Review Article

An Indicator Framework for Assessing Socio-Ecological Resilience of Candaba Wetlands, Philippines

Abstract

Candaba Wetlands is important production landscape and declared as a priority wetland in the Philippines. The socio-ecological system of Candaba Wetlands is characterized by the synergy of agriculture and ecology in providing various ecosystem services and improving the well-being of the residents. However, the wetland is not secured from recurrent disturbances. This paper presents an indicator framework utilized in the analysis of the socio-ecological resilience of Candaba Wetlands. A review of literature related toresilience and Socio-Ecological Production Landscape and Seascapes (SEPLS) served as the backbone in integrating various perspectives. SEPLS resilience highlights the interactions of the ecological and social system. Thus, the indicators identified in this paper is grounded on four areas of SEPLS: (a) ecosystem protection and maintenance of biodiversity; (b) agricultural biodiversity; (c) knowledge, learning and innovation, and (d) social equity and infrastructure. The indicators in each area were further classified according to ecosystem, agricultural and social dimensions of Candaba Wetlands. The framework also offers a way to communicate with the stakeholders in maintaining and enhancing the resilience of the wetland.

Keywords: resilience, socio-ecological system, Candaba Wetlands, wetland, indicators

1. Introduction

The resilience concept became the point of interest of many researchers in the study of disturbance and change of socio-ecological systems(Callo-Concha and Ewert, 2014; Ifejika Speranza et al., 2014; Quandt, 2018).Socio-ecological systems (SES) are shaped by the interactions of the social system and ecosystem (Chaffin and Scown, 2018; Cumming et al., 2017; Cumming and Peterson, 2017; Dennis, 2015; Ives et al., 2007; Knapp et al., 2010) and these interactions affect the biodiversity and the ecological processes in SES. In addition, temporal changes in the SESalso has an impact on the ecosystem services of the wetland(Liu et al., 2007). In a socio-ecological system perspective, resiliencecharacteristic of the system allowed the system to absorb disturbance and reorganize while undergoing change and retaining its function, structure, identity, and feedbacks(Adger, 2005; Folke et al., 2004; Gunderson and Holling, 2002; Holling, 1973; Panpakdee and Limnirankul, 2018; Smit and Wandel, 2006; Urruty et al., 2016; Walker et al., 2006).

Due to the complexity and dynamics of interrelations in SES, measuring its resilience is difficult. Thus, the Japan Satoyama-Satoumi Association (2010) integrated this resilience thinking to socio-ecological production landscapes and seascapes (SEPLS). SEPLSrefers to the mosaic production landscapesformed by the human-nature interaction that sustains the human well-being while maintaining the ecosystem services. It links the biological, physical, social components which are manifested in the traditional knowledge and sustainable use of biodiversity(Boafo et al., 2016; Fiksel, 2007; Folke et al., 2002; Takeuchi et al., 2016)

In the Philippines, Candaba Wetlands has been exposed to various recurrent disturbance such as agricultural activities and flooding. Despite these disturbances, this wetland is still hailed as key biodiversity area in the Philippines and globally important in the East Asian Australasian Flyway of waterfowls. The residents have been living with recurrent floods and have adapted to the changing landscape through shifting livelihood. From this picture, resilience is manifested in the wetland.

But the question is "What makesCandaba Wetlands resilient?"Considering the concepts of resilience and SEPLS, we identified indicators suitable to the context of Candaba Wetlands that could be used in measuring or assessing its socio-ecological resilience and have a better understanding in the adaptive mechanisms.

2. Resilience

Holling(1973) introduced and defined resilience as a measure of persistence of a system and its ability to absorb change of state variables, driving variables and parameters and still maintain the same relationship with the variables. He contrasted the terminology resilience to stability which he defined as the ability of a system to return to an equilibrium state after a temporary disturbance and results to the degree of fluctuation. The resilience and stability viewpoints of the behavior of the systems have varying approaches to resource management. The former emphasizes "*domains of attraction and the need for persistence*" while the latter stresses "*the equilibrium, maintenance of a predictable world, and the harvesting of nature's excess production with little fluctuation possible.*" Other authors consider resilience as a time required for a system to return to an equilibrium or steady state following a perturbation. In this definition, the measure of resilience is how far the system has moved from the equilibrium and how quickly it can go back to its steady state.

Gunderson (2000) stated that resilience is an emergent property of the ecosystem related to self-organized behavior over time. He referred self-organization as the interaction between structure and process which eventually leads to the development of the system. This definition is related to the exploitation phase of Holling's adaptive cycle in which the system can absorb range disturbances which means the ecological system is high. When the system reached its limits in conservative growth, it will eventually become ready to fuel rapid structural changes.

Walker et al. (2004) defined resilience as "*the capacity of a system to absorb disturbance and reorganize while undergoing change to retain substantially the same function, structure, identity, and feedbacks.*" This means that the ability of the ecosystem to reorganize and renew to a desirable state after the perturbation is dependent on states and dynamics at scales. It is a dynamic property of the system that changes through time in which human actions slowly erode resilience and disturbance previously absorbed can lead to a regime shift. Thus, resilience considers both elements of recovery and change; focusing on adaptive capacity, balanced by the sensitivity of the human and ecological systems (Ibarraran et al., 2008).

Mumby et al. (2014) identified the pros and cons of the two forms of resilience which has been already mentioned in the differentliterature. The ecological resilience considers ecosystems that can move towards one or more community types even in the absence of acute disturbance events. It is ideal where an ecosystem risk is losing its ability to recover and driving itself to an undesirable state and can be challenging to quantify often requiring ecological models or extensive time series from the same environment. On the other hand, engineering resilience applies to systems that always recover towards the same long-term state. It is useful where an ecosystem recovery is common, but it cannot cope with the reversals of community trajectory since it focused on an equilibria state which rarely occurs in systems with frequent disturbances.

3. The Socio-Ecological Production Landscapes and Seascapes Concept

3.1. Origin of the SEPLS Concept

Satoyama, a Japanese term, is a mosaic of different ecosystems such as secondary forests, farmlands, irrigation ponds and grasslands and human settlements (Ichikawa, 2013; JSSA, 2010). This type of landscape provides diverse land uses that offer benefits among people's lives and agricultural production. Aside from the provisioning services, the*satoyama* landscape also provides regulating services such as flood prevention and watershed conservation, landslide and erosion prevention functions and pollination (Takeuchi et al., 2016). The different environmental conditions of the mosaic of ecosystems contain more species in the whole landscape. The concept has been extended to *satoumi*, which constitutes marine and coastal ecosystems. It denotes to the spatial structure of coastal areas and the use and management of fisheries resources within these areas.

These two concepts depict the relationship of the mutually beneficial interaction of human and environment, allowing sustainable use of resources. This *satoyama-satoumi* concept, internally known as traditional socio-ecological production landscapes and seascapes, is a historical model for environmental stewardship and resource management that contributes to human well-being (Hashimoto and Nakamura, 2014; JSSA, 2010).

The Japan Satoyama-Satoumi Assessment (JSSA) focuses on the link between humans and different landscape ecosystems in Japan and how they interrelate each other. It follows the framework of sub-global assessments developed by the Millenium Ecosystem Assessment. JSSA adopts the ecosystem services conceptual framework developed by MA due to the following reasons: (a) centrality of human-wellbeing in considerations of ecosystem services, (b) recognition of the interdependency, synergy, and trade-offs between ecosystem services and human well-being, and (c) acknowledgment of different temporal and spatial scales that impact interdependency.

3.2. Concepts and Characteristics of SEPLS

SEPLS consists of dynamic mosaics of habitats and land and sea shaped by the interactions between people and the environment over the years while maintaining biodiversity and providing a bundle of ecosystem services for human well-being (Gu and Subramanian, 2014; Ciftcioglu, 2017). SEPLS are "*found in many parts of the world, of different socio-economic context, where humans are directly linked with nature through various forms of resource use, including primary industries, subsistence activities, tourism, and cultural uses"*(Gu and Subramanian, 2014). In SEPLS, biodiversity and ecosystems support humans by delivering ecosystems services such as food, fuels, shelter, cultural values, while in return, humans support biodiversity and ecosystems through managing the natural resources for its sustainable use (Subramanian et al., 2014). The SEPLS concept also gives importance to traditional knowledge which is useful in building sustainable management for further development of the landscape. Hence, the socio-ecological characteristics of these SEPLS differ depending on their area as their sustainable use and management rest on traditional norms, beliefs and practices and customs of the local inhabitants (Boafo et al., 2016; Kadoya and Washitani, 2011). SEPLS is also characterized with enhanced biodiversity due to mosaic ecosystems that can support organisms.

The SEPLS concept also trailed the core objective of Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES), which understands the ecosystem production, function, and services in balancing conservation and development goals, and integration of scientific findings into policies while improving human well-being (Indrawan et al., 2014).

Cognizant to the sustainability perspective, the SEPLS shares the basic premise of socio-ecological systems and resilience thinking, which holds that "*social and ecological systems are linked and adaptive management is necessary to address ecosystem changes*" (Gu and Subramanian, 2014). It also emphasized that SEPLS provides ecosystem services, not only for local communities but also for a higher population beyond their borders in which its production and harvesting processes are further predisposed by external demands, pressures and policy decisions at national and international level (Gu and Subramanian, 2014; Hashimoto and Nakamura, 2014). SEPLS are dynamic in nature and are sustained through adaptive co-management regimes, with interlinkages amongst natural and cultural processes that operate on different time frames (Gu and Subramanian, 2014)

3.3. Changes in SEPLS

There has been a rapid decline in SEPLS in many parts of the world. SEPLS suffered loss and degradation due to anthropogenic and natural drivers, which jeopardize its sustainability. These influential factors contributing to changes in SEPLS are dependent on the socio-economic context of each region.

The changes in SEPLS are shaped by the interactions between people and nature (Ichikawa, 2013). JSSA (2010) listed down several factors in changes in SEPLS. These are (a) indirect factors, such as economics, culture and religion, science and technology, population and public policy, and (b) direct factors such as changes in land use (development and loss of mosaic), underuse, and overhunting /overharvesting, climate change, increasing non-native species, and pollution. Consequently, Gu and Subramanian (2014) summarized the drivers of change in

SEPLS. These include (a) socio-political transformation, (b) legal rights and autonomy, (c) economic globalization, and (d) demographic and socio-cultural changes.

The following case studies illustrate varying drivers of changes in SEPLS. Depending on the socio-economic situation of each country, different drivers of change has been pointed out in the decline of SEPLS.

In the context of Africa, the continent's SEPLS are faced by several threats and challenges due to interrelated natural and anthropogenic factors. Major factors include climate change, unsustainable resource extraction, population pressure, and governance and institutional issues. The changing rainfall and temperature patterns in the continent resulted in water scarcity, severe impacts on rain-fed agricultural production. This also impacted food security on the continent. As the demand for mineral resources and fossil fuels increases around the world (Mapani and Kribek, 2012), the African government give out large areas of the rural landscapes mining concessions to local and foreign investors for exploration. And, this conversion of large tracts of land for plantation agriculture and mining concessions among other purposes resulted inadverse impacts to the landscape. To meet the daily food and energy needs, locals tend to extract and use ecosystem services in an unsustainable manner. This scenario is due to lacking sufficient understanding of the long-term consequences of some production practices. Population pressure and urbanization are putting more significant strain on ecological resources and human well-being. The increasing population adds more pressure on ecosystem goods and services provided by SEPLS. Due to urbanization and population increase, natural ecosystems are modified and converted for settlements and industrial purposes (Boafo and Ichikawa, 2016).

On the other hand, the SEPLS of Noto Peninsula in Japan have different socio-economic factors influencing its changes. The sustainability of Noto's SEPLS is held up due to the rapid depopulation and aging of the local community. These two factors eventually resulted in the gradual collapse of the balance between human and nature, causing abandonment of farmland and forests, and increasing the incidence of human-wildlife conflict(Hashimoto and Nakamura, 2014). It was also reported that even fishing resources areabundant around the peninsula, the lack of large, flat plains became difficult to improve agricultural productivity through mechanization and farmland consolidation. The ongoing trend of aging in the local communities of Noto has further aggravated the situation.

In Cambodia, the SEPLS are becoming uniform due to land use change occurring in the place. In the 1990s, governmental forest management in Cambodia only focused on timber production from high-value forests managed by private companies under large-scale forest concessions. The concession forestry has resulted in high levels of illegal logging and degradation of forest resources. This is exacerbated by conflicts over rights with local communities who traditionally used to collect natural resources from the concession forests. When the Cambodian government has opened the international investment for cash cropping, conversion from shifting agriculture to cash crops increased. Development of road networks, population increase, inadequate enforcement of land laws, and dissolution of the communal system has led the farmers to sell land to outsiders (Ichikawa, 2013).

The mosaic of forest, maquis, agriculture, coast and marine in the Lefke Region of North Cyprus delivers a significant role in the production of ecosystem services. This portrays the integrative relations of humans and nature. But, the mosaic of the ecosystem is threatened by land use change due to the impacts of urbanization and land abandonment. Other factors such as low level of management, migration, lack of job opportunities, aging of society have led the transformation of the SEPLS of Lefke Region (Ciftcioglu, 2016, 2017a)

As depicted inseveral case studies, there are a lot of factors that contribute to changes in SEPLS. Aside from climatic variability, government policies, population, and land use change are key influences in the decline of SEPLS. Policies on mining concession in Africa and forestry concession in Cambodia have triggered the conversion of rural landscapes. Though these policies aim to improve livelihood and food security and reduce poverty, these public policies have negative impacts in maintaining the SEPLS structures and dynamics (Indrawan et al., 2014). Changes in demography also affect the land use change(Gu and Subramanian, 2014). The increasing population has impacted the unsustainable use of natural resources in Africa and the conversion of shifting agriculture to cash crops in Cambodia. On the contrary, rapid depopulation and aging of the community have led to the abandonment of SEPLS in rural areas in Lefke Region of North Cyprus and Noto Peninsula of Japan. Migration is also a factor in the land abandonment in Lefke Region. As people look for job opportunities in other places, lands in the rural areas were abandoned, which in return, the mosaic of ecosystems was converted to a uniform state.

4. Conceptualizing the socio-ecological resilience of Candaba Wetlands

There are various cross-disciplinary frameworks and models that have been developed but the SEPLS approach is the only framework that treats the social and ecological systems in equal depth (Binder et al., 2013; Ciftcioglu, 2017b; Jain, 2012). Due to the dynamic nature and complexity of interrelations of SEPLS, indicators were designed to capture thevarious factors vital in sustaining a resilient landscape.A set of indicators have been already identified but these were not regarded as defined set of measurements but rather as a guide to understanding and strengthening SEPLS resilience(UNU-IAS, 2013). Thus, these indicators can be modified and localized depending on the user and the socio-ecological system to be assessed.

SEPLS resilience includes four areas: (1) ecosystem protection and maintenance of biodiversity; (2) agricultural biodiversity; (3) knowledge, learning and innovation; (4) social equity and infrastructure.But these areas can be further grouped according to its respective dimension.

a. Ecosystem Dimension

Ecosystem protection and maintenance of biodiversitycould enhance the resilience of an ecosystem. The diversity and interactions of species in Candaba Wetlands reflects the ecosystem health(Fischman, 2004).Biodiversity, encompassing variationfrom within species to across landscapes, is crucial in the resilience ofunderpinning ecosystem functions and the services(Convention on Biological Diversity, 1992; Levin, 2013; Oliver et al., 2015). By protecting the ecosystem and maintaining the biodiversity, the community settling in the Candaba Wetlands could gain from the ecosystem serviceswhich are either sustained or degraded by the human practices and the institution that regulate the use of natural resources(Yao et al., 2015). Spatial heterogeneity and multifunctionality of the landscape create a mosaic of habitats, thus, increasing the biodiversity(Benton et al., 2003; Oliver et al., 2015; Sutti, 2016). Designating protected areas is also critical in conserving biodiversity as this measure safeguard not only the species, but also the habitat (BMB, 2015; CBD, 2008). The rate of recovery from the extreme environmental and climate change-related stresses and shocks is also vital as this will determine the ability of the Candaba Wetlands to bounce back to its original state (Adger, 2005; UNU-IAS, 2013).

b. Agricultural Dimension

The agricultural biodiversity in Candaba Wetlands creates the nexus of its ecosystem health and the community(UNU-IAS, 2013). This is linked by the array of functions such as maintenance of agroecosystem functions, sustainable production of food and other agricultural products, and biological support to production(Convention on Biological Diversity, 2013; Cromwell et al., 1999; FAO, 2019; GIZ, 2014). Thus, it is essential to maintain, document and conserve the wetland's agricultural biodiversity.To conserve the Candaba Wetlands, a range of different measures such as on-farm management, restricting farming intensity, prevention of farmland abandonment, establishment of gene bank, botanical garden, agricultural research stations and tissue culture collections, and following eco-agriculture practices(Fransiska et al., 2015; GIZ, 2014; Kleijn et al., 2011) could be conducted. The agricultural biodiversity could also be improved by involving and recognizing the role of the farmers in conservation(Abay et al., 2009), thereby, also have a positive impact in the adaptive capacity of Candaba Wetlands (Dennis, 2015). Horizontal networks such as intercommunity resource trade could also enhance the resilience to perturbation, particularly climate variability.

c. Social Dimension

The social dimension of Candaba Wetlands encompasses knowledge, learning and innovation; and social equity and infrastructure. The resilience of a community is strengthened by learning from different knowledge systems such as traditional and local adaptation strategies, customs, agricultural traditions, local languages, cultural values, and social institutions(UNU-IAS et al., 2009). Though the local knowledge is considered outdated, local knowledge is built upon the practical knowledge of the past experience and delivered from skilled generations(Panpakdee and Limnirankul, 2018). These knowledge systemsthat shaped the Candaba Wetlands is strongly linked the community and ecosystem. Maintenance of the local knowledgeis significantly anchored by the ability of the community to document local knowledge(Ifejika Speranza et al., 2014; Panpakdee and Limnirankul, 2018), access and exchange of local knowledge(Ifejika Speranza et al., 2014; Panpakdee and Limnirankul, 2018; Subramanian et al., 2017), transmit local knowledge to younger generations(Elgar, 2013; Panpakdee and Limnirankul, 2018; UNU-IAS, 2013), uphold cultural traditions related to biodiversity(Ducusin et al., 2019; UNU-IAS, 2013), interact with the landscape, use of terminology or indigenous languages(UNESCO, 2003), and maintain diversity of local food system(Bioversity International, 2019) and local medical system(Alves and Alves, 2011; Nascimento et al., 2016).

The resilience of Candaba Wetlands is alsoreliant on the availability of and access to functioning social infrastructures, such as communication, health, and education. The resilience of the SEPLS could also improve with effective local resource governance with efficient institutional devolution and institutional arrangements(Senga, 2001; World Bank, 2003) that distinguishes property rights and autonomy in relation to land and resource management(Young, 2011). Fostering gender equality could also build and enhance resilience in the community as the women's leadership and decision-making are empowered and recognized(Chanamuto and Hall, 2015; Collord, 2018; Jenson, 2015). Resilience in the Candaba Wetlands is also dependent on the adaptive mechanism to disasters(UNISDR, 2015) as flooding is recurrent in the area. As a hotspot for migratory birds, ecotourism also has a contribution to resilience of the wetland(Hall, 2013)as this nature-based type of tourism was considered a solution to the disconnect between sustainability and development (Kiper, 2013).

Accordingly, a set of suitable resilience assessment indicators forthe ecological, social and agricultural systems of the Candaba Wetlands wasdeveloped by reviewing relevant references. The suitable indicators are detailed in Table 1.

5. Conclusion

This paper conceptualizes the socio-ecological resilience of Candaba Wetlands drawing on the concept of SEPLS. Using the SEPLS model in assessing the resilience of Candaba Wetlands, due to its participatory in nature, would elicit information to understand the interactions of the ecological and social systems.As the SEPLS model recommends the use of Likert scale as measurement, the proposed measurement scale provides simple way of capturing people's impressions and ideas in a quantitative way (Ifejika Speranza et al., 2014; UNU-IAS, 2013). The measurement scale can also serve as a tool for monitoring the contributions of the actorsin maintaining and enhancing the resilience of the socio-ecological system of the wetland during perturbation(Jain, 2012).The model also highlights the important of the knowledge system in the transformation of Candaba Wetlands as anthropogenic activities were greatly related to the knowledge and learning of the residents. The approachcan also bring together key stakeholders from Candaba Wetlands and jointly formulate policies and tools relevant to the three dimensions of the wetland.

6. References

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