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Locally assessing the economic viability of blue carbon: A case study from Panay Island, the Philippines

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ABSTRACT

Previous blue carbon studies have focused on discrete carbon stock assessments and overarching systematic reviews which broadly speculate that it may be economically viable to incorporate mangroves into existing carbon finance platforms. There is a discernible need to test this hypothesis through case-specific investigations that determine this presumed viability in a local or regional context – at scales meaningful for policy development. The current study investigates whether the carbon values of mangrove forests on Panay Island, the Philippines, are sufficient to offset the opportunity costs of milkfish (*Chanos chanos*) aquaculture – the primary cause of mangrove deforestation in the Philippines. Profit margins associated with milkfish aquaculture are calculated through a municipality-wide survey (779 ± 140 US\$ ha^{-1} yr^{-1}). Concurrently, the carbon stocks of two heterogeneous mangrove forests are quantified and compared. Creditable CO_2 emissions reductions are modelled under a broad range of assumptions. These emissions are valorised, and a sensitivity analysis is performed to establish the minimum price at which opportunity costs are offset across a range of methodological and accounting preferences. It is determined that carbon prices of around 5–12 US\$ tCO_2e^{-1} would be required to compensate landowners for their lost aquaculture profits. The implications of our findings are discussed.

1. Introduction

1.1. Background

Ecosystem services are the benefits that humans derive from ecosystems (Nicholson et al., 2009). Market-based mechanisms, such as Payments for Ecosystem Services (PES), create financial incentives for conservation through valorisation: placing a monetary value on these services that ecosystems provide to humankind for free. Payments are used to compensate landowners for their opportunity costs: the profits forgone by not converting a habitat to a land-use regime that can generate revenue. Mangroves provide a plethora of ecosystem services such as nutrient filtering, fish nursery habitat, food provision, and coastline protection (see Spalding et al., 2010 for a full account), which disappear following conversion. Notwithstanding, these services have proved incapable of levering the economic support necessary to oppose lucrative acts of conversion, partly because they only benefit those living in close proximity, and the economic values are difficult to quantify robustly. However, despite being restricted to tropical coastlines, mangroves also store and sequester considerable volumes of 'blue carbon' (Pendleton et al., 2012; Siikamäki et al., 2012a, 2012b; Donato et al., 2011; Murray et al., 2011; Nellemann et al., 2009). Blue carbon is carbon that is stored and sequestered by aquatic ecosystems, which also include saltmarshes, kelp forests, and seagrasses. Mangrove ecosystems typically store more carbon in their biomass and sediments than terrestrial forests (Donato et al., 2012). This is partly because of their high net primary productivity, and large proportion of below-ground biomass (BGB) (Chmura et al., 2003); though particularly notable was the discovery that a huge proportion (49–90%) of ecosystem carbon is stored in their deep, anoxic soils (Donato et al., 2011). Furthermore, tidal inundation maintains a continuous conveyance of these sediments to the oceanic realm for long-term burial (McLeod et al., 2011).

Since it is easily quantifiable, omnidirectional, and because the resulting benefits of climate stability accrue globally, carbon storage has become the most accepted ecosystem service for PES projects. A carbon credit is one ton of carbon dioxide equivalent

Abbreviations: AGB, above ground biomass; BGB, below ground biomass; DBH, diameter at breast height; OC, soil organic carbon; PhP, Philippine peso (1 USD = 43 PhP in 2011); REDD+, reducing emissions from deforestation and degradation

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(tCO_2e) sequestered or safeguarded by a forest. It is a commodity, traded through various carbon finance platforms that can be grouped into compliance markets (for companies obligated to cut CO_2 emissions), and voluntary 'over-the-counter' markets (for philanthropic deeds). In 2011 credits were selling at US$15.68–19.18 on the compliance market and US$6–7 on the voluntary market (Peters-Stanley et al., 2011). The United Nations Framework Convention on Climate Change's (UNFCCC) Reducing Emissions from Deforestation and Degradation (REDD+) Programme could offer an alternative future option, but it is yet to be ratified. The extent to which these platforms may be suitable for blue carbon credit trade has been comprehensively discussed elsewhere (see Ullman et al., 2013; Herr et al., 2011; Emmett-Mattox et al., 2010). All carbon finance platforms apply a non-tradable buffer to insure against impermanence,[1] spatial leakage[2] and other uncertainties[3]; this is normally based on an assessment of the project's security, with higher risk projects requiring higher buffers, hence resulting in fewer sellable credits (see Broadhead, 2011). Importantly, up till now, only carbon credits generated from terrestrial forests have been traded on such platforms (Broadhead, 2011).

Mangrove forests are one of the most threatened and undervalued ecosystems on Earth (Nellemann et al., 2009); between 0.75% and 2.1% are lost annually (FAO, 2007; Alongi, 2002). Globally, pressure on these ecosystems is high, with approximately 44% of the world's population living within 150 km of the coastline (Cohen et al., 1997). Brander et al. (2012) estimated that by 2050, the forgone annual benefits provided by mangroves would be US $2.2 billion. The most common pressure is habitat conversion to more profitable land-use regimes. While, these include agriculture and urban development, the largest immediate threat is conversion to aquaculture (Duke, et al., 2007), which may have contributed up to 52% of global mangrove loss (Valiela et al., 2001). Aquaculture alone contributes ~0.96% to annual CO_2 emissions (Hall et al., 2011). The draining and excavation of wetlands exposes deep sediments that undergo oxidation, resulting in the slow release of carbon that took millennia to accumulate (Emmett-Mattox et al., 2010), while clear felling instantaneously eliminates on-going sequestration activity by the vegetation (Chmura et al., 2003). Landowners can generate significant gross returns by converting mangrove forests into aquaculture operations. Financial incentives such as PES have the potential to encourage landowners against conversion by providing compensation for profits forgone.

Offsetting opportunity costs is a prerequisite for determining whether a PES project could be economically viable; the blue carbon value (creditable emissions reductions) must exceed the conversion value. Siikamäki et al. (2012a) used aggregated regional data for opportunity costs, carbon storage, and mangrove loss rates to conclude that conserving mangroves based on the carbon they store was an 'economically viable proposition'. However, at the local scale, a practical evaluation of the economic viability of blue carbon is still needed (Siikamäki et al., 2012a; Herr et al., 2011), especially research that estimates aquaculture profit margins within the Asian Pacific region (Murray et al., 2011). Here, we present the first local assessment of whether mangrove-based carbon payments are sufficient to offset aquaculture opportunity costs; and hence, whether blue carbon PES is an economically viable option for mangrove conservation at our study site, Panay Island, Western Visayas, the Philippines – where the unregulated conversion of mangroves to milkfish (*Chanos chanos*) aquaculture fishponds is the biggest threat (Primavera, 2000).

1.2. Case study focus

1.2.1. Philippine mangroves and fishponds

The Republic of the Philippines is an archipelagic country composed of 7150 islands scattered within the South China Sea and Sulawesi Sea in Southeast Asia. With a national population of approximately 99 million, the country has by far the highest people–mangrove ratio of any Southeast Asian state (Primavera, 2000). The Philippines supported ~500,000 ha of mangroves in 1918 (Brown and Fischer, 1918). Today, the two most recent assessments suggest mangroves occupy an area between 256,185 ha (Long and Giri, 2011) and 256,482 ha (Spalding et al., 2010). Between 1951 and 1988, around half of the 279,000 ha of mangroves lost was due to conversion to aquaculture (Primavera, 2000), and 95% of ponds developed during this boom were formerly mangrove (PCAFNRRD, 1991). Today, despite laws that prohibit the cutting of mangroves, a lack of awareness, compliance and enforcement exist, and many cases exist where landowners have expanded the pond area illegally (Primavera, 2000; Farley et al., 2010). Previous disputes over mangrove land tenure are being remedied by the creation of Community-based Forest Management Agreements, granted by the government on a 25-year rolling contract. This approach decentralises ownership by transferring forest rights from the national government to a responsible 'People's Organisation' made up of community members whose duty it becomes to sustainably manage and protect their adjacent forests.

Fish from aquaculture and coastal fisheries make up 65% of the nation's protein consumption (Primavera, 2000) and contribute 2.4% to its GDP (Hoegh-Guldberg et al., 2009). However, coastal fishery yields are decreasing, leading to ever-growing concern that environmental legislation may become more lenient as human demands escalate, i.e., more coastal land will be converted to aquaculture to safeguard the future protein supply (Janssen and Padilla, 1999). Such legislative reversals have occurred in other parts of the world; for example, unanticipated legislative change has resulted in accelerated coastal development in Mexico (López-Medellín et al., 2011), and the Brazilian government have succumbed to agricultural interests and altered a law on forest conservation that could further threaten their rainforests (Tollefson, 2012). These examples highlight a key argument for preventive action to conserve ecosystems even if the legislative situation is tolerable at present. Ultimately, added motivation for mangrove conservation in the Philippines would be desirable, and there is rising interest in the country for participation in forest carbon markets (Lasco et al., 2011).

1.2.2. Study sites

Two mangrove sites were used for the study – a 75-ha basin mangrove in Bugtong-bato, Ibajay, Aklan province and a 29.5-ha fringing mangrove in Pedada, Ajuy, Iloilo province – in the north and southeast, respectively, of Panay Island (Fig. 1). Using both a basin (estuarine) and fringing (oceanic) forest is important because different types of forest have been shown to possess different dynamics and characteristics, which can affect carbon potential (see Donato et al., 2011; Murray et al., 2011). Both sites feature climax stands – of *Avicennia rumphiana*/*Avicennia officinalis* in Ibajay and *Sonneratia alba* in Ajuy – but the former is probably older, based on biomass of 385.22 $m^2\,ha^{-1}$ in the *A. rumphiana* zone, versus 106.08 $m^2\,ha^{-1}$ in Ajuy (ZSL-CMRP, 2012), see Table 1.

[1] Impermanence = emissions are released during or after payments are received.

[2] Spatial leakage = emissions are released from a different location (e.g., mangrove is converted to fishpond further down the coastline).

[3] Other uncertainties relate to methodological constraints and limited scientific validity.