development goals (SDGs), Publications Office of the European Union, Luxembourg, ISBN 978-92-76-00159-1, https://doi.org/10.2760/31812, JRC114177, 2019.

Cudennec, C., Leduc, C., and Koutsoyiannis, D.: Dryland hydrology in Mediterranean regions – a review, Hydrolog. Sci. J., 52, 1077–1087, https://doi.org/10.1623/hysj.52.6.1077, 2007.

Cudennec, C., Liu, J., Qi, J., Yang, H., Zheng, C., Gain, A. K., Lawford, R., de Strasser, L., and Yillia, P. T.: Epistemological dimensions of the water–energy–food nexus approach: reply to discussions of "Challenges in operationalizing the water–energy–food nexus", Hydrolog. Sci. J., 63, 1868–1871, https://doi.org/10.1080/02626667.2018.1545097, 2018.

De Olde, E. M., Oudshoorn, F. W., Sørensen, C. A. G., Bokkers, E. A. M., and de Boer, I. J. M.: Assessing sustainability at farm-level: Lessons learned from a comparison of tools in practice, Ecol. Indic., 66, 391–404, https://doi.org/10.1016/j.ecolind.2016.01.047, 2016.

Fadul-Pacheco, L., Wattiaux, M. A., Espinoza-Ortega, A., Sánchez-Vera, E., and Arriaga-Jordán, C. M.: Evaluation of Sustainability of Smallholder Dairy Production Systems in the Highlands of Mexico During the Rainy Season, Agroecol. Sustain. Food, 37, 882–901, https://doi.org/10.1080/21683565.2013.775990, 2013.

FAO (Ed.): Building a common vision for sustainable food and agriculture: principles and approaches, Food and Agriculture Organization of the United Nations, Rome, 50 pp., E-ISBN 978-92-5-108472-4, 2014a.

FAO: The Water-Energy-Food Nexus: a new approach in support of food security and sustainable agriculture, https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/421718/ (last access: in February 2023), 2014b.

Faye, A., Zucchini, E., Ngom, Y., Vignaroli, P., Tarchiani, V., and Dia, D.: Assessing the Sustainability of Horticultural Farms in Central Senegal: An Adaptation of the IDEA Method, J. Agric. Sustain., 13, https://doi.org/10.28924/ip/jas.1923, 2020.

Heal, K. V., Bartosova, A., Hipsey, M. R., Chen, X., Buytaert, W., Li, H.-Y., McGrane, S. J., Gupta, A. B., and Cudennec, C.: Water quality: the missing dimension of water in the water–energy–food nexus, Hydrolog. Sci. J., 66, 745–758, https://doi.org/10.1080/02626667.2020.1859114, 2021.

Hoff, H.: Understanding the Nexus, in: The Water, Energy and Food Security Nexus, Bonn, https://www.sei.org/publications/understanding-the-nexus/ (last access: 16 May 2022), 2011.

Liu, J., Yang, H., Cudennec, C., Gain, A. K., Hoff, H., Lawford, R., Qi, J., Strasser, L. de, Yillia, P. T., and Zheng, C.: Challenges in operationalizing the water–energy–food nexus, Hydrolog. Sci. J., 62, 1714–1720, https://doi.org/10.1080/02626667.2017.1353695, 2017.

Marchand, F., Debruyne, L., Triste, L., Gerrard, C., Padel, S., and Lauwers, L.: Key characteristics for tool choice in indicator-based sustainability assessment at farm level, Ecol. Soc., 19, 46, https://doi.org/10.5751/ES-06876-190346, 2014.

Merheb, M., Moussa, R., Abdallah, C., Colin, F., Perrin, C., and Baghdadi, N.: Hydrological response characteristics of Mediterranean catchments at different time scales: a meta-analysis, Hydrolog. Sci. J., 61, 2520–2539, https://doi.org/10.1080/02626667.2016.1140174, 2016.

M'Hamdi, N., Aloulou, R., Hedhly, M., and Ben Hamouda, M.: Evaluation de la durabilité des exploitations laitières tunisiennes par la méthode IDEA", BASE [En ligne], numéro 2, volume

13, 221–228, https://popups.uliege.be/1780-4507/index.php?id=3865 (last access: 16 May 2022), 2009.

Salas-Reyes, I. G., Arriaga-Jordán, C. M., Rebollar-Rebollar, S., García-Martínez, A., and Albarrán-Portillo, B.: Assessment of the sustainability of dual-purpose farms by the IDEA method in the subtropical area of central Mexico, Trop. Anim. Health Prod., 47, 1187–1194, https://doi.org/10.1007/s11250-015-0846-z, 2015.

Srour, G., Marie, M., and Abi Saab, S.: Evalu ation de la du rabilité des élevages de petits ru min an ts au Liban, in: Changes in sheep and goat farming systems at the beginning of the 21st century : research, tools, methods and initiatives in favour of a sustainable development, edited by: Pacheco, F. and Morand-Fehr, P., Zaragoza: CIHEAM/DRAP-Norte/FAO, 21–35 (Options Méditerranéennes: Série A. Séminaires Méditerranéens, n. 91, 2009.

Zahm, F., Viaux, P., Vilain, L., Girardin, P., and Mouchet, C.: Assessing farm sustainability with the IDEA method - from the concept of agriculture sustainability to case studies on farms, Sust. Dev., 16, 271–281, https://doi.org/10.1002/sd.380, 2008.