Evaluation of the economic value of mangrove ecosystem in west coast of Papua based on the Ecosystem services framework

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Abstract

Mangrove forests are a unique and peculiar ecosystem which, if managed properly, can provide serious benefits through a plethora of services.
Due to different causes, among which overexploitation, climate change and others, these wetland forests are receding worldwide.
This work presents a brief analysis, ran on STELLA^{TM} of the ecosystem services mangroves can provide focusing in particular on the mangrove forest of the West coast of Papua over a period of one year.

1. Introduction

Mangroves are marine ecosystem lying along sheltered coastlines of the tropics and subtropics regions (Shams Uddin *et al*., 2013), they display a complex structure and several physiological adaptations to living within a challenging environment (high salinity, anaerobic soils, extreme tides) (Katerisan and Bigman, 2001). Due to its heterogeneity, mangrove forests create a unique environment that harbors rich assemblages of species, thus providing a number of goods and services for human wellbeing (Katerisan and Bigman, 2001 & Shams Uddin *et al*., 2013).

Local and national economies from where mangroves occur are greatly influenced by these forests (fisheries, forest products harvest, coastal protection, climate regulation, etc.) (Shams Uddin *et al*., 2013) however, in spite of its acknowledged ecological and economical importance, mangrove forests have been disappearing worldwide in an alarming rate, with overexploitation, climate change and lack of appropriate management being the main contributors for mangrove loss (Brander *et al*., 2013 & Shams Uddin *et al*., 2013).

This chapter will discuss the contribution of mangrove ecosystem services (namely Provisioning, Regulation, Cultural, and Supporting) for the economic value of the mangrove forest on the coast west of Papua, Indonesia. The aim of this chapter is to apply a hypothetical graphical simulation model that follows the West Papua mangrove Economics over 1 year using the STELLA SIMULATION MODEL SOFTWARE* to understand how different ecosystem services can play a role in determining the economic value of an ecosystem.

2. Material and Methods

The Stella model software was created by Berry Richmond and it stands for the principle that by increasing people's awareness and insight about the system around them, they can better make logical decisions (LaVigne and Stuntz, 2016).

The modeling relies on the use of interconnectors in a system, that through mathematical functions can generate graphical simulations (LaVigne and Stuntz, 2016): **The stock**: is the amount desired to track in a model. **The flow** represents the increasing or decreasing in the amount of "something" in the stock. **Converter**: these are parts that represent how the system works. **Connectors**: show the interaction between converters and how they affect one another.

For the current model the specifications were the following:

2.1. The main stock that represents the Economic value (*endpoint*)

A starting value of 750EUR was given to the main stock, it is under the control of the 4 ES chosen, whose equation depends on such. The **increased flow** is at the charge of all 4 ES, and the **decreasing flow** is mostly influenced by Provisioning services (Fisheries and wood exploitation) and slightly affected by tourism.

a) **Increasing economic value of the West Papua mangrove**

   Eq.1 Cultural_services+Provisioning_sevices+Regulating_services+Supporting_services

b) **Decreasing the economic value**. **Eq.2** Provisioning_sevices*2

2.2. Four sub-stocks and respective converters

Each of the four sub-stocks represents a single ES. Overall, it was assumed that each ES has an heterogeneous contribution to the economic value although, the same initial value was attributed for the sub-stocks the effectors behind each some of them follow particular interactions. At least 3 converters were chosen for each sub-stock as can be seen in the table below:

Table 1: Description of the equations used in the model for each ecosystem service.

ES	Equation
Provisioning	(Aquaculture*1.3) + (Fisheries*1.3) + Wood_exploitation
Regulating	(Air_purification + Coastal_Protection + Regulation_of_water_quality)
Supporting	(Decomposition + Nursery_grounds + Primary_productivity)
Cultural	(Ecotourism + Education + Spiritual + Tourism) Tourism*1.5 DECREASE

3. Results

Figure 2. Graphical representation of how the values of the Ecosystem Services and of the economic value are varying in one year

As we can see from the graph (fig. 2), all the services are slowly increasing and so the economic value of the mangrove ecosystem. Some of them like the cultural, supporting and regulating are directly increasing the value while provisioning services are contributing both positively and negatively. This happens when an overexploitation of the resources happens and the value of the ecosystem decrease exponentially.

4. Discussion

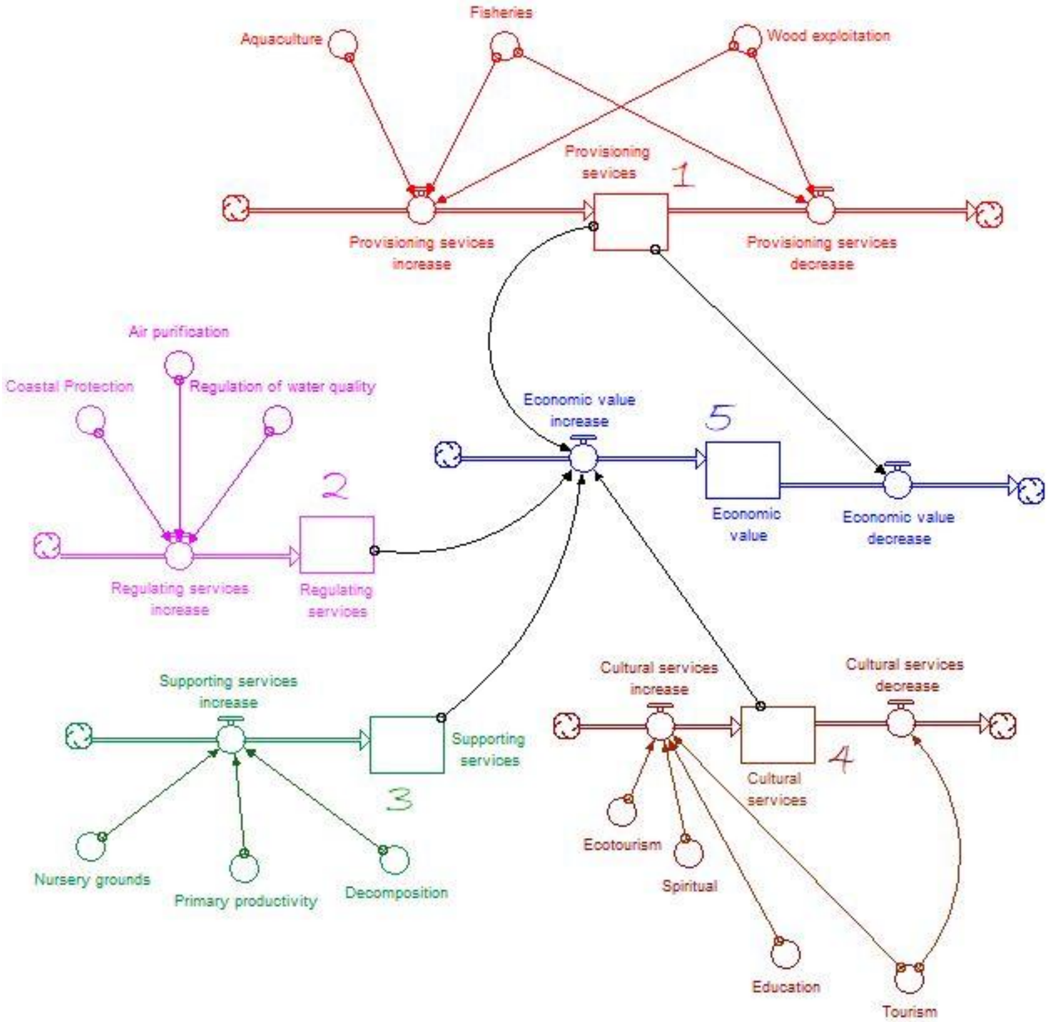

Fig. 1. The contribution of the ecosystem services for the economic value of the West Papua mangrove forest.

3.1. Provisioning services

Mangroves are very important ecosystems, underpinning a wide variety of services of which some are described here:

- **Aquaculture**

Human's dependence on aquaculture products have been growing in the last decades, and mangrove specifically can role as an important aquaculture site for shrimp farming. However, damages associated with such practices constitute a drawback for mangrove ecosystems, for that, a special sustainable type of aquaculture has emerged: **the integrated mangrove-shrimp farming** (thus the 2 connectors coming from aquaculture contribute for both increase and decrease of the economic value).

This method, also named as organic aquaculture, establishes that deforestation does not exceed the 50% of the total farming area, in those aquaculture fields the mangrove destruction is regulated and the sustainability initiative also ensures that reforestation achieves/recovers the 50% of coverage lost in the next 5 years (Ahmed *et al.,* 2018)**.**

- **Fisheries**

The mangrove forest is a highly productive ecosystem due to the organic flow, they support a great diversity of fauna Crabs, lobsters, shrimps and various types of fishes of commercial importance are some of the numerous organisms that depend on mangroves at least once during their lifecycle, for that 50% of the commercial fisheries are related to mangrove forests (Carrasquilla-Henao *et al*., 2013)

- **Wood exploitation**

Mangroves are a source of different materials useful to humans. Mainly they are used for woods and fuels but there are several different employments for mangrove derivates. From the bark of mangrove stems are extracted different kind of medicinals useful for constipation and menstruation disorders. Some dyes are extracted from stems both for tanning and for being applied on the internal of canoas for their preservative quality. The logs of some species of mangroves when burnt produce lots of smoke and so they are powerful insecticides and can keep away mosquitos (Dahdouh-Guebas *et al.,* 2000).

3.2. Regulating services

- **Coastal protection**

Mangroves act as a natural barrier of the coast against waves, winds, currents and extreme events that happen offshore, they mitigate the effect of cyclones, typhoons, and tidal waves nearly half of the population of the world lives in the coastal zones (44%) directly benefiting for this protection (Sandilyan and Kathiresan, 2012).

- **Air Purification**

Carbon storage capacity is a crucial feature of mangroves, that they are even considered among the greater carbon-rich biomes with 937 tC ha-1 (Alongi, 2014). They play an important role in Carbon-Oxygen cycle (Monaco and Prouzet, 2014) through **photosynthesis**: releasing breathable oxygen to the atmosphere affecting the local microclimate; **respiration**: 50% of the assimilated CO_2 is released via above and below-ground respiration and most importantly, **carbon sequestration** where mangrove plants allocate the majority of the sequestered carbon belowground in a large pool of dead roots and soil (Monaco & Prouzet, 2014; Alongi, 2014). In the present model, carbon loss via respiration was neglected.

- **Water purification**

Water filtering is one of the benefits from mangroves provided by its structural complexity and associated deposit and suspension feeder fauna (Mutua *et al* 2011; Monaco & Prouzet, 2011), they trap nutrients and junks of trash, reducing the load of such in ocean waters, thus fostering the development of seagrasses and corals whose need for clear water is indispensable (Mutua *et al*., 2011)

3.3. Supporting services

- **Nursery grounds**

Numerous marine species, including fish and shrimp, use mangroves as nurseries during early life stages. An accumulation of bacteria and mangrove tree detritus provides plenty of food for growing youngsters and, hidden in the thickets of the mangrove roots, juveniles are more likely to avoid predation from larger animals. When the mangrove refuge is no longer required, these animals venture out into the adjacent reefs or the open ocean. In this manner, mangroves act as a critical source to replenish some of the ocean's fish stock. This is the most important supporting service of the Mangroves ecosystem (Journal of Experimental Marine Biology and Ecology).

- **Primary productivity and decomposition**

Mangrove forests play an important role in the functioning of tropical coastal ecosystems, as well as unique wetland ecosystems in intertidal coastal regions of the tropics and subtropics. Mangroves are also important contributors of nutrients to estuarine and inshore productivity through litterfall, which is a valuable indicator of their total net primary productivity.

However, these coastal forested wetlands are among the most productive ecosystems in the world, playing a major role as sinks in the global carbon (C) cycle and oxygen production. Mangroves are generally nitrogen-deficient but are nonetheless highly productive. This apparent paradox can be explained by the high rate of biological nitrogen-fixing activity in sediments, the rhizosphere of the mangrove trees, decomposing leaves, and aerial roots and bark. So while nitrogen fixation in sediments is likely to be limited by insufficient energy sources, the mangrove rhizosphere sustains high rates of nitrogen-fixing activity, which may contribute significantly to the health and sustenance of the ecosystem by supplying most of its nitrogen requirements. Moreover, the fluctuations in oxygen tension that occur in the rhizosphere due to tidal cycles also favour the growth and establishment of denitrifying bacteria in the mangrove rhizosphere which implies a loss of fixed nitrogen via denitrification.

3.4 Cultural services

- **Tourism**

Tourism in mangroves ecosystems seems to be still underappreciated and not examined thoroughly. Still, there is evidence that, while mangroves may not be a primary drive for destination choice, they are an important attraction (see also Spalding and Parrett, 2019). The main activities tourists have in mangroves are boating, hiking and fishing. In the model presented in this work, the value multiplier given to the tourism variable is high, this is to point out that among cultural services, tourism is the biggest contributor.

- **Ecotourism**

In this model, there is a discrimination between tourism and ecotourism, that is only a subset of the former. This was a deliberate choice to underline the fact that tourism, while profitable, can lead to the degradation of the habitat, and, with it, to a net decrease in value of other services. The degradation of mangrove ecosystems due to tourism is known in literature (Brenner et al., 2018). In the study cited, the authors reported a decline in mangrove cover in Mexico caused, among other factors, by tourism development. In particular, in prime tourism destinations such as Cancùn and the northern part of Riviera Maya the decrease peaked at around 28% from 1980 and 2010. It can be argued that ecotourism, as “the right way to be a tourist” could help in this regard. As an example, Satyanarayana et al. (2012) suggested in fact ecotourism as a management strategy that could help the sustainment of mangrove ecosystem in Gambia in the face of population growth.

- **Spiritual and Education**

Using the ecosystem services framework as a mean to integrate economy and ecology and, in doing so, express the value of ecosystems in dollars has pros and cons. At one side it makes easier to express the value of an ecosystem as a number, thus helping when communicating to the general public or to policymakers. On the other side, however, it makes difficult to integrate those services that don’t produce a direct or tangible economic benefit (Chan et al., 2012). It could be said that some services of mangrove ecosystems are, in fact, qualitative. As an example, mangroves forests seem to have a spiritual and/or a religious significance: James et al., (2013) found that mangrove forests in the delta of Niger are used as sites of religious practice, although they also reported a decrease is such activities. In the model presented, the value given to the variables “spiritual” and “education” are low to reflect the inherent difficulties in assigning a number to such services. A suggestion to circumvent these difficulties is to approach the ecosystem services framework with more tools from different disciplines such as sociology (Chan et al., 2012).

5. Conclusions

In conclusion we can say that Mangrove ecosystem is providing plethora services that are fundamental for the life of communities that live nearby. This report suggests that with a correct management of services and of the exploitation the coexistence between mangroves and humans can endure in time.

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