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Towards a framework for assessing the sustainability of social-ecological landscapes

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Summary

The report proposes a framework for assessing the sustainability of social-ecological landscapes (SEL) to be used by the West and Central African Food Systems Transformation (TAFS-WCA) initiative for research, planning, and implementation of its Work Package 3 (WP3). It builds on existing assessment frameworks from relevant fields (e.g., Eco agriculture, Agroecology, Integrated Landscape Management, etc.). At the center of a Sustainable Social-Ecological Landscape (SSEL) is the improvement of the management of land and the natural resource base in such a way that land use concurrently meets three goals: (i) provision of products (e.g., food) and services on a sustainable basis, (ii) support for sustainable livelihoods for all social groups and (iii) conservation of the full complement of biodiversity and ecosystem services. Globally, SSEL-related approaches like eco-agriculture, agroecology, and landscape approaches are already being applied, with promising results, especially in places where food production, poverty alleviation, and conservation of biodiversity, water, and ecosystem services are all high priorities. However, a comprehensive framework for measuring/monitoring landscape status and performance vis-a-vis competing landscape uses and management interventions has not been given much priority in the literature. Different forms of land use, such as forestry, agriculture, extraction of minerals, conservation/protected areas, and settlements, are interdependent. Therefore, landscape performance and monitoring frameworks that focus exclusively on protecting natural resources or the intensification of agriculture and other land uses can only give an incomplete viewpoint/overview of landscapes with all their uses and stakeholders. Considering the SSEL goals above, a holistic conceptual framework for landscape-based assessment is needed; such a framework must consider the drivers and effects of land use and the individual management interventions as well as the complex interactions among different land uses and interventions across the landscape. The present study proposes the Drivers-Pressure-State-Impact-Response (DPSIR) framework for SEL. It is important to emphasize that this study recognizes that different individuals and organizations under the TAFS-WCA initiative may have different interests in understanding the status and performance of selected SELs. The research envisages two important applications of a framework for measuring and understanding SEL: i) it can facilitate inclusive decision-making by multiple stakeholders working in the same landscape by explaining interactions, synergies, and trade-offs among SSEL goals and landscape components, and ii) when SSEL-related management innovations are successful (or otherwise), the framework can help document the same, reinforcing the case for adopting and scaling up innovations.

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Acronyms

CA	Content Analysis
DPSIR	Drivers-Pressure-State-Impact-Response
ILM	Integrated Landscape Management
ILAM	Integrated Landscape Assessment and Management
IWMI	International Water Management Institute
SES	Social Ecological Systems
SEL	Social Ecological Landscapes
SSEL	Sustainable Social Ecological Landscapes
SSLR	Semi-systematic Literature Review
SDG	Sustainable Development Goals
TAFS-WCA	Transforming AgriFood Systems in West Central Africa

1.0 Introduction

In development research, the landscape is considered a "socio-ecological system that consists of natural and/or human-modified ecosystems that are influenced by distinct ecological, historical, political, economic and socio-cultural processes and activities" (Denier et al., 2015). With their natural resources, landscapes provide opportunities for sustainable livelihoods for people in rural areas. Using resources such as land and water opens the potential for developing disconnected regions and can improve people's living conditions (Ellis & Allison, 2004). In addition, intact landscapes provide important ecosystem services which form the basis for the survival of life. These include drinking water, clean air, food, energy sources, building materials, recreational opportunities, carbon storage, and climate regulation. How resources are used impacts biodiversity and the global climate, among other things. Landscapes, therefore, provide opportunities for slowing the progression of climate change (Cole, et al., 2022). However, landscape pressures are growing (Bugri, Yeboah, & Knapman, 2017). In areas with a high population growth rate, there is high demand for roads, dwellings, industry and trade, and agriculture/aquaculture. Multiple local, national and global stakeholders are also placing demands on using natural resources (Mekuria, Haileslassie, Tengberg, & Zazu, 2021). Consequently, many landscapes are under threat, with landscape resources being overused and misused in many places, compounded by the impacts of climate change (Schütz, 2019). As a result, biodiversity and ecosystem services are dwindling, and agricultural production systems and livelihood sustainability are being compromised. (Schütz, 2019). Against this background, research and strategies for integrated landscape assessment and management (ILAM) for Sustainable Social-Ecological Landscape (SSEL) are gaining prominence.

At the center of SSEL is improvement in the management of natural resource base in such a way that land use concurrently meets three goals: (i) provision of products (e.g., food) and services on a sustainable basis, (ii) supports sustainable livelihoods for all social groups, and (iii) conservation of the full complement of biodiversity and ecosystem services. Globally, SSEL related approaches like *agroecology, eco-agriculture and integrated landscape management approaches* are already being applied, with promising results in places where food production, poverty alleviation and conservation of biodiversity, water, and ecosystem services are all high priorities (Kozar et al., 2014; Sayer, 2013). These approaches are applied on productive landscapes with different forms of land use, such as forestry, agriculture, extraction of minerals, conservation/protected areas, and settlements, which are symbiotic. Therefore, measurement frameworks that focus exclusively on, for example, the protection/conservation of natural resources on the one hand or agriculture and other land uses, on the other hand, can only give an inadequate perspective/overview of landscapes with all their uses and stakeholders. Moreover, despite the significance of disciplinary research, it is increasingly becoming ineffective to study the social and ecological systems separately when addressing issues related to their interactions (See Schütz 2019; Ostrom, 2009; 2007a; Folke, 2006; Young et al., 2006; Newell et al., 2005). As a result, there is an emerging consensus on the need to conceptualize both the human and natural systems as components of a larger system, SES (Daron et al., 2015; Binder et al., 2013; Ostrom, 2009:2007b; Young et al., 2006). This implies drawing on inter-/multi-disciplinary approaches to study impacts on the SES, which could produce solutions to the interactive problems associated with the coupled social and ecological sub-systems (Daron et al. 2015). Consequently, there is need for a comprehensive framework for understanding the status and measuring/monitoring social-ecological landscape performance v*is-a-vis* competing landscape uses and impacts of institutional responses. Considering the above SSEL goals, a comprehensive conceptual framework for landscape-based assessment is needed; such a framework must consider the drivers and effects of land use and individual management interventions as well as the complex interactions among different land uses and interventions across the landscape. A comprehensive framework forms the foundation for sustainable management of landscapes that enables compromises between the various interests. Thus, this report proposes such a framework and discusses its application.

1.2 Overview of the report

This research is commissioned by the International Water Management Institute-Ghana (IWMI-Ghana) as part of the Transforming AgriFood Systems in West and Central Africa (TAFS-WCA) initiative. The study is intended for the spectrum of individuals and organizations involved in the research, planning, and implementation of Work Package 3 (WP3) of the TAFS_WCA. This research aims to propose a framework for assessing the sustainability of social-ecological landscapes. The study builds on existing assessment frameworks from relevant fields (e.g., Eco-agriculture, Agroecology, Integrated Landscape Management, etc.). It is important to emphasize that this study recognizes that different individuals and organizations under the TAFS-WCA may have different interests in understanding the status and performance of selected social-ecological landscapes in the various target countries and landscapes. Consequently, the framework and identified indicators are generic for a wide range of landscapes, allowing for the selection of place-specific variables by country teams. The research envisages two important applications of this framework: i) it can facilitate inclusive decision-making by multiple stakeholders working in the same landscape by explaining interactions, synergies, and trade-offs among SSEL goals and landscape components, ii) when SSEL related management innovations are successful (or otherwise), the framework can help the documentation of the same, bolstering the case for adopting and scaling-out innovations.

1.2 Methods

Semi-systematic literature review

A literature review can broadly be described as a more or less systematic way of collecting and synthesizing previous research (Baumeister & Leary, 1997; Tranfield, Denyer, & Smart, 2003). Knowledge production within the field of business research is accelerating at a tremendous speed while at the same time remaining fragmented and interdisciplinary. This makes it hard to keep up with state-of-the-art and to be at the forefront of research, as well as to assess the collective evidence in a particular area of business research. This is why the literature review as a research method is more relevant than ever. Sometimes the criticism is that traditional literature reviews often lack thoroughness and rigor and are conducted ad hoc, rather than following a specific methodology. Therefore, questions may be raised about the quality and trustworthiness of these types of reviews. However, an effective and well-conducted review as a research method creates a firm foundation for advancing knowledge and facilitating theory development (Webster & Watson, 2002). It also helps to provide an overview of areas in which the research is disparate and interdisciplinary. In addition, a literature review is an excellent way of synthesizing research findings to show evidence on a meta-level and to uncover areas in which more research is needed, which is a critical component of creating theoretical frameworks and building conceptual models.

The is study adopted a semi-systematic literature review (SSLR) approach. When wanting to study a broader topic that has been conceptualized differently and studied within diverse disciplines, this can hinder a full systematic review process. Instead, a semi-systematic review approach could be a good strategy for example mapping theoretical approaches or themes as well as identifying knowledge gaps within the literature (Snyder 2019). The study was conducted using literature search in several web-based databases and sources. Key of the web-based databases include Google Scholar, Science Direct, and Scopus. The study used content analysis (CA) to review research articles, books, and grey literature project and program documents that reflect activities in the context of Integrated Landscape Management (ILM), ecoagriculture and agroecology. CA is a commonly used technique for SSLR and can be broadly defined as a method for identifying, analyzing, and reporting patterns in the form of themes within a text (Braun & Clarke, 2006). In all, 25 journal articles and 5 reports were reviewed for this study.

According to Snyder (2019), the semi-systematic literature review approach is ideal for model/framework development. This type of analysis can be useful for detecting themes, theoretical perspectives, or common issues within a specific research discipline or methodology or for identifying components of a theoretical concept (Ward, House, & Hamer, 2009).The use of this method was underpinned by the need to do a more creative collection of literature considering that the purpose of the review was not to cover all articles or documents on the topic but rather to combine perspectives to propose an analytical framework for landscape state/performance assessment.

2.0 Conceptual and theoretical overview

Frequently measuring many landscape elements can be very expensive and time-consuming. SEL systems are complex. As a result, assessment approaches cannot realistically measure all system components (Sayer, 2015). Consequently, several questions may need clarification: At what scale or scales should assessments be conducted? To what extent should assessments combine more accurate direct measures with cost-efficient proxy measures? Should assessments be tied to specific conservation and rural development projects or independent?
Additionally, ecosystems are subject to a certain degree of natural variability and human interferences, making it difficult to separate human effects from natural ones (Hooper, et al., 2005). As alluded to earlier, most literature (scientists) tends to specialize and as a result, developing an integrated framework for SEL assessment and monitoring requires a paradigm shift towards more multidisciplinary approaches/conceptions. This section of the report explores the conceptual and theoretical issues, proposes a suitable approach to each issue, and further integrates these approaches to define a framework for measuring landscape state and performance in the context of SSEL.

2.1 Natural Landscapes, components, structure and functions

Within every landscape are functional, compositional, and structural elements that, when combined, define the ecological system and provide a means to select a suite of indicators representative of the key characteristics of the system (Odion et al., 2011). All ecological systems have elements of composition and structure that arise through ecological processes. The characteristic conditions depend on sustaining key ecological functions, which, in turn, produce additional compositional and structural elements. If the linkages between underlying processes and composition and structural elements are broken, sustainability and integrity are jeopardized and restoration may be difficult and complex (Virginia & Suzanne , 2001). Ideally, the suite of indicators should represent key information about structure, function, and composition (Figure 1). The series of nested circles in figure 2 suggests that knowledge of one part of the circle may provide information about the other facets of the system. For example, often, it is easier to measure structural features that may help to make inferences about the state of compositional and functional elements of the system than to directly measure composition or function (Lindenmayer et al., 2000). It is also true that sometimes measures from one scale can provide information relevant to another scale. For example, the size of the largest patch of habitat often restricts the species levels of animals that can be supported based solely on their minimal territory size (Dale et al., 1994).

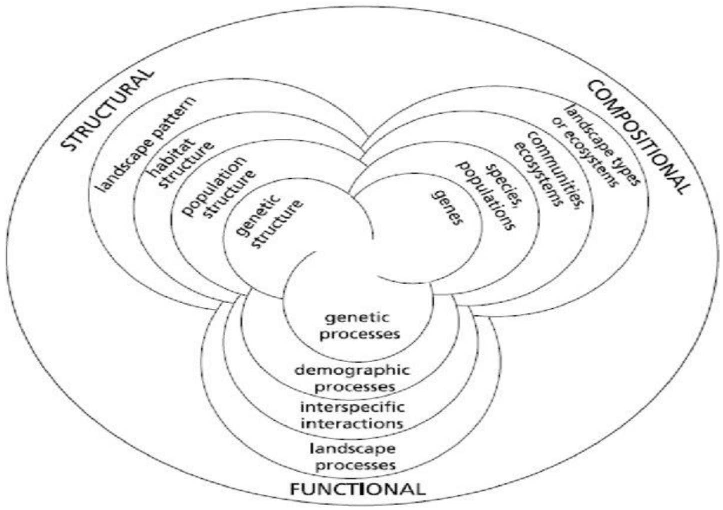

Figure 1: Conceptual model of the landscape composition, structure, and function (Noss 1990).

2.2 Landscapes as coupled Social-Ecological Systems

In the social system (human system), rules and institutions are created and used to govern society's use of natural resources and constitute the knowledge and ethics systems that interpret nature from a human perspective (Nelson, 2007; Berks & Folke, 1998). In this system, social and political actors create the preferred rules, institutions, knowledge, and ethics systems. On the other hand, the ecological system (natural or environmental) refers to the biological and biophysical processes and products (Berks & Folke, 1998). Society depends on nature for many ecological goods and services (See Millennium Ecosystem Assessment, 2005). Humans depend on nature for goods and services such as clean air, fresh water, food, medicine, raw materials, drought and flood mitigation, maintenance of biodiversity, partial stabilization of climate and so on. However, the very components and processes of nature on which humans depend are threatened by human actions or inactions (anthropogenic climate change, land fragmentation, water resource degradation, deforestation, etc.), which further compromises the adaptation ability of a society or increases the frequency of hazard events (like droughts, floods, hurricanes, heat waves, etc.). In effect, continued exploitation and degradation of ecological resources, combined with the associated hazards, further compromises the adaptive capacity of the individual components and the entire social-ecological system (SES). According to Marina et al. (2011), the SES (also known as a human-natural system or human-environment system) is an approach for assessing the interface and interactions between human (social, economic, etc.) and natural (climate, atmospheric, biological, etc.) sub-systems of the earth. In the frame of this report, SES refers to any dynamic and complex bio-geophysical unit and its associated social actors and institutions (Daron et al., 2015; Ostrom, 2009). Such a system is characterized by regular interaction at various spatial, temporal, and organizational scales, which may or may not be hierarchically related (Ostrom, 2009). For this report, the scale of application is the landscape level.

In the context of integrated landscape management, considering a landscape as SES ensures inclusive management of human activities, including livelihood systems and the natural resource base, in a way that simultaneously promotes symbiotic and sustainability goals (Atampugre et al. 2021). It is important to also understand the distinction between Landscape ecology thinking and social-ecological system (SES) thinking regarding the relationship between humans and the environment. ‘Space’ is at the center of Landscape ecology studies and tends to investigate the interactions between human activities and ecological processes within selected spaces (Pickett & Cadenasso,1995; Turner, 1989; Wu Hobbs, 2002). SES, on the other hand, takes a ‘systems’ approach to examine the reciprocal relationships among components in both social and ecological sub-systems (Berkes and Folke 1998; Ostrom 2009). It has been argued that inter/multidisciplinary frameworks should be developed to incorporate landscape ecology’s spatial perspective into sustainability studies underpinned by ‘system thinking’ (Cumming et al. 2013). Howeverlandscape, studies addressing the complexity of SES remain scarce (Li, Fassnacht, & Burgi, 2021).

2.3 Project-level vs landscape-level assessment

At a project level, individual projects are identified, and specific requirements for the project's completion are identified to run the project. This could be classified in various ways: quantifiable and non-quantifiable projects, sector projects (agriculture sector, irrigation, power, social services, etc.), and techno-economic projects. Landscape-level can be defined as the combination of several land-use types over tracts of land that might be an administrative area, a community territory, a watershed, or an arbitrarily determined area several square kilometers in extent (Forman,1995).

One aspect of integrated landscape management that differentiates it from earlier approaches like agroecology is its focus on the landscape scale when setting goals and measuring results (Buck, Milder , Gavin, & Mukherjee, 2006). Although there are several advantages to taking a landscape view of the system, landscape-level assessment alone is usually poorly suited to guiding adaptive management at the project level. Most projects or management interventions that seek to advance the goals of ecoagriculture (e.g., rural development initiatives, conservation efforts, or eco-certification schemes) occur at scales other than the landscape scale (usually much smaller in extent, whereas others address broader-scale public policy issues). A mismatch between the scale of a project and the scale at which monitoring, and evaluation (M&E) occurs can be a serious problem (Buck, Milder , Gavin, & Mukherjee, 2006). For example, even if quite successful, a village-level project will probably have a negligible impact on landscape-scale indicators. Generally, project-level M&E usually focuses on the spatial scale and the set of indicators that will reveal the success or failure of project activities (Buck, Milder , Gavin, & Mukherjee, 2006). According to Conservation Measures Partnership (2004:13), “by focusing your M&E efforts squarely and almost exclusively on your goals, objectives, and activities, you are more likely to collect only the information that will be useful to you as you adaptively manage your project.” They recommend therefore that M&E efforts be matched “to the scale you expect to influence with your intervention”. Sustainable social-ecological landscape approaches like eco-agriculture and ILM seek to move beyond thinking of the project level to understand the interactions and potential synergies among the three goals of eco-agriculture (See Section 3.2 of this report). It also seeks to move beyond individual projects to create collaborative initiatives in which different types of interventions, led by different organizations, contribute to the whole SES landscape. Explicitly, a landscape measurement framework should include project-level evaluations of specific interventions and landscape-scale assessments that can tease out interactions, synergies, trade-offs, and the effect of outside forces beyond the control of individual projects (Sayer, et al., 2017).

2.4 landscape performance analysis vs Landscape Status analysis

Landscape performance can be defined as measuring the effectiveness with which landscape solutions fulfil their intended purpose and contribute to sustainability. It involves the assessment of progress toward environmental, social, and economic goals based on measurable outcomes. Landscape performance draws upon research and knowledge from various disciplines, including landscape architecture, horticulture, ecology, civil engineering, transportation planning, urban economics, other social sciences, and public health. Measuring and documenting the performance of sustainable landscapes in a way that is understandable and accessible to a wide array of decision-makers has a multi-pronged effect: 1) It leads to more effective management. It informs incremental adjustments to improve the performance of built landscape systems. 2) It leads to better future designs incorporating lessons illuminated through the performance evaluation process. 3) It helps bridge the knowledge gap about the value of landscape solutions in the design, development, and policy realms. Access to evidence of proven benefits reduces the risk for investors and allows advocates to better make their case.

A Landscape Status analysis outlines the strengths, resources, and needs of a particular area under consideration. It provides a framework for designing a service and ensuring that it is embedded directly in the needs of the people in that area. Doing a landscape status analysis will allow for a thorough map of the area's needs and desires, which will guide strategic decision-making toward improving an area to achieve sustainability. This will enable programs to always keep the actual needs of the area in mind rather than hypotheses about its needs. Doing this essential groundwork will aid in designing an effective tutoring program that the whole community values.

2.5 Eco-agriculture vs Agroecology

While “agroecology” was coined in 1928, “eco-agriculture” was not coined until 2002. The word is just one of the hundreds used to express the more general term “integrated landscape management (ILM)”. While communities worldwide practice eco-agriculture, it has not yet benefitted from a large-scale farmer-to-farmer movement that spreads its principles with minimal NGO intervention. And since all stakeholders in the landscape must come together to determine how the landscape is managed—including government bodies and businesses—eco-agriculture is far less political. In effect, the two concepts are complementary. Ecoagriculture is the application of integrated landscape management in landscapes where agriculture is an important land use. And agroecological farm-level practices—like crop rotation, integrated pest management, agroforestry, and building soil nutrients with compost and crop residue—form one important component of eco-agriculture.

The term eco-agriculture covers several related systems of agricultural practice, all of which are concerned with improving and/or maintaining the status and productivity of soil systems while at the same time reducing negative environmental impacts. This encompasses more approaches to agricultural production with some common elements and differences in emphasis for certain practices (Malherbe & Marais, 2015). A central concern in eco-agricultural approaches is promoting and maintaining soil health, sustainability, and connectedness. It is argued that the best way to reduce the impact of agricultural modernization on ecosystem integrity is to intensify production to increase yields per hectare and, in this way, spare natural forests from further agricultural expansion. They argue that feeding a growing world population without further endangering the natural environment and its biodiversity requires evaluating those emerging technologies' role in helping meet food needs at a reasonable environmental and social cost. This practice tries to embrace alternative, low-input agricultural systems. Ecoagriculture practices do not discount chemically-based, high-yielding, intensive agricultural systems as part of their strategy for protecting wildlife while feeding the world's population. (Patel, 2019)

Agroecology can be defined as a set of agricultural practices which aims at developing a more "environmental-friendly" or "sustainable" agriculture (LEISA, 2008). This involves the various approaches to solving actual challenges of agricultural production through the development of practices or technologies designed to increase yields and improve profit margins. For any agroecosystem to be fully sustainable, a broad series of interacting ecological, economic, and social factors and processes must be considered (Gliessman, 2016).

3.0 Review of some existing conceptual frameworks

3.1 Driving Forces – Pressures – State – Impacts – Responses (DPSIR) framework
The Driving Forces – Pressures – State – Impacts – Responses (DPSIR) framework (Figure 2) is one framework that supports the "systems approach". Since its development in 1999 by the European Environmental Agency (EEA), it has evolved into one of the most valuable tools for organizing and communicating complex social-ecological system (SES) issues. The DPSIR framework is a systems-thinking framework that assumes cause-effect relationships between interacting components of social, economic, and environmental sub-systems in a landscape. The DPSIR framework has been widely used to integrate issues related to agricultural systems, water resources, land and soil resources, biodiversity, and marine resources into a single framework.

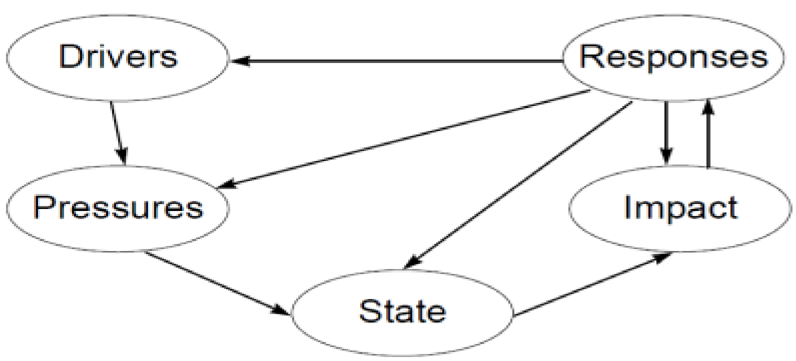

Figure 2: Original DPSIR framework by the EEA (1999)

According to Gari, Newton, and Icely (2015), two factors have contributed to the wide use of DPSIR: (i) it structures the indicators with reference to the political objectives related to the environmental problem addressed; and (ii) it focuses on supposed causal relationships in a clear way that ap- peals to policy actors (Smeets and Weterings, 1999). The DPSIR framework has been extensively used, but it has also been subject to many criticisms. Though the DPSIR framework is useful, EEA (1999) warns that the real world is far more complex than can be expressed by simple causal relations and stresses the need for clear and specific information on the five categories for the purpose of making policies. DPSIR is also useful for describing the origins and consequences of environmental problems, but the links between the categories should be focused to understand their dynamics (EEA, 1999). This is to elucidate, that the level of influence of each category on the other, is determined by ecological, technological, and social factors (Gari, Newton, & Icely (2015).

3.2 Sustainable Social-Ecological Landscape 'Stool'

Sustainable social-ecological landscape management is a key strategy to achieve the SDGs in agricultural and forestry production landscapes (Bürgi et al. 2017; Thaxton et al. 2015). Sustainable landscape management is also termed "integrated landscape management" (Scherr et al. 2013) or "landscape approach" (reflecting the ten principles defined by Sayer et al. (2013). Specifically, sustainable landscape management conceives the conservation and restoration of biodiversity, the production of food, the protection of critical ecosystem services, and rural livelihoods as joint objectives rather than dealing with them in isolation or confrontation (Tanentzap et al. 2015). Landscape approaches to sustainability are all multi-stakeholder and multi-objective, and they explicitly address spatial interactions (Angelstam et al., 2019). SDG implementation through sustainable landscape management builds on multifunctional land-use systems that contribute to the mutual alignment of frequently confronted production and conservation aims (O'Farrell & Anderson, 2010). Lee, Karimova, and Yan (2019), the 'stool' concept represents an integrated landscape management that involves collaboration among different groups of stakeholders (supportive institutions for inclusive planning and implementation) to solve common problems and strengthen synergies among three landscape objectives (three 'legs' of the 'stool') such as viable local livelihoods, biodiversity conservation, and agricultural production (Figure 3).

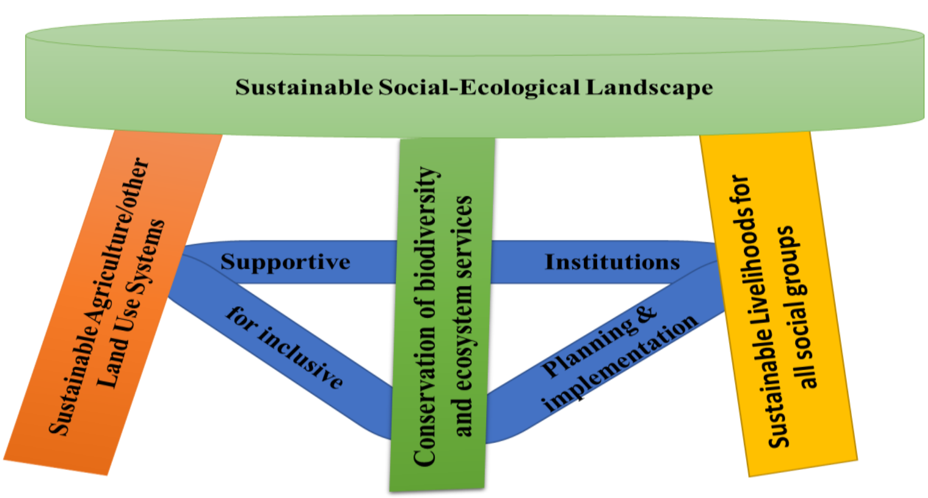

Figure 3: Sustainable Social-Ecological Landscape 'Stool' adapted from Scherr et al. (2014)

The concept of sustainable landscape management implies managing agriculture and natural resources simultaneously for food and fiber production, support of biodiversity and ecosystem services, and fostering overall contributions to human well-being. A landscape approach enables synergies and trade-offs among ecological, economic, cultural, and social objectives to be examined at a larger-than-farm scale to reveal how interactions among different land uses are complementary and/or competing. Management strategies within and across the four objectives, thus, can be negotiated to produce an optimal balance within any given landscape context. Adopting such an approach to management implies working across sectors to ensure that knowledge and information, land uses, markets, and policy strategies are adequately integrated. This "integrated" approach to realizing sustainable landscapes is, thus, a fundamental precept of sustainable landscape management (Denier et al. 2015; Scherr et al. 2013).

3.3 Indicators for measuring eco-agriculture landscape performance

When developing a measurement framework, it is pointless to identify specific indicators until one has defined the goals or desired outcomes against which to measure a system, program, or project (Buck et al. 2006). In the context of ecoagricultural systems, some of these goals are dictated by the definition of ecoagriculture, whereas others must be place specific. Some ecoagricultural goals are so universally applicable that they should be embedded in the framework. In contrast, others must be formulated according to each eco-agricultural landscape's particular needs and context. Once the goals have been agreed upon, context-appropriate indicators and means of measure can be identified to measure progress toward these goals. These considerations point to the benefit of a hierarchical framework—an approach used in many other measurement frameworks. The eco-agriculture measurement framework is organized into a hierarchy with four levels:

Level 1: Broadest-level goals of eco-agriculture – *universal*- Four goals define the eco-agriculture concept and are, therefore, the foundation of the measurement framework:

i. Conserve, maintain, and restore wild biodiversity and ecosystem services.
ii. Provide for sustainable, productive, and ecologically compatible agricultural production systems.
iii. Sustain or enhance the livelihoods and well-being of all social groups in the landscape.
iv. Establish and maintain institutions for integrated, ongoing planning, negotiation, implementation, resource mobilization, and capacity-building to support eco-agriculture goals.

Level 2: Sub-goals, or criteria – also *universal*-

Under the four goals are 20 criteria (or sub-goals) presumed to be desirable in any landscape (See s***ection on indicators below***).

Level 3: Indicators of each criterion/sub-goal – *usually place-specific*

Indicators are the actual factors that are measured to reveal how well each criterion is being fulfilled. Some indicators—especially "integrative" indicators that provide information about all three eco-agriculture goals—may be as important or useful as universally applicable. However, most indicators will be place-specific as well as scale-specific. For example, appropriate indicators of human health in the United States might include rates of obesity and diabetes. In contrast, appropriate indicators in the Amazon Basin might include malaria incidence. Each of these indicators only makes sense in a specific context where it is measuring a health issue of local concern. In many cases, indicators can or should be developed collaboratively with local stakeholders. This is particularly true for livelihood indicators when the goal is the well-being of these very stakeholders.

Level 4: Means of measure – *place-specific.*
Means of measure evaluate each indicator on a quantitative or qualitative scale. Examples of means of measure include wildlife censusing techniques, land use land cover analysis, and farmer interviews.

4.0 Proposed DPSIR-SEL Assessment Framework

The purpose here is not to present an entirely new conceptual framework for analyzing social-ecological landscapes (SEL). The intended aim is to draw insights from the works of Sayer et al. (2017), Maes et al. (2016), Scherr et al. (2014), Buck et al. (2006), DFID (1999), and the case studies of the Satoyama Initiative to develop a relatively comprehensive framework to understand the driving forces and pressures that are underpinning changes in the state of SELs as well as their implications for human well-being, ecosystems services and sustainable landscape management in general. The DPSIR-SEL assessment framework (Figure 4) is a coupled social-ecological framework informed by systems thinking. It is a tool that can be used to inform the assessment of landscape-level phenomena. Essential aspects of the DPSIR-SEL include recognizing five key components that interact at the landscape level and significantly influence the benefits derived from the landscape. The proposed DPSIR-SEL presents an innovative way of applying the original DPSIR framework together with other approaches. DPSIR-SEL considers the impact as affecting the human welfare, and expands the state change to the impact on the environment thereby giving more greater clarity. It is however important to mention that, for the best performance of the DPSIR-SEL, a good knowledge of the productive landscape under study and the objectives of the researcher are critical. For example, where the system characteristics are less known, synergies may not be considered and a clear cause-effect relations may not be apparent. Similarly, the degree of soundness (i.e., clarity and focus) of the researcher's objectives are likely to affect the extent to which social ecological problems in relation to the human welfare are addressed.

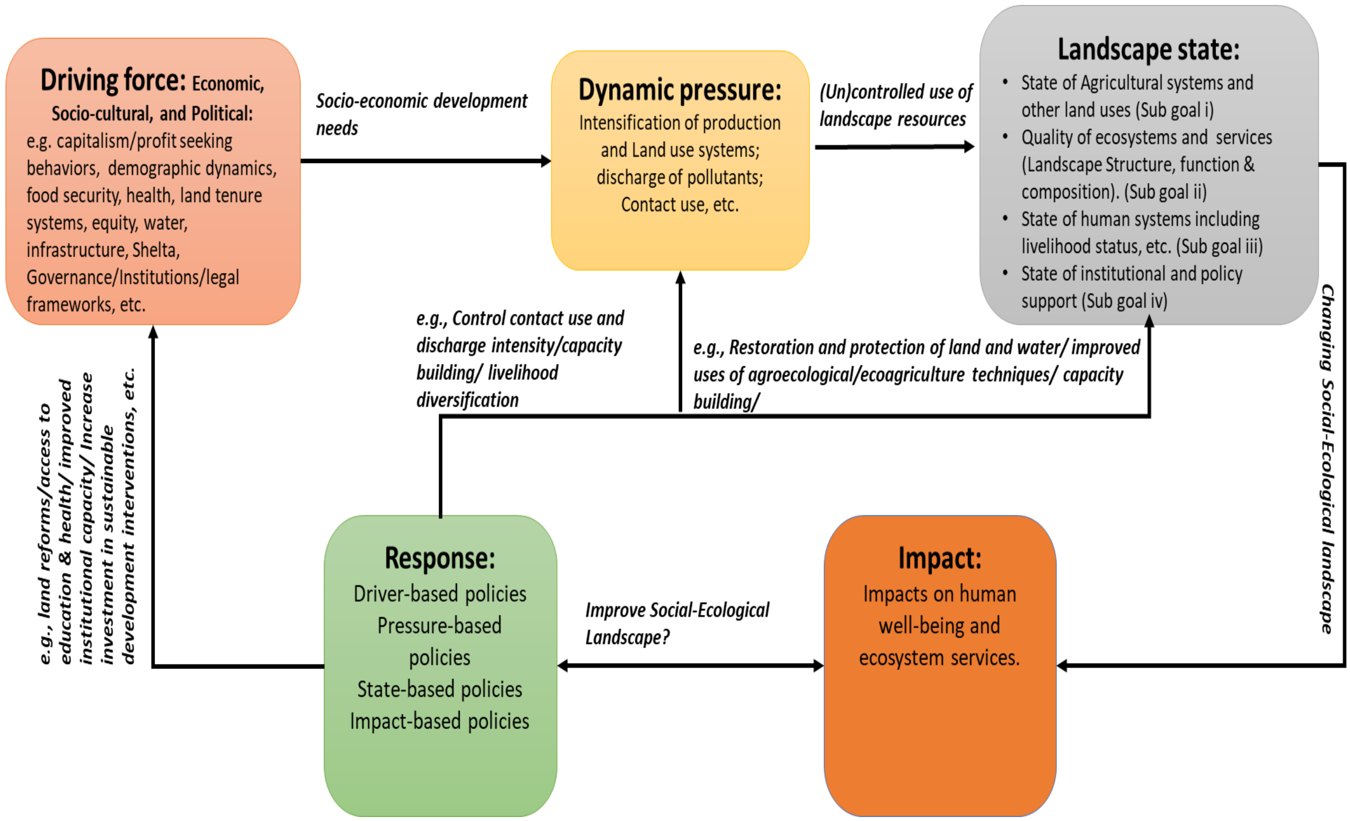

Figure 4: Proposed DPSIR-SEL assessment framework

Driving Forces are the factors that motivate human activities and fulfill basic human needs, which have been consistently identified as the necessary conditions and materials for a good life, good health, good social relations, security, and freedom. *Driving Forces* describe "the social, demographic, and economic developments in societies". Social determinants also have a strong influence on SEL dynamics. Therefore, for this framework, *Driving Forces* have been broadened to include socio-cultural and political factors.

Pressures are defined as human activities derived from the functioning of Social and Economic Driving Forces that induce changes in the environment or human systems. Pressures are not stressors. Stressors are the components of the state that are changed by pressures (e.g., land development [the pressure] - increases sediment [the stressor] in urban watersheds, which then may stress the ecological components of the reef). Examples of pressures:

- Land use changes resulting from alterations of the natural landscape;
- Discharges of pollutants may result from the operation of industries or vehicles or the diffuse distribution of contaminants from agricultural lands, roads, or lawns through groundwater or storm-water run-off.
- Contact uses are human activities that lead to a direct alteration or manipulation of the environment and include:
    - Physical damage – direct degradation through mining, dredging and filling, deforestation;

- Biological addition – ballast discharge, the release of non-natives, feeding, creation of artificial habitat;
- Biological harvest – harvesting, fishing, accidental by-catch, clear-cutting

State refers to the state of the natural and built environment. It provides information on the quantity and quality of the following components of the landscape;

- physical,
- chemical,
- biological
- And human systems

Impacts on ecosystems and human well-being: Changes in the structure, functioning and composition of the ecosystem will impact the production of ecosystem goods and services and, ultimately, human well-being (Figure 5).

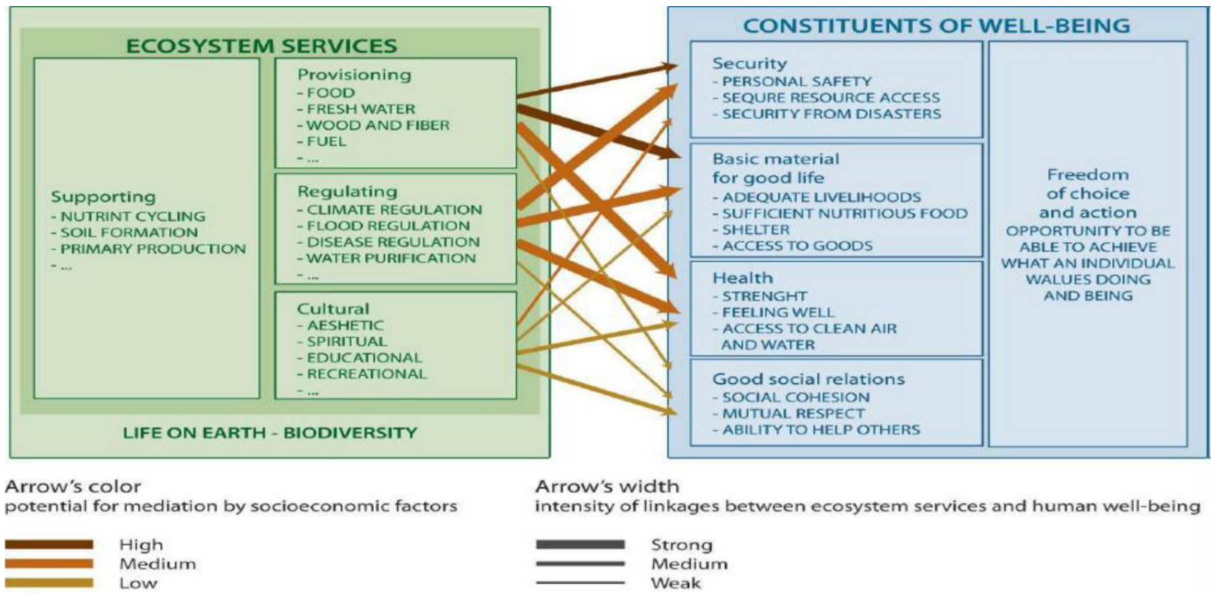

Figure 5: The links between ecosystem services and human well-being (Source: MEA 2005).

- ***Impacts on ecosystem goods and services*** have been defined as ecosystem processes or the products of those processes that directly or indirectly benefit humans.
    i. *Provisioning services*
    ii. *Regulating services*
    iii. *Cultural services*
    iv. *Supporting processes*

- ***Impacts on human well-being*** is an abstract concept that captures a mixture of people's life circumstances and quantifies the degree of fulfilment of basic human needs for food, water, health, security, culture, and shelter. Human Well-being reflects a positive physical, mental and social state. Human Well-being can be quantified by metrics reflecting how well human needs are being met, including needs for basic materials, social relations, good health, security, and freedom. Human Well-being includes: *Economic prosperity (e.g., productivity, ability to work, income), Health and safety (e.g., life span, medical or insurance costs, sick days, pain and suffering), Cultural and social well-being (e.g., "happiness", sense of belonging, community vibrancy, spiritual fulfilment)*

Responses: A key benefit of using the DPSIR framework is that it explicitly includes an Action or Response component that can be taken at any level of the causal network. In the DPSIR-SEL assessment framework, responses are actions taken by groups or individuals in society and government to:

- prevent
- compensate
- ameliorate
- adapt to changes in the state of the environment
- modify human behaviours that contribute to health risks
- directly modify health through medical treatments or to compensate for social or economic impacts of the human condition on human well-being.

Responses may be directed at driving forces, pressures, landscape state, or impacts. In response to driving force may be agriculture reforms, education reforms, technological innovations, equity policies, and decision support tools. If responses target pressures, strategies may include land use planning and management, strategies targeting human behavior modifications, discharge limitations, resource use management, outreach and education, etc. State-based responses may include revitalization, remediation, landscape and community planning, restoration, evaluation, etc. These impact-based responses may include adaptation strategies, livelihood diversification, mitigation, indexing of well-being, ecosystem service evaluation and monitoring, etc.

4.1 Indicators under the DPSIR-SEL assessment framework

Social-Ecological Landscapes (SEL), like eco-agriculture landscapes, may be distinguished from more conventional agricultural landscapes by considering two basic characteristics: i) SELs consist of a mutually interdependent set of agricultural, semi-natural, and natural ecosystems, where land management practices actively govern this interdependence; ii) SELs usually include a wide variety of production systems, which could include annual and perennial cropping, various livestock systems, agroforests, wild forests, fisheries, mining, lumbering, etc.

Agricultural production systems are critically dependent upon healthy ecosystems to provide groundwater and surface water for irrigation, to sustain wild pollinators of crops, to regulate crop and livestock diseases, to maintain soil fertility, to protect crops or livestock from the sun or wind, and to decompose wastes. Wild species also play an important role in providing livestock fodder, fuel, medicines, soil nutrient supplements, and construction materials. Historically, though, agricultural practices have often degraded the very biodiversity and ecosystem functions on which they depend through impacts ranging from land conversion and hydrological modification to pollution and sedimentation to the elimination of beneficial species and the introduction of nuisance invasive species. In contrast to many aspects of conventional agricultural practice, eco-agriculture (a sustainable social-ecological strategy) promotes synergies between production and ecosystem functioning. Rather than turning to artificial substitutes, eco-agriculture/ILM practitioners seek to capture the value of natural services by taking specific management actions to sustain biodiversity and ecosystem functions that support production. For example, watershed functions can be conserved by maintaining natural soil structure to promote rainfall infiltration, maintaining native riparian vegetation, preventing agricultural pollution and wastes from entering streams or groundwater, maintaining soil cover year-round, protecting wetlands, and allowing streams and rivers to meander in their natural course. Based on the above, the following five general indicators are proposed under the production goal of sustainable social-ecological landscapes [SSEL) (See Table 1).

Table 1: Landscapes that maintain sustainable, productive, and ecologically compatible production systems.

Indicator 1	Do agricultural production systems satisfy the food security and nutrition requirements of producers and consumers in the region?
Indicator 2	Are agricultural production systems financially viable, and can they dynamically respond to economic and demographic changes?
Indicator 3	Are agricultural production systems resilient to natural and anthropogenic disturbances?
Indicator 4	Do agricultural production and other land use systems improve or have a neutral impact on the wild biodiversity and ecosystem services in the landscape?
Indicator 5	Is agrobiodiversity optimally managed for current and future use?

In the context of SSEL, conservation encompasses two closely linked environmental assets: biodiversity and ecosystem services (Table 2). Biodiversity can be defined simply as “the variety of life on Earth and the natural patterns it forms” (CBD, 2000). Ecosystem services—the second part of the conservation goal—are ecological processes and functions that sustain and improve human life (Daily, 1997). These can be divided into four categories: 1) *provisioning services*, or species that provide us with food, timber, medicines, and other useful products; 2) *regulating services* such as flood control and climate stabilization; 3) *supporting services* such as pollination, soil formation, and water purification; and 4) *cultural services*, which are aesthetic or recreational assets that provide both intangible benefits and tangible ones such as ecotourist attractions (Kremen & Ostfeld, 2005). Ecosystem services play a central role in multifunctional landscapes and represent an important “bridge” among the goals of ILM or eco-agriculture. Biodiversity and ecosystem services require explicit consideration in an SEL, considering they are closely linked but not synonymous. Based on these definitions, the DPSIR-SEL framework adopts five generic indicators under the conservation goal of SSEL:

Table 2: Conservation Goal: Landscapes that protect, conserve, maintain and restore wild biodiversity and ecosystem services

Indicator 1	Do land use patterns across the landscape optimize habitat value and landscape connectivity for native species?
Indicator 2	Are natural and semi-natural areas within the landscape highly intact?

Indicator 3	Are all critical populations, species, and ecosystems within the landscape conserved?
Indicator 4	Does the landscape provide a high level of locally, regionally, and globally beneficial ecosystem services?
Indicator 5	Do productive areas of the landscape limit the degradation of nearby natural areas, upstream and downstream?

SSEL seeks opportunities to move beyond either-or approaches to land use where possible or to zone land use such that conservation and economic activity are appropriately balanced on the landscape. This is contrary to the historical notion of conservation and livelihood support being in conflict (Buck et al., 2006). In the context of SSEL, three aspects of sustainable livelihood are considered important for evaluation. The first is ***basic subsistence and human welfare***. This may include the necessities of life; health care, adequate nutrition, and housing. The second aspect relates to ***sustainability***. This examines whether the available and accessible, sustainable livelihood assets are decreasing, maintained, or increasing (Carney, 1998). A critical dimension of sustainability is whether households can cope with and recover from environmental or economic stresses and shocks without undermining the natural resource base (Scoones, 1998). Third, the framework embraces ***finance and other social aspects of livelihood support***. As households and communities become increasingly connected to regional and global economies, cash income enables them to improve their living standards by investing in health, nutrition, housing, infrastructure, and economic development (Buck et al., 2006). The role of income generation in the framework is tied to its effect on securing social, cultural, and environmental well-being. ***Equity or equality*** is an important mediating factor when considering sustainable livelihood parameters. A relatively equal distribution of food, income, access to resources, or services can maximize the number of persons and households benefiting from the aggregate wealth within a community or landscape.

On the other hand, stark inequalities are likely to exacerbate poverty, curtail opportunities for livelihood improvement, and undermine participatory projects. Thus, livelihood outcome measures must consider equity across many variables, including gender, ethnicity, and class. Livelihood performance in an SEL needs to be considered at the household, community, and landscape levels. Based on the above considerations, the DPSIR-SEL framework adopts the following indicators to assess the sustainable livelihood goal of SSEL (Table 3).

Table 3: Livelihoods Goal: Landscapes that sustain or enhance the livelihoods and well-being of all resident social groups.

Indicator 1	Can households and communities meet their basic needs while sustaining natural resources?
Indicator 2	Is the value of household and community assets increasing?
Indicator 3	Do households and communities have sustainable and equitable access to critical natural resource stocks and flows?

Indicator 4	Are local economies and livelihoods resilient to changes in human and non-human dynamics?

Although the role of institutions is discussed in earlier writings on eco-agriculture (McNeely & Scherr, 2003, Buck et al., 2004), these publications do not identify institutional capacity as an explicit goal of SSEL compared to the goals on conservation, production, and livelihoods (Buck et al., 2006). However, institutions are relevant to achieving SSEL goals considering that they legitimize practice and rules of conduct, which are imperative in defining access to resources and the different adaptive capacities of individuals, households, and communities (Yaro et al. 2015). It has also been argued that institutions tend to situate the interaction between individuals, groups, and the state through the regulatory structuring of coping and adaptation options, opportunities, and limitations (Dovers & Hezri, 2010). In some settings, institutional capacity may be an important forward-looking measure of landscape performance. That is, landscapes that are currently in good condition concerning the other three SSEL goals but lack adequate governance structures, markets, and social capital are prone to deteriorate.

In contrast, those that benefit from effective institutions are likely to improve, even if their current condition is poor. Since the creation of robust institutions and organizations often precedes the realization of tangible benefits from these institutions, including institutions in the framework is important for predicting the trajectory of landscapes over time. If this holds about institutions, institutional goals and indicators must be fully incorporated into any DPSIR-SEL assessment framework (Table 4).

Table 4: Institutions Goal: Institutions are present that enable integrated, ongoing planning, negotiation, implementation, resource mobilization, and capacity-building in support of the goals of a sustainable social-ecological landscape

Indicator 1	Are mechanisms in place and functioning for cross-sectoral planning, monitoring and decision-making at a landscape scale?
Indicator 2	Do farmers, other land users, and communities have adequate capacity and are they effective in support of eco-agriculture/agroecology innovation?
Indicator 3	Do public institutions effectively support social-ecological landscape sustainability?
Indicator 4	Do markets provide incentives for social-ecological landscape sustainability?
Indicator 5	Are supporting organizations in place to facilitate eco-agriculture/agroecology?
Indicator 6	Do local knowledge, norms, and values support the sustainability of the social-ecological landscape?

4.2 Methods applicable under the DPSIR-SEL assessment framework

Modelling tools that may be used interactively within the context of the proposed DPSIR-SEL framework include (these tools are open-sourced and freely available):

- The ***Clu-Mondo land systems model*** (for analyzing land use change in response to market demand and policy/program interventions (Asselen & Verburg, 2013); The CLU-Mondo model is the most recent version from the CLUE model family that has been used in many local, national and continental level land use change studies (Asselen and Verburg, 2013). Clu-Mondo provides a flexible and innovative approach to land-use change modeling to support integrated assessments. In the model, demand for goods and services is supplied by various land systems characterized by the land cover mosaic, the agricultural management intensity, and livestock production systems. Together these are called land systems. The CluMondo model can be influenced by promoting or even enforcing interventions, as defined by stakeholders, that only allow, restrict or stimulate certain land use and land cover types that contribute to positive effects on the various landscape ambitions. More info on CluMondo can be found at https://www.environmentalgeography.nl/site/data-models/models/clumondo-model/.

- The ***GLOBIO model*** assesses impacts on biodiversity from human-induced pressures (Schipper et al., 2016). GLOBIO can be used to quantify various dimensions of human-nature interactions, including:
    - Benefits that people obtain from nature (ecosystem services, also called nature's contributions to people or nature-based solutions)
    - Impacts of human activities on biodiversity and ecosystem services
    - Production- and consumption-based biodiversity impacts ('footprints')
    - Patterns and trends in biodiversity and ecosystem services under future socio-economic development scenarios
    - The effectiveness of large-scale policy options for conserving biodiversity and ecosystem services

  GLOBIO is a modelling framework used to calculate the impact of Social-Ecological drivers on biodiversity. GLOBIO is based on cause-effect relationships derived from the literature, and the model uses spatial information on environmental drivers as input. The GLOBIO model quantifies biodiversity as the mean species abundance (MSA), which is calculated by dividing the abundance (density, numbers or coverage) of each species in disturbed conditions by its abundance in an undisturbed reference situation (Alkemade et al., 2009). Pressures included in the GLOBIO model are climate change, atmospheric nitrogen deposition, human land use intensification, infrastructure and human encroachment, discharge pollution, and direct contact use of natural resources. In general, the GLOBIO model does not cover all aspects of biodiversity but provides an idea of the naturalness of the landscape. See http://www.globio.info for more information on GLOBIO.

- ***Mapping Ecosystem Services for human well-being (MESH) tool*** (Johnson et al., 2019). The Mapping Ecosystem Services to Human well-being (MESH) tool is an integrative modelling platform that calculates and maps ecosystem service supply under different landscape management scenarios. MESH runs on a backbone of InVEST toolkit models (Sharp et al., 2018) that can be tuned to local situations. For the TAFS-WCA WP3 target landscape, the ecosystem services models may include the following:

i. watershed water provisioning, representing water available for agriculture;
ii. erosion control by avoiding sedimentation through mining and lumbering;
iii. nutrient exports (nitrogen and phosphate) as an indication of water purification;
iv. carbon storage; and
v. food provisioning.

With MESH models, a specific land systems outcomes map is used to produce spatial and landscape level outputs on the same resolution of the supply of the selected ecosystem services. These outcomes are then used to calculate the relative supply change between the current and future scenarios and between scenarios. More info on MESH can be found at https://www.naturalcapitalproject.org/mesh/.

Considering that the above models are limited concerning the state of interactions and outcomes in the institutional action arena, the ***Evaluation and Development of Institutional Capacity model*** developed by Lee, Karimova, and Yan (2019), which is based on the IAD framework (Ostrom 1990) and Healey's theory of collaborative planning (2002) may also be adopted/adapted (See Figure 7). For more information, visit https://satoyama-initiative.org/case_studies/towards-an-integrated-multi-stakeholder-landscape-approach-to-reconciling-values-and-enhancing-synergies-a-case-study-in-taiwan/).

This assessment model answers the following questions:

i. Firstly, is any existing participation mechanism fit for bridging diverse values and building partnerships among various stakeholders in the target institutional action arena (this is more of a current status review)?
ii. Secondly, suppose there is no such mechanism. How should a Multi-Stakeholder Platform and an Action Plan be designed and implemented to reconcile diverse values and enhance collaborative governance among stakeholders (new forum/action plan design and implementation)?

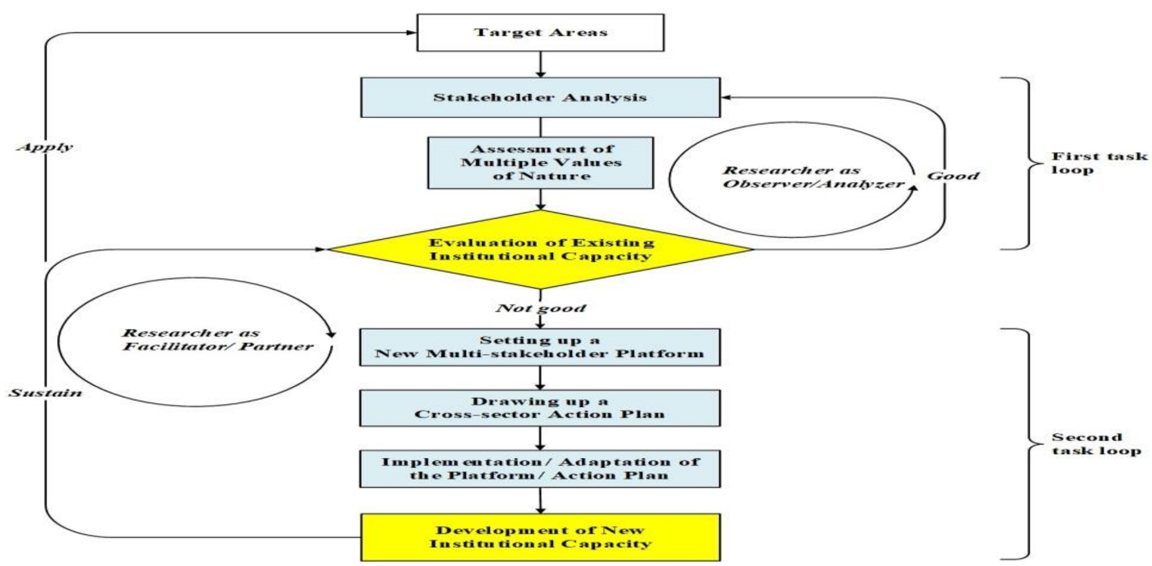

Figure 6: An action research framework for evaluating and developing institutional capacity (Lee, Karimova, & Yan 2019).

4.3 DPSIR-SEL framework and the implementation of WCA-RII WP3

Table 5: Linking DPSIR-SEL assessment framework with WP3

WP3 Outputs	Application of DPSIR-SEL	Comments
RQ 3.1 How can participatory water and land resources decision support system (WRDSS) strengthen landscape resilience planning for enhanced production of nutrient-rich crops and fish		
OP3.1.1. Water quantity, quality and risks data available from participatory approaches and citizen science	Situational analysis	The challenge will be applying citizen science, considering the timeframe for the situational analysis.
OP3.1.2. Inclusive regional Water & Land Resources Decision Support System operational and accessible to stakeholders.	Data and information from the situational analysis will inform the DSS's co-development activities. After the implementation of the DSS as an innovative response, the framework can be used to evaluate the impacts on the sustainability of the target landscape.	
OP3.1.3 A participatory toolbox for land and water resources assessment and co-designing landscape management plans is available	Data and information from the situational analysis will inform the activities for the co-development of a participatory toolbox and the co-designing of landscape management plans.	Landscape-specific data/information underpins must support the co-development of relevant participatory guides and management plans.
OP3.1.4 Landscape management plans are co-designed, implemented and owned by communities and local support institutions	For example, the effects of using co-designed landscape management plans by stakeholder platforms can be evaluated using DPSIR-SEL.	Considering that landscape character evolves, there is a need for continuous learning, and DPSIR-SEL allows for this through sensitivity analysis.
RQ 3.2: How can innovations be OneHealth-sensitive and scaled to contribute to a healthy and productive environment for livelihood improvement		
OP3.2.1. Sustainably intensified OneHealth-sensitive water and energy-efficient production at the landscape level.	Considering that DPSIR-SEL has a feedback loop, the effects of these interventions can be assessed vis-a-vis the landscape situational analysis.	
OP3.2.2. OneHealth-sensitive bundles (fish-small livestock-crop) of GAP for intensification and diversification at the landscape level	Considering that DPSIR-SEL has a feedback loop, the effects of these interventions can be assessed vis-a-vis the landscape situational analysis.	
RQ 3.3: How can ecosystem services/functions and biodiversity be sustained, water management, soil and biomass flow improved, and resilient agrifood systems supported for improved communities' livelihoods?		
OP3.3.1. Improved knowledge of ecosystem services/functions and preservation of biodiversity for healthy ecosystems.	Considering that DPSIR-SEL has a feedback loop, how generated knowledge is applied, and its effect can be assessed vis-a-vis the landscape situational analysis.	

OP3.3.2. OneHealth sensitive circular bio-economy innovations like Black Soldier Fly (BSF) for conversion of waste from biomass flow into new value chains and sustainable agro-livestock production.	Considering that DPSIR-SEL has a feedback loop, the effects of these interventions can be assessed vis a vis the situational analysis.	
OP3.3.3 Capacities built for robust integrated monitoring and management of OneHealth challenges	DPSIR-SEL is ideal for monitoring and evaluation.	
Cross-cutting: Systemic analysis of WP3 plans and activities	DPSIR-SEL is ideal for the systematic analysis of WP3, considering that it is dynamic/flexible and based on systems thinking.	

5.0 Conclusion

This study is premised on the argument that sustainable social ecological landscape approaches are applied on productive landscapes with different forms of land use, such as forestry, agriculture, extraction of minerals, conservation/protected areas, and settlements, which are symbiotic and therefore, measurement frameworks that focus exclusively on, for example, the protection/conservation of natural resources on the one hand or agriculture and other land uses, on the other hand, can only give an inadequate perspective/overview of landscapes with all their uses and stakeholders. The study builds on existing assessment frameworks from relevant fields (e.g., Ecoagriculture, Agroecology, Integrated Landscape Management, etc.) to proposes the DPSIR-SEL framework for the comprehensive assessment of the sustainability of landscape state/performance. The research envisages two important applications of this framework: i) it can facilitate inclusive decision-making by multiple stakeholders working in the same landscape by explaining interactions, synergies, and trade-offs among SSEL goals and landscape components, ii) when SSEL related management innovations are successful (or otherwise), the framework can help the documentation of the same, bolstering the case for adopting and scaling-out innovations.

6.0 Next steps

The next steps will include the following:

- The review and validation by diverse experts in the fields of conservation and rural development
- To field test the framework, indicators, and methods in a site with a diversity of biophysical, socio-cultural, economic, and institutional contexts.
- To use the experience of the field-testing to revise and refine the framework as part of an iterative process of continual improvement.

To use the results of the field testing to examine the performance of eco-agriculture landscapes to Inform adaptive management and policy making.

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