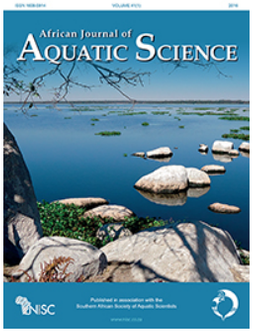

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Mangrove reforestation: greening or grabbing coastal zones and deltas? Case studies in Senegal §

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Besides their important contribution to global biodiversity, mangroves provide many services. Nevertheless, due to an increase of human activities and to climate change, in less than 20 years these ecosystems have lost one fifth of their global surface area. In response to this decrease, mangrove reforestation incentives have spread throughout the world. The scientific and societal legitimacy of reforestation actions still remain in question. Focusing on two case studies, the Saloum Delta and Lower Casamance, Senegal, our methodology was mainly based on the analysis of environmental narratives and discourses between 2009 and 2013, and on reforestation campaigns conducted by NGOs. We highlight the complexity of the system of values associated with the mangroves, as well as the positive and negative interactions between the services. Even although the reforestation campaigns were generally successful in terms of reforested surfaces and international visibility, they were poor in terms of biological and cultural diversities and led to spatial injustice. Moreover, the extensive reforestation with a unique mangrove species, *Rhizophora mangle*, was perceived as means of 'green grabbing', and the simultaneous buying of carbon tax by industrial conglomerates induced disempowerment of the local communities. More integrated research programmes must be developed towards the extensive knowledge of the mangroves.

Keywords: carbon forestry, ecosystem services, global climate change policy, green grabbing, mangrove ecology, political ecology, reforestation

Introduction

In accordance with the principles of inter- and intra-generational equity and environmental justice (Millennium Ecosystem Assessment 2005; CBD-UNEP 2008), shared and sustainable governance of coastlines is a crucial issue in the Global South. It is particularly the case for African countries, which are among the poorest in the world, and where the constraints (sea level rise, climate variability, salinity, etc.) and pressures (urbanisation, pollution, tourism, migration, etc.) are multiple. Coastal areas are multipurpose systems and environments with among the most diverse ecological functions and services, and most valuable resources, but are exposed to major changes (Costanza et al. 2014). The elaboration of an operational analysis framework on biodiversity and ecosystem services is an ethical imperative, but also a scientific challenge because of the uncertainty of data and the complexity of the changes from local to global scales.

This article focuses on the critical question of equity and long-term sustainability linked to neo-liberal environmental governance and, more precisely, the legitimacy of reforestation projects in the framework of Reducing Emissions from Deforestation and Forest Degradation (REDD) and REDD+ (Blom et al. 2010; Leach and Scoones 2013). There is a growing literature on REDD+ and poverty alleviation with various approaches (theoretical, methodological / modelisation, empirical / case studies, etc.). In particular, it addresses the commodification of nature (Maris and Revéret 2009; Kosoy and Corbera 2010; Salles 2011; Cannavo and Lane 2014), environmental justice (Schlosberg 2007; Matulis 2014; Sikor and Newell 2014; Corbera 2015), the politics of carbon forestry and the political ecologies of green grabbing (Saturnino et al. 2011; Max-Neef 2014). The REDD+ mechanism is a particular form of market environmentalism: new protocols are focused on counting and accounting for forest carbon as a commodity and bring risks of negative implications for local people, despite the best intentions of project proponents (Leach and Scoones 2013). Beyond that, it is a form of environmental injustice. Native people and the poor, who are the most vulnerable to biodiversity erosion and ecosystem services degradation, most often are excluded from institutional decision-making (Sunderlin et al. 2014; Veronesi et al. 2015).

In the context of climate change mitigation and under the umbrella of COP21, there is a plethora of contemporary REDD-related initiatives focused on mangroves for sequestering carbon. Nevertheless, little is known about their ecological effectiveness and social acceptability. Literature on REDD+ and on West African mangrove reforestation (Beymer-Farris and Bassett 2012) is very scarce. Besides, mangrove economic evaluations (since the pioneering work

§ This article is based on a paper presented at the Afrideltas conference 'Contemporary Evolution of African Floodplains and Deltas', held 27–30 May 2014, Dar es Salaam, Tanzania, and is part of a suite of papers from the conference, guest-edited by S Duvail and DW Nyingi

of Costanza et al. 1997) are being done more and more frequently and are well documented. However, social and cultural assessments have largely been left out of these evaluations, raising the question of values assigned to the mangrove (by whom, for whom, for what?) and of the methodologies developed. Thus, socio-cultural services and integrated approaches linking biodiversity conservation and livelihoods need further investigations (Wilson and Howarth 2002; Rodriguez et al. 2005; Duvail et al. 2012; Geijzendorffer et al. 2015; Oleson et al. 2015).

Questions and hypothesis

As a contribution to the politics of carbon forestry and the political ecology of green grabbing, this paper questions the scientific and societal relevance of mangrove reforestation actions based on two case studies in Senegal: one in the Saloum Delta and the other in the Lower Casamance (Figure 1). In these areas, the main species used for reforestation was *Rhizophora mangle* (Oceanium 2010). Our hypothesis is that the sole use of *R. mangle* does not integrally restore the mangrove biodiversity. It is based on the main argument that the mangrove is a socio-ecosystem that cannot be reduced to a mangrove forest (Cormier-Salem 2014a), and more importantly that it cannot be reduced to a single-tree-species plantation. Moreover, the system of values associated with this socio-ecosystem in Senegal is very complex: the cultural and religious values of shell middens or tumuli older than five millennia (Cormier-Salem 1999), have justified, among other criteria, the inscription of Saloum Delta on the UNESCO World Heritage list. From trees to communal territory (Cormier-Salem 2006), mangroves constitute complex ecotones, and it is thus very difficult to give standard numbers, cost amounts and thresholds for management and conservation.

Methods

As there is a lack of scientific data on the systems studied, our method was mainly based on the analysis of environmental narratives and discourses with Senegalese managers and NGO experts, public and private stakeholders: more than 250 interviews and qualitative surveys and 4 focus group discussions were conducted with local communities between 2009 and 2013, both in the Saloum Delta and the Lower Casamance (Figure 1). We also conducted in-depth interviews with public agencies (n = 20) and project stakeholders (n = 15). We focused specifically on the Oceanium NGO reforestation campaigns conducted in the Lower Casamance since 2006, and in the Saloum Delta since 2008, and its programme 'Plant your tree' (Oceanium 2010). This reforestation programme has benefited from funds from a consortium of big companies, called the Livelihoods Fund, including the Danone Company, the Yves Rocher Foundation and the French Fund for World Environment.

Following our previous publications on Casamance (Cormier-Salem 1992), the 'Southern Rivers' from Saloum to Sierra Leone (Cormier-Salem 1994, 1999) and the Saloum Delta (Cormier-Salem 2006), and more recently the work developed over the past five years on the governance of West African deltas as part of an international joint laboratory (LMI) PATEO ('Heritage and territories of the water'; www.pateo.ird.fr), this paper examines different services from mangroves and the effects of conservation policies on the dynamics of these socio-ecosystems. More particularly, it questions the scientific and societal legitimacy of reforestation policies, as carbon sequestration through REDD+ is considered as one of the major challenges for the coming decades, with the aim of maintaining the

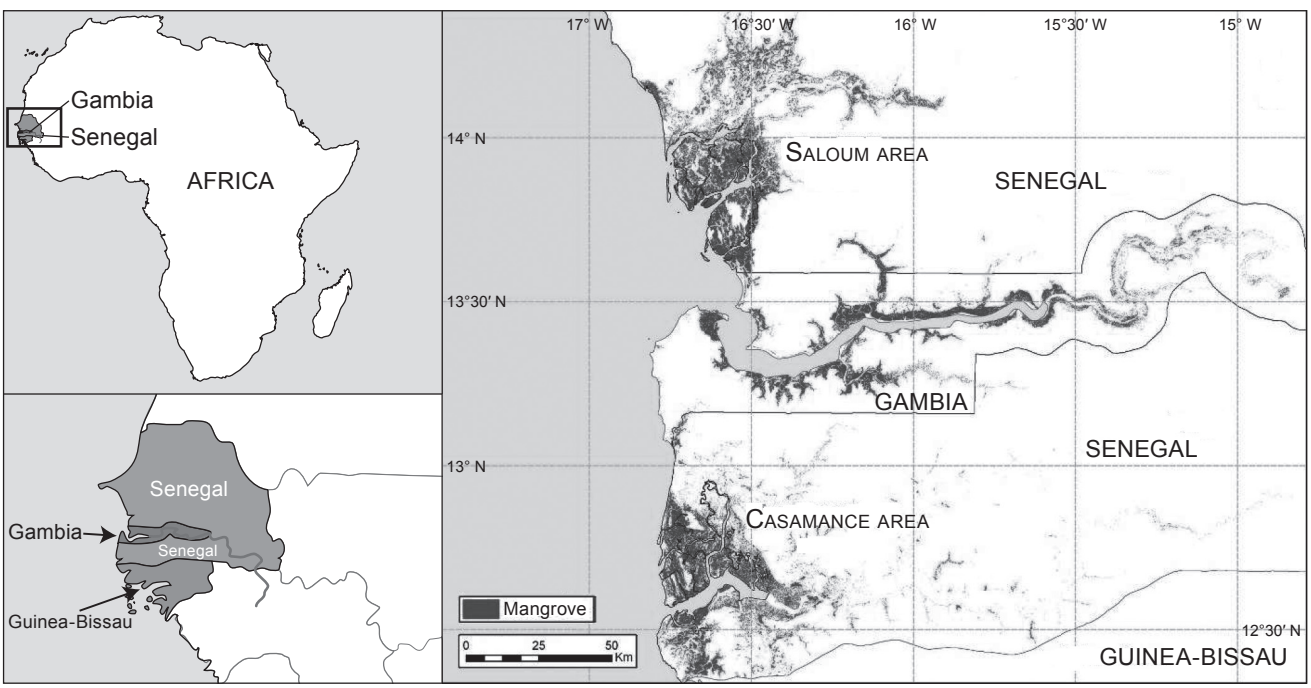

Figure 1: Mangrove areas in Senegal: Saloum Delta and Casamance Basin in 2010 (courtesy of USAID Dakar)

threatened mangrove services. First, the international and national context and stakes were evaluated. Second, the actors in and actions on mangrove restoration, conducted in two Senegalese estuarine areas, the Saloum Delta and the Lower Casamance, were examined to assess the positive and negative interactions between mangrove services in this area (overall carbon sequestration versus other bio-ecological and socio-cultural services).

International and national agendas and their stakes in mangrove ecosystems

Mangroves play a predominant role in all subtropical and tropical areas around the world, providing a wide range of ecological and social services (Table 1 and Walters et al. 2008). These services cover domains such as regulation, air purification with carbon export or sequestration, biodiversity, food supplies and culture (Moberg and Rönnbäck 2003). Multiple local and global pressures may influence, or even threaten, the evolution of mangrove ecosystems. The alarming loss of mangroves during recent decades (20% of the total mangrove area since 1980, according to FAO 2007) is due to various human pressures such as growing populations, large-scale conversion of mangrove areas for fish or shrimp farming, agriculture outputs, sewage effluent disposal, infrastructure and tourism, pollution, and also climatic pressures, including sea level rise and tsunamis (Alongi 2008). Mangrove ecosystems are therefore considered 'at risk', and their accelerated decline led to programmes to restore and protect them.

The practice of reforestation has now spread throughout the world (Walton et al. 2006) in order to rebuild their associated services (McNally et al. 2011). Clear criteria for evaluating success, greater accessibility of information by managers, and application of relevant ecological and socio-economic theories are still necessary to improve the

Table 1: Services provided by mangroves

Role	Services from mangroves	Main functions
Regulation	Erosion control	Stabilisation of shorelines, trapping of sediments by mangrove roots
	Protection against storms	Mangrove forests act as a buffer against storms, cyclones and tidal waves, damping the waves
	Flow regulation	Circulation and water exchange by tidal and river systems and coastal currents
	Waste treatment	Assimilation of waste-water by the plant biomass
Self-production or support	Air purification	Carbon export or sequestration by mangrove (carbon sink or source depending on the year)
	Water purification	Processing and storage of energy via biomass; sequestration of metal contaminants from the soil
	Constitution of the soil	Reclamation and colonisation of soft substrate in low-oxygen conditions by the root system
	Nutrient cycling	Processing and storage of energy and materials (e.g. photosynthesis, biomass of mangrove trees, bioturbation and burial of leaf litter by burrowing crabs, and litter mineralisation by the benthic macrofauna)
	Enrichment of coastal waters	Direct transfer of the productivity of mangrove forests to coastal waters via tidal channels and flooding; decomposition and mineralisation of detrital organic matter; mixing of continental water with ocean water; export of materials by migration of macrofauna
	Biodiversity	Refuge habitat for birds; nursery for fish fauna (retention area, feeding and growth for aquatic life); spawning ground for many species (fish, shrimp); refuge from predators with shade trees, tangle of mangrove roots, turbidity; habitat of grazing gastropods (*Littorina* sp., *Pachymelania* sp. and *Terebralia* sp.) and of filter-feeding bivalves such as oysters, cockles and *Cardium* sp.
Provision	Food	Mangrove forests, tidal channels and associated ecosystems: agro-silvo-pastoral resource support, fisheries and food (rice, salt, honey, fish, shellfish, etc.)
	Drinks and alcohol	Wood, flowers, leaves and fruit: fermented beverages, alcohol, vinegar and tea
	Fuelwood	Firewood and charcoal (domestic cooking, fish smoking, heating the brine to manufacture salt)
	Health	Leaves and fruits for medicinal and cosmetics use
	Material	Timber: poles for houses (piles), boats, farm tools, fishing gear (dam fences, traps and scoop nets), kitchen utensils (e.g. mortar and pestle); bark: tannin and dye, baskets; sticks for diverse uses; lime shells: lime fertiliser and building materials
	Trade	Commercial and small-scale fishing of coastal and estuarine fish (mullet, captain, carp and shrimp); collection of crabs, clams, oysters; aquaculture
	Livestock feeding	Forage and grazing for herds of cattle, goats and other; salt cure
Culture	Spiritual	Sacred sites; totemic species
	Recreation	Tourism and ecotourism (boat rides, wildlife viewing, fishing, etc.); hunting
	Aesthetic	Oral traditions (myths, songs and poems) inspired by mangroves

success of mangrove restoration projects (Ellison 2000), because scientific surveys evaluating the societal and ecological effects of reforestation are still scarce. Over time, policies involved in mangrove management and restoration have been diverse, leading to different uses, from the radical conversion to intensive monocultures (e.g. rice fields and shrimp farms), to the restriction of usage protecting emblematic species or sanctuaries.

A rich, but threatened ecosystem

From field surveys conducted on mangrove ecosystems in West Africa since 2005 (Cormier-Salem et al. 2010; Sarr et al. 2011), and analysis of various documents and reports on the Saloum Delta (Cormier-Salem 1999, 2006), it appeared that the main services 'in the words of local actors' are production and 'socio-cultural' services. In contrast, the 'national' actors (state and public institutions, NGOs, etc.) and international actors put more emphasis on the ability of the mangrove ecosystem to sequester carbon. Table 1 summarises the different services coming from mangroves.

For example, among their diverse services, the yield from dense mangrove forests, including fish, prawns and shellfish, is on average of 90 kg ha^{-1} y^{-1}, with a maximum of 225 kg ha^{-1} y^{-1} in some areas. The annual economic value of mangroves, including products and services, has been estimated to be US$200 000 to US$900 000 ha^{-1} (Wells et al. 2006). For example, revenues from mangrove-enhanced fisheries are estimated at US$10 000 ha^{-1} y^{-1} in some tropical areas (Walters et al. 2008). The value of the biofiltering function of mangroves has been estimated to be US$1 193 to US$5 820 ha^{-1} y^{-1} (Walters et al. 2008), and the function of protection against cyclonic events has been estimated at US$300 000 km^{-1} (Lewis 2005). All these estimates are general, but are very difficult to assess and/or verify. It will be shown in the following sections that such overall estimates related to the mangrove ecosystem are very difficult to validate.

Use and misuse

Worldwide, mangroves cover up to 140 000 km^2, and they extend over a latitudinal range from 30° N to 38° S (Duke et al. 1998; Giri et al. 2011). Nevertheless, due to an increase of human activities and climate change along tropical coastal zones, these ecosystems have lost one fifth of their global surface area in less than 20 years (Valiela et al. 2001). Habitat destruction in mangrove ecosystems has taken place mostly in emerging countries, where 90% of mangroves are located. Aquaculture accounts for 52% of mangrove loss globally, with shrimp farming being responsible for 38% of mangrove deforestation (Valiela et al. 2001). The main areas impacted around the world are Asia and the Americas, mainly because there is a very low development of aquaculture in Africa. Other factors responsible for mangrove forest decline include industrial timber and wood-cutting, freshwater diversion, reclamation of land for other uses, herbicide impacts, agriculture, salt ponds and other coastal development (Valiela et al. 2001). The range of reported costs for mangrove restoration is US$225 to US$216 000 ha^{-1}, but not including the cost of the land itself (Lewis 2005), and again these cost numbers are very difficult to verify.

If the loss of mangroves worldwide is around 20%, the decline is similar or worse in Senegal, West Africa, as mangrove areas decreased from 2 300 km^2 in 1990 to 1 760 km^2 in 2008 (UNEP 2007). Between 1972 and 1986, the decline of mangroves in the Saloum Delta has been estimated at 34.8%, but it was especially bad in the northern part of the delta, which is hypersaline. For example, the reduction of mangrove cover between Foundiougne and Kaolack cities was estimated to be more than 25% (Andrieu and Méring 2007). Since then a moderate recovery of the mangroves started between 1986 and 2011, and was confirmed by Dieye et al. (2013). The rainfall deficit and the drought in the area over the past 50 years (Pages and Citeau 1990) was the primary cause for the degradation of mangroves. Ndour (2005) and Sakho (2011), however, refined this analysis by taking into account the impacts of sedimentation, erosion and submersion level of mudflats in the Saloum.

Intensive logging of mangroves is the second degradation factor commonly cited. They are used for construction, especially firewood and charcoal for fish smoking and domestic needs. According to Pirard and L'Hoir (2002), the current exploitation of mangrove wood is greater than the average productivity of *Rhizophora* spp. in the Saloum, threatening to end the wood stock of mangroves, estimated at 660 km^2 of mangrove. Cutting the *Rhizophora* roots for picking oysters is also a commonly mentioned factor for the degradation of mangroves. In Casamance, southern Senegal, 670 km^2 of the ecosystem disappeared between 1972 and 2010 (Dieye et al. 2013). The same factors of degradation highlighted in the Saloum Delta have been put forward in Casamance. First, the drought in the area has generated a hypersalinisation of the Casamance River, with salinities of up to 170 g l^{-1} in the Middle Casamance in the 1980s (Le Reste et al. 1986). Secondly, the conversion of the mangroves for rice cultivation or mismanagement in some Casamance areas contributed to mangrove loss (El Hadj Balla Dieye and colleagues, University of Ziguinchor, Senegal, unpublished data).

Incentives to stop degradation

Preserving mangroves is cheaper than restoring them. For instance, in Thailand the cost of mangrove restoration is currently about US$946 ha^{-1}, while the cost of protecting existing mangrove habitats is only US$189 ha^{-1} (Lewis 2005). A quantification of integrated services could also be undertaken to evaluate the restoration effectiveness, as it has been calculated recently for mangroves included in marine protected areas (Sala et al. 2013): economic valuation shows that mangroves can yield up to US$37 500 ha^{-1} y^{-1} as nurseries for adjacent fisheries, while conversion to shrimp farming yields only US$1 220 ha^{-1} y^{-1}.

Measures for protecting mangroves, or for sanctuary and heritage building, are varied (Cormier-Salem 2014b): as early as the 1970s, mangrove areas have been listed as Ramsar sites because they were considered as wetlands of international importance. Some emblematic species such as migratory birds were then protected thanks to CITES and the IUCN Red List. In Senegal, the Saloum Delta became a national park in 1976, then a biosphere reserve in 1981, and finally a UNESCO World Heritage site in 2011. This

characterisation as protected area was accompanied by the restriction of access rights and uses, even with the strict prohibition of some activities, such as timber collection. Other incentives have been undertaken by the IUCN as the sensitisation of the population for sustainable uses of the mangrove, *tanne* or salt flats restoration, and biodiversity valorisation through tourism and ecotourism, and qualification of localised products (Sarr et al. 2011). Nevertheless, in Senegal, reforestation campaigns predominated in the past decade. The primary goal of such policies is carbon sequestration, through REDD+, but their ecological, social and economic relevance can be called into question.

The Senegalese mangroves: a cultural landscape, a controversial heritage

The Lower Casamance and Saloum Delta coastal wetlands are made up of a multitude of mangrove-fringed channels and flats subjected to the tides. Six species of mangrove have been identified here: *Rhizophora racemosa*, *Rhizophora mangle*, *Rhizophora harisonnii*, *Avicennia germinans*, *Conocarpus erectus* and *Laguncularia racemosa* (Ndour 2005). The *tannes* – hypersalted, barren and sterile surfaces – extend between and behind the mangroves (Cormier-Salem 1999). During the Sahelian drought in the 1970s, 1980s and 1990s, salinisation and acidification, combined with over-exploitation for poles and fuel-wood and mismanagement (bridges, roads, dams, etc.), caused an expansion of the *tannes*, often at the expense of mangrove forests (Cormier-Salem 1999; EHB Dieye et al. unpublished data). Since the 2000s, because of a more favourable rainfall regime and better governance, mangrove forest areas are expanding (Andrieu and Méring 2007; Conchedda et al. 2011; EHB Dieye et al. unpublished data). However, the gains are not uniformly distributed. There have been losses in some islands and inner parts of those two estuaries, areas more exposed to coastal erosion or salinisation, as well as a decrease of the quality of the forests in terms of species diversity, height, density and productivity, undermining the capacity of mangrove forests to provide key ecosystem goods and services (Conchedda et al. 2011).

In previous publications (Cormier-Salem 1992, 1999, 2006), we reported the changes in perception, uses and governance of Senegalese mangrove socio-ecosystems, and highlighted the particular interrelations between the Senegalese peasant-fishermen and the mangroves. Coastal wetlands of the 'Southern Rivers', from Senegal to Sierra Leone, form an ecological and socio-cultural continuum, a cultural landscape, characterised by the conversion of mangrove swamps into rice cultivation, attested by the Portuguese navigators at least since the 15th century. Mangrove resources are the basis of a multiple-use system controlled by the local peoples. Women are engaged in rice cultivation, gathering of cockles and oysters, extraction of salt, tannins and medicines, while men are engaged in fishing, rice cultivation, collection of honey and harvesting of poles and fuel wood. The access and use rights to mangrove resources are clearly defined by customs, managed by traditional institutions, known and transmitted from one generation to another. Mangrove socio-ecosystems, from rice fields to mudflats, forests, channels or *bolongs* and rivers, are part of their marine communal territories.

The changing legal status of the Senegalese mangroves is a key question, leading to territorial claims and conflicts (Cormier-Salem 2006): in the Lower Casamance and Saloum Delta, mangroves have long been communal territories, used, managed and owned by local peoples. With the 'white' penetration and colonisation, then independence, ownership of non-managed or non-permanently exploited flats and wetlands has been transferred into the national domain. Since then, under the umbrella of political decentralisation, a plethora of laws and rules, negotiated between rural communities (traditional land owners) and government institutions, have emerged: for instance, some mangroves in the Saloum Delta are public goods (national park), some biosphere reserve and world heritage (UNESCO), and others remain communal goods ruled by local conventions. Finally, some are private goods owned by local actors, but increasingly also, by foreigners such as tourist operators and private entrepreneurs. With the recent initiatives of mangrove rehabilitation, restoration and reforestation, the question of enclosure and privatisation appears to be on the rise.

Results

The first reforestation actions started in Senegal in the 1980s because local communities were very sensitive to mangrove degradation in some areas (Cormier-Salem 1992). They developed a few reforestation plans through voluntary initiatives, with a bottom-up control, on a small scale, based on empirical knowledge, with or without the help of scientists, public agencies or small NGOs (WAAME, West African Association for Marine Environment; NCD, Nature Conservation Développement, etc.). Since the 2000s, large-scale reforestation campaigns have been initiated and operated by NGOs which were active in Senegal (e.g. IUCN, Oceanium), and were sustained by private companies such as Danone and Yves Rocher. Since 2009, €4 million have been funded by the Danone company, the Insolite Batisseurs Foundation, and then by the Carbon Livelihoods Venture Fund, for mangrove reforestation in Senegal.

The Oceanium NGO is a Senegalese association which actively fights against environmental damage. The 'Plant your tree' programme conducted by Oceanium has been implemented in the two largest estuaries of the country. It was supposed to be 'a unique example of mangrove ecosystem large-scale participative restoration' (Guillaume Durin, Oceanium, pers. comm.). However, sensitisation of the local communities on reforestation actions was carried out without co-sharing guidelines, i.e. without consulting the population, nor using a participatory approach, but rather with norms imposed by private companies, and remuneration of the actors involved in the field.

After these large campaigns, results put forward by Oceanium and the media were spectacular: between 2006 and 2013, 14 000 ha of mangrove forest were replanted (10% in the Saloum Delta and 90% in Lower Casamance). More than 300 000 villagers have been involved. According to a manager of this project (G Durin, pers. comm.), the approach was based on three major principles:

- 'Sensitisation': Oceanium actions under the direction of Haidar El Ali were different from previous reforestation programmes. The main aim was to communicate and educate the largest number of inhabitants, and to favour a quantitative approach. The guiding spirit was militant and was communicated by social or popular ecology speakers. Movies, focused on environmental education, were also shown in villages during the programme.
- Guidelines: Villagers were employed to gather mangrove tree seeds (propagules), to deliver them to targeted areas and to replant them in the muddy soil along equidistant lines.
- Remuneration: For a bag of 50 kg of propagules, the collector was paid between US$2 and US$3.2. Remuneration was supposed to be limited to a total of US$418 per family, with a maximum of 100 bags per family. One reforested hectare was remunerated at a rate of US$15.

One other Senegalese NGO, WAAME, was also involved in the Saloum mangrove plantation, and based its action on the voluntary nature of collecting seeds. Meanwhile, Oceanium introduced a competitive relationship between the reforestation activities that biased participant motivation. Importantly, the form of remuneration directly encouraged quantity over quality. For example, unripe propagules were transported and planted, thus jeopardising the success of reforestation. Finally, targeted areas were chosen according to their accessibility and visibility for advertising, which meant that they were along the major roads, but possibly not in the most favourable areas for growth success (Figure 2).

Discussion

The 'Plant your tree' programme was the first to be registered with the UNFCCC (United Nations Framework Conventions on Climate Change) in agroforestry. The monitoring targeted the amount of carbon sequestered by the project through a specific process defined by the 'Clean Development Mechanism and Voluntary Carbon Standard'. At the end of this process the project was supposed to issue 'carbon' credits, issued by Oceanium through the Livelihoods Fund, and which could be sold on the market. The first credits of the 2008–2012 programmes were expected in late 2014 but, to date, no credit has been allocated. The sponsorship of €4 million by Danone, and the background livelihoods, were linked to the process of carbon offsetting, which becomes ineffective when mangrove plants do not grow. Danone did not continue this reforestation programme because it considered that it was not a success in terms of carbon sequestration, and preferred investing in countries with more opportunities (or facilities) to replant mangrove forests (G Durin, pers. comm.). The effects of carbon sequestration on biodiversity and on socio-economic outputs remain unclear after the end of these programmes.

Effects in terms of carbon sequestration

Regarding the carbon offsets linked to reforestation, and according to a study in Dassilamé-Serere (Ndour et al. 2011), carbon sequestration makes little sense since it depends on the level of growth of mangroves and their plant productivity. In addition, the roots and stems seem to provide greater carbon sequestration than the leaves. The size and the density of the mangrove are important factors (Ndour et al. 2011). The location of the replanting plots can also be a factor because mangroves need an area with a dynamic water regime and clay sediment, with a grain size of less than 40 µm (O Rüe, Groupe de Recherche et Réalisation pour le Développement Rural [GRDR], pers. comm.). Determinants for successful reforestation are then not only the salinity level, but also the tides.

The capacity of the mangrove to store carbon, in comparison with other ecosystems, is estimated to be very high (Bouillon et al. 2008). The net primary production of the mangrove is estimated between 218 billion tonnes (Bouillon et al. 2008) and 6.5 billion tonnes (Siikamäki et al. 2012) of carbon y^{-1}. Teams from Davis University, California, and the 'Resources for the Future' estimated the total carbon sequestered by mangroves globally (forest biomass and soil) at 6.5 billion tonnes, even when they only constitute 0.7% of the 140 000 km² of global tropical forests (Giri et al. 2011; Siikamäki et al. 2012). In the Saloum Delta, 1 936 tonnes of carbon were estimated to have been sequestered in two years (Ndour et al. 2011). The huge variability in the estimates shows that there is a lack of scientific data about carbon sequestration by mangroves. Besides, according to the criteria for defining a forest in Senegal – the height, the density and the surface area colonised by trees – these plantations are 'patches' or 'groves', rather than 'forests'. To circumvent this the private companies succeeded in changing the legal definition of Senegalese forests, so that in 2012 the accredited designated operational entity, Ernst & Young, certified that the project met all relevant UNFCCC requirements for the Clean Development Mechanism (CDM) (http://cdm.unfccc.int/DNA/index.html). Countries may submit their own national standards. Senegal has defined new criteria: the minimum tree cover changed from 30% to 10%, the minimum area from 1 ha to 0.05 ha and the minimum tree height from 5 m to 2 m (Ernst & Young 2012).

There are differences between replanted and recolonised areas, which have unequal success rates, and these differences have not always been distinguished. The reforestation of mangroves suffers from a substantial mortality rate. The causes can be diverse, including both physical and chemical, or purely biological or socio-economic, factors. The method of reforestation is also in question: e.g. planting of propagules or transplanting seedlings germinated in nurseries. After a phase of colonisation, root density decreases naturally until mortality (Jimenez and Lugo 1985). There is still a debate on the legitimacy of mangrove reforestation worldwide, especially in Senegal (Ndour et al. 2011). Regarding the factors behind the success or failure of plantations, many factors can be involved: the species reforested and the type of seed produced, the type of mudflat reforested (its hydrosedimentary characteristics), the frequency and height of flooding, the degree of occurrence of parasites and predators of young plants, the duration of exposure to the sun, the turbidity of estuarine waters and/or silt mudflats, the level of salinity related to rainfall (abundance, drought or rainfall deficit), and the spacing of plants. In this latter respect, for example, Ndour et al. (2011) found that high density did not significantly affect plant mortality.

Figure 2: Example of unsuccessful reforestation in the Saloum Delta in 2013 (photo: MC Cormier-Salem)

Effects on biological diversity

The choice of monospecific replanting with *Rhizophora mangle* in Senegal is questionable. It was favoured because it is easier to replant than other species. For example, for *Avicennia* sp., it is necessary to sow the seeds in tree nurseries to ensure the first growth, and then to transplant them to definitive sites. The process is longer and more risky, with more failure. However, *Avicennia* is more resistant to salt and can live in an anoxic environment. There is a need to adapt the choice of replanted species to the function of the targeted sites. A constraint for the diversity of the reforestation can also be financial, as highlighted by the Oceanium action: low financial support for the reforestation with other mangrove species can be a major constraint. Line shape transplanting has also been criticised, because it is considered as too tight and not allowing good subsequent growth of the plant.

Effects of tree reforestation* per se *versus mangrove 'natural' regeneration

The plantation campaigns probably accelerate the process of regeneration, but do not have a 'positive' effect on biological diversity *per se*. The main issue is that there were no pre- or post-scientific studies recording the changes in terms of either biodiversity (variety and richness of species, site and habitat status) or cultural diversity (techniques and practices), or on the trade-off between services. Moreover, reforestation leads to spatial competition with birds at the level of shoals and mudflats, which are feeding and resting sites, and with shellfish harvesting (areas of picking, gathering for women), which are covered by trees after reforestation.

One of the subsequent questions is the impact of overall carbon sequestration on specific services, compared to other bio-ecological and socio-cultural services. In other words, is carbon sequestration more important than biodiversity, or the availability of fish in the mangroves, or ecotourism? Instead, mangrove desalinisation action may be a better strategy to reduce the expansion of *tannes*, to protect and sometimes to rehabilitate rice fields (Scholander 1968; Cormier-Salem 1994). In the Tobor rural community, Casamance, where a reforestation programme was initiated in 2006, 30% of the rice fields that were lost have now recovered. People also reported that there are more fish, oysters and cockles at present (Sane and Dieye 2012), but it is questionable if these observations were linked to mangrove reforestation, to 'natural' mangrove regeneration, or to more favourable rainfall conditions. There is still a lack of data on impacts of reforestation on fish, crustacean and waterfowl populations and communities.

Effects on socio-cultural diversity

There is also a lack of monitoring of the impacts on the local population in reforestation areas. There have been no scientific studies on how the reforested mudflats have reduced access for shellfish collection or for fisheries. The impact on adjacent or contiguous ecosystems related to the replanted sites is even less well understood, and has, in fact, been neglected.

The processes linked to mangrove reforestation completely leave aside the question of the long-term status of replanted mangroves. For at least 30 years (the duration of REDD+ contracts), the private companies have controlled the reforested mudflats (Ernst & Young 2012). The reforested plots have been privatised to the detriment of the 'commoners' (Ostrom et al. 2002), i.e. the local people who used to be the traditional users and owners of these territories, but also to the detriment of the public institutions: in Senegal, as mentioned above, mangroves are part of the public domain. They are national public goods, over which the Senegalese State is sovereign. Furthermore, the Senegalese State is responsible of their conservation as world heritage (Cormier-Salem 2006).

Figure 3: Poster campaign of one candidate to the Senegalese presidency in 2012 (photo: MC Cormier-Salem)

The trade-off between services is a major issue that has been insufficiently studied. For example, shellfish gathering (Saloum Delta), small-scale aquaculture and fisheries could be negatively affected resulting in environmental injustice (Schlosberg 2007), as could the limitation of alternatives such as rice cultivation. Who are the ultimate beneficiaries of the reforestation? Are they the traditional users, the public institutions or the private companies? The boundaries between green washing and land grabbing seem unclear, to say the least.

Lessons learned from the Senegalese case studies

At first it appeared that, even although the reforestation campaigns were generally considered successful in terms of planted surface areas and international visibility, because of the fundamental difference between simply planting and succeeding in establishing a functional and productive mangrove, the results were poor in terms of carbon sequestration and in terms of effects on biological and socio-cultural diversity. There was also a lack of follow-up surveys to assess the biological impact of the reforestation campaigns. Without accompanying studies, data on possible positive synergies are lacking. In principle, reforestation has had a positive impact on overall biological diversity. For example, fishermen attest that where there are mangroves there are more fish. There were probably positive impacts on sedimentation and the prevention of coastal erosion and salinisation. However, local stakeholders felt that the natural systems, characterised by a diversity of mangrove species, had been negatively affected by the plantations. People also regretted the lack of prior consultation: the so-called participatory approach was limited to financial incentives (payment for the collection of propagules, for example) as well as the lack of recognition of their knowledge, practices and logic. Women, in particular, complained about the expansion of these plantations into areas traditionally used for collecting shellfish. Similarly, the forestry services of the Senegalese government felt ignored, in spite of the fact that they have been – and still are – very involved in the long-term conservation and restoration of the mangroves in the Saloum Delta.

Indeed, the policies favouring a single service (in this case, carbon sequestration) or a compartment of this ecotone (here, the mangroves), or a species (here *Rhizophora mangle* propagules) on the basis of the comparative simplicity of propagule collection and planting, possibly led to negative synergies between services, and induced environmental injustice. Yet alternatives for livelihood improvement exist. Our research laboratory, for example, supports local initiatives fostering the heritage of the Niominka people, indigenous to the Saloum Delta, such as labelling of localised products (honey, nuts, shellfish, etc.) and the establishment of ecotourism trails and open-air museums. We have supported an inventory of heritage objects and the mapping of key heritage sites, such as old and new shell middens.

Finally, we argue that the extensive planting of a single mangrove species, *Rhizophora mangle*, is a means of green grabbing. The buying of carbon offsets by industrial conglomerates has disempowered local communities: carbon trade prices have dropped dramatically from their peak in mid 2008. According to Aubertin (2015) the carbon market is a fiction. Its purpose is more political – to get power – than financial. Thus, in Senegal, when the reforestation actions coincided with the 2012 presidential election campaigns, they were used by some politicians to influence public opinion (Figure 3).

Conclusion: towards an integrative approach of mangrove services trade-off

From our first results, the reforestation campaigns appeared more or less successful, in terms of replanted surfaces and international visibility, but poor in terms of biological

and socio-cultural diversity and they curtailed development options. The transfer of ownership and control to private companies, from previously open-access areas for traditional livelihood activities, led to environmental injustice (Beymer-Farris and Bassett 2012).

We argue that extensive planting of a single mangrove species, *Rhizophora mangle*, is a means of green grabbing (Fairhead et al. 2013). Carbon sequestration is a pretext simultaneously (i) to disempower the local communities and to have power over them (the coinciding reforestation and election campaigns in 2012 testify to such political diversions and instrumentalisation), and (ii) to empower private enterprises for the purchase of carbon offsets. REDD+ initiatives opened up opportunities for 'mangrove grabbing'. As an analogy to land-, green- or ocean-grabbing (Bennett et al. 2015), it refers to the dispossession or appropriation of use or control of, or access to, mangrove resources and lands by traditional users, territorial use rights holders and inhabitants. Inappropriate governance processes undermine local livelihoods and produce impacts that threaten socio-ecological well-being. As advocated by Leach and Scoones (2013), clear monitoring, review and verification systems must be in place to avoid fraud and diversion, and ultimately to ensure that carbon is not released, and climate change mitigation actually occurs.

Finally, we plead for the development and implementation of methods that take into account all the services (or values) derived from mangroves, and not only carbon storage, integrating dynamic interactions, their effects in terms of amenities and the well-being for human populations. The challenges are both scientific and ethical: mangrove services cannot be readily replaced, restored or sustained without extensive knowledge of the dynamics and multi-functionality of, and connectivity between, ecosystems (Moberg and Rönnbäck 2003). More integrated research programmes must be developed towards this goal.

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