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Mini Review Article

Exploring Connections in Agroecosystems

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Abstract

A challenge of the Anthropocene is to advance human development without undermining critical natural processes. At the heart of this challenge is a better understanding of the interactions and feedbacks between nature, ecosystem services, and human well-being, in dynamic and complex social-ecological systems. These interrelationships have been the focus of much work in the past decades, however, more remains to be done to identify and quantify them, at different scales.

Keywords: Agroecosystems; Ecosystem Service; Resilience; Soil Functions; Research Frameworks

Introduction

Agroecosystems as described by Gliessman [2] is a framework with which to analyze food production systems as wholes including their complex sets of inputs and outputs and the interconnections of their components parts. Agroecosystems are ecological systems transformed and simplified for the purpose of producing food, fiber, or other agricultural products Falco, et al. [1] They are very productive suppliers of biomass-related provisioning ecosystem services, e.g. food, timber, and energy. At the same time, they are connected and highly dependent with natural ecosystems, particularly with soils', and their ecological principles and conditions, such as soil fertility, water supply or soil erosion regulation. Human transformation and alteration of ecosystems, for the purpose of converting natural landscapes for establishingagricultural production, makes agroecosystems very different from natural ecosystems. However, some of the characteristics, structure and processes of natural ecosystems are still fundamental in agroecosystem's function. Assessments of this interplay of ecosystem conditions and services are very important to understand the relationships in highly managed systems. (Figure 1) illustrates the dynamic processes occurring within an agroecosystem. Solid lines represent the flows of energy, whereas dashed lines show movements of nutrient. It is crucial to understand these processes because the function of the agroecosystem will determine the difference between the success and failure of management practices Gliessman, et al. [2].

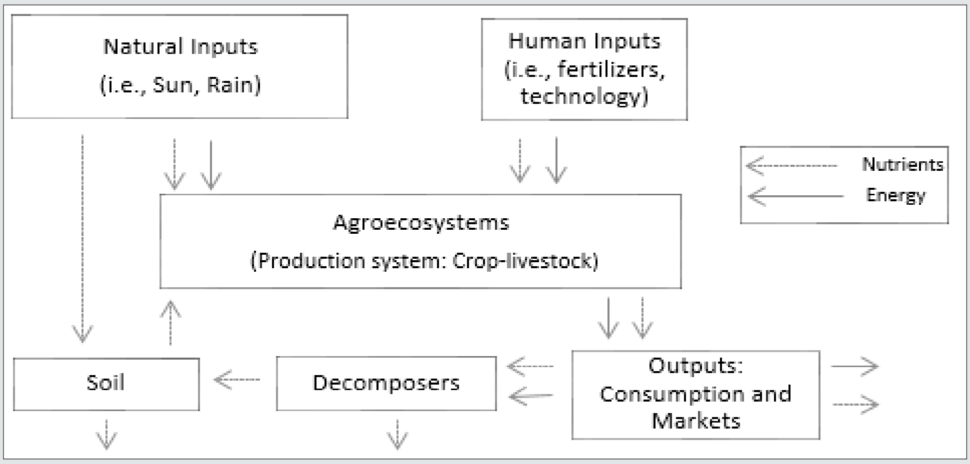

Figure 1: Functional components of an agroecosystem (Source: adapted by Gliessman, et al. [2])

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Soil ecosystem services (ES), which are of particular importance for agroecosystems, are the maintenance of the genetic diversity, the nutrient cycles, the biological control of pests and diseases, erosion control and sediment retention, and water regulation Swift, et al. [3]. Soil ES have been the subject of multiple scientific researchers over the years. Ecologists and biologists are studying the supporting services and ecosystem processes of soil, i.e., soil formation, soil binding by vegetation. Benefits for human beneficiaries more often are translated into economic values studied by social scientists, i.e., avoided erosion and sedimentation, water for agriculture.

Agroecosystems depend on ES to function and be productive. Sustain ES ensures the resilienceof agroecosystems as pointed to meet the stress of global challenges. Soil is a vital pore for life, representing an economic asset, particularly for agriculture, which is one of the main activities of the use of soil resources. Global changes increasingly influence soils, their biodiversity, and the ecosystem services that they provide. Since the agricultural sector constitutes a significant part of the economy of several countries, this indicates the need for sustainable soil and land management practices. Different land-use planning, mechanisms, and policies could mitigate some effects of agricultural expansion by identifying where soil natural capital is limiting and how it can be improved.

The unique role of soils in influencing the management and use of other resources such as water, land, nutrients, and biodiversity validates the efforts of the scientific community towards integrated resource management. Agriculture, and consequently, soils are at the heart of the Sustainable Development Goals (SDGs) and fundamental to achieving them. The SDGs lay the groundwork in the quest to achieve a healthy and sustainable future for our planet. The unique position of soils as a link between the use and management of other natural resources makes it useful in the overall assessment of ecosystems allowing relevant actors and stakeholders, e.g., scientists, economists, policymakers, to connect different SDGs and actions towards a common goal Keesstra, et al. [4]. For instance, SDGs 2, 3, 6, 13, 14, and 15 have targets that explicitly bind them with soil functions and ecosystem services. The success of the SDGs rests, to a large extent, on effective accounting, monitoring, review, and follow-up processes.

Proposed framework for agroecosystems

This section aim is to explore the links between anthropogenic activities and the ecosystems, focusing on the intersection of agroecosystems, soil natural capital and human well-being. Critical physical and social components of human well-being are dependent on well-functioning ecosystems, e.g.., quality and quantity of nutritious food, clean water, stable income, integrated communities, preservation of ecology. The objective is to provide a broader conceptual framework that consistently accounts for the above relationships, also exploring the feedback effects.

ES are defined as the beneficial flows (amount per unit time) of services-depend on natural capital stocks (total amount)-from ecosystems to societal groups and fulfill human needs. For instance, soil structure can supply nutrients. The provision of the ecosystem service ‘support plant growth’ depends on the amount of soil organic carbon in the soil (stock) and the timing of the availability of the storage volume regarding a land use change. Furthermore, the value of these services depends on the beneficiary’s usage. The important first step is to frame and understand the interacting ecological and societal processes in interest. A Driver-Pressure-State-Impact-Response approach is a framework that captures the cause-effect relationships of a system and assisting in many steps of the decision process Lewison, et al. [5]. This framework could be used for structuring problems and facilitating empirical research for agroecosystems planning. The DPSIR framework starts by identifying the various driving forces, e.g., political, economic, ecological, demographic, and social, that cause direct pressure on the state of SESs and impact their ability to deliver a range of ESs. Eventually, changes in SESs lead to societal responses to mitigate pressures Rounsevell, et al. [6]; Gupta, et al. [7].

The framework in (Figure 2) assumes cause–effect relationships between interacting components of social, economic, and environmental systems, which are described below and exemplified through the issue of land use and soil natural capital and ES provision:

a) Driving forces of natural and anthropogenic change (e.g., increasing atmospheric greenhouse emissions and land use change)

b) Pressures on the SES (e.g., soil degradation and livestock emissions)

c) State of the environment (e.g., lowered crop production)

d) Impacts on population, economy, ecosystems (e.g., food insecurity)

e) Response of society (e.g., policy response, such as the Kyoto protocol for reducing greenhouse gas emissions and car or the EU Common Agricultural Policy).

Pressures refer to the state of the natural capital stocks and processes, which in turn affect the input flows in the agroecosystem. Ecosystem services flow from natural capital stocks and processes and create benefits and value for the societies. This interpretation of state deviates from suggestions within the scientific community Sch¨oßer, et al. [8]; Helming, et al. [9] who have continued to consider ES changes as parts of the state, and have evaluated impacts only in terms of changes in human well-being. I argue, however, that social aspects of agroecosystems are defined as contributions to human well-being, and changes of these can therefore be best assessed as parts of the state component.

In this framework, I use an example of an agricultural area as a demonstration. The value of agricultural land is based on three factors, productive capacity, location, and beneficiaries. The service is the part of an ecosystem function, which is the supply that intersects with human locations and activities. So, it is important to define a context to delineate the area over which this service operates and where the demand for the service is. The area should be selected in terms of potential service improvement by paying attention to the relationships and trade-offs between soil ES and land assets and people's access to these values. Finally, to better understand how each of the system's dimensions varies and interacts requires adequate monitoring and assessment of all its components and the subsequent dissemination of data and products. Based on available data for the research area, a causal analysis can be performed to explore the relationship between different drivers and identify those that significantly influence ES and human well-being. The description of all the causal chains of the framework will allow selecting the indicators that significantly impact the DPSIR sectors. Despite existing investigations, less work has been done on demonstrating the mutual impacts between the DPSIR sectors quantitatively Hou, et al. [10].

Discussion

Apart from describing the relationships in figure 2 conceptually, it remains to quantify and address them physically in terms of spatial boundaries, relations and synergies with the surrounding social and natural world and distinguish the different sources of inputs to an ecosystem Bagstad, et al. [11]. A critical point that remains a challenge within the conceptual frameworks is to differentiate between ecosystems functions and processes, their services to human well-being and the generating benefits to avoid the double counting but also to use the correspondent indicators for their evaluation Silvia Silvestri [12]. (Table 1) presents an example of an initial set of indicators that could serve as a basis for the development of the described framework (Figure 2). Furthermore, to analyze potential future consequences of alternative land uses for both soil conservation and economic objectives, scenario analysis can be used identify determining factors.

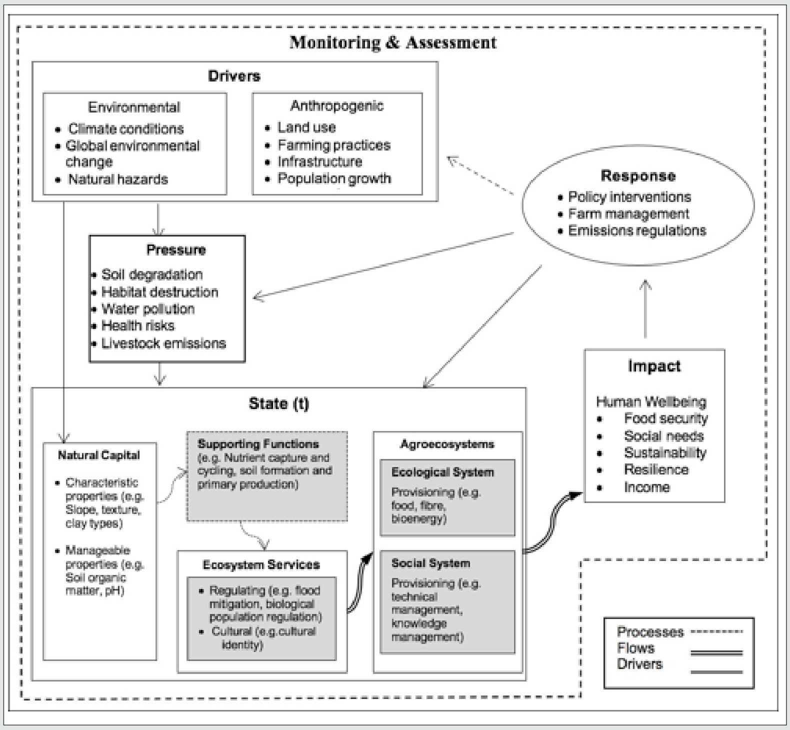

Figure 2: Conceptual DPSIR framework for human-agricultural systems interaction cycle. The framework applies to the agricultural territory. The arrows represent the interplay of structure and processes. The structural part of the state components 'Social system' refers to human inputs such as sociotechnical networks, collectives, planning, or agroecosystem management. The 'Monitoring and assessment involves the outline of a set of recommendations for indicators, monitoring procedures and the evaluation of the DPSIR steps. The text in the boxes is illustrative, not exhaustive. (DPSIR framework originally developed by the European Agency for Environment).

Table 1: Initial elements for building up the framework for valuing and quantifying ES in an agroecosystem.

Dimensions	Elements	Variables/Metrics
Livelihood	Population density	People per km^2
	Food and nutrition security	Food consumption, DES (kcal/person)
	Age of farmer, education, farming experience	Years
	Food crops output	Tonnes

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Resources	Technology	Percentage of farms with technical assistant
	Infrastructure	Distance to roads
	Land tenure	Rights of the plot
	Agrarian structure, Arable land	Farm size, Total arable land (ha/capita)
Financial	Labour	Number of people
	Income	Average net income per capita in rural area
	Connection to markets	Index representing the degree of connectivity
Ecological	Land cover	Land cover data
	Organic carbon	Organic carbon density (kg/m^2)
	Use of fertilizers and pesticides	Kg/ha
	Soil properties	Soil type, classes of fertility, texture, slope
	Climate factors	Average precipitation, temperature, relative humidity
	Biodiversity	Type of vegetation per plot

Different scenarios can identify mixed strategies that could be used to compare with the baseline scenario, which does not account for any policy and further intervention for the role of soil ES in production decisions. In the DPSIR framework baseline scenario represents the increased pressures while the alternative scenarios are capturing response measures. The scenario approach will also allow assessing how choices in public policy can influence change by building different strategies considering various policy options. For example, as part of the global warming mitigation strategies, to estimate the reduction in CO2 emission caused by the sequestration of soil organic carbon (SOC), because of alternative farm practices that increased SOC storage. The most important for a practical analysis is to develop scenarios appropriate for the context and have the potential to yield information that advances decision making McKenzie, et al. [13]

Conclusion

This qualitative study demonstrates the potential of the DPSIR framework for analyzing and structuring leading cause and effects problems of agroecosystems. Thus, it is an aid to sustainable governance through developing strategies and targeted policies towards systems thinking approach. This framework identifies that, apart from the critical ecological aspects, social aspects of agroecosystems are defined as contributions to human well-being, and changes of these can therefore be best assessed as parts of the agroecosystem's state. The discussed framework must be applied empirically to accurately monitor and quantify the multiple elements of the system status.

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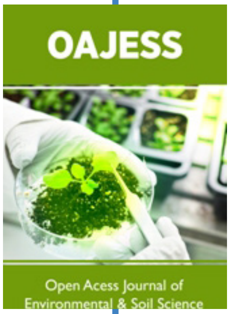

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