Rapid assessment
Valuing four community reforestation projects by IED Afrique in the region of Kaffrine, Senegal

Executive summary

Forests provide variety of environmental services that contribute to household welfare and livelihoods. But there are widespread misconceptions about the importance of wild resources, as sources of income and safety nets to poor households. This stems from a lack of basic data on the true contribution of ecosystems to rural households. In this study we make a first attempt to quantify the local economic returns to four reforestation projects, led by the NGO IED Afrique in the region of Kaffrine, Senegal. In doing so, we account for the value of energy, food, construction materials, forage and other Non Timber Forest Products (NTFPs) to subsistence or cash uses over a 15-year period. We find that the present value benefits are in the order of FCFA 56 million, of which the sustainable provision of fuelwood account for 42%, construction timber for 32%, livestock forage for 2% and other NTFPs (cashew nuts, gum arabic and medicinal plants) for another 24%. The reforestation activities also contribute to carbon sequestration, worth some FCFA 2 billion over 15 years in terms of avoided global damages. On the whole, the size and magnitude of the direct benefits to the local population outweigh project implementation costs, resulting in a Net Present Value benefit of FCFA 6.7 million. This is a noteworthy finding, especially considering that IED's reforestation projects are also affecting key hydrological processes and soil functions - that has not been quantified here – and which are of value to local populations.

Table of contents

1. Introduction 2
The importance of wild resources to rural livelihoods 2
Study sites 3
2. Methodolgy 5
The CBA decision criteria 5
Estimating benefits from enhanced carbon sequestration 6
Social cost of carbon 7
Estimation of benefits from fuelwood collection 7
3. Tree-by-tree data inputs 7
Acacia senegalensis 7
Acacia Seyal 8
Acacia Nilotica 9
Anacardium Occidentale 9
Sterculia Setigera 10
Bombax Costatum 11
Eucalyptus Camaldulensis 11
Prosopis Juliflora 12
Project Costs 12
4. Results 12
The value of environmental income 13
The value of carbon sequestration 14
Net present value benefit of IED project interventions in Kaffrine 14
5. Caveats and perspectives 16
6. Conclusion 17
References 18
Appendices 24

1. Introduction

Croplands, pastures, plantations and urban areas have strongly expanded in Senegal in the recent 20 years, especially in groundnut production areas and in the arid and semi-arid subhumid zones of the country (Bakoum et al., 2012; Paeth, 2006). Cropland extension has replaced mainly grass, shrub and forestland — a change that amounts to land degradation due to the low ecosystem value of crops compared to their former states (Nkonya et al. 2015). Sow et al., (2015), estimates the cost of land degradation due to Land Use and Cover Change (LUCC) in Senegal to be about USD 0.41 billion or about 4 % of the GDP.

In addition to land degradation arising from LUC, Senegal also faces increasing vulnerability to climate extreemes, such as floods and droughts. Moreover, the downstream position of several of Senegal's large rivers and its largely flat topography[1], leads to poor drainage and problems of soil salinity. It is estimated that 645,000 ha of land is affected by salinity (DPS 2004). This is about 6.8 % of 9.5 million ha agricultural land (World Bank 2012).

Responding to the need to plan for and adapt to climate variability, the Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED) programme, led by IIED, IED Afrique and the NEF consortium, has worked to incorporate climate variability in development planning in Mali and Senegal. This is done recognizing that local communities are best placed to decide which climate change investments will strengthen their resilience, while building upon an ongoing decentralization process in both Mali and Senegal through decentralized climate funds (DCF). The close collaboration between local government structures and communities ensures that decision-making and access to the funds is in the hands of those most directly affected and most able to identify strategies for building local resilience (IIED blog)

In Senegal, IED Afrique has implemented a large number of projects to increase climate resilience and amongst these, the restoration and the rehabilitation of ecosystems[2], based on a mixture of native and exotic species (Dietta et al., 2007; NEF, IIED and IED Afrique 2014). The following study focuses on these interventions, with a view to valuing their societal net-benefits.

The importance of wild resources to rural livelihoods

While reforestation and restoration efforts can repair damaged ecosystem functions and combat land degradation, wild habitats such as natural forests, woodlands, wetlands, rivers and grasslands can also be of direct value to rural households, providing energy, food, construction materials and medicines both for subsistence and cash uses (see e.g. Sunderlin *et al.*, 2005, Pouliot, M. & Treue, T. 2013, Angelsen et al., 2014). These natural endowments, if managed efficiently, can provide a capital base—a foundation for greater economic viability, and a stepping-stone beyond mere subsistence (WRI 2005).

Chao (2012) estimate that as much as 90% of those who live in extreme rural poverty are to some degree reliant on forests for their livelihoods. In a global meta-study synthesizing 54 case studies, Vedeld et al. (2007) estimated that forests income contribute an average of 22% of

[1] Average altitude is less than 50 m above sea level

[2] The society for ecological restoration defines restoration as « the intentional alteration of a site to establish a defined indigenous, historic ecosystem » and rehabilitation as « the repair of damaged or blocked ecosystem function with the primary goal of raising ecosystem productivity for the benefit of local people » (Aronson et al., 1993). IED's reforestation projects serve both purposes.

total household income, while CIFOR's Poverty and Environment Network (PEN) suggests that environmental income contributes 28 percent of total income to households in or near forests - a figure that was only marginally lower than that of crop income (Angelsen et al., 2014).

There is thus increasing evidence that wild resources are a critical element of poor people's livelihood strategies. Regrettably however, the importance of natural ecosystems and non-cultivated habitats to household wellbeing is a poorly understood area in international development and conservation planning. As the research for this paper has proven, data on wild products and rural communities' reliance on nature is very limited. For example, use of forest products is rarely not captured through household surveys undertaken by National Statistical Offices (such as the World Banks LSMS, Surveys on living conditions and integrated household surveys) and at the macro level, data on the contribution of forestry to gross domestic product is often aggregated with agriculture and fishing because 'data on forestry' are sparse.

With scarce data on the quantified dependence on nature and few systematic analyses to adequately guide policy, nature has been is undermined in respectively development planning and poverty prescriptions. This leads to misguided and inequitable land management policies that undermine the importance of natural resources as income sources and safety-net to rural households (FAO, CIFOR, International Forestry Resources and Institutions (IFRI) and World Bank. 2016).

To address this situation and contribute to an enhanced understanding of the real value of forest rehabilitation and restoration, the following study is an economic valuation of 4 reforestation projects, led by IED Afrique, in the region of Kaffrine in Senegal. We estimate the additional forest income that may be derived from products that can be harvested and collected, including timber, NTFPs (gum arabic, medicinal plants, cashew nuts) and livestock fodder to local communities.

IED Afrique

IED Afrique is an independent, non-profit organization, based in Senegal, which capitalizes about fifteen years of experience in Francophone West Africa. It promotes sustainable development and improved livelihoods in Africa, by using participatory processes and innovative novel research and development methods (http://www.iedafrique.org/-IED-Afrique-.html)

Study sites

In the following we briefly outline the main features of the four main reforestation projects undertaken as part of a series of Decentralised Climate Funds (DCF) under the BRACED programme by IED Afrique. All projects started in 2016 or 2017 and cover a total of 81.5 hectares (table 1).

1. "Dimal" Création of fuelwood in the villages of the valley of Dimal, Gama, Ngordjilene Mouride and Korky Bambara, located in the borough of Keur Mbouki and the department of Birkilane.

The villages of Dimal, Gama, Ngordjilen, Mouride and Korky Bambara have a strong agricultural orientation. Main crops grown include cashew, la pastèque, beans, millet, corn and cotton. The villages also have a rich and varied parkland including pastoral zones and 'pistes'. However, the parkland is subject to a progressive degradation due to a significant exploitation of forest resources. Moreover, parts of Diamal, touches the coastal inlet and are therefore exposed to salt water intrusion. Soil salination is halted by thorny shrubs such as *le sidem, le soump et le*

neb neb that are heavily exploited by the local population. The project aims to attenuate pressures on this vegetation through the planting and densification of fast growing tree species such as *Ecaluptus amaldilensis* and *Prosopis juliflora*. *Ecaluptus camaldilensis* and *Prosopis juliflora* may be sustainably used by the local population for domestic use and sale of fuelwood and construction poles. The project is implemented over 30 hectares, with the aim of ensuring the replanting and protecting some 30'000 plants.

2. "Mbeuleup" The restoration and the conservation of the community forest of Mbeuleup in the region of Kaffrine.

With the aim of combating continuous degradation the main interventions consist of enriching an existing 30 hectares forestland with rare and endemic tree species (Acacia Senegal, Acacia Seyal, Anacardium Occident) and exotic species such as Ecaluptus camaldilensis and Prosopis juliflora, alongside with the development of a tree nursery and education on reforestation techniques. The municipality of Mbeuleup has 8405 inhabitants. The main beneficiaries are 5 neighbouring villages, counting approximately 5000 inhabitants.

3. "Keur M'boucki" Reforestation and restoration of the banks of the tributary of the Saloum Inlet in the commune of Keur M'bouck

The municipality of Keur M'boucki is affected by salination, deforestation, abandonment of fallow periods, combined with limited availability of agricultural inputs and use of manure, as most of the pastoral activity in the area is characterized by transhumance (no settlement). In order to address this situation, *IED Afrique* and the municipality has begun a project to reforest and restore the banks of the tributary of the Saloum inlet over a 14 km distance. This corresponds to some 14 hectares of land, assuming that the banks are 10 meters broad. The purpose is to fight against wind erosion and salination through reforestation and bank restoration and to protect the reforested banks against bush fire.

4. "Kahi" Restoration of the classified forest of Kaffrine

Implemented in the municipality of Kahi in Kaffrine, the project involves the restoration of 12.5 hectares of forestland to enhance availability of NTFP and deadwood used for fuelwood. The main beneficiaries are 60 members of the "association des femmes forestières de Kaffrine" and the surrounding villages, counting a total population of 6000. 15 km of wildfire protection corridors have also been established.

Table 1: Summary of tree species used in IED's restoration interventions and accounted for in the valuation study

	Creation de bois de Village, 'Dimal'	**Restoration and conservation of the community forest of 'Mbeuleup'**	**Reforestation and restoration of the banks of the tributary of the Saloum Inlet 'Keur M'Boucki'**	**Restoration of the classified forest of Kaffrine 'Kahi'**	**Total hectares**
Hectares per project	**30**	**25**	**14**	**12.5**	**81.5**
	Share	**Share**	**Share**	**Share**	
Anacardium Occident	0.05	0.3	0	0.1	10.25
A. Senegal	0.05	0.25	0.2	0.2	13.05
A. Seyal	0	0.05	0.4	0.2	9.35
Eucalyptus Camaldilensis	0.3	0.2	0	0.2	16.5
Prosopis *juliflora*	0.6	0.1	0.4	0	26.1
Others, distributed as followed (author's own assumption)					
Sterculia setigera	0	0.03	0	0	0.75
Bombax costatum	0	0.03	0	0.2	3.5
A. Nilotica	0	0.04	0	0.1	2.25

2. Methodolgy

Rural households make use of a variety of sources of income and subsistence activities to make their livings. Many of these are directly based on nature—such as fishing, hunting, and collecting of firewood, herbs, or other natural products. These may be sold for cash or used directly for food, heat, building materials, or innumerable other household needs.

This "environmental income" may be boosted through the restoration of natural ecosystems. In the Kaffrine region of Senegal, IED Afrique has used a range of tree species in their reforestation efforts. Each of these species has unique properties. In valuing the net-benefit from the reforestation activities, we thus take a tree-by-tree approach. This makes sense in the context of the study, which focuses on the provisioning ecosystem services generated by the reforestation projects, in addition to the sequestration of carbon.

The CBA decision criteria

In Cost Benefit Analysis, benefits and costs are expressed in monetary terms and are adjusted for the time value of money. The Net Present Value (NPV) is known as a reliable decision criterion in CBAs and less vulnerable to generate ambiguous results compared to other criteria (Olschewski, 2006). To derive the **NPV** of a project intervention, costs are subtracted from benefits for every year and discounted to reflect the net-benefits in present value terms. These are then summed for the whole time horizon (T) that is being evaluated (equation 1).

$$\text{Equation 1} \qquad \text{NPV} = \sum_{t=0}^{T} (B_t - C_t)/(1+r)^t$$

Where, B_t = benefit at time t (in FCFA or FCFA/ha), C_t is the cost at time t, r is the real discount rate, and t (0, 1, 2,… to 20), is the project duration T in years[3]. In general, policy initiatives with positive *net present value* should be considered; the greater the *net present value*, the more justifiable the initiative.

The analysis employ a time horizon (T) of 15 years, as this is a sufficiently long period for ecosystem service benefit to materialise, but also sufficiently short to mitigate significant uncertainties around changing market conditions, etc. We assume a modest discount rate ® of 2%, to account for the fact that inflation has not been factored in the cash flow and assuming that the IED restoration activities have been financed at low lending rates.

Costs in equation 1, refer to the project implementation and management costs incurred by IED Afrique. Quantified monetary **benefits** include enhanced carbon sequestration and additional forest products that can be harvested, consumed or sold by local populations as a result of the restoration interventions. The economic value of this environmental income is calculated following equation 2:

[3] Sensitivity analysis may be conducted to determine the impacts of changes in the discount rate, costs, climatic variables and output prices, on NPV. But this is outside the scope of this assessment.

Equation 2 $$\text{Environmental income} = \sum_{i=1}^{n}(p_i q_i) - \sum_{j=1}^{m}(p_j x_j)$$

Where environmental income is given by the revenue (price p times quantities q of all *n* products harvested) less total variable costs (price times quantities of all *m* purchased inputs) employed to collect or harvest the products. Variable costs are assumed to be negligible in this analysis, as we do not have access to data on them. Information on prices and quantities of harvested forest products, have been obtained from secondary literature and a semi-formal interview with Mr Bocar Sall from the Senegalese department for the management and planning of water resources (Sall 2017). Information on the costs of restoration interventions has been obtained from IED's Afrique project documents. All data and assumptions are explained in chapter 3.

Estimating benefits from enhanced carbon sequestration

The Agriculture, Forestry and Other Land Use (AFOLU) sector is responsible for approximately a quarter of total greenhouse gas (GHG) emissions (Smith et al., 2014). At the same time, the AFOULU sector offers considerable carbon mitigation potential from soil carbon sequestration and the avoidance of new emissions sources from fires.

Estimates from carbon sequestration are calculated for each tree species reforested or regenerated using a combination of IPCC Tier 1 and 2 methodology[4] from the Good Practice Guidelines (IPCC, 2003). Total carbon sequestration resulting from a particular land use is calculated as the aggregate of above ground and below ground carbon stocks, following equation 3 to 5.

Equation 3. $G_W = MAI \bullet D$
Equation 4. $G_{TOTAL} = G_W \bullet (1 + R)$
Equation 5. $\Delta C_{FL} = [G^{TOTAL} \bullet (1 + R)] \bullet CF$

Where:
G_W = Average annual aboveground biomass increment in, tonnes DM/ha/yr
MAI= The mean annual increment[5] (m^3/ha/year)
ΔCFL = Average annual change in carbon stocks per hectare in living biomass in forest land, tonnes C/year
G_{TOTAL} = Average annual biomass increment above and below ground, tonnes DM/ha/year
R = Root-shoot ratio of 0.31 for woodland (obtained from Myint 2017)
CF = Is the carbon fraction (default 0.5) of tonnes C in DM
D = Basic wood density, tonnes DM/m3

Finally, the annual change in carbon stocks should be converted to units of CO_2 equivalent by multiplying it by 3.67, which is the ratio of the atomic mass of CO_2eq to C, respectively.

[4] Tier 1 uses default values of the average annual increment in aboveground biomass (GW). Tier 2 method uses country specific data to calculate the gross mean annual biomass increment. The country-specific data is often linked to merchantable volumes, data on biomass expansion factor and basic wood density.
[5] The MAI (Mean Annual Increment) is the volume of wood growing on one hectare of forest during one year (m^3/ha/year) on average since the forest has been established. For a tree plantation, the MAI is the present total growing stock volume of one hectare divided by the total age.

Social cost of carbon

The benefits from the mitigation of green house gasses are usually valued using the social cost of carbon. The social cost of carbon (SCC) estimates the discounted value of the damage associated with climate change impacts that would be avoided by reducing carbon dioxide (CO_2) emissions by one metric ton in a given year (Anthoff et al., 2009). These damages include decreased agricultural productivity, damage from rising sea levels, and harm to human health. We use USD 37 (FCFA 23'000) as an approximation of the Social Cost of Carbon from EPA (2013) on the basis of damage estimates from DICE, FUND, and PAGE integrated assessment models. Recent studies however, suggest that USD 37 is a very conservative estimate of the SCC, e.g. Moore et Diaz (2015) who argues for using a SCC of USD 220/tonne CO_2equivalent.

Estimation of benefits from fuelwood collection

With the exception of projects (in Dimal and Keur M'Boucki) where fast growing timber species, E. Camaldilensis and P. Juriflora are introduced, we assume that firewood collected in the reforested areas is restricted to deadwood, so as to ensure the sustainable forest management of the reforestation efforts.

In practice however it is also feasible to prune trees for additional fuelwood, although this would typically compromise the availability of NTFPs. Thus, to avoid double counting, it is only the contribution of deadwood to household income that is accounted for, for all but the 2 exotic timber species considered in this analysis.

To estimate the quantity of deadwood collected by local population, we follow IPCC (2003) guidelines, assuming that deadwood corresponds to 11% of total available woody biomass. As woody biomass is a readily marketable product, we use the farmgate market price of fuelwood to estimate its value (using equation 2). We assume that fuelwood sells for 3.6 FCFA/kg (similar to the fuelwood price in Benin (from Westerberg et al., 2017).

3. Tree-by-tree data inputs

The following chapter investigates the provisioning services provided by each trees species that have been favored by IED Afrique's interventions. Since only secondary literature has been used, estimates are subject to uncertainty and does not account for all the locally appreciated benefits that the interventions may be yielding. As explained above, we use a tree-by-tree approach. The net-benefit of a given project is therefore a function of the area occupied by each species and their respective per hectare benefits (see spreadsheet for more detail). The data and assumptions used is summarized appendix 1 and 2.

Acacia senegalensis

Acacia 7rabic7 is a wide spread, Sub-Saharan tree legume, reportedly important for the sustainability of open parkland, agroforestry and alley cropping systems in Sub-Saharan Africa (Bationo, 2007). A 7rabic7 grows in the gum belt of Africa, which stretches from Senegal in the west to Somalia in the east (CBI 2016). Its gum is internationally traded and of high quality. Gum Arabic is used in confectionary, beverages, pharmaceutical, artistic materials, printing, and pesticides. A. Senegal is also a source of fuelwood from older trees that no longer produce significant or good quality gum, and fodder for livestock.

Yields of gum Arabic

Gum Arabic yields are variable, with average yields cited between 150 g/tree (in FAO 1982) to 250 g/tree (in Boer 2002). In Harmand et al., (2012) gum production varied from 0.1 to 0.5 kg per tapped tree, corresponding to 50-250 kg/ha with a density of 500 trees/ha (Harman et al. 2012). These numbers are in alignment with Rahim et al. (2007), who has analyzed the evolution of gum yields with trees age in the Kordofan state of Sudan (table 2). Gum Arabic from cultivated trees typically increase up to the age of 15 years, where after they level off and then begin to decline after 20 years. The collection of gum starts in the 5th year after planting and continues until the 25th year. We have used experimental data from Rahim et al., (2007), to estimate potential revenues that local populations in Kaffrine may enjoy from the harvesting of gum Arabic.

Table 2: Gum Arabic yields by year

Production of gum 8rabic according to age of the tree	**Gum Arabic yield Source: Rahim et al., 2007**	**Harvest of gum Arabic per hectare (assuming 400 trees per ha).**
5th to 9th year	0.12 kg/tree	48 kg
10th to 20th year	0.4 kg/tree	160 kg
21st to 25th year	0.23 kg/tree	92 kg

Gum Arabic prices

For the purpose of valuing the benefits of enhanced *A. 8rabic8* reforestation, prices of local traders buying from collectors in Senegal have been used. In Mujawamariya and Burger (2012) prices range from 350 FCFA/kg to 900 FCFA/kg depending on the season, the region it is sold and the quality of the gum.

Wood production for fuelwood

Acacial Senegal is known to produce excellent fuelwood (Orwa et al., 2009) 5-year-old trees have been reported to have a mean annual wood volume increment of 5.4–5.9 m³ per ha per year. In gum plantations wood production is only 0.5–1 m³ per ha per year, so as not to compromise the production of gum Arabic (Boer 2002).

Protective functions (non-valued)

Appendix 2

Senegal also has a number of protective functions. The deep taproot and extensive lateral root system of the tree makes it effective in reducing runoff, increasing water infiltration, and trapping and stabilizing sediment (Barbier, 1992). Problems of downstream siltation in water reservoirs are thereby mitigated. Other ecosystem services include the fixation of atmospheric nitrogen and improved soil moisture, which contribute to restoring soil fertility and increasing crop yields in agroforestry (Ong et al., 1996, Ricome et al., 2015).

Acacia Seyal

Acacia Seyal is native to Senegal and the Sahel region as well as parts of eastern and southern Africa (Orwa, 2009a). It provides a lower quality gum than that of A. Senegal, but is a source of livestock fodder and has been cited as the preferred choice for firewood in Senegal (Kazzi, M., 2016). Acacia Seyal is moreover tolerant to flooding, fire, salty soils, and high pH soils (Orwa et al, 2009a).

Browse production

The bark from A. Seyal is extensively used for feeding cattle, sheep and goats during the dry season in Sahelian countries. When fresh, it is smooth and soft. During the dry season, thick

branches are lopped and animals browse the bark and eat the leaves. The pods and leaves are also nutritious and palatable to livestock (Orwa et al., 2009a).

Browse product is influenced by factors such as climate, soil type, management and history of exploitation by man and animals. Leave and fruit production from the Sahelian West African zone is reported in Otsyina et al, ranging from 0.7 to 3 kg DM of leaves/tree/year to 0.1 to 2.5 kg for pods. In general, fodder production from trees and shrubs differ significantly in different ecological zones and according to tree density (Otsina et al., 1999). This study assumes an average fodder yield (pods, seeds and leaves) of 5 kg/tree.

Prices for fodder from acacia trees

With no local data on prices for fodder from acacia trees, we have use estimates from Sibidé et al (2014) obtained from the market of Kona in Mali, where a bag of fodder from F. Albida weighing 15 kg, is sold at FCFA 35, equivalent to 2.3 FCFA/kg.

Seyal Gum yield and price

Seyal gum (talha gum) is darker and inferior in quality to that of A. Senegal (gum 9rabic) (Orwa et al., 2009). Using data from Nour et al., (2015) from the South Korfodan State of Sudan we presume that the average yield of gum talha is 33 gram per tree (conservative estimate) and sells at the same price of gum arabic.

Acacia nilotica

Acacia nilotica is native to Africa, the Middle East and the Indian subcontinent. Its dry, dehiscent fruits are highly valued as fodder for pastoral livestock.

Browse production

On the Borana Plateau in Ethiopia, Atsedu et al., (1994) measured fruit production from mature trees from 5 different sites. Fodder yields ranged from 0 to 40 kg Dry Matter per tree overall, with an average of 5.3 kg DM per tree per year, or 650 kg DM/ha in an open canopy area. We presume that A. Nilotica fodder sells at the same price as fodder obtained from other acacia trees (using 2.3 FCFA/ha from Sibidé et al., 2015)

Fuelwood

Acacia nilotica is also appreciated for it fuelwood and has been used as a pioneer species in land rehabilitation and as a barrier to desertification. The Mean Annual Increment of A. Nilotica in planted semi-natural forest in North Africa ranges between 12 and 15 m^3/ha/year (FAO 2006). We use a working hypothesis of 13 MAI with approximately 150 trees/ha, slightly denser than in open canopy areas. Non-forage/timber uses include gum, tannin, traditional medicine and vertebrate poisons (Tropical Forages 2017)

Anacardium occidentale – Cashew nut

Anacardiu occidentale is cultivated for its nuts, and the wood is also popular for firewood and charcoal. Because of its extreme tolerance of external conditions, it has been planted in poor soils to check erosion. The tree can adapt to very dry conditions as long as its extensive root system has access to soil moisture.

Yields of cashew nuts

Trees are planted at a wide spacing (6 to 10 m) for cashew production. In this assessment we assume an average spacing of 10 m (=100 trees per hectare). Trees produce fruits between 5 and 30–40 years: one hectare typically yields between 200 to 800 kg of nuts depending weather, soil qualities and how the plantation is managed (Westerberg et al., 2017). Following the planting of cashew trees, we presume that their yields are similar to that of newly established cashew plantations in Benin (figure 1), planted at an optimal spacing density of 10 x 10 m (from Westerberg et al., 2017).

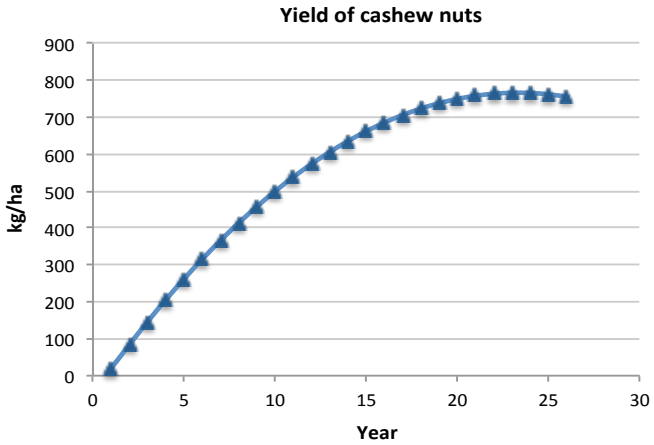

Figure 1: Relationship between Cashew yields and age of the trees (from Westerberg et al., 2017)

Cashew nut prices

With no local data available on the market price for cashew nuts, we presume that cashew nuts are sold for an average of 600 FCFA/kg, as in Benin in 2016 (Westerberg et al., 2017).

Sterculia setigera

Locally known as Mbepp, Sterculia setigera is a member of the family Sterculiaceae, a multipurpose savannah tree with a wide ecological spread in tropical Africa. It is found mostly in the wild. Sterculia setigera is used in traditional medicine in Senegal (Sall 2017) and is used in the treatment of severe diarrhea, dysentery, and jaundice and as a painkiller (Zaruwa et al., 2016). Analyses of *S.* setigera for their nutritional composition has revealed that the plant has high crude protein, fiber, amino acids, minerals, carbohydrate, fat contents and that it is rich in sodium, iron, zinc, manganese, vitamin A, B1, B2, B6, B12, and E (Noitang et al., 2009)

Without data on the yield of *S*. setigera pods, seeds and leaves, we assume that the production values are within the range of other tree species in West Africa (from Houérou 1980 and Baumer 1992). On this basis, we stipulate that the each tree yields an average of 2 kg DM of leaves and 50 kg DM of pods, 7 years after planting

Economic value of *S. setigera* seeds and leaves

A bag of S. setigera leaves of 100g DM sells for approximately FCFA 25 (=250 FCFA/kg DM of leaves) on local Senegaleese markets (Sall, 2017). We do not posses any data on the market price of *S. Setigera* seeds. However, we know from Idu et al., (2008) that the pods have a high calorific value (7'000- 8'000 kJ/kg of DM) in the order of that of from F. Albida trees (6'000-

7'000 KJ/kg DM) (Bernard 2002). Since fodder from F. Albida trees sells for 2.3 FCFA/kg (Sidibé et al., 2014), we use the same price to infer the nutritional value of S. Setigera.

Bombax costatum

The silk cotton tree *Bombax costatum* is found in Sahelian-Sudanian and Guinean open woodland and savannah lands. Its distribution is restricted to the 11rabic11t zones of West Africa from Senegal to the Central African Republic (from Senegal to central Africa, from Guinea across Ghana and Nigeria to southern Chad). It is often found on rocky hills or lateritic crusts. It can grow up to 25 m high, but hardly higher than 6 m in the sahel (Orwa et al., 2009c). It is a true multipurpose tree, providing medicines, fibres, food, oil, timber (Tropical plant database 2014) and it is particularly appreciated for its edible calyx (Achigan-Dako E. 2009). The calyx of the flowers is used in 'futo' or sauces and the young fruit is cut around August and September, dried, and used for the preparation of meals.

Economic value of calyx

The market value of calyx varies between 750 FCFA/kg and 1000 FCFA/kg depending on whether they are sold in the dry season or wet season (Ouédraogo et al., 2014) and between 400 FCFA/kg to 1000 FCFA/kg for Bissap Calyx (Mady 2010). As most calyx is typically sold shortly after harvesting time and we do not know the quality of what may be harvested, we use a conservative price of 300 FCFA/kg. Under favorable conditions, 3-5 kg Calyx per tree can be obtained from the 10th year onwards (Boericke, W., 2013).

Other services – Climate resilience, erosion control, fodder, medicine and Kapok (not valued)

Leaves highly digestible and eaten by livestock, but the tree regenerates quickly after grazing. The bark is used for the treatment of skin diseases, yellow fever and headache. The tree also serves protective functions, being effective in controlling erosion on dry lateritic soils and the leaf litter enhances soil fertility. Its tuberous roots act as water and sugar storage facilities during long drought periods – a valuable service, since the tree is well adapted for agroforestry or growth nearby settlements. *Bombax costatum* is also valued for its Kapok (producing 5-8 g of kapok per tree). Kapok was formerly exported from francophone West Africa. Today, the fibre and other products are only traded locally.

Regrettably, the species is said to be disappearing from the Sahel and Guinean woodland areas of its range (Burkil 2004). Excessive harvesting of flowering branches contributes to the decline of the species (Orwa et al., 2009c).

Eucalyptus Camaldulensis

The natural habitats of Eucalyptus genus extend across the Australia mainland and some species into New Guinea. Eucalyptus genus is globally one of the most planted tree genera with an estimated 15 million ha of eucalypt plantations worldwide of which over 2 million ha are in Africa, where E. grandis and E. camaldulensis are the most planted species (Coppen 2002).

E. camaldulensis is used as pulp raw material and fuelwood, as well as sawn timber and reconstituted wood products. In Senegal, E. camaldulensis is mainly cultivated to be sold or used for construction poles at the end of its rotation (Sall, 2017).

Fuelwood and timber

E. camaldulensis grow fast as an exotic, with a mean annual increment of 15 m3/ha/year or more (FAO 1979). Moreover, a thinning from an initial 1000 stems/ha to less than 700 stems/ha at 5 years provides posts, poles, fuelwood and pulpwood, leaving the better trees for the

production of poles at the end of the rotation (Orwa et al., 2009b). We therefore assume that E. camaldulensis is thinned in year 5 and 6 for fuelwood. The other major economic output from E. camaldulensis is the sale of construction poles when they are cut at the end of a typical rotation period of 15 years. One pole sells for approximately 300 FCFA (Sall 2017). The density of the wood is 900-980 kg/m^3 (Ugalde et Perez 2001).

Prosopis juliflora

Prosopis Juliflora is an esteemed fuelwood source in several tropical countries and valued for the shade and timber it can provide (National Academy of Sciences 1980). Prosopis julflora grows fast. On a 15-year rotation, the expected yield is 75-100 ton per ha; on a 10-year rotation, it may be 50-60 ton per hectare (NAS 1980). Like E. camaldulensis it is used principally for construction poles and fuelwood (Mwangi and Swallow 2005). We assume that thinning's are made in year 5-6 after planting and that the trees are felled in year 15 to be sold for poles (as above).

Summary of data and assumptions used in the forest benefit analysis

Table A1 in Appendix 1 provides a summary of the key parameters influencing the economic benefits from the restoration and reforestation of the 8 tree species considered in this analysis.

Project Costs

The success of restoration projects is conditional on effective stakeholder participation, buy-in of local populations, state-of-the art knowledge of restoration techniques, training and capacity building of local actors and other elements. As such, there are significant costs above and beyond the actual costs associated with establishing nurseries and sourcing materials inputs (seeds, nurseries, planting tools,…) for the restoration interventions. On the basis of IED project documents, the present value project implementation costs for each of the 4 projects 'Dimal', Mbeuleup, Keur M'Boucki and Kahi, are in the order of between FCFA 8 to 20 million for the first 2 years of the interventions and the present value cost across the 4 projects is approximately FCFA 48 million (table 1). A more detailed breakdown of the major cost components for each reforestation project is provided in appendix 2.

Table 1: Present value cost of IED's 4 reforestation projects in Kaffrine

Broad cost categories across all 4 projects	**FCFA**
Material project inputs	18'859'000
Awareness raising, education, technical training and support	5'700'000
Establishment of firebreaks	1'182'500
Other (transportation, enclosures, zoning, hired labour, surveillance control, hydrological works, weeding and planting management…)	22'685'000
Total Cost over first 2 years	48'890'500
Total Present Value Cost	**47'951'700**

4. Results

While project investment costs are typically incurred within the first years of an intervention, benefits from ecosystem restoration attain to the long term. In the following chapter, we

consider the economic revenues that may be derived from the individual tree species used in the reforestation activities and the project specific returns.

The value of environmental income

As shown in figure 2, most provisioning services from trees, do not provide visible yields until 5-6 years after the trees have been planted. The timber species provide the majority of their return when they are cut for merchandise – in this case 15 years after they have been planted. The figures also highlight the interest in mixing species that yield different benefits at different moments in time, helping communities diversify income sources and hedge against tree crop specific risks.

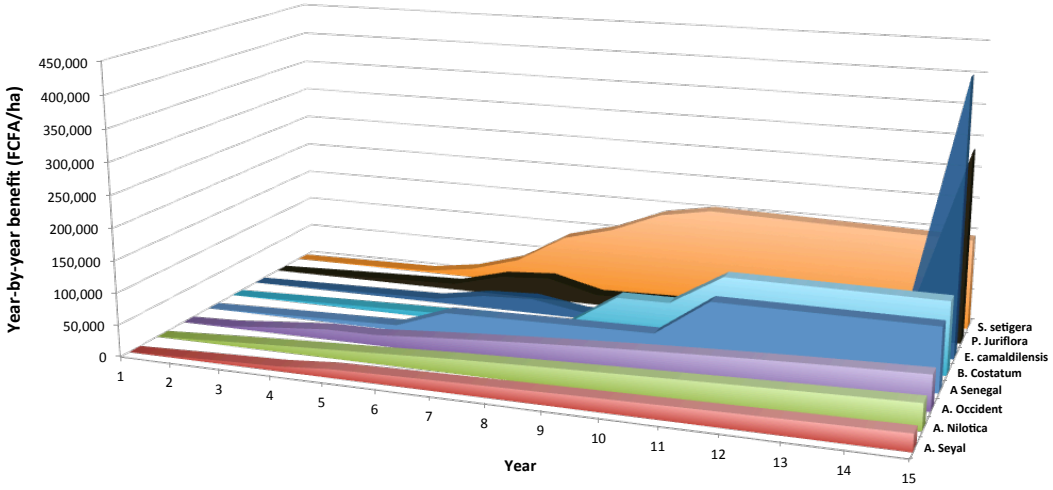

Figure 2: Year-by-year present value economic benefits from 8 different tree species

Figure 3 shows the sum total in present value terms of the stream of benefits for each of the tree species analysed over 15 years. The expected returns are for the most part in the range of 400'000 FCFA to 700'000 FCFA per ha cultivated with a given species.

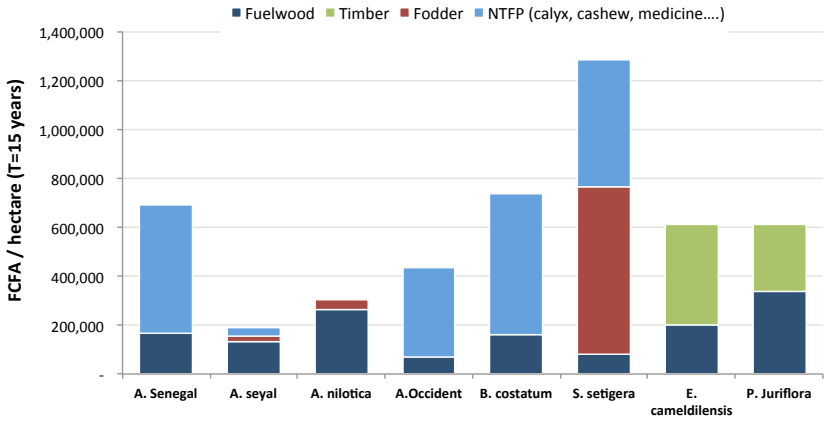

Figure 3: Aggregate present value benefits from 8 key tree species used in IED's reforestation interventions

While not suitable for timber harvesting, some slower growing species such as A. Senegal, A. Occident, B. Costatum and S. Setigera may provide substantial revenues to local communities from the harvest of NTFPs, such as cashew nuts and gum Arabic. Our estimates suggest that

such revenues are in the order of 400'000 FCFA/ha planted with the given tree species. Indeed figure 3 suggests that the majority of the the direct benefits from the trees species favoured in IED's restoration interventions derive from fuelwood, followed by timber, NTFPs and finally browse forage for animals.

The value of carbon sequestration

The restoration of degraded soils and vegetation can mitigate the effect of increasing carbon dioxide concentrations in the atmosphere. On the basis of the assumptions outlined in appendix 1 and methodology in section 2, our results suggest that IED Afrique's recent reforestation investments in Kaffrine, will result in the sequestration of an additional 108'110 tons of carbon dioxide equivalent emissions over the next 15 years. Using a social cost of carbon of FCFA 23'000 (USD 37), the global benefit in terms of avoided emissions amount to FCFA 2 billion, or approximately, FCFA 24.7 million per hectare reforested.

Regrettably, till this date, there are few effective mechanisms for such global benefits to be harnessed at the local level. In the voluntary carbon market for example, the supply of carbon credits still exceed demand for these (Environmental Finance 2016) and figures from the Ecosystem Marketplace's 2017 State of the Voluntary Carbon Market report shows that the average carbon price for afforestation/reforestation projects was in the order of USD 8.1 per ton CO_2 eq in 2016 (Forest Trends 2017) – far from the conservative social cost of carbon of USD 37 used in this study.

Net present value benefit of IED project interventions in Kaffrine

Table 5 and figure 5 to 8 summarizes the present value project costs and benefits relating directly to the 4 restoration interventions in Dimal, Mbeuleup, Keur Mboucki and Kahi. As can be seen form table 5, potential environmental income to local communities is in the order of FCFA 55'000 million over a 15-year period, over and above project implementation costs (of 47'000 million FCFA) in present value terms (table 5), leading to a NPV benefit of FCFA 7.6 billion. Across the 4 project sites, each project provides multiple revenue sources (from timber, fuelwood, NTFPs and livestock feed). Overall, fuelwood account for 42% of the potential economic revenue, construction timber for 32%, livestock forage for 2% and other NTFPs (gum Arabic, cashew, etc) for another 24%.

Additionally, it should be highlighted that since additional cash flows will enter into the economy, they create additional economic activity through backward and forward linkages to other sectors. Forward linkages for example include local traders, merchants, carpenters and food producers who are engaged in further marketing or enhancing the value derived from the primary forest products. These linkages generate multiplier effects, whereby the total impact of smallholder production may be amplified by 10 to 20 (GEF 2009). When accounting for the carbon sequestered, benefits largely exceeds the costs – leading to a Net Present Value benefit of FCFA 2 billion over a 15-year period for the 4 sites in Kaffrine.

Table 5: Net Present Value (r=2%) from IED's reforestation interventions

	Creation de bois de village, Dimal	Restauration de la forêt communautaire de Mbeuleup	Restauration des berges de l'affluent du Saloum – Keur Mboucki	Restauration forêt classée de Kaffrine	Total
PV benefit per project	**17'079'694**	**14'560'716**	**5'587'176**	**6'417'660**	**54'641'375**
PV cost per project	-8'762'265	-6'917'782	-21'232'425	-10'099'030	**-47'951'730**

NPV	**7'247'720**	**6'223'055**	**-16'652'984**	**-4'313'103**	**7'629'873**
NPV including carbon sequestration	**865'331'881**	**563'512'760**	**311'290'412**	**269'565'495**	**2'009'700'550**

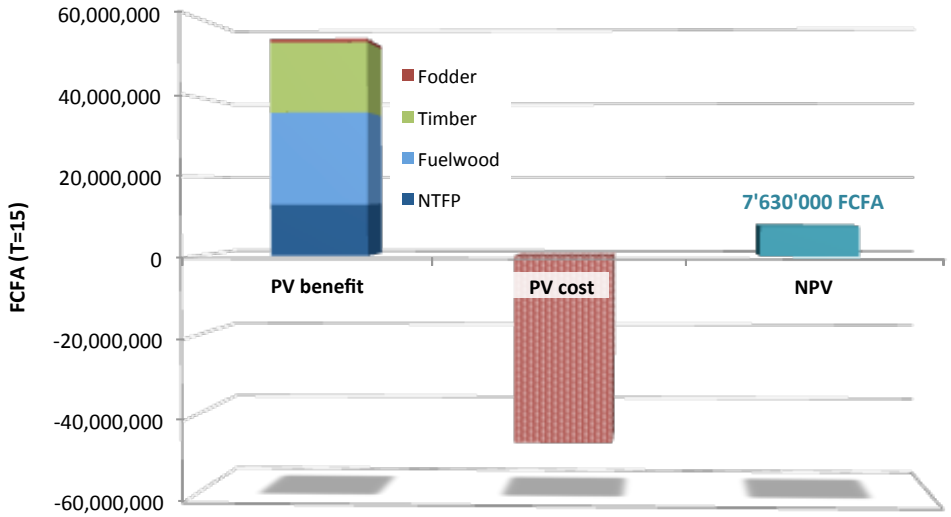

Figure 4: PV Benefits, PV Costs and PV Net-benefit from IED's reforestation projects in Kaffrine (r=2%)

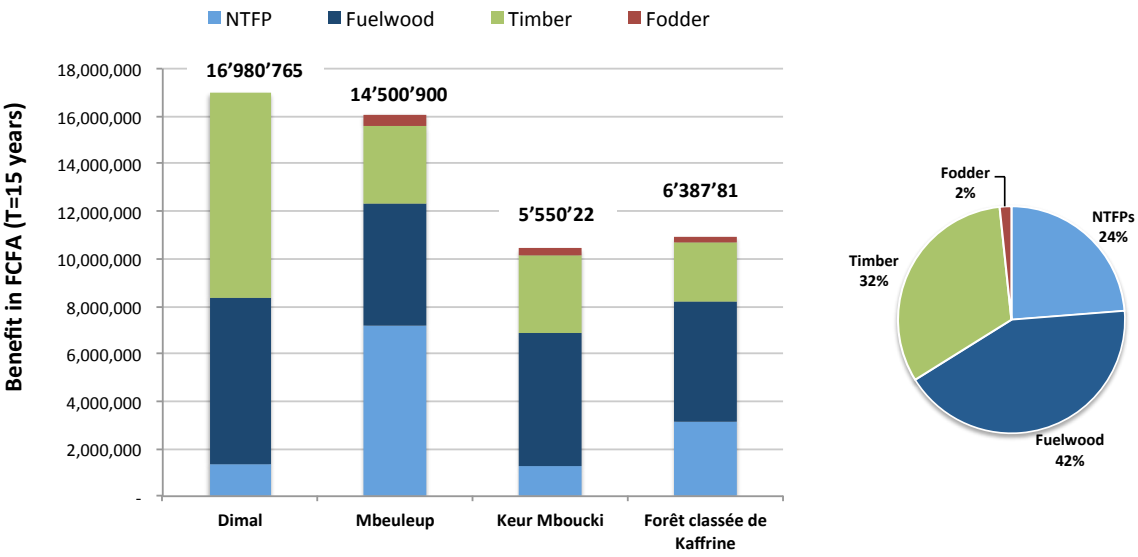

Figure 5: Project specific PV benefits and value of product share

For individual projects, such as Keur Mboucki, the provisioning services do not outweigh the implementation costs (figure 6). However, to the extent that this project aims to reduce salination by lessening pressure on existing native vegetation, farmers will enjoy enhanced soil fertility relative to the baseline of continued soil degradation and salination. In this regard, it is worth recalling that we only provide partial insight into the many ecosystem service benefits provided by IED's rehabilitation and restoration projects. Other important benefits derive from cultural or regulating ecosystem services, such as soil stabilisation, nitrogen fixation, groundwater water purification and infiltration, enhanced biodiversity and tourist activity.

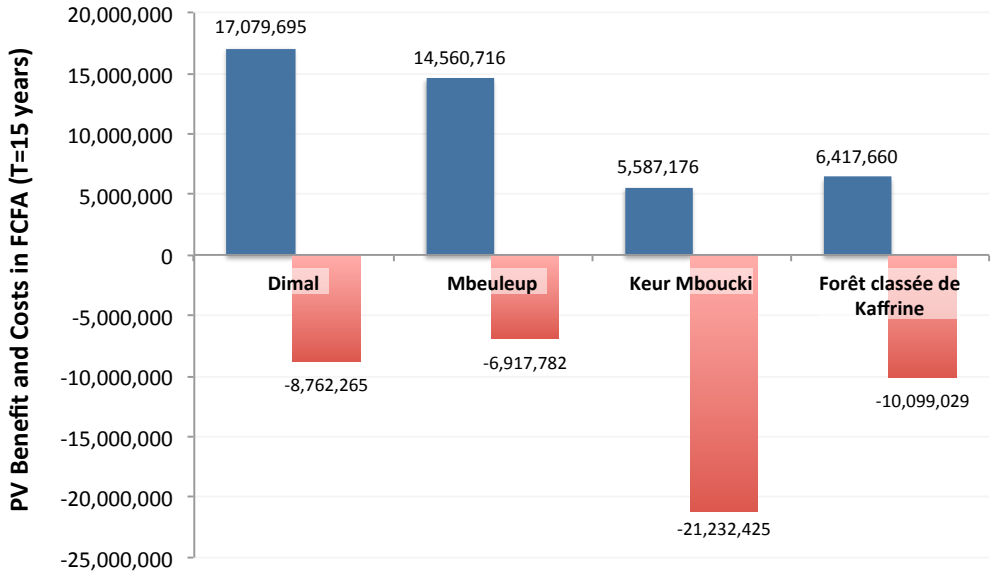

Figure 6: project specific PV benefits and PV costs

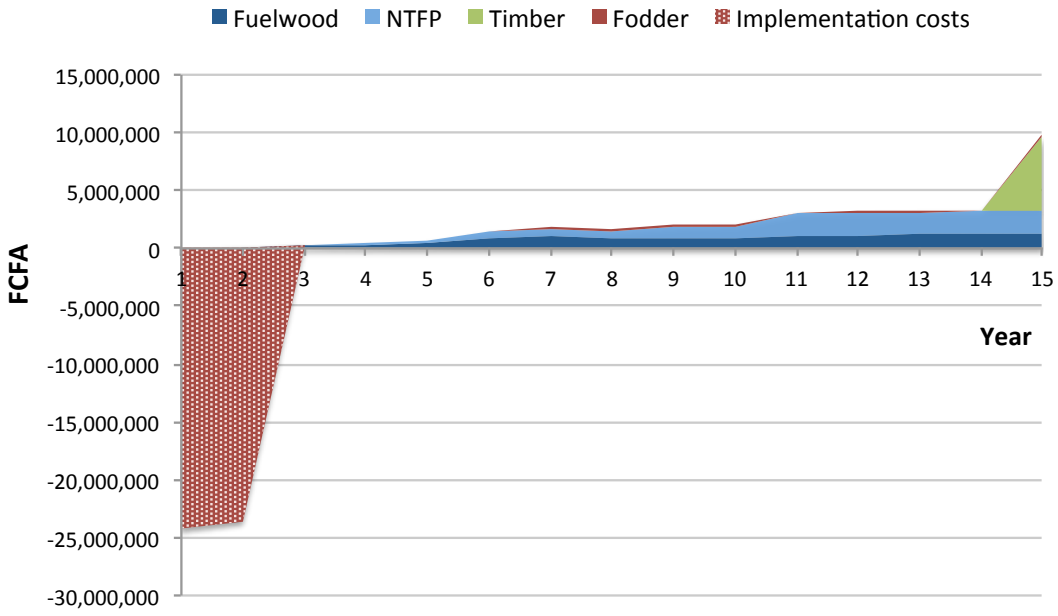

Figure 7: project specific PV benefits and PV costs

5. Caveats and perspectives

This study is a preliminary and partial attempt to comprehensively assess the true economic value of the ecological restoration and rehabilitation interventions undertaken by IED Afrique. As such, the study offers several opportunities for improvement. Firstly, the current analysis has focused on species that are known by the corresponding author to be used in the reforestation

efforts by IED Afrique, at the time of writing. Inevitably more species have been used than those accounted for here. Additionally, in relying on secondary data and literature, it has not been possible to capture the full range of provisioning services provided by every tree, nor the accurate yields or prices at which the good sell or trade in local markets.

Therefore, a useful extension to the current study would be the roll-out of expert interviews with foresters to obtain more robust estimates (and cross validations) of NTFP yields; village and market surveys to establish local prices for NTFPs, timber and fodder; and forest inventories to gauge the 'additionality' of IED Afriques interventions, in terms of number trees planted per hectare, their survival rate and the tree species.

Since the reforestation activities have started in 2016 or 2017, the implementation of representative household surveys including forest enterprise budgets, could also be used establish a baseline of communities' actual environmental income. Provided that a follow-up survey is undertaken some 5 to 15 years from now, it may be used to estimate the impact of the reforestation projects on overall community or household welfare. The impact assessment[6] should ideally be designed using experimental or quasi-experimental techniques to ensure that any potential welfare impact can be attributed to the interventions themselves.

Finally and as previously mentioned, the reforestation interventions evaluated here are also contributing to enhanced biodiversity and regulating ecosystem services such as water purification, groundwater infiltration, soil stabilisation and nitrogen fixation. In a more comprehensive study, hydrological services can be quantified using Soil Water Assessment (SWAT[7]) or Artificial Intelligence for Ecosystem Services (ARIES[8]) tools and further valued using stated preference, revealed preference, production functions or avoided cost and market based valuation methods.

6. Conclusion

In the course of 2016 and 2017, the not for profit organization IED Afrique has begun a set of reforestation activities in the region of Kaffrine, in collaboration with local and departmental authorities. The implementation costs of such regenerative activities are not negligible, costing some FCFA 48 million for 4 projects covering some 82 hectares.

While the implementation costs associated with ecosystem rehabilitation are most significant within the first years of a project, they are likely to yield long-term benefits to communities, wildlife and overall ecosystem integrity. More uncertainty intervenes when estimating such benefits over a longer time horizon, e.g. due to unpredictable climates and changing market conditions. We therefore use a relatively short time horizon of 15-years to assess the economic values from the reforestation activities. In doing so, we find that reforestation efforts using A. Nilotica, B. Costatum and S. Setigera, A. occident, E. Cameldilensis and P. Juriflora A. Seyal, A. Senegal species, can provide an additional FCFA 55 million in environmental income to local communities through the enhanced availability of fuelwood, timber and diverse non-timber

[6] Impact evaluation is an assessment of how an intervention affects outcomes, whether these effects are intended or unintended. A proper analysis of impact requires a **counterfactual** of what those outcomes would have been in the absence of the intervention.
[7] http://swat.tamu.edu/
[8] http://aries.integratedmodelling.org/

forest products.

The value of these provisioning ecosystem services are more than sufficient to offset the project investment costs, leading to a NPV of approximately FCFA 7 million, when using a modest discount rate of 2%. If we had accounted for multiplier effects and changes to hydrological services and soil fertility, the local net-benefits would inevitably have been several folds higher. From a global perspective, we find that the NPV benefit from IED's interventions exceed FCFA 2 billion, when accounting for enhanced carbon sequestration and associated avoided global damages.

As such, this study has helped enhance our understanding of forests' role in climate change mitigation and local economic development in the Kaffrine region, notably, as a source of cash income, energy and food security that contributes to household welfare and livelihoods. As highlighted by FAO, CIFOR, IFRI and the World Bank (2016), such services are especially important for the poorest people in many regions.

Conclusively, it may be argued that valuation efforts should not stop here. Research for this study has proven that readily available data on tree products and prices are scarce. In the context of the 2030 Agenda for Sustainable Development, better socioeconomic data on forests are needed in order to give adequate consideration to forest production and consumption benefits in conservation and policy planning. Better data may in term contribute to more targeted and cost-effective development policies for accelerating the achievement the Social Development Goals.

References

Achigan-Dako, E., (2009). Traditional Vegetables in Benin. Publisher. Darwin Initiative; International Foundation for Science Year 2009

Akpo L. E., I. Coly, D. Sarr, Ngom et S. Ndao, (2004). Modes d'utilisation des terres et diversité floristique dans le terroir de la Néma en zone Semi-aride (Sénégal, Afrique de l'Ouest). Journal of agriculture and environment for international development, Vol. 98, No. 3(4).

Angelsen, A., Jagger, P., Babigumira, R., Belcher, B., Hogarth, N.J., Bauch, S., Börner, J., Smith-Hall, Appiah, M., Blay, D., Damnyag, L., Dwomoh, F.K., Pappinene, A., Luukkanene, O., (2009). Dependence on forest resources and tropical deforestation in Ghana. Environ. Dev. Sustain. 11, 471–487.

Aronson, J., Floret, C., LeFloch, E., Ovalle, Pontanier, C., (1993) Restoration and Rehabilitation of Degraded Ecosystems in Arid and Semi-Arid Lands. I. A View from the South. Journal of Restoration Ecology.

Atsedu M., Coppock, D. L., Detling, J.K., (1994). Fruit production of Acacia tortilis and A. nilotica in semi-arid Ethiopia. Agroforestry Systems 27: 23-30, 1994.1994 Kluwer Academic Publishers. Printed in the Netherlands.

Bakhoum C., Ndour B., Akpo L.E., (2012). Typology of woody stands in Senegal: case of the Groundnut Basin. International Journal of Science and Advanced Technology (ISSN 2221-8386,) Volume 2 No 2 February, http://www.ijsat.com, pp. 26-35.

Barbier, E.B. (1992). Rehabilitating Gum Arabic systems in Sudan: Economic and environmental implications. Environmental and Resource Economics, 2 : 341-352.

Bationo, F. (2007). Prise en compte du réseau sociotechnique de maintenance dans la conception d'équipements : cas des petites unités de transformation agroalimentaire des pays d'Afrique de l'ouest. Grenoble, INPG.

Baumer, M., (1992) Trees as browse and to support animal production in Legume trees and other fodder trees as protein sources for livestock. FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS Rome, 1992. ISBN 92-5-103203-3

Bernard, C., (2002). Faidherbia albida (Delile) A.Chev. [Internet] Record from PROTA4U. Oyen, L.P.A. & Lemmens, R.H.M.J. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http ://www.prota4u.org/search.asp>. Accessed 2 November 2017.

Boer, E., (2002). Acacia 19rabic19 (L.) Willd. [Internet] Record from PROTA4U. Oyen, L.P.A. & Lemmens, R.H.M.J. (Editors). PROTA (Plant Resources of Tropical Africa / Ressources végétales de l'Afrique tropicale), Wageningen, Netherlands. <http://www.prota4u.org/search.asp>

Boericke, W., (2013) Pockeet Manual of Materia Medica and Pharmacology.

Burkil H. M. (2004) The Useful Plants of West Tropical Africa. Year 1985 – 2004. Publisher Royal Botanic Gardens; Kew. http://www.aluka.org/

CBI (2016). Exporting Gum Arabic to Europe. Ministry of Foreign Affairs. Available from URL: https://www.cbi.eu/market-information/natural-food-additives/gum-arabic/.

Cavendish, W., 2000. Empirical regularities in the poverty-environment relationship of rural households: evidence from Zimbabwe. World Dev. 28 (11), 25.

Chao, S., 2012. Forest Peoples: Numbers Across the World. Forest Peoples Programme, Moreton-in-Marsh, U.K.

Cisse, M. I., & Kone, A.R. (1992). The fodder role of Acacia albida: Extent of knowledge and prospects for future research.In: Vandenbeldt R. J.(Ed.). Faidherbia albidain West African semi-arid tropics. Proceedings of a workshop held in Niamey, Niger, pp. 29-37.
Coppen, J.W., Eucalyptus, Ed., Taylor & Francis (2002), London, UK.

Delgado-Matas, C., and Pukkala, T., (2011). Comparison of the Growth of Six Eucalyptus Species in Angola. International Journal of Forestry Research. Volume 2011 (2011), Article ID 980259, 9 pages

Diatta S., Douma S., Houmey V. K., Banoin M.et Akpo L. E., (2007). Potential de régénération naturelle d'un ligneux fourrager (Maerua crassifolia Forsk.) en zone sahélienne, Revue Africaine de Santé et de Productions Animales, E.I.S.M.V. de Dakar, 5(1-2) : 23-28.

Environmental Finance (2017). Low prices, but high hopes for the voluntary carbon market. 6th of June 2016. Field Gibson Media Ltd 2017. Available from URL: https://www.environmental-finance.com/content/analysis/low-prices-but-high-hopes-for-the-voluntary-carbon-market.html

FAO (1979). Food and Agriculture Organization of United Nation (FAO), Eucalypts for Planting, Food and Agriculture Organization of United Nation, 1979.

FAO (1982). TROPICAL FOREST RESOURCES ASSESSMENT PROJECT. FOREST RESOURCES OF TROPICAL AFRICA. PART I: REGIONAL SYNTHESIS. Available from URL:
http://www.fao.org/docrep/007/ad909e/AD909E09.htm

FAO (2006). Global planted forests thematic study: results and analysis, by A. Del Lungo, J.Bal and J. Carle.

Planted Forests and Trees Working Paper 38. Rome. http://www.fao.org/forestry/12139-03441d093f070ea7d7c4e3ec3f306507.pdf

FAO, CIFOR, IFRI and World Bank (2016). National socioeconomic surveys in forestry: guidance and survey modules for measuring the multiple roles of forests in household welfare and livelihoods, by R.K. Bakkegaard, A. Agrawal, I. Animon, N. Hogarth, D. Miller, L. Persha, E. Rametsteiner, S. Wunder and A. Zezza.

FAO Forestry Paper No. 179. Food and Agriculture Organization of the United Nations, Center for International Forestry Research, International Forestry Resources and Institutions Research Network, and World Bank.

FAO (2014) State of the World's Forests 2014. Enhancing the socioeconomic benefits from forests. Rome (available at http://www.fao.org/3/a-i3710e.pdf).

Forest Trends (2017). Unlocking Potential. State of the Voluntary Carbon Markets in 2017. Forest Trends' Ecosystem Marketplace. https://www.cbd.int/financial/2017docs/carbonmarket2017.pdf

GEF (2009) Timberland investment & emerging markets: A fresh review & outlook. September 2009, Global Environment Fund.

Harmand, J.M., Ntoupka, M., Mathieu, B., Forkong Njiti, C., Tapsou, J.M., Bois, J., P. Thaler, P., Peltier, R., (2012). Gum 20rabic production in Acacia 20rabic20 plantations in the Sudanian zone of Cameroon: Effects of climate, soil, tapping date and tree provenance. Bois et Forêt des Tropiques, 2012, 311(1). Avaiable from URL : http://bft.cirad.fr/cd/BFT_311_21-33.pdf

Houérou (1980). Browse in Africa. The current state of knowledge. Edited by H.N. Le Houérou. International Livestock Centre for Africa. Addis Ababa. Ethiopia.

Illukpitya, P., Yanagida J.F., 2008. Role of income diversification in protection natural forests : evidence from rural households in forest margins of Sri Lanka. Vol 74 (1), pp.51-62

IIED Blog. Decentralising Climate Funds in Mali and Senegal. Available from URL: https://www.iied.org/decentralising-climate-funds-mali-senegal

Kizito F., Sene M., Dragila M.I., Lufafa A., Diedhiou I., Dossa E., Cuenca R., J. Selker J., Dick R.P., 2007. Soil water balance of annual crop–native shrub systems in Senegal's Peanut Basin: The missing link. Agricultural water management 90: 137 – 148.

Mady, C., (2010). Literature review and Background information of Bissap. African Food Tradition rEvisited by Research. Avaiable from URL https://www.after-fp7.eu/content/download/4133/31061/version/4/file/Literature-review+of+Bissap.pdf

Mohammed S. A. Abdalla, Izeldin A. Babiker, Abubakr M. Idris, Kamal F. Elkalifa. Potential Nutrient Composition of Acacia seyal Fruits as Fodder for Livestock in the Dry Lands in Sudan. Development in Analytical Chemistry Volume 1, 2014)

Mujawamariya, G., Burger, K., Haese, M., (2012). Quality of Gum Arabic in Senegal: Linking the Laboratory Research to the Field Assessment. Quarterly Journal of International. Agriculture 51 (2012), No. 4: 357-383

Mwangi E., Swallow, B., (2005). Invasion of Prosopis juliflora and local livelihoods: Case study from the lake Baringo area of Kenya. ICRAF Working Paper – no. 3. Nairobi: World Agroforestry Centre. Available from URL: www.worldagroforestry.org/downloads/Publications/PDFS/WP13657.pdf

NAS (1980). Firewood Crops. Washington, DC: National Academy of Sciences, 1980.

National Academy of Sciences (1980). Firewood crops. Scrubs and Tree species for Energy Production. Report of the Ad Hoc Panel of the Advisory Committee on Technological Innovation. National Academy of Sciences, Washington DC.

NEF, IIED, IED-Afrique Consortium (2014). Programme Development Report #5. Knowledge on adaptation and the Reduction of Climate Risks and Disasters in Mali and Senegal – A summary Report. Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED)

Nkonya, E., Anderson, W., Kato, E., Koo, J., Mirzabaev, A., von Braun, J., & Meyer, S. (2015). Global cost of land degradation. Springer (chapter 6).

Noitang, S., S.A. Sooksai, T. Foophow and A. Petsom, 2009. Proximate analysis and 21rabic-chemical properties of flour from the seeds of the china chestnut *Sterculia monosperma*Ventenat. Pak. J. Biol. Sci., 12: 1314-1319.

Nour, T., Mohammed, E.Y., Bekele, T., (2015). The Effect of tapping methods and some tree growth parameters on productivity of Acacia seyal in South Korfofan State, Sudan. International Journal of Agriculture, Forestry and fisheries. 3(2), 44-51.

Ong, C., Black, C.R., Marshall, F.M., & Corlett, J.E. (1996). Principles of resource capture and utilization of light and water. *In* Ong, C.K. & Huxley, P. (Eds). *Tree-crop interactions: A Physiological Approach*. London, UK: Oxon.

Orwa C., A Mutua, Kindt R , Jamnadass R, S Anthony. (2009). Agroforestree Database: a tree reference and selection guide version 4.0 (http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp)

Orwa C., A Mutua, Kindt R , Jamnadass R, S Anthony. (2009a). Agroforestree Database: a tree reference and selection guide version 4.0. Acacia Seyal. Available from URL: http://www.worldagroforestry.org/treedb/AFTPDFS/Acacia_seyal.PDF

Orwa C., A Mutua, Kindt R , Jamnadass R, S Anthony (2009b). Agroforestree Database: A tree reference and selection guide version 4. www.worldagroforestry.org/treedb/AFTPDFS/Eucalyptus_camaldulensis.PDF

Orwa, C., Mutua, A., Kindt R., Jamnadass R., Anthony, S., (2009c). Agroforestree Database:a tree reference and selection guide version 4. http://www.worldagroforestry.org/treedb/AFTPDFS/Bombax_costatum.PDF

Orwa C., Mutua, Kindt, R., et al., (2012). Simmondsia chinensis, Agroforestry Database: a tree reference and selection guide version 4.0

Otsyina, R. M., Norton, B. W., Djimdé, M., (1999). Fodder trees and shrubs in arid and semi-arid livestock production systems. In: In 'XVIII International Grassland Congress, vol. 2, pp 429-438. Avaiable from URL: http://www.internationalgrasslands.org/files/igc/publications/1997/iii-429.pdf

Paeth (2006). The climate of tropical and northern Africa-a statistical – dynamical analysis of the key factors in climate variability and the role of human activity in future climate change. In bonner Meterologische Abhandlungen, 61, 340 S.

Kazzi, M., (2016). A Case Study of the Performance, Adoption, and Dissemination of Improved Clay Cook Stoves in Rural Senegal. Submitted in partial fulfillment of the requirements for the degree of MSc of forest resources. University of Washington. Available from URL: http://depts.washington.edu/sefspcmi/wordpress/wp-content/uploads/2016/07/Kazzi-Thesis.pdf

Pouliot, M., Treue, T. (2013). Rural people's reliance on forests and the non-forest environment in West Africa: evidence from Ghana and Burkina Faso. *World Dev*elopment, 43: 180–193.

Rahim, A.H., van Ierland, E.C., & Wesseler, J. (2007). Economic incentives for abandoning or expanding gum 22rabic production in Sudan. Forest Policy and Economics, 10(1): 36-47.

Rayamajhi, S., Smith-Hall, C., Helles, F., 2012. Empirical evidence of the economic importance of Central Himalayan forests to rural households. Forest Policy Econ. 20, 25–35

Ricome, A., Myint. M., Westerberg, V. (2014). An economic valuation of sustainable land management through agroforestry in eastern Sudan. Report for the Economics of Land Degradation Initiative by the International Union for Conservation of Nature, Nairobi, Kenya.

Sall, A. B., (2017). Personal communication from Bocar Abdallah Sall. Ingénieur Génie Rural. Direction de la Gestion et de la Planification des Ressources en Eau (DGPRE)/MHA. Email: bocarsall55@gmail.com

Sidibé, Y., Myint, M., & Westerberg, V. (2014). An economic valuation of agroforestry and land restoration in the Kelka Forest, Mali. Assessing the socio-economic and environmental dimensions of land degradation. Report for the Economics of Land Degradation. By International Union for Conservation of Nature, Nairobi, Kenya. Available from: www.eld-initiative.

Sow et al., (2015) Cost, Drivers and Action Against Land Degradation in Senegal (chapter 19) in Global cost of land degradation. Ephraim Nkonya, Stefan Meyer and Edward Kato https://link.springer.com/content/pdf/10.1007%2F978-3-319-19168-3_19.pdf

Sunderlin, W.D., Angelsen, A., Belcher, B., Burgers, P., Nasi, R., Santoso, L., *et al. (2005).* Livelihoods, forests, and conservation in developing countries: An overview World Development, 33 (9), pp. 1383-1402

Thiombiano (2014). Productivité et valeur économique des calices de Bombax costatum Pellegr. & Vuillet en zone soudanienne du Burkina Faso. BOIS ET FORÊTS DES TROPIQUE S, 2014 , N° 319 (1) FOCUS / BOMBAX COSTATUM

Tropical Forages (2017). Acacia nilotica. Available from URL: http://www.tropicalforages.info/key/Forages/Media/Html/Acacia_nilotica.htm

Tropical plant database (2014). Bombax costatum. Useful Tropical Plants Database 2014 by Ken Fern, web interface by Ajna Fern. Available from URL: http://tropical.theferns.info/viewtropical.php?id=Bombax+costatum

Ugalde, L., Pérez, O., (2001) MEAN ANNUAL VOLUME INCREMENT OF SELECTED INDUSTRIAL FOREST PLANTATION SPECIES. Forest Plantations Thematic Papers. http://www.fao.org/3/a-ac121e.pdf

Westerberg, V., Golay, A., Houndekon, V., Costa, L., (2017) L'économie de la dégradation des terres au Benin : Cas de la commune de Bantè. Rapport pour L'initiative sur L'economie de la degradation de la terre.

World Resources Institute (2005) in collaboration with United Nations Development Programme, United Nations Environment Programme, and World Bank. 2005. World Resources 2005: The Wealth of the Poor—Managing Ecosystems to Fight Poverty. Washington, DC: WRI

Zaruwa, M. Z., Ibok, N. I., Ibok, I. U., Onyenonachi, E. C., Danchal, C., Ahmed, A. G., … Sudi, I. Y. (2016). Effects of *Sterculia setigera* Del. Stem Bark Extract on Hematological and Biochemical Parameters of Wistar Rats. *Biochemistry Insights*, *9*, 19–22. http://doi.org/10.4137/BCI.S36143

Wunder, S. C., 2014. Environmental income and rural livelihoods: a global-comparative analysis. World Dev. 64 (1), S12–S28.

Appendices

Appendix 1 – Summary of data inputs used in the estimation of environmental income and the value of carbon sequestration

Table A1: Summary of data inputs used in the economic analysis of forest income and carbon sequestration

Prices	UNIT	Estimate
Fuelwood	FCFA/ton	3600
Gum Arabic A. Senegal	FCFA/kg	625
Fodder from A. Seyal and A. Nicoltina trees	FCFA/kg	2.3
Price per timber pole E. camaldilensis	FCFA/pole	300
Price per timber pole P. Juriflora	FCFA/pole	400
Cashew nuts	FCFA/kg	600
Bombax costatum Calyx	FCFA/kg	300
Sterculia Setigera seeds for fodder	FCFA/kg DM	2.3
Sterculia Setigera leaves (medicinal)	FCFA/kg DM	200

NTFP yields		
Gum Arabic yields		
5^{th} to 9^{th} year	kg/tree	0.12
10^{th} to 20^{th} year	kg/tree	0.4
21^{st} to 25^{th} year	kg/tree	0.23
Gum 24rabic A. Seyal	kg/tree	0.033
Fodder yield from Acacia Seyal (by the 5^{th} year)	kg/tree	5
Fodder yield from A. Nicoltina (by the 5^{th} year)	kg/tree	5.2
Yield of Acacia nuts	kg/ha	Yield = - 50 + 68*year – 1.5*$year^2$
S. Setigera leaves (by the 7^{th} year)	kg/tree	2
S. Setigera seeds and pods (by the 7^{th} year)	kg/tree	50
Bombax costatum Calyx (by the 10^{th} year)	kg/tree	2

Mean annual increments (MAI)	m3/ha/year	5
E. camaldulensis	m3/ha/year	10
E. camaldulensis	m3/ha/year	15
Anacardium Occident	m3/ha/year	4.1
Anacardium Occident	m3/ha/year	5
S. setigera	m3/ha/year	4
A. Senegal	m3/ha/year	5.6
A. Seyal	m3/ha/year	5.6
A. Nilotica	m3/ha/year	13
Prosopis *juliflora*	m3/ha/year	20
Other	m3/ha/year	8

Carbon	Unit	
CF – The carbon fraction	tonnes C/tonne DM	0.5
R – Root to shoot ratio	dimensionless	0.31
DW – Deadwood conversion factor	dimensionless	0.11
X – Conversion factor of atomic mass of C to CO_2 equivalent	dimensionless	3.67
D – Basic wood densities		
D – Anacardium Occident	tonnes DM/m3	0.52
D – A. Senegal	tonnes DM/m3	0.76
D- A. Seyal	tonnes DM/m3	0.68
D – E. Camaldulensis	tonnes DM/m3	0.9
D – Other	tonnes DM/m3	0.7
SCC – Social cost of carbon	FCFA/tonne CO2 eq	23000

Appendix 2 – Detailed breakdown of reforestation project costs

Table A2: IED project implementation costs over the first 2 years of the project duration

DIMAL – Creation of fuelwood in the villages of Dimal, Gama, Ngorhjilene Mouride and Korky Bambara in the department of Birkilane	**FCFA**
Equipment and tools (rakes, wheelbarrows, cutting torque, forks..)	1126000
Inputs used in the reforestation (seeds, soil, phytosanitary products, water etc..)	2900000
Awareness rising within each of the 4 villages concerned together with officials from the agency of forest and water	400000
Transportation of inputs	400000
Delineation of zones to be restored and reforested	1200000
Hole digging	500000
Support for the planting	2000000
Establishment of firebreaks	500000
Total Cost	**9'026'000**
Present Value Total Cost (r=2%)	8’762’265

MBEULEUP – Restoration and conservation of the community forest of Mbeuleup	**FCFA**
Equipment and tools (rakes, wheelbarrows, cutting torque, forks …etc)	1126000
Inputs used in the reforestation (seeds, soil, phytosanitary products, water etc..)	2900000
Awareness raising activities	500000
Transportation of plants and inputs	400000
Hiring of technical agents	1200000
Identification of zones to be reforested	500000
Construction of firebreaks	500000
Total Cost	**7'126'000**
Present Value Total Cost (r=2%)	**6'917'782**

KEUR MBOUCKI – Reforestation and restoration of the banks of the tributary of the Saloum Inlet in the commune of Keur M'bouck	FCFA
Equipment, tools and inputs	**6881500**
Awareness raising and education	2920000
Transportation of inputs	250000
Establishment of tree nursery	4800000
Weeding, planting, management/maintenance	5320000
Other	1700000
Total Cost	**21'871'500**
Present Value Total Cost (r=2%)	**21'232'425**

KAHI - Restoration of the classified forest of Kaffrine in Kahi	TOTAL FCFA
Educational activities	531000
Awareness raising amongst villagers	1349000
Establishment of enclosures	2437500
Small equipment (rakes, wheelbarrows, cutting torque, forks..)	755500
Larger equipment (donkeys, wagons)	200000
Gardien (paid labour)	1320000
Plant production material	2970000
Plantation	657500
Protection (firebreaks and weeding)	182500
Total Cost	**10'403'000**
Present Value Total Cost (r=2%)	**10'099'029**