CHAPTER 13

A methodology framework to access the impact of rural practices in the food-water-energy security nexus

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1. Introduction

According to Bosshard (2000), the concept of sustainability is one of the most challenging of recent times. This concept began to be disseminated in some specific disciplines in the 1970s. Almost two decades later, with the Brundtland Report (Western Cape Education Department, 1987), this term gained notoriety and expanded to different areas of research, in addition to being projected among decision makers worldwide. In this report, sustainable development is considered a process of change in which the exploitation of resources, the orientation of investments, the directions of ecological processes and institutional change are harmonized and in accordance with the needs of current and future generations. This concept of sustainability derives from the view that humans are impacting the environment at such an intense pace (using nature unsustainably) that it will soon result in the depletion of natural resources.

At the Rio 92 World Conference, the term sustainability was finally fully incorporated into the global agenda. Since then, the challenge of reconciling economic growth, environmental preservation and improving the population's living conditions is increasingly greater. Faced with this challenge, the restrictions imposed by environmental legislation and society's demand for environmentally friendly production, multiple approaches and tools are important strategies to support best land use decision. These functionalities have been developed to assess the impacts of (planned) activities on either individual dimensions of sustainability (e.g., environmental impact assessment; social impact assessment), as well as impacts on the interrelations of all three dimensions (sustainability impact assessment) (Schindler, Graef & König, 2015). However, existing frameworks still miss indicators to assess impacts on the food-water-energy nexus.

By 2030, it is estimated that the world population will be 8.3 billion people, putting further pressure on energy, water, food, land use and mineral extraction, especially in the developing world (Rockefeller Foundation & GBN, 2010). Between the years 2000 and 2050, maintaining the current pace, it is estimated that the global water demand will increase by up to 400% for the industry; 140% for energy generation; and 130% for supply, with irrigation decreasing by approximately 15%. These concerns are exposed in the 2030 Agenda, mainly highlighted in the sustainable development goals (SDG 2) Zero Hunger, (SDG 6) Clean Water and Sanitation and (SDG 7) Affordable and Clean Energy.

When translating the projections into quali-quantitative terms and their impacts on estimated economic costs, the World Economic Forum on global risks identified water security as one of the major global challenges, which could exceed $ 400 billion of business risks. Marcial (2015) highlights that, for the next nine years, the biggest concerns will be the industrial sector and the water supply for society. The author also points out that, by 2030, approximately one billion more people will live in areas with water scarcity and almost half of the world population will live in areas with severe water stress. On the other hand, integration between water user sectors is expected, especially in developed countries, generating greater benefit in the allocation of water resources (NISTEP, 2010).

In this context, changes in the flow of rivers will also affect the water levels in the reservoirs used to generate electricity, which is an intensive use of water resources (Trivedi et al., 2012). Meeting the growing energy demand will generate increased pressure on continental water resources, with repercussions on other users, such as those in agriculture and industry (WWAP, 2015).

Agricultural activity follows the same trend. By 2050, agriculture will need to produce 60% more food globally, and 100% more in developing countries. Since the current global growth rates of water demand for agriculture are unsustainable, the sector will have to increase its efficiency in the use of water, reducing losses and, even more importantly, increasing the productivity of crops in relation to the water resources used (WWAP, 2015).

Thus, it is imperative to create synergies to maximize the efficiency of natural resources according to the needs of society. One way is to consider sustainable rural practices as potential facilitators of this process, in view of the multifunctionality of agriculture (Vos & Hoogendoorn, 2000).

As questions on food, water and energy are complex, they need to be addressed in combination and cannot be treated as stand-alone problem. Applying a nexus approach allows a systematic integration to address issues related to food, water and energy security at various levels, generating different scenarios (Rasul, 2014; WEF, 2011; Hoff, 2011; Hellegers et al., 2008). This approach looks for ways to conceptualize and, if possible, quantify the links between FWE in a single structure capable of generating integrated assessments focused on food, water and energy security (Flammini et al., 2014).

Some of the elements considered by FWE nexus include: (i) the three sectors have billions of people without access (quantity, quality or both); (ii) there is a growing global demand and resource constraints for all of them;

(iii) the different availability on a regional scale and variations in supply and demand; (iv) the strong interdependencies with climate change and with the availability of natural resources (Bazilian et al., 2011).

While the nexus approach is growing in popularity to address the interconnected issues of global challenges, there is a lack of problematization of the concept of nexus governance (Urbinatti et al., 2020). To manage the highly interlinked dimensions of food, water and energy, it is required in fact strong coordination and negotiation across sectors and temporal and geographical scales, making the nexus governance a multi-level challenge involving a variety of actors and institutions (Pahl-Wostl, 2019; Stein, Barron & Moss, 2014; Weitz et al., 2017). Conflicting interests of stakeholders, as well as consolidated institutions and policies that address sectoral pressures in silos, need to be understood to build up mechanisms that allow continuous dialogue throughout the project's implementation.

In this sense, citizens as stakeholders are increasingly demanding to be engaged in planning decisions that affect them and their communities, at scales from local to global and this requires changes in how models are built (Voinov et al., 2016), as an alternative to promote a more effective governance process.

2. Multi-functional agriculture and the FWE nexus

Multifunctional agriculture (MFA) refers to the ability of agricultural activity going beyond its primary role of producing food and fibre; and also providing several other functions such as renewable natural resources management, landscape and biodiversity conservation, and contribution to the socio-economic viability of rural areas (Renting et al., 2009). This concept can be extended to the notion that the contributions of agriculture to environmental externalities also covers development challenges like food security, poverty alleviation, social welfare and cultural heritage.

In general, it is possible to affirm that agricultural lands represent an opportunity to improve the ability of soils to provide ecosystem services through the adoption of good agricultural management practices, since these practices can maintain or even increase the input of organic matter in the soil (Novotny et al., 2020). Therefore, the main drive of the MFA is agricultural practices. On one hand, conventional practices can affect the water sector through land degradation, changes in runoff, and disruption of groundwater discharge;

however, conservation agriculture can improve the soil quality and contribute to MFA.

The agricultural sector is relevant for the national economy – after achieving record growth in 2020, the Brazilian agribusiness Gross Domestic Product (GDP) rose by 5.35% in the first quarter of 2021 (CEPEA, 2021). Thus, it is important to integrate the food production vision in generating other benefits for society. The main objective of this chapter is to present a methodology framework for evaluating the impact of rural landscape management practices on the FWE nexus.

To this end, the Rio Claro municipality, in Rio de Janeiro State, is used as a case study, located in the Atlantic Forest biome. The Atlantic Forest is the Brazilian biome with the highest population density within the country, hosting 72% of the population, and contributing for 70% of the Brazilian GDP (SOS Mata Atlantica, 2020). In this way, the demand for water, energy and food in this biome is high. The intensive use of their land for agriculture, urbanization and industrialization has led to high rates of deforestation, which resulted in the loss of many ecological functions, especially those related to the supply of FWE (Joly, Metzger & Tabarelli, 2014; Rezende et al., 2015).

Rio Claro municipality has about 20,000 inhabitants (IBGE, 2020) and its entire area contributes directly to the Ribeirão das Lajes reservoir, an important source of water and energy for the metropolitan region and the city of Rio de Janeiro/Brazil, the second most populated city in the country. The predominant land use is pastures, and it presents a low use of agriculture conservationist practices; thus, environmental problems resulting from the degradation of its lands. This is a very common scenario that we can find in the cities in the Atlantic Forest biome. Hence, developing integrated studies considering the FWE security nexus is fundamental in this context, especially the possibility of transforming the landscape through conservationist practices that can restore the quality of the lands, increasing agricultural production, reducing erosion and optimizing water use and energy generation.

3. The FWE methodology framework

We considered the FoPIA (Framework for Participatory Impact Assessment) methodology (Morris et al., 2011) a starting point to build our FWE nexus evaluation. The FoPIA is meant to enable assessments of policy impacts that are sensitive to national, regional and native sustainability priorities by harnessing the knowledge and expertise of national, regional and native stakeholders who play a central role within the analytical process. The analysis of specific sustainability problems gives rise to realistic national and regional policy and land use change scenarios (Morris et al., 2011; Coutinho et al., 2017). Still, the FoPIA has been useful to arrange for the participatory assessment of serious changes in land use and within the possibility of sustainability, key elements in our investigation.

Additionally, due the complexity of food security, water security and energy security concepts, this methodology is framed to evaluate the "availability and stability" dimensions of each security component.

Therefore, the methodology framework was developed as followed:

i. Project support database

A database was built using secondary data available in official dataset (free data) to subsidize the landscape characterization; the rural practices to be evaluated; the definition of attributes and indicators and the indicators' analysis performance. This database was also used to establish the areas of direct (municipality of Rio Claro) and indirect influence (other municipalities of the study area) on the Ribeirão das Lajes Reservoir (Figure 1).

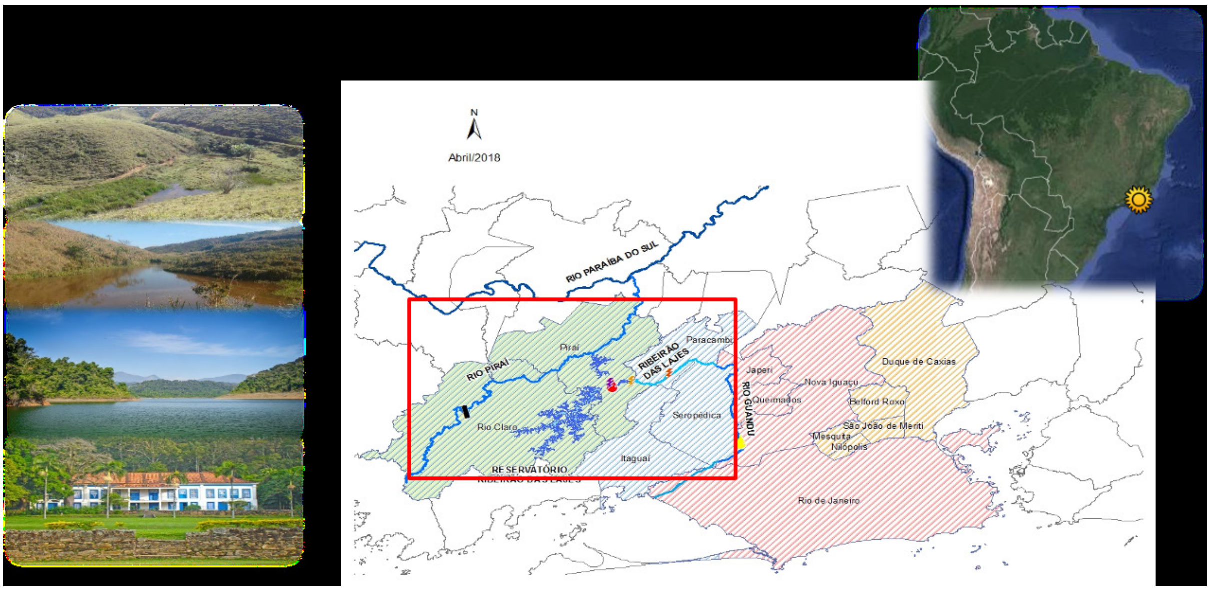

Figure 1. Study area and its surroundings.
Source. Elaine Cristina Cardoso Fidalgo.

In order to validate the information, two field trips were carried out: one in the first year of the project and the second one in the third year. The main goal of the first field trip was to support the final list definition of the agriculture practices to be evaluated in our study. Thus, based on the IBGE agricultural census, from the years 1995, 2006, and 2017 and in a field trip, we defined agroforestry, spring protection, pasture rotation and sanitation as the most relevant rural practices considering the past and present land use in Rio Claro municipality.

The second field trip's main goal was to present the information that has been collected to the local rural extension agents, and make adjustments, if necessary.

ii. Literature review

We performed a literature review to assess research papers that link rural practices and their impact on food, water and energy production. Brazil is a country with an important agricultural sector, and there are many studies investigating the impact of agricultural practices on soil erosion and water runoff within Brazilian landscapes (Xiong, Sun & Chen, 2018). We focused on the Brazilian Atlantic Forest biome as a study case. We searched the Web of Science database, using a combination of keywords with at least one rural conservation practice (Spring protection / Headwater protection; Riparian restoration; No tillage; Conventional crop / Conventional agriculture; Minimum crop; Organic crop / Organic Fertilization / Organic agriculture; Green adubation / Green fertilization; Crop rotation; Terrace; Level crop; Containment basin; Basic sanitation; Rural tourism / Agritourism; Agroforestry / Agroforestry; Fallow; Soil manage / Soil management; Pasture rotation / rotational grazing; Manure treatment), and one security aspect (Water; Energy / power / hydropower; Food; Agricultural production; Crop production) and one location-related word (Brazil; Atlantic Forest). We restricted our search to terrestrial landscapes in rural, agricultural, mixed rural-urban or natural habitat regions, in the Atlantic Forest Biome, thus excluding strictly urban or marine landscapes (Duarte et.al., 2021).

iii. Public Policies survey

A survey and systematization of public policy instruments on federal (national level), state (State of Rio de Janeiro) and municipal (with a focus on Rio Claro municipality) was carried out. The correlated public policies were analyzed one by one regarding their relevance for the study region and in relation to FWE security.

The policies were classified and selected using the following criteria: being in force, taking into account the aggregation of income, containing terms related to sustainability, including participatory processes, contributing to the provision of ecosystem services, providing for awareness and training actions, and having terms related to FWE security.

iv. Participatory workshop and definition of landscape attributes and indicators

At the end of the first year of the project, a group of 32 professionals joined an expert workshop held at Embrapa Soils, Rio de Janeiro - Brazil. The goal was to adapt part of the FoPIA methodology, basically comprised in three stages: (1) to define the project baseline, based on all the secondary data collected and systematized (items i and ii); (2) The definition of the landscape attributes; (3) The definition of indicators for each landscape attributes defined for each FWE nexus security.

The landscape attributes were proposed based on the concept of "Land Use Functions" (Pérez-Soba, Petit, & Jone, 2008; Turetta & Coutinho, 2015), that are related to the way each land use class can contribute to a certain objective. For the purpose of our study, the concept is understood as how each land use / land cover can contribute to FWE nexus security.

Organized in thematic groups – food, water, energy – the experts had the chance to discuss and define the most appropriate landscape attributes and indicators to evaluate the impact of rural practices in the FWE security nexus, that was presented in the closing plenary. We can cite "diversification of agricultural production" as an example of the landscape attribute set by the thematic group dedicated to the "food" pillar. And the indicator selected to evaluate the performance of this attribute was the "nutritional value of agricultural production per inhabitant" (Fidalgo, Turetta & Pedreira, 2021).

The criterion to determine the landscape attributes were their ability to trigger changes in the availability and stability dimensions; and the criteria to set the indicators were their capacity to demonstrate the impact of a rural practice in FWE security nexus as well as their availability on the project database (item i).

v. Data integration

The data integration will follow a quantitative analysis, based on data collection to identify and assess the interlinkages between water, energy and food systems. This work clarifies which environmental and social resources are under pressure, identifies critical interlinkages, competing interests and therefore which 'nexus' issues may arise in the future. It includes collecting data on both the status of the ecosystem resource as well as socio-economic aspects, making use when possible of existing datasets (Flammini et al., 2014).

For each indicator, a benchmark value was established, based on existing legislation/literature or comparing Rio Claro performance with the municipalities that are part of its micro-region, which is an administrative level based on similarities set by the IBGE (2017). Then, based on the literature review (item ii) we could determine the impact of the selected rural practices - agroforestry, spring protection, pasture rotation and sanitation - on each indicator, evaluating the FEW security nexus in a business-as-usual scenario and considering a scenario of each rural practice implementation.

The results were presented for the most relevant stakeholders for our study case (Melloni et al., 2020) in order to check the adequacy of the proposed interventions and generate validated results that are able to be applied and contribute to an improvement in the FWE nexus security. It can raise awareness of the interlinked nature of global resources systems to be considered in decision-making processes (Flammini et al., 2014).

vi. E-learning platform

To facilitate and encourage the implementation of rural practices aligned with the framework proposed in the project in question, we adapted the benchmarking concept. In the project, it refers to the process of comparing the individual performance of each rural property with the performance of others that are engaged in similar activities, resulting in learning from the lessons of these comparisons, involves measurements and evaluations based on the proposed indicators production (food), environmental impact (water and energy) and the conservation practices adopted. Thus, an electronic platform was developed so that rural producers in the Rio Claro region, and similar contexts, with the support of technicians from rural extension institutions, can access performance indicators related to nexus, in addition to exchange integrated practices carried out in the basin (Ribeiro et al., 2020).

The platform is organized into 6 parts: (i) Home page, that contains general information about the project, the team, the platform itself and the registered properties; (ii) Indicators tab, with interactive graphics for direct comparison of properties after choosing attributes and indicators; (iii) Practices tab, that allows spatial visualization of applications; (iv) Benchmarking tab, that performs graphical comparisons between performance and practices, based on the nexus dimensions; (v) the Success Cases tab that contains different rural conservation practices from outside the basin; and (vi) Practice Registration to upload new practices.

vii. Nexus FWE governance assessment

The start point was a preliminary stakeholder analysis that identified actors and institutions that should be involved in the decision-making process, and also a panorama of entities, categorized in private, public, academia, and nonprofit entities with different interests that required communicative efforts to ensure participation and public representation regarding the FWE nexus evaluation (Melloni et al., 2020).

Based on the sustainability impact assessment tool, ScalA, we suggest a set of criteria to address such issues in an ex-ante assessment: (i) accountability gaps, (ii) administrative gaps, (iii) policy gaps, (iv) capacity gaps, and (v) data and information gaps; and 43 indicators from the nexus literature and the OECD categorization of multi-level governance gaps were defined to address a multilevel governance (Löhr et al.; OECD, 2018).

We summarize the methodology steps in figure 2.

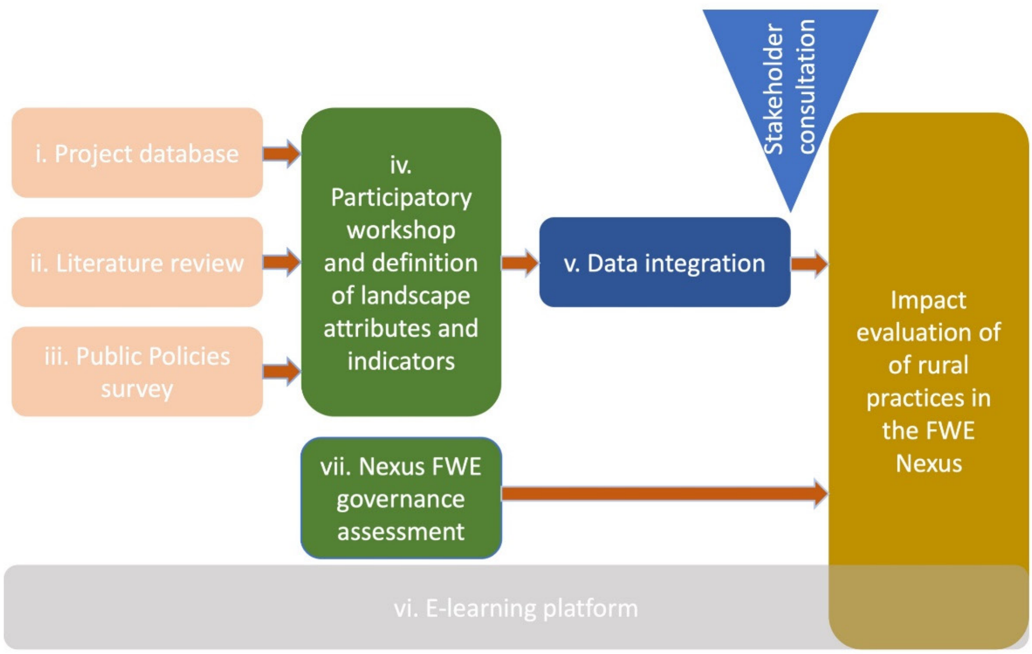

Figure 2. Methodology steps to evaluate the impact of rural practices in the FEW nexus.
Source. Ana Paula Dias Turetta.

4. Conclusions

Considering all the scenarios about population growth and the increasing demand for food, water and energy, we highlight the potential of MFA to provide a range of benefits – beyond its primary function that is to produce food – through the promotion of conservationist practices in rural landscapes.

We presented a feasible methodology framework to evaluate the impact of rural practices on the FWE security nexus in the Atlantic Forest biome. The basis of this methodology is the use of secondary data and a participatory approach. Thus, we ensure a bottom-up approach, promoting the stakeholder engagement and a low cost, promoting its applicability.

One of the main advantages of the framework is to use secondary data, available on official database. It reduces the cost, since the data is free, and stimulates its application by decision makers, especially those responsible by the cities' administration. Thus, we expect to promote a horizontal flow of information and decisions that can be helpful and easy to reproduce in other situations, improving the operationalization and FWE nexus governance.

However, the application and use of this FWE nexus assessment is subject to the supply of knowledge and the right technical expertise, as well as the data availability in adequate spatial and temporal scale. It's therefore important that the relevant actors identify experts, define training needs and consider the specified data sources.

In order for this approach to be implemented as an instrument of territorial management and development, we also highlight the importance to take in account the existing political instruments at different levels (national, regional and local), capable of encouraging and ensuring changes in an integrated manner with positive impacts on FWE security.

With the results of this nexus assessment, it is possible to compare the impacts of rural landscape interventions on FWE nexus. The advantages include the best decision on the employment and capital costs; and to determine how an intervention can perform in different contexts. All this enables the decision makers to prioritize and provide interventions considering the 'nexus' interlinkages.

The nexus FWE approach provides an innovative and versatile framework to systematically assess cross-sectoral interactions and is a noteworthy tool for analysis and for triggering more inter- disciplinary work. To reach this goal, it requires strong coordination and negotiation across sectors and across temporal and geographical scales, making the nexus governance a multi-level challenge involving a variety of actors and institutions.

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THE WATER-ENERGY-FOOD NEXUS

WHAT THE BRAZILIAN RESEARCH HAS TO SAY

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