# Economic Analysis of a Low Carbon Economy for Liberia

23 November 2009

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**Acknowledgements**: Representatives were consulted from a wide range of sectors, including from forestry; agriculture, planning; lands, mines and energy; infrastructure; public works; finance; the governance commission; internal affairs and LISGIS, as well as representatives from industry, the World Bank, United Nations, civil society, and academia. The Office of the President provided invaluable overarching support to the process. Other Conservation International staff have provided valuable inputs and comments to this report. All remaining errors, of course, are our own.

## Executive Summary

Liberia is blessed with extensive natural assets, including forests and bountiful land. Decisions will be made about how to use these assets as Liberia develops. This study explores the merits of a low-carbon development strategy, including the costs involved, the amount and potential value of the 'carbon credits' that could be generated and the potential funding sources for these revenues. The study concentrates on deforestation and degradation, rather than other sources of carbon emissions such as energy and transportation.

A 25-year low-carbon development strategy could provide substantial benefits for Liberia:

- Carbon revenues of over **$55 million per year**, assuming a price of $5 per ton is received (revenues could increase to three times this amount if prices of carbon credits continue to rise);
- More efficient, higher-yielding agriculture;
- Increased protection of natural and cultural heritage within protected areas; and
- Status as a regional leader in the world's newest industry, creating green jobs.

This strategy would incur set-up costs, management costs and lost timber revenues, which average to around **$22 million per year**, plus an additional $5 million or so per year for national coordinating and monitoring institutions (which could also coordinate climate-change adaptation policy). However, these costs would not be spread evenly over the 25 years; costs would be significantly higher in the early years as programs are initiated and set-up costs incurred. Liberia can look for opportunities to partner with organizations prepared to fund these set-up costs.

Global efforts to limit global warming by reducing the quantity of carbon emitted into the atmosphere are expected to result in an enormous new market. When emissions are reduced, such as through policies to reduce deforestation or regenerate forest, carbon credits can be generated. This may be particularly cost-effective in developing countries like Liberia. Developed nations may be prepared to buy these credits - through multilateral agreements such as that being developed by Norway and Guyana; through voluntary transactions between private parties; or through a market framework, such as the proposal to create a mechanism known as Reduced Emissions from Deforestation and Degradation (REDD) within the global negotiations currently taking place on climate change.

Realizing revenues of the magnitude indicated above will not be straightforward; this would require an ambitious and challenging program, including changes to some well-established policies and practices. Revenues from carbon credits would be performance based, meaning that Liberia would only receive revenues if it is successful in reducing its deforestation rate and increasing regeneration rates. This highlights the crucial importance of establishing robust governance structures and monitoring programs, and of heightening capacity to implement schemes.

The study has analyzed low-carbon policy options for Liberia, finding several that are highly competitive and that together could comprise a robust low-carbon development strategy for Liberia.

The proposed low-carbon development strategy would include:

- Moving to **a more efficient agricultural system** can be an extremely cost-effective way to generate carbon credits. By replacing shifting cultivation with either conservation agriculture or irrigated lowland rice cultivation, or by subsidizing fertilizer inputs, Liberia can reduce amount of forest lost to slash-and-burn practices each year. Under these systems there would be enough land available to both produce Liberia's food needs and assign large areas to regenerate the natural forest cover.

  These policies require significant set-up costs, but would then be profitable for farmers on an ongoing basis, even without carbon credits. Carbon finance could certainly help to fund the set-up costs; at a price of $5 per ton of $CO_2$ saved, these policies would all be profitable for Liberia.

  The challenges in changing the dominant mode of agriculture should not be understated: land tenure is often insecure; access to capital, knowledge, and appropriate land is often absent; and mindsets are difficult to change.

- There is already legislation in place to create 1.5 million hectares of **Protected Areas**. Accelerating the establishment of these areas would further reduce carbon emissions, as well as protecting the cultural and natural assets they contain. Carbon revenues could help fund the set-up costs involved; at $5 per ton of carbon dioxide, this acceleration would be profitable for Liberia.

- Ensuring that tree crop **plantations are located on degraded land** rather than forest areas can generate significant carbon credits at virtually no cost.

- Reducing the number of **Timber Sales Contracts** issued, and instead placing these areas into carbon concessions, would save large amounts of carbon relatively cheaply, due to the intense nature of the logging of these areas. The agricultural land that these areas produce would not be needed if the above agricultural policies are also implemented.

- Introducing **energy-efficient stoves for charcoal and fuelwood** would reduce pressure on the forests. This policy would be profitable for Liberia if $5 per ton of carbon dioxide were received for them.

The study has also identified other policies that could be attractive, depending on market conditions. These are not included within the numbers presented above.

- Replacing some **commercial timber** with carbon concessions could be financially beneficial if the price of carbon credits relative to timber rises or if the Liberian forests are found to contain less timber than estimated. This also depends upon the financial performance of logging concessions and whether the profits generated stay within Liberia. If the FMCs succeed in delivering $8m^3$ of timber per harvested hectare on a sustainable basis, with export prices at $\$230/m^3$, then a price of at least $\$13.50/tCO_2$ would be required before it becomes beneficial to Liberia to reduce the targeted area of FMCs. This carbon price is not achievable in current markets, but it is realistically possible that this price could be reached under a REDD market in the future. If the FMCs fail to deliver to these projections, then it would be beneficial to Liberia to reduce the targeted area of FMCs at lower prices, perhaps as little as $7.25/tCO_2$.

These same issues also apply to the decision of whether community forest areas should be managed for sustainable forestry or as carbon concessions, although the ability of the community to capture revenue and other benefits may vary between carbon and forestry.

As a result, although the low-carbon development strategy proposed here does not include a reduction in the area of FMCs, the forestry sector can still be involved in carbon. Liberia may wish to seriously consider:

- Establishing **pilot areas under carbon concession deals**, to test the performance of these deals. Similar projects could also take place within community concessions.
- Enacting a **two-year moratorium** on new forestry concessions. There are major advantages in having time to "wait and see" how markets for carbon credits develop and how commercial forestry performs. Liberia would retain more options on how to optimize the profitability of forest use.
- Consider revoking forestry concessions if they **fail to meet the terms of their contract**. This would give commercial concessions opportunities to prove themselves, but would quickly replace them with substantial carbon revenues if they fail to abide by sustainable logging regulations.

- Improving the efficiency and regulation of **pitsawing** could generate significant carbon credits by reducing the intensity of the pressures placed on the forest.

The table and diagram overleaf summarize the key results by policy.

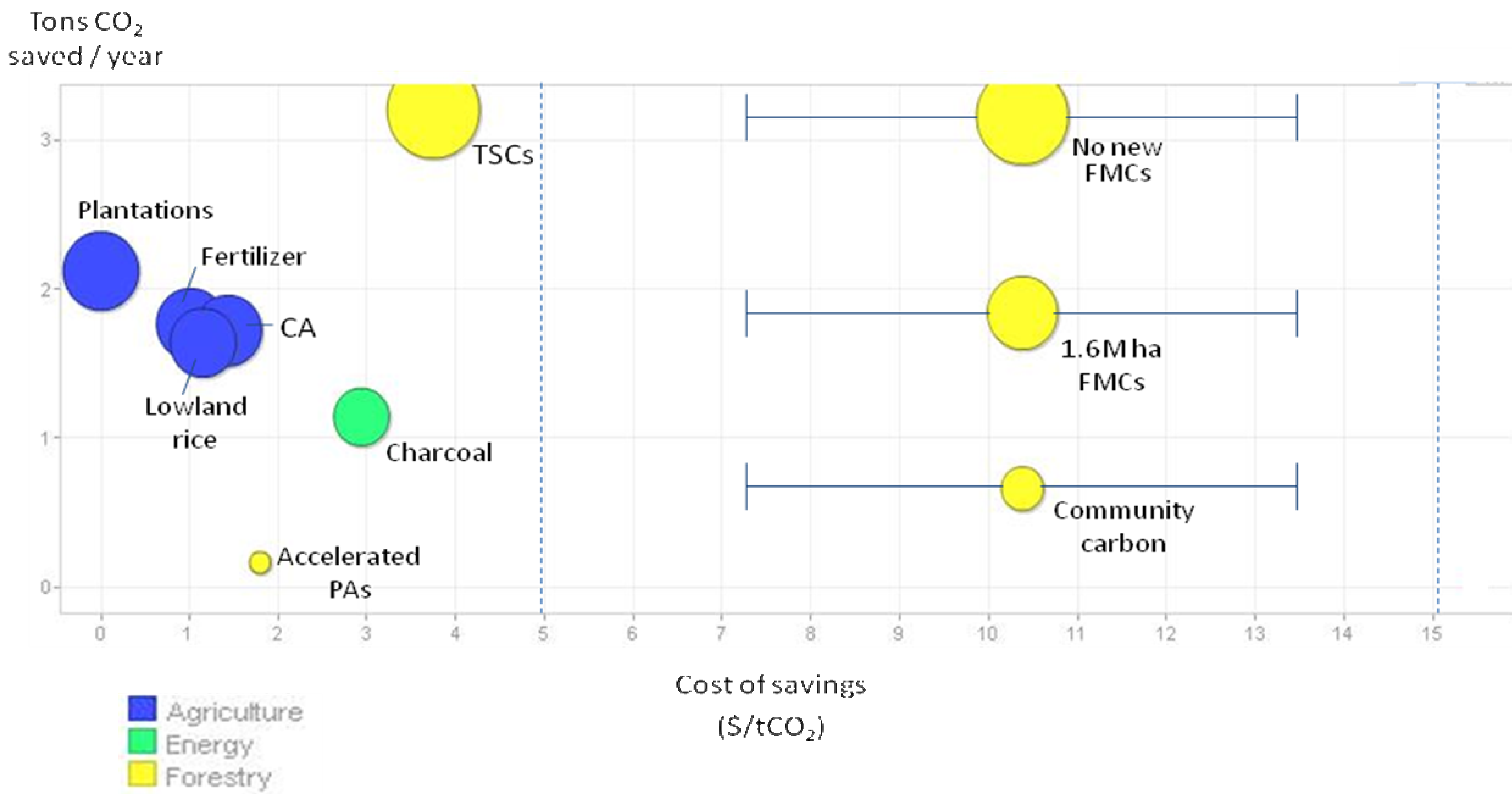
**Table A: Key results by policy, including potential carbon revenues**

| Policy | Average CO2 saved per year (million tons) | Cost of carbon saved ($/tCO$_2$) | $5/ton: Carbon revenues per year ($M) | $5/ton: Net benefit / cost per year ($M) |
|---|---|---|---|---|
| 100,000ha of plantations are located on degraded land rather than forest areas | 2.1 | Very low | 10.6 | 10.6 |
| Fertilizer subsidies to increase efficiency of shifting agriculture | 1.8 | <2 | 8.8 | 7.1 |
| Lowland rice promoted in place of shifting agriculture | 1.6 | <2 | 8.2 | 6.3 |
| Conservation agriculture promoted in place of shifting agriculture | 1.7 | <2 | 8.6 | 6.1 |
| Accelerated creation of Protected Area Network | 0.2 (0.8 for 5 years, then zero) | <2 | 0.8 | 0.5 |
| Increased efficiency of charcoal production & use | 1.1 | 2.67 - 3.20 | 5.7 | 2.1 |
| No further TSCs | 3.2 | 3.75 | 16.0 | 4.0 |
| ***Sub-total for potential low-carbon development strategy*** | ***11.7*** | | ***58.7*** | ***36.7*** |
| Restrict FMCs to 1.6 million ha | 1.8 | 7.25 - 13.50 | 9.2 | -4.1 to -15.6 |
| No new FMCs | 3.2 | 7.25 - 13.50 | 15.8 | -7.1 to -26.9 |
| Community forest areas are managed as carbon concessions | 0.7 | 7.25 - 13.50 | 3.3 | -1.5 to -5.6 |
| ***Sub-total for additional quantified strategies***[1] | ***4.0*** | | ***19.1*** | ***-8.6 to -32.5*** |
| Two year moratorium on new concessions | Only temporary gains | n/a | n/a | n/a |
| Revoke existing forestry concessions that fail to meet terms of contract, replace with carbon concession | Unknown | n/a | n/a | n/a |
| Improved efficiency of pitsawing | 3 | n/a | 15.0 | n/a |

[1] excluding restricting FMCs to 1.6 million ha, as this would be double-counting with the 'no new FMCs' policy

Figure A plots each policy on two axes: the x-axis shows the cost per ton of $CO_2$ saved; policies to the left of the first dotted line are beneficial to Liberia at a price of $5/ton $CO_2$, and are included in the proposed low-carbon development strategy. All policies lie to the left of the second line; they are all beneficial at $15/ton $CO_2$. Error bars indicate the level of uncertainty of the costs. The y-axis shows tons of $CO_2$ saved annually.

**Figure A: Volume of $CO_2$ saved and cost of $CO_2$ savings for each quantified policy**



Producing carbon credits can provide profit opportunities for entrepreneurs and would be a source of green jobs. As the nation best endowed with forest in West Africa, Liberia has the opportunity to be a regional market leader in this industry, which could easily be worth billions of dollars regionally. This will require effort; land must be monitored for illegal logging and protected from forest fires. Agriculture must become more productive; products and services like organic and inorganic fertilizer, irrigation, and grading will be procured, often locally. Data must be collected and new payment methods developed. New technologies such as efficient charcoal kilns can be manufactured locally. Once Liberians have gained expertise in these areas, they can apply it in other countries as the carbon industry expands.

These proposed policies will be challenging to implement for a number of reasons. Changes in agricultural practices will need better definition of property rights, capacity building amongst farmers and extension agents, coordination across communities and land owners, and a total change in mindset for subsistence farmers. Changes in expectations of the forestry sector will face political and implementation challenges. Finally, generating carbon revenue, even from great policies well implemented, is not easy, and requires a flexible national and legal policy framework and strategy.

Beyond generating revenues, policymakers will want to consider their distributional implications, in particular that any revenues feed down to local landowners, for two reasons:

1. Deforestation rates will only be reduced, and forest regeneration will only take place, if local communities are engaged in the program and incentivized to follow the necessary land-use practices. As the financing mechanisms may be performance based, this means that communities' behaviors will be critical in determining the level of revenues received; and
2. Poverty reduction (and equitable distribution of benefits) is a key goal of Liberia's strategy, as outlined in the Poverty Reduction Strategy (Republic of Liberia, 2008).

Governance structures will be required at all levels from community to national. Indeed, this process can provide the catalyst for establishing strengthened governance structures that can, if well designed, help to reduce the potential for conflict in rural areas, and can subsequently be employed on other issues such as adapting to the impacts of climate change, and preserving the water services provided by forests. The proposed National Climate Change Steering Committee and Climate Change Secretariat will be important bodies for managing the implementation of a low-carbon development strategy.

This study intends to stimulate a discussion on the low-carbon policies that are feasible for Liberia. If the GoL uses this discussion as a launching-pad to create a detailed national proposal for a Low-Carbon Economy, it can create an emissions-reducing "product" and market this to the global community, potentially generating very substantial revenues and creating a new sector of green jobs.

## Contents

## 1. Introduction

Liberia is blessed with extensive natural assets, including forests and bountiful land. Decisions will be made about how to use these assets as Liberia develops. This study is designed to inform the Government of Liberia (GoL) about the potential for pursuing a low-carbon development strategy based on policies to reduce deforestation and regenerate forest. The study was requested by the GoL as a response to growing interest in the role that emerging markets for carbon emissions could play in Liberia's development. It concentrates on deforestation and degradation, rather than other sources of carbon emissions such as energy and transportation.

*This document is a work in progress.* These initial results will be discussed by policymakers from a variety of sectors at a workshop on 25 November 2009, to identify the practicality and desirability of implementing the policies discussed in these pages, plus any others. The report will subsequently be refined to reflect new information; to incorporate updated policy direction from the GoL; to better cost out programs as they become specifically proposed for the Liberian context; and to quantify additional cost and benefit flows as new data sources are identified.

Global efforts to limit global warming by reducing the quantity of carbon emitted into the atmosphere are expected to result in an enormous new market. When emissions are reduced, such as through policies to reduce deforestation or regenerate forest, carbon credits can be generated. This may be particularly cost-effective in developing countries like Liberia. Developed nations may be prepared to buy these credits - through bilateral agreements such as that recently signed between Norway and Guyana; through voluntary transactions between private parties; or through a market framework, such as the proposal to create a mechanism known as Reduced Emissions from Deforestation and Degradation (REDD) within the global negotiations currently taking place on climate change), hosted by the United Nations. The quantity of compensation would be performance based; it would be tied to monitored and verified reductions in carbon emissions.

The report identifies policies that could help Liberia to reduce carbon emissions, and provides information about the relative costs and benefits of these, including the magnitude and cost-effectiveness of each option in terms of reducing carbon emissions. It also briefly discusses the potential funding sources for these revenues. This is intended to be an illustrative list to inform policy decisions, and to highlight the magnitude of the contribution each option could make to a Low Carbon Economy. It does not constitute an official policy position, but is a 'menu' of options to consider. In its current version, it focuses more on carbon potential and cost-effectiveness rather than on political feasibility, leaving the question of feasibility open for discussion as policy decisions are taken. Policies were selected following consultation with policymakers in all relevant sectors, plus a review of existing reports and data.

Results will inform strategic planning, and will help to identify and leverage prospects for international carbon financing that would help to make low carbon interventions economically viable for Liberia.

The analysis will provide information about the economic costs and benefits of the policy, the tons of carbon saved, the cost per ton of carbon saved, the area affected, and in some cases the impact on employment levels. In Section 2 we describe the methodology for the analysis. The form of the results vary somewhat from one policy to another, depending on available data and the nature of the policy decision. Section 3 details the quantified policies considered for the forestry, agriculture, and energy sectors; all of these are directly related to land use and forest cover. In Section 4, an additional set of policies are briefly discussed but not quantified. Section 5 explores the potential for carbon revenues and the merits of different policy designs of carbon mechanisms, including a bilateral deal and/or engaging in a future REDD market. It also assesses the potential carbon revenues that might potentially be earned from each of the candidate policies under these mechanisms. It is worth noting that Liberia's development path will also be influenced by a wide variety of factors that are not captured in this exercise, such as policies with respect to rural credit, global trade, property rights and so on.

These initial results will be presented at a workshop on 25 November 2009. The workshop will give policymakers an opportunity to discuss these candidate policies based on the information presented here, to refine the assumptions and policy details to better reflect the situation on the ground, and potentially to agree upon a provisional 'road map'. This road map would lead towards a national plan/proposal for reducing Liberia's carbon emissions and generating revenue from these, while also meeting development targets. It can be designed to be taken to potential partner organizations to discuss financing and implementation solutions. The workshop will be accompanied by a discussion of a proposal to establish a National Climate Change Steering Committee for Liberia in order to coordinate low-carbon activities as well as climate-change adaptation policy. The following day, another workshop will develop Liberia's negotiating stance at the COP-15 in Copenhagen.

## 1.1. Background and context

Following fourteen years of conflict which led to a collapsed economy, destroyed infrastructure and hundreds of thousands of displaced persons, Liberia is rapidly restructuring its governance institutions and developing a platform for strong and sustainable economic development. Following the 2003 peace agreement, economic growth quickly rebounded to an estimated 9.4% in 2007 and 7.1% in 2008 according to World Bank estimates. Liberia still faces a number of difficult challenges, with over half of all Liberians living below the poverty line, high unemployment rates, few functioning schools and hospitals, and very little viable water and electricity infrastructure outside of Monrovia.

Sustainable use of Liberia's natural resources may prove to be a key driver in rebuilding Liberia. With around 45% of the country forested (see Table 1), the forestry sector can potentially create jobs, drive economic growth and provide revenues from the global REDD market. Guidelines in the new forest reform law provide the legal framework for sustainable forest management and establish oversight for an industry that once fueled the country's conflict. The burgeoning global carbon market also warrants attention as an alternative source of revenue that would enable Liberia to financially benefit from its forests without degrading them.

To fully benefit from the potential bounty of Liberia's forests, a holistic approach to Liberia's economy needs to be taken to reduce conflict between the various sectors. Illegal pitsawing, mining activities, and fuel wood and charcoal collection may also increase deforestation and need to be included when examining the development of the forestry sector. In addition, the expansion of shifting cultivation fueled in part by the repopulation of rural areas will require a significant amount of land and will most likely encroach into forests. Making this agriculture and forestry-related activities more efficient, and freeing up degraded land to return to forest, will benefit Liberia in the long run and can be catalyzed with REDD finance.

Consideration should also be given to the benefits the forests provide that are often excluded from economic analyses. Many Liberians rely on the forest for non-timber forest products (NTFPs), including bush meat, spices, and medicinals. Likewise, the forests provide protection from soil erosion, a source for clean water, and habitat for wildlife including rare and endangered animals like the pygmy hippopotamus and the Nigerian chimpanzee.

The anticipated increase in rubber and palm oil plantations will also play a significant role in the future economic development of the country as well as impact the carbon stock. The allocation of land for plantations and other land uses will be a critical component of the low-carbon economy strategy. Understanding the trade-offs between policy options, including opportunity costs, land requirements, distribution of benefits and impact on local communities will all be important factors in determining the most appropriate approach for implementing a low carbon economy.

Liberia is currently engaged in the REDD Readiness Preparation Proposal (R-PP) process under the World Bank's Forest Carbon Partnership Facility. This document, and the policy discussion that it stimulates, will greatly facilitate the preparation of that proposal. Equally important, this document will enable the GoL to consider carbon options outside that particular initiative.

## 2. Methodology

This section describes the general approach undertaken in order to (1) identify candidate policies to be assessed; (2) model the costs, benefits and carbon impacts of each policy; and (3) assess the potential for each policy to generate carbon revenues. Section 3 describes the specific method used to assess each policy in more detail.

*1.* **Identify candidate policies with potential to reduce carbon emissions**

A list of candidate policies was drawn up based on extensive government input from a range of ministries, a review of sectoral literature and development plans, and ideas drawn from best practices elsewhere. This list of candidate policies is in no way intended to represent an official policy position; rather it presents options for policymakers to discuss and potentially to choose from. It is not exhaustive in scope.

Policymakers in a wide range of sectors were consulted during trips to Liberia by the analysis team. Sectors included forestry; agriculture; planning; lands, mines and energy; infrastructure; public works; finance; the governance commission; internal affairs and LISGIS, as well as representatives from the private sector, international organizations, civil society and academia. Contacts were asked to suggest and appraise 'low-carbon' alternatives to the 'business-as-usual' policy scenario i.e. the existing and planned strategies for their sector.

Some of the policy ideas were generated during these meetings; others originated from a review of development plans, reports and data from government and non-government sources; and some came from reviewing best practices that are being implemented or tested elsewhere.

A policy was included if it was a plausible alternative for Liberia to implement at some scale, if there is a clear mechanism through which the policy would reduce deforestation and/or forest degradation, and if it was possible to quantify. Section 4 briefly discusses an additional set of policies that are considered to be plausible options for Liberia, but are more difficult to quantify without further data gathering.

*2.* **Economic modeling of the costs, benefits, and carbon impacts of each proposed policy**

Each individual policy was assessed to determine the economic costs and benefits involved in implementation. Particular attention was given to projecting the physical tons of carbon projected to be saved by the policy, through projected changes in deforestation and/or forest degradation.

Different approaches were required for each proposed policy, depending on the nature of the policy (e.g. whether it changes the area under a given land use, or changes the practices of the land use) and the availability of different types of data sources.

In general, the main results presented in Section 3 are as follows. The exact nature of the results varies somewhat due to the difference in the methodology employed:

- Revenues ($)
- Costs including opportunity costs ($)
- Total carbon saved (tons)
- Cost per ton carbon saved ($/ton)

- Area affected (hectares)
- Employment impact (*where this was possible to estimate*)

**Other types of benefits**, such as biodiversity gains or impacts on water supply, are generally not calculated here; these should be considered additional benefits to those shown here.

This fits with the general principle of being **conservative** in calculating the benefits (including the carbon potential). Conservative assumptions have been chosen wherever there is uncertainty present. Results should therefore be considered to be at the lower end of the likely range of net potential benefits of each policy.

Where appropriate, these results are presented as **annual** values i.e. the amount of carbon saved is shown as tons per year. For some policies, it was more relevant to show total results over a period of time e.g. the total tons carbon saved over a 25-year period. This is clearly denoted in the text.

In some cases, the analysis started by calculating per hectare results, and then combining these parameters with data on the **total land area** in each use, to characterize the total anticipated changes at the national level. In other cases it was more appropriate to start from the total effect of the policy (e.g. in the charcoal sector, where the activity is not necessarily directly linked to a set area of land). Section 2.1 describes the areas under each land-use in Liberia currently, and the sources used to determine this.

It will be important to consider the **distributional implications** of the alternative scenarios for different stakeholders. While some of these can be roughly quantified, in most cases the distribution of benefits will depend on the details of the policies used to achieve the carbon savings. For instance, deforestation may be avoided through a faster roll-out of Protected Areas. How that affects men versus women, or middle-income versus poor Liberians, will depend on the specifics of how the areas are protected, how local communities are provided for, and which livelihoods are created as a result of the program. The same will also be true for most other policies. As the low-carbon development strategy for Liberia becomes better defined, distributional questions should remain front and center for program design. Future iterations of this document may be able to quantify this aspect of the policies as their details become clearer.

*3.* **Assess the potential for carbon revenues**

Section 5 considers the contribution that carbon revenues could make to Liberia, and how these revenues could affect the choices of policies from the candidate list described above. It carries out two functions:

- Summarizes the options for carbon mechanisms in Liberia, including the option of signing a bilateral deal, which could provide a one-stop shop for carbon finance in the near term, and/or engaging in the current voluntary REDD market and the formalized Clean Development Mechanism (CDM) that may require less national direction to get in place;
- Calculates the potential carbon revenues that could be earned from each of the candidate policies under a range of different future carbon prices, including a brief discussion of the practical issues involved in generating these revenues in each case.

## 2.1. Liberia's Land Uses by Area

Based on LANDSAT imagery and existing data sources, Liberia has at least 3.4 million ha of agricultural land. This is divided into lowland (swamp or irrigated) and upland areas, with potential lowland areas representing roughly 600,000 ha, and upland areas representing the remainder of arable land (Kiazolu and Tucker, 2008).

Prior to the war, 600,000 ha of this land was cultivated, with 220,000 ha under permanent rotation or in plantations (FAO Comprehensive Assessment, 2007). Given our analysis of available data, we estimate that up to 507,000 ha are currently under cultivation.

As shown in Table 1, in any given year up to 2.8 million ha of land is in a fallow period but under shifting cultivation, bringing the total estimate of land used by Liberian smallholder farmers to an estimated 3.3 million ha. In 2007, there were an estimated 406,000 farming families with an average range of 0.6 -1.5 ha of land each (MOA, 2007). If we assume a 10% growth rate,[2] we conservatively assume that there are 484,000 families currently engaged in farming activities in Liberia. Food crops such as rice, cassava, and other vegetables are the predominant crops grown; many families also have small plots of cash crops such as rubber and cocoa. Shifting cultivation is the dominant farming strategy used in the uplands, where land is cleared and used as crop land for one to two years and then lays fallow for up to 8-10 years (CFSAM). There is a combination of short fallow periods in the populated areas and long periods with nearly abandoned farmland in the less populated areas.

When the estimated 124,000 ha of plantations that grow rubber trees and palm oil are added in, the total land used for agriculture totals to 3.4 million ha.

Total forest area is estimated at around 4.4 million ha, from LANDSAT satellite monitoring (classes 3.1, 3.2 and 3.3). This corresponds to around 45% of Liberia's total area. This total would vary if a different definition of 'forest' were used i.e. if degraded forest were included following different rules. Around 3.2 million ha of this forest has not yet been allocated as confirmed concessions or Protected Areas; although much of it has been designated as either commercial, conservation, or community areas in the Forest Code (2006).

This leaves a balance of just over 1 million ha of land that is neither forested nor under agricultural rotation. This includes urban areas, open water and unused coastal areas, wasteland and some potentially productive land that is currently unused. An additional 182,000 ha of pastureland have been targeted for rehabilitation (CAFSM).

[2] In order to estimate how much land in Liberia is not required for agriculture, and therefore may be utilized in carbon sequestration, we must estimate how much land is employed each year in agriculture. The most conservative strategy, that errors on the side of caution when estimating carbon benefits, assumes a generous amount of land involved in farming.

**Table 1: Areas under each land use, 2009**

| Land use | Area (ha, 2009)* | Source |
|---|---|---|
| **Land currently in active cultivation** | | |
| Upland rice (shifting cultivation) | 286,000 | CFSAM[i]/HFP[ii] |
| Lowland rice | 26,000 | CFSAM |
| Cassava (shifting cultivation) | 110,000 | CFSAM/HFP |
| Cocoa | 25,000 | CFSAM/Kiazolu[iii] |
| Smallholder rubber | 51,000 | Guenette[iv] |
| Sugar cane | 9,000 | FAOSTAT[v] |
| Total | **507,000** | |
| **Fallow land** under shifting cultivation (with an 8-year rotation for rice & cassava) | **2,772,000** | |
| **Commercial Plantations** | | |
| Rubber | 118,000 | Guenette, Milbrandt[vi] |
| Palm oil | 6,000 | |
| Total | **124,000** | |
| **Total land in agricultural system** (total subsistence crops & plantations) | **3,403,000** | |
| **Forested Areas** | | |
| FMC | 1,007,000 | Milbrandt[vi] |
| TSC | 30,000 | Milbrandt[vi] |
| PAs | 194,000 | FDA[vii] |
| Forest not yet allocated | 3,162,000 | |
| **Total Forested Areas** | **4,393,000** | LANDSAT |
| **Non-forest area not allocated or used** | **1,016,000** | |
| **Total land area** | **9,600,000** | Liberia MoA[viii] |

*Assuming a 10% growth rate per year

[i] Food and Agriculture Organization (FAO)/World Food Programme (WFP). 2006. Crop and Food Security Assessment (CFSAM)

[ii] World Food Programme – Joint Assessment. 2008. The Impact of High Prices on Food Security (HFP) in Liberia

[iii] Kiazolu, James and A. Tucker (2008) Assessment of Agricultural Information Needs in African, Caribbean and Pacific (ACP) States: West Africa: Country study Liberia. Technical Centre for Agricultural and Rural Cooperation (CTA)

[iv] Guenette, Paul (2007) Cocoa, Palm & Rubber: Opportunities in the New Liberia. The Africa Journal Rebranding Africa. The Corporate Council on Africa

[v] Food and Agriculture Organization (FAO). Liberia Production. FAOSTAT. 11/2009. http://faostat.fao.org

[vi] Milbrandt, Anelia. (2009) Assessment of Biomass Resources in Liberia. Liberia Energy Assistance Program (LEAP)/USAID

[viii] Forestry Development Authority (2009) Alternatives to Commercial Logging in Liberia A Policy Discussion Note DRAFT

[viii] Ministry of Agriculture (2007) Comprehensive Assessment of the Agricultural Sector in Liberia Volume 2.2 – Sub-Sector Reports

**Lowland rice**
As aforementioned, 600,000 ha of the arable land in Liberia are considered suitable for lowland agriculture. It is estimated that 3% of this land equaling 18,000 ha, is used for agriculture (CFSAM).[3] Since rice is the primary crop grown in these environs, it is assumed that the full 18,000 ha of land is used to grow lowland rice. With a 10% growth rate, we can assume that 26,000 ha of land are now being used for lowland rice farming (CFSAM).

**Upland Rice**
In 2005, Liberia had an annual production of rice totaling 84,649 tons. The average yield per hectare in 2005 was only 0.4 t/ha, a drastic (70%) reduction in productivity due to pests and other problems (CFSAM). This production amount would imply 212,000 ha of rice given the yield of 0.4 t/ha. After subtracting the 18,000 ha of land used for lowland rice farming, there would be 195,000 ha of land for upland rice farming. Again, if we assume a 10% growth rate over four years, then 286,000 ha of land is now being used for upland rice farming.[4]

**Cassava**
Along with rice, cassava is considered a staple crop for Liberian families. There is no large-scale production of cassava; it is cultivated at the subsistence scale using basic tools and intensive labor. In 2004, 75,000 ha of land was used for cassava production, yielding an average of 6.53 t/ha (Kiazolu and Tucker, 2008). However, given the difficulty in gathering data on cassava cultivation at the subsistence level, the estimate of land used for cassava cultivation could be considerably higher or lower. CFSAM for instance, estimates that as much as 106,000 ha were used for the production of cassava in 2005. And, pre-war estimates indicate that 58,254 ha were used for cassava cultivation in 1988 (CFSAM).

If we apply the 10% growth rate to the estimate of 75,000 ha of land used for cassava, then we can assume 110,000 ha of land were used for cassava production in 2009.

**Rubber**
In 2006, the export of rubber, estimated at $150 million, constituted 90% of export revenue. (Kiazolu and Tucker, 2008). Before the war, large-scale rubber plantations provided the bulk of the rubber, however the majority of these plantations were abandoned during the war and are no longer viable. Currently, it is estimated that 118,000 ha of land is used for large-scale rubber plantations, with another 35,000 hectares of smallholder production (Milbrandt, 2009 and Guenette, 2007) used for rubber production. If we assume the same growth rate (10%) for small-scale rubber production as for the rest of the agricultural sector, than 51,000 ha of land was used in 2009 for small-scale rubber production, bringing the total to 169,000ha.[5]

Given the age and conditions of the large-scale and government-run plantations, it is possible that a significant percent of the land is not productive. In 2001, 110,000 tons of rubber was exported from Liberia. If it is assumed that one ha produces an average of 1.2 tons of rubber (global yields tend to range between 1.0 and 1.8 t/ha), then the total amount of land with productive rubber trees

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[3] In personal correspondence with officials at the Ministry of Agriculture, we learned that up to 20% of suitable lowland agriculture may have been laid out. The exact number, however, does not have direct consequences at this stage of the analysis.
[4] The 2008 Annual Report of the Ministry of Agriculture estimated a yield of 0.74t/ha for upland rice; higher production was therefore estimated across the country, but the acreage would not be drastically affected.
[5] Authors met with Sustainable Tree Crop Program rubber specialists in September 2009, who were using an estimate of 170,000-200,000ha of rubber in Liberia.

would be closer to 92,000 ha, with the remaining 77,000 ha being recently planted or unproductive.

**Palm Oil**

Many of the palm oil plantations were also abandoned during the war and there has been little maintenance or replanting in the past 20 years (Kiazolu and Tucker, 2008). Currently there are an estimated 6,000 ha of palm oil plantations that are in production and an additional 30,000 ha of abandoned plantations that are available to be refurbished. A significant amount of palm oil is also assumed to be produced at the subsistence level from wild groves of palm trees.

According to FAOSTAT, in 2007 Liberia produced 34,800 tons of palm oil. If 4 tons of palm oil was produced per ha, the 6,000 ha of oil palm plantations would account for 24,000 tons of palm oil with production from the wild groves constituting the remaining 10,800 tons.

**Sugar Cane**

In 2007, 265,000 tons of sugar cane was produced in Liberia, according to FAOSTAT. Assuming a rather low level of productivity of 40 tons per ha, roughly 6,625 ha of land was used for sugar cane production (Alam, 2007).

**Cocoa**

An estimated 17,000 ha of land is used for the production of cocoa (Kiazolu and Tucker, 2008) with an average of 2,000 – 3,000 tons produced each year. Again, if we apply the 10% growth rate, we can assume roughly 25,000 ha of land is currently being used for cocoa production.

**Coffee**

The effects of the war virtually destroyed the coffee industry in Liberia. The coffee trees that were not destroyed during the war are not overgrown and are not viable for production. In 2001, only 66 tons of coffee was produced in Liberia, according to FAOSTAT, indicating a negligible amount of ha for coffee production.

## 3. Assessment of Policies

### 3.1. Forestry

The forest sector is central to Liberia's low-carbon future. Policies pursued by the Government of Liberia with respect to commercial timber, protected areas, REDD transactions, community forestry, and the pitsawing industry will have an enormous impact on carbon balances retained in Liberia's forests, and thus in the overall emissions profile of the country. At the same time, these policies are vitally important with respect to employment and revenue derived from Liberia's forest sector.

To illuminate the implications of various potential policy choices, a basic model of commercial forestry in Liberia was developed, drawing heavily on existing analyses by the FDA, the World Bank, and others. Given data constraints, this model must be viewed as a stylized representation that remains subject to further refinement. Nevertheless, the model permits illustration of the impacts under different policy scenarios. Prior to discussing these scenarios, the basic model is presented below. It takes as its point of departure the sustainable logging protocol developed by the FDA, which may be summarized as a 25-year rotation system.

**Table 2: Basic Production Model: Sustainable timber harvest**

| | | | |
|---|---|---|---|
| Recoverable area | 80% | | Remainder of concession area off limits to harvesting because of slopes, waterways, etc. Sources suggest a range of 75-80%. |
| Annual coupe | 4% | | 25 year rotation. Some analyses suggest this is not sufficient for recovery of commercial stock (Shearman 2009). |
| Production for active hectare (m3/ha/yr) | 8 | | Figures in the available literature range from 3-15. Shearman (2009) suggests that 8 is likely, 15 possible if FDA regulations are ignored; historical sources suggest that even 8 may be a generous assumption. A key consideration is whether an area was previously logged or not - previously logged areas could yield as little as 3 or 4 $m^3$/ha or less. The question is whether 8 is a fair assumption as a weighted average for the country, noting that analysis of a specific area would require more fine scale data for credible quantification. |
| Production for average hectare in concession (m3/ha/yr) | | 0.256 | This may be optimistic given most actual production figures, such as FDA 2001 revenue reports that indicate average harvest of .18 $m^3$ per concession ha. |

This simple characterization of timber production assumes that the FDA is able to enforce its sustainable logging requirements to ensure compliance with regulations by timber operators. Using this production model and parameters drawn from literature and analyses provided by the FDA, indicative per-hectare values for variables of interest can be derived, as reported in the table below. Again, these are derived as averages of national aggregates, and require more detailed modeling for application to specific smaller areas.

**Table 3: Per hectare revenue estimates**

| Item | Value per 1 ha in commercial concession | Notes |
|---|---|---|
| Government revenue | | |
| - FDA fees ($/ha) | $11.52 | Figures in various sources imply a range of $7.5 to $20 per hectare, aggregating all taxes and fees (FDA 2001, FDA 2006, FDA 2009, World Bank 2009). |
| - Corporate tax ($/ha) | $5.47 | Calculated from model, using 25% corporate tax rate on net revenue |
| Net profit ($/ha) | $16.42 | |
| Employment (jobs/ha) | .0018 | Reliable data not available; this figure derived from Poverty Reduction Strategy (PRS) estimate of approx. 7,000 jobs to produce approx. 1 million $m^3$; consistent with rough estimates available in other sources (FDA 2006, World Bank 2009). Note that this figure reflects direct employment and does not include multipliers; the analysis remains valid if multipliers are assumed to be comparable for alternative activities, and no available evidence exists to the contrary. |

The revenue numbers are generated assuming that foresters are able to get prices on export lumber of $230/$m^3$ f.o.b. and on domestic lumber of $140/$m^3$.

Finally, carbon implications of the basic model are characterized, taking into consideration emissions released during harvest and carbon sequestered during regrowth under the rotation system (figures will be presented in terms of $CO_2$ rather than carbon, as prices and transactions in carbon credits are based on $CO_2$). The conclusion is that the FDA's sustainable logging regulations would result in a permanent net loss of about 66 tons of $CO_2$ per average hectare within a timber concession, or about 12.5% of the original carbon stock, relative to its original state. This estimate is driven by the conservative assumption that sustainable logging results in removal of 30% of biomass per hectare under active harvest, followed by regrowth during the remainder of the rotation.

**Table 4: Carbon impacts of sustainable logging**

| Item / assumption | | Notes |
|---|---|---|
| Average tons of carbon/ha | 144 | FAO (2009). Consistent with Brown and Gaston (1996) and other sources. As with production per ha above, this serves as a national average that does not differentiate forests on the basis of how recently they have been disturbed (i.e. logged vs. unlogged forest). |
| Average tons of $CO_2$/ha | 527 | This is the above figure multiplied by the conversion factor (3.66) |
| % biomass loss under sustainable logging | 30% | Houghton (1999) estimates 20-80%. Other sources suggest that 30% is a conservative assumption |
| Tons $CO_2$ lost per harvested ha | 158 | This is consistent with Pinard and Putz (1996) who find 44 tons of carbon (or 161 tons of $CO_2$) lost per ha under RIL in Saba. |
| Tons $CO_2$ lost per average concession ha per year | 5.06 | This allows for the fact that only 80% x 4% of the concession is cut each year |
| **$CO_2$ gained through regrowth** | | |
| Assume total time needed for regrowth | 25 | FDA sustainable production model assumes 25 years. Sources cited in Shearman (2009) suggest at least 50 years. Houghton and Hackler (2001) state that 30 years are required for carbon recovery. We note that our results for $CO_2$ losses from forestry are contingent on the 25-year period proving sufficient for full regrowth. If this period proves to be insufficient, then our results will be overly conservative i.e. they will underestimate the $CO_2$ losses from forestry (and the carbon revenues that could be achieved from reducing the extent of commercial forestry). |
| Regrowth per average concession hectare per year (tons of $CO_2$) | 0.202 | In reality, the regrowth rate is not constant but changes over time. A simplifying assumption is necessary here: We assume that lost $C0_2$ is regained in equal increments over the above regrowth period. The result is roughly consistent with Houghton et al (1997). |
| Average $CO_2$ content per hectare in steady state under 25 year rotation | 461 | This steady state reflects an equilibrium in which each harvestable hectare has been exploited at some point in the 25-year cycle, and some are nearly fully regrown, some are just beginning to regrow, and the rest fall somewhere in between, such that the total $CO_2$ content remains constant. |
| Reduction in average $CO_2$ content per concession ha in steady state after 25 years, compared to original state (tons) | 66 | |

Taken together, the per-hectare figures presented above can be used to illustrate results under different policy scenarios. The baseline scenario is that the FDA allocates 2.3 million ha to commercial forestry, as per currently articulated forestry policy.

The table overleaf summarizes estimated benefits derived from allocating 2.3 million ha to commercial forestry, as well as the amount of $CO_2$ released. Against this must be set the costs to the Government of Liberia of managing the commercial timber sector at this scale. These costs principally comprise the budget needed for the FDA to execute its regulatory and oversight functions, manage contracts, and ensure compliance by commercial operators. There may also be an additional cost of maintaining the chain-of-custody system until it becomes self-financing (which is projected to be achieved at 1.6 million ha of active concessions).

**Table 5: Impacts of current FDA policy**

| | FDA Policy | Per hectare |
|---|---|---|
| Hectares allocated to commercial timber concessions | 2,300,000 | 1 |
| Government revenue (per year) | | |
| *FDA taxes and fees* | *$ 26,496,000* | $11.52 |
| *Corporate income tax* | *$ 12,585,600* | $5.47 |
| **Total** | **$ 39,081,600** | **$16.99** |
| **Private sector net profit (per year)** | **$ 37,756,800** | **$16.42** |
| Employment | 4,140 | 0.0018 |
| **$CO_2$ loss** (tons) (total reduction in $CO_2$ stored after 25 years, compared to original state) | **151,281,562** | **66** |
| **$CO_2$ loss** (tons) (average per year) | **6,051,262** | **2.64** |

### 3.1.1. Restrict forest concessions to 1.6 million ha

One policy option to consider is reducing the total area to be allocated to concessions to 1.6 million ha, and pursue REDD carbon credits on the remainder. Monitoring and oversight functions depend critically on the presence of an effective chain-of-custody system. Such a system has been designed and deployed, and requires a minimum of 1.6 million ha under commercial timber concessions to be financially viable.

By removing 700,000 ha from the commercial timber sector, Government revenues from timber fall by nearly $12 million per year, and net profit in the private sector declines by about $11.5 million per year (note that these changes are relative to the FDA policy scenario, which has yet to take effect). In addition, we factor in the costs of managing an area of forest under some form of carbon contract; we apply a management cost of $2.38 per hectare, which is drawn from analysis of the costs of managing Liberia's proposed Protected Areas (FDA 2006).

On the plus side, the loss of about 46 million tons of $CO_2$ is avoided over a 25-year period, representing an enormous potential revenue opportunity if these avoided emissions can be sold as carbon credits. The costs of this policy – management costs and foregone government revenue and private sector profit – are equivalent to $13.50 per ton of $CO_2$ loss avoided.[6] Historically, the preponderance of profits from the logging sector have been repatriated abroad, suggesting that the government revenue portion of opportunity cost may be more relevant; considering government revenue only, a minimum price of about $7.40 per ton of $CO_2$ is needed to make carbon transactions more attractive for the Government of Liberia than commercial concessions.[7] Note that these price conclusions are based on several conservative assumptions in the forestry model

[6] For simplicity, all calculations ignore the effect of the timing of the costs versus the timing of the carbon impacts (i.e. no discounting is applied), unless otherwise noted. In this case, the carbon benefits tend to be front-loaded whereas the costs are spread evenly over time; so ignoring discounting is a conservative approach here, which will tend to overstate the cost per ton of $CO_2$.
[7] Ideally, cost would reflect foregone value-added to the economy of Liberia – the contribution to GDP. However, data constraints preclude such an assessment.

that result in optimistic characterization of revenues and regeneration; this means that carbon deals are likely to be favorable at even lower prices. The table below shows the impact of changes in a few key parameters. The cost of each ton of $CO_2$ avoided is therefore estimated to be in the range \$7.25 to \$13.50/t$CO_2$, depending on the assumptions made.

**Table 6: Sensitivity analysis of the cost of emissions reductions**

| Parameter Change | Cost of $CO_2$ reductions (\$/t$CO_2$) |
|---|---|
| Harvestable volume per hectare is 4 $m^3$/ha rather than 8 $m^3$/ha | \$7.25 |
| Export price is \$200/$m^3$ rather than \$230/$m^3$ | \$11.15 |
| Regrowth period is 30 years rather than 25 years (and FDA policy is adjusted accordingly) | \$11.55 |
| Biomass loss as a result of harvesting is 45% rather than 30% | \$9.10 |

Removing 700,000 ha from the commercial sector for allocation to carbon transactions would displace about 1,260 jobs, but also create new employment opportunities to meet monitoring and enforcement requirements, while reducing some of the commercial management and oversight burden on the FDA.

### 3.1.2. No new forest concessions

A more ambitious low-carbon option would be to dismiss the 1.6 million ha threshold for the chain-of-custody system and desist from granting any new concessions beyond those that have already been issued. Existing concessions amount to about 1.1 million ha, so this policy would make 1.2 million ha available for carbon transactions, or 500,000 additional hectares compared to the previous scenario. Relative to the FDA policy scenario, foregone revenue, employment, and private sector profit are correspondingly greater, as are the avoided emissions.

One additional consideration here is that the carbon buyer may have to contribute towards sustaining the chain-of-custody system; the SGS group has been contracted with the expectation of at least 1.6 million ha being under commercial timber. This could be achieved either through providing additional funding (which would raise the cost of $CO_2$ emissions averted to above the \$13.50/ton quoted previously), or by negotiating with the SGS Group to provide services for the carbon sector in place of the timber sector.

Assuming that a deal could be struck where no additional cost is imposed due to the chain-of-custody system, the per-hectare calculations are identical to those for restricting total concession area to 1.6 million hectares; the total costs of this policy are equivalent to **between \$7.25 and \$13.50 per ton of $CO_2$** avoided. An additional 900 jobs may be lost relative to the 1.6 million ha scenario, but again, these will be offset to some extent by employment in forest management for carbon concessions.

Table 7 summarizes the implications of the three scenarios discussed thus far: the FDA policy scenario, limiting commercial area to 1.6 million ha, and freezing the granting of new concessions. Results here are based on the high-end cost assumptions discussed earlier.

**Table 7: Impacts of the 2 proposed policies for FMCs, compared to current FDA policy**

| | FDA Policy | Restrict to 1.6 million ha | | No new concessions | |
|---|---|---|---|---|---|
| | **Level** | **Level** | ***Difference from FDA Policy*** | **Level** | ***Difference from FDA Policy*** |
| Hectares allocated to commercial timber concessions | 2,300,000 | 1,600,000 | *700,000* | 1,100,000 | *1,200,000* |
| **Total government revenue (p.a.)** | **$ 39,081,600** | **$ 27,187,200** | ***$ 11,894,400*** | **$ 18,691,200** | ***20,390,400*** |
| **Private sector net profit (p.a.)** | **$ 37,756,800** | **$ 26,265,600** | ***$ 11,491,200*** | **$ 18,057,600** | ***19,699,200*** |
| Employment | 4,140 | 2,880 | *1,260* | 1,980 | *2,160* |
| **$CO_2$ loss** (tons) (total reduction in $CO_2$ stored after 25 years, compared to original state) | **151,281,562** | **105,239,347** | ***46,042,214*** | **72,352,051** | ***78,929,510*** |
| **$CO_2$ loss** (tons) (average per year) | **6,051,262** | **4,209,574** | ***1,841,689*** | **2,894,082** | ***3,157,180*** |

As noted earlier, the collective impact of several conservative assumptions (i.e. assumptions that make the prospects for commercial forestry appear relatively favorable) is likely to be significant. Constraints to government ability to capture revenue, lower productivity in the commercial timber sector, incomplete compliance with regulations by private operators, or slower regeneration of commercial stock and biomass would reduce the returns from commercial forestry and increase the potential gains from carbon transactions.

### 3.1.3. Two-year moratorium on new concessions

The policy for consideration here is to defer granting any new concessions for two years, providing a window of time during which several important factors will become clearer: the rules governing forest-carbon transactions, the methods for determining reference scenarios, the quantity of marketable wood in the forest, and the price for carbon credits derived from avoided deforestation projects. Perhaps most importantly, a moratorium would allow Liberian institutions the opportunity to prove their ability to enforce the regulations of sustainable forestry that were negotiated over the course of several years. Should those institutions fail to enforce the terms of the forestry contracts that have been signed with concessionaires, the economics of forestry will be drastically worse, as the resource will be over-exploited and unavailable for future generations.

The costs of such a moratorium depend on the likely rate at which new concessions would be sought and granted over the course of two years in the absence of a moratorium, noting that the current 1.1 million ha granted as concessions do not meet the minimum threshold needed for the chain-of-custody system. To date, the rate of recovery in the commercial timber has been disappointing, so it is not reasonable to suppose that the sector would expand rapidly toward the FDA's current policy scenario of 2.3 million ha under contract.

### 3.1.4. Revoke existing concessions that fail to meet requirements

Under the letter of the law, the FDA may revoke concessions if concessionaires fail to comply with forestry regulations and terms of concession agreements. Historically, such revocation has been rare. Thus, the Government of Liberia needs to consider whether the necessary political will can be brought to bear to apply the relevant measures. Importantly, a revoked concession can be made available to new concessionaires, or for possible carbon transactions – a key policy decision. One avenue worth exploring is a transaction under which a carbon investor bids for the right of first refusal for areas made available by revoking concessions for non-performance.

In the simplest scenario, a breach of contract on the part of the concessionaire resulting from technical violations (e.g. not logging within defined distance of waterways, on slopes in excess of defined gradients, or trees below the minimum diameter) provide obvious metrics for compliance. Timely payment of taxes and fees would also seem to be a clear minimum expectation.

If these criteria are not met, the benefits provided by the concessions to Liberia would be lower than those shown in Table 7. This would tend towards favoring the conversion of the forestry concessions into carbon concessions - the cost per ton of $CO_2$ avoided through such conversion would fall, and the carbon price required to make this policy worthwhile would likewise fall.

### 3.1.5. Decrease in the number of Timber Sales Contracts issued

Thus far, the discussion has ignored the distinction between Forest Management Contracts and Timber Sales Contracts (TSCs). When aggregating to the national level, the impacts of TSCs may appear to be relatively minor; the maximum size of a TSC is 5000 ha, and the total area identified for potential TSCs by FDA amounts to 195,000 ha. Moreover, TSCs serve a purpose different from that of the FMCs – the latter are intended to implement the FDA's sustainable logging policy, while the former allow small-scale operators to execute short-term harvesting plans, as part of a land conversion process.

However, although TSCs represent much smaller parcels than do FMCs, the greater intensity of biomass removal means that per hectare carbon implications are much greater. Under a TSC, 80% or more of biomass may be removed in as little as three years and conversion to an alternative use would preclude the same regrowth, implying $CO_2$ emissions of as much as 420 tons per hectare or more, depending on post-conversion use. Even under low projections for carbon prices, this suggests potentially large carbon revenues from decreasing the number of TSCs issued in the future, as 195,000 ha equates to more than **80 million tons of $CO_2$**.

Over three years under a TSC, assuming 80% of the area is harvestable and the maximum yield of 15 $m^3$ per hectare is achieved, FDA revenue projections suggest the results per hectare shown in Table 8.

**Table 8: Revenues from TSCs**

| | Per Ha per Year |
|---|---|
| Government revenue | |
| *FDA taxes and fees* | *$ 372* |
| *Corporate income tax* | *$ 299* |
| Total | $ 671 |
| Private sector net profit | $ 896 |

Given these figures, a $CO_2$ price on the order of **\$3.75/t$CO_2$** would be sufficient to offset the timber-related opportunity cost of converting a TSC area to a carbon concession.[8] Given that a carbon concession would be a long-term proposition and a TSC only last 3 years, the employment impact is that fewer jobs would be created, but they would last much longer. Again, generous assumptions were used in this calculation, such that the actual threshold for the required $CO_2$ price is likely to be lower.

### 3.1.6. Accelerated creation of Protected Area Network

Liberian legislation stipulates that 1.5 million ha of the country's area is to be conserved in a national network of protected areas. Necessarily, a large portion of this total will be forested land. The degree to which placing a forested area under formal protection reduces emissions from deforestation and degradation depends on several factors, notably the deforestation rate without protection and the reduction in this rate when protected. The level of expenditure on monitoring and enforcement post gazettement is also critical in both assessing the costs of the policy, and the likely impacts on deforestation. In addition, the rate at which protection is extended to the 1.5 million hectares over time critically influences the total emissions avoided over time – the sooner that effective protection is put in place, the lower the emissions.

Table 9 overleaf characterizes two possible timelines for creation of planned protected areas (with an additional 'not specified' category reflecting the difference between total planned protected areas and the legal requirement to reach a total of 1.5 million hectares). "Establishment Timeline 1" reflects a series of establishment dates for the protected areas that conforms, more or less, to current plans and capacities. "Establishment Timeline 2" is an accelerated schedule, which would require a concerted effort on the part of the Government of Liberia, as well as increased levels of resources and technical support from donors in the near term. Impacts in terms of costs and employment are seen in timing, not magnitude (and therefore not presented in the table), but the impact in terms of $CO_2$ emissions can be substantial – more than 4 million tons of avoided emissions.

The figures presented in Table 9 assume that in the absence of a protected area, these areas are subject to an average deforestation rate of 0.5% per year, and that designation as a protected area will reduce this rate to 0.125% per year (noting that perfect enforcement is rarely seen anywhere). These assumptions can be refined upon further scrutiny; ideally, background deforestation rates would be empirically ascertained for the particular regions surrounding each proposed protected

[8] To fully capture the opportunity cost, one would have to determine the post-conversion use of the area in question. The net benefits derived from post-conversion use increase the $CO_2$ price needed to offset the full opportunity cost. However, as the land-use section describes, enough degraded land exists in theory to accommodate any productive use if some of the agricultural policies in the next section detail.

area. Of course, the establishment timelines could be re-examined as well, both for the reference scenario and the accelerated schedule. Finally, the figures are based on an average $CO_2$ content per hectare of 527 tons, as used in analysis in previous sections, and an assumption that deforestation results in a loss of 80% of that content. All of these parameters can readily be adjusted, but the key conclusion is that an accelerated schedule of protected area creation can lead to substantial carbon savings, potentially forming the basis for innovative forest carbon transactions.[9]

**Table 9: Protected Areas and their timeline for establishment**

| Protected Area | Area (ha) | Forested Area | Establishment Timeline 1 | Establishment Timeline 2 | Δ years | Δ ha forest | Δ tCO2 |
|---|---|---|---|---|---|---|---|
| Sapo | 150,482 | 150,328 | *established* | *established* | n/a | n/a | n/a |
| East Nimba | 13,569 | 9,510 | *established* | *established* | n/a | n/a | n/a |
| Wologizi-Wonegizi | 137,427 | 122,646 | 2011 | 2010 | 1 | 460 | 193,918 |
| Lake Piso | 33,914 | 0 | 2010 | 2010 | - | - | - |
| Bong Mountain | 24,822 | 7,144 | 2013 | 2011 | 2 | 53 | 22,549 |
| Marshall Islands | 23,813 | 0 | 2012 | 2012 | - | - | - |
| Nimba West | 10,482 | 4,299 | 2012 | 2011 | 1 | 16 | 6,797 |
| Kpo Mountains | 83,709 | 71,212 | 2015 | 2012 | 3 | 798 | 336,519 |
| Foya | 164,628 | 141,491 | 2017 | 2013 | 4 | 2,110 | 889,836 |
| Lofa (Gola) | 97,975 | 96,189 | 2012 | 2010 | 2 | 720 | 303,602 |
| Cestos | 80,348 | 61,423 | 2015 | 2012 | 3 | 688 | 290,260 |
| Grebo | 97,136 | 91,282 | 2012 | 2011 | 1 | 342 | 144,328 |
| Gbi | 88,409 | 81,827 | 2015 | 2012 | 3 | 917 | 386,681 |
| Grand Kru-River Gee | 135,100 | 101,814 | 2012 | 2011 | 1 | 382 | 160,980 |
| **Total** | **1,141,813** | **939,165** | | | | **6,488** | **2,735,471** |
| Not specified | 358,187 | 294,616 | 2017 | 2014 | 3 | 3,302 | 1,392,235 |
| **Grand Total** | **1,500,000** | **1,233,781** | | | | **9,790** | **4,127,706** |

Earlier analyses of the costs and benefits of Liberia's proposed protected area network also examined the costs of establishing and managing protected areas (FDA 2006). The required budget for a given protected area depends on a range of site-specific factors such as size, location, ecosystem type, etc. For the present purposes, results can be distilled into average costs per hectare. These amount to an average start up cost of $3.75 per hectare, and an average recurrent cost of $2.38 per hectare. The bulk of these costs relate to deploying and sustaining a minimum adequate enforcement presence to prevent illegal activities; therefore, these costs also may be used as parameters for establishing and maintaining areas under carbon contracts.

One can characterize the potential carbon revenue per hectare from accelerating protected area creation. Reducing the deforestation rate through protected area establishment avoids the release of about 1.6 tons of $CO_2$ per hectare per year for the average hectare in the protected area. Even at

[9] The table above lists the Marshall Islands site as having no forest area. However, this site features significant at-risk mangrove areas, which also serve an important carbon storage function. Further work is needed to determine the potential for carbon transactions that target Liberia's mangroves.

a low price per ton of $CO_2$, and subtracting management costs as described above, this implies net potential revenue for the number of years by which establishment is accelerated relative to the baseline schedule.

The costs and benefits of accelerating protected area creation are reflected in timing – accelerated protection results in greater amounts of carbon saved, earlier responses to threats to biodiversity and ecosystem services, and earlier job creation in the conservation sector. Costs arise in the form of earlier expenditures (which may not be problematic, as the bulk of financing for protected area creation is expected to be sought externally), and incurring opportunity costs sooner (and thus in greater amounts) as encroachment and illegal resource use are curbed.

If effective Protected Area management can displace the illegal activities to degraded areas in Liberia at a cost of $2.38/ha/year, this policy would generate the 4.1 million tons of $CO_2$ emissions reductions quite cheaply; the additional costs of the accelerated schedule amount to $7.4 million, or less than **$2/ton $CO_2$** saved.

### 3.1.7. Community forest areas are managed as carbon concessions

FDA policy with respect to community forestry remains to be elaborated in further detail. To date, policy documents envision the allocation of 500,000 ha to community forestry. If this land will be used for sustainable logging, under the same model as that applied in the commercial sector, then the same parameters can be applied as above (this assumption may be fair given that sustainable logging in community forest areas might reasonably be expected to take place in partnership with commercial operators). Alternatively, Government policy may be to facilitate carbon transactions with communities; we again apply the same parameters as above, i.e. avoided emissions of about 66 tons of $CO_2$ per hectare over 25 years. The cost per ton of $CO_2$ avoided is therefore also the same as in commercial forestry scenarios: **between $7.25 and $13.50 per ton of $CO_2$**. If, say, half of the target area for community forestry is used this way, this amounts to **16.5 million tons of $CO_2$**.

### 3.1.8. Improved efficiency and regulation of pitsawing

Given delayed recovery of the commercial timber sector and high domestic demand for timber as Liberia proceeds with reconstruction, particularly in Monrovia, the informal timber sector is of great importance. Although illegal, pit-sawing employs a substantial number of people (between 1500 and 4000) and supplies an essential input for rebuilding the country. The estimated volume of production of sawn timber is about 87,000 to 200,000 $m^3$ per year, which, at a recovery rate of 31% (which may be an overestimate), implies a total harvest on the order of 280,000 to 650,000 $m^3$ (Blackett et al., 2009). The implications are significant, as summarized by Blackett et al. (2009: p. 15):

> The commercial Annual Allowable Cut (AAC) projected by the FDA is likely to be about 750,000$m^3$, possibly rising to 1.3 million m3 as the formal logging sector is re-established, according to the Diagnostic Trade and Industry Study (Anon, 2008). At a recovery rate of 31%, harvesting by chainsaw loggers may be responsible for the unregulated removal of anything from 22 to 50% of the higher projected AAC or from 37 to 87% of the lower projected AAC. This does not factor in possible illegal exports or the possibility that recovery rates could be much lower than 31%. Chainsaw logging is a serious threat to Liberia's aspirations to develop a major timber product exporting industry.

Necessarily, then, the pitsawing industry also has major implications with respect to carbon emissions. Characterizing the carbon impact of pitsawing requires a number of simplifications, as the activity is widely dispersed and highly variable. Noting that the calculations for commercial logging imply losses of 19.8 tons of $CO_2$ per $m^3$ (including the timber as well as collateral forest impacts), based on a sustainable production model, we can assume that 19.8 tons of $CO_2$ per $m^3$ is a conservative estimate of losses that attend pitsawing harvests. Applying this to the total harvest, pitsawing may account for somewhere between 5.5 million and 13 million tons of $CO_2$ emissions per year.

Assuming a standing stock of 15 $m^3$ per hectare,[10] and that pitsawyers will maximize harvest volume and disregard FDA sustainability requirements, this is equivalent to a loss of 296 tons of $CO_2$ per hectare on somewhere in the range of 18,700 to 43,000 ha per year. With respect to emissions over time, a complication arises because while some of this is subject to regrowth, a portion of harvested areas becomes subject to agricultural conversion.

Blackett et al. (2009) consider policy options for the Government of Liberia ranging from letting the status quo continue, to banning pitsawing, to legitimizing and regulating the sector using various tools. The current analysis will not delve into the particulars of each of these options, in part because, at present, it remains difficult to quantify the necessary increase in management and enforcement capacity on the part of the FDA to achieve meaningful change in the sector.

Moreover, the FDA position on pitsawing may be described as a hands-off policy (except for the collection of waybill fees), assuming that the sector will fade away and be replaced or absorbed by the formal commercial sector over time.

A more proactive policy to constrain pitsawing or accelerate the transition to formal activities may be beyond FDA capacity, and could have important ramifications for employment and supply of raw materials for Liberia's reconstruction.

There is however substantial room for efficiency improvements in pitsawing practices. As noted, estimates of current recovery rates may be inflated, but even if accurate suggest a possible avenue for improved productivity and reduced forest impacts. For instance, an increase in recovery rate from 31% to 40% – well within technical possibility as shown by comparisons to chainsaw logging in Ghana (Blackett et al. 2009) – reduces the high-end estimate of total annual $CO_2$ loss by 23%, or **nearly 3 million tons**, holding total production constant. Thus, there is ample reason to explore policies and measures by which to promote or require adoption of improved equipment and practice. The cost of this policy is not yet known, so it has not yet been possible to estimate a cost per ton of $CO_2$ saved for this policy.

Government revenue derived from the pitsawing sector (despite its being illegal) is based on waybill charges per plank transported to Monrovia. In 2007 and 2008 these revenues totaled $472,500 and $625,000 respectively (Blackett et al. 2009). However, the capture of this revenue stream is likely to fall short of total potential due to various collection challenges. Importantly, the tax burden imposed on pitsawing is far lower than that faced by commercial timber activities, such that transition from informal to formal supplies over time should significantly enhance revenue prospects for the Government. Blackett et al. (2009) estimate that Government earnings on 2009 harvest levels would be between $12.9 to $29.9 million under the formal taxation system, whereas they amount to only $784,000 to $1.8 million under the waybill system that is applied to pitsawing.

[10] This assumption is consistent with the upper limit of stock per hectare suggested by Shearman (2009), ignoring FDA rules and regulations.

## 3.2. Agriculture

There is an enormous potential for making REDD gains through a change in agricultural techniques. It is estimated that Liberia has up to 5 million ha of arable land; however at any given time only 500,000 ha of it is under active cultivation. Most Liberian farmers use shifting agricultural practices, also known as extensive agriculture or 'slash-and-burn'. So long as there is enough land, and when there are no profitable alternative uses for that land, farmers will let a field lay fallow for 8-10 years, allowing soil nutrients to regenerate. However, when population pressures increase, or land values go up, more intensive cultivation will be undertaken. If not managed properly, this can result in the destruction of soil quality.

In the case of Liberia, there are at least three alternate approaches to intensify agricultural practices: conservation agriculture, lowland agricultural development, and increased adoption of fertilizer practices. Since such practices would reduce the land area needed for agriculture, there is a vast potential for carbon savings by adding up to 3 million ha of land to the forestry base. How much carbon does this represent? If each hectare regenerates 4t C,[11] or nearly 14.7t$CO_2$, per year over the next 25+ years from natural regrowth (before the carbon level stabilizes) that represents a potential total of 44 million tons $CO_2$ saved per year. Clearly land-use change on this scale will not happen overnight, however.

We analyze each option in turn, including its cost and effect on productivity, before exploring the potential to replant trees to sequester carbon even more efficiently in the land made available. Of course, the challenges in changing the dominant mode of agriculture in Liberia should not be understated: land tenure is often insecure; access to capital, knowledge, and appropriate land is often absent; and mindsets are difficult to change. These sorts of interventions have been proposed for over 70 years with limited success. Clearly these programs can only achieve partial success at best, and to work at all they will require more incentives to farmers than the aid-as-usual approach applied in various settings over the past decades.

The three options are alternative routes to address the same set of carbon emissions – those from deforestation caused by shifting cultivation – by making agriculture more efficient, freeing up degraded land to return to forest. Intensifying agriculture is not sufficient to realize the carbon savings: land use patterns must also change in order to allow the degraded land to return to forest. Each proposed program does not envisage all of shifting cultivation ending; they are designed to be ambitious yet realistic. The three programs could therefore all be implemented simultaneously.

All three policies would incur significant set-up costs. Note that as this report does not employ discounting, the fact that costs are incurred sooner than benefits are received is not factored into the results presented here. In any case, Liberia should aim to find partners willing to fund these up-front costs.

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[11] Houghton et al, 1997 give a range of 2.5-6 t C/ha/year sequestered for tropical secondary forest regrowth. This may be an underestimate. In Cameroon, carbon sequestration was found to be 2.89 t C/ha/year for the first two years after a field was retired, increasing to 8.5 t C/ha/year as the regrowth became denser. If the 4t C/hectare/year were applied linearly to a cleared area, it would imply 36 years to reach full growth. This is appropriately longer than the 25-year assumption used in the forestry section, in which only the highest level of the forest canopy is replaced.

### 3.2.1. Conservation Agriculture

Conservation, or sustainable, agriculture (CA) refers to a set of practices that increases soil fertility and reduces erosion while allowing intensive cultivation without fallow. According to the Food and Agriculture Organization (FAO):[12]

> CA is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment. CA is based on enhancing natural biological processes above and below the ground. Interventions such as mechanical soil tillage are reduced to an absolute minimum, and the use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that does not interfere with, or disrupt, the biological processes. CA is characterized by three principles which are linked to each other, namely:
>
> 1. Continuous minimum mechanical soil disturbance.
> 2. Permanent organic soil cover.
> 3. Diversified crop rotations in the case of annual crops or plant associations in case of perennial crops.

The benefits from a carbon perspective may be significant. First, CA would allow farmers to till the same field year after year. This would free up unused land for reforestation and therefore carbon sequestration. Second, during the process of CA, carbon is sequestered in the soil. According to the FAO, during the first 10 years of CA adoption, each hectare of farming sequesters 1.8 tons $CO_2$ per year.[13]

To see how large the benefits may be we consider a farmer practicing extensive cultivation with a conservatively-estimated three-year fallow (note the longer the fallow, the more potential carbon benefits from switching to CA since more land is freed up from shifting agriculture). Think of a 4 ha area of land – in any given year, 1 ha is harvested and 3 ha are left fallow, to be harvested in a subsequent year. The same amount of crops - or more - can be grown on a single ha of land under CA, used year after year. This therefore frees up 3 ha to be left to regenerate naturally. For each hectare of agriculture converted from slash-and-burn to CA, 44 tons $CO_2$ may be sequestered through the process of natural regeneration on the remaining 3 ha, and an additional 1.8 tons $CO_2$ may be sequestered in the soil itself. For this to occur, ambitious programs must be put in place and farmers must adopt CA practices.

Do farmers benefit from CA adoption? Dozens of studies have looked into the productivity changes that may result from CA adoption. Two papers review these studies; Pretty (1999) finds that "a 50 to 100 percent increase in basic grain yields is clearly possible with sustainable agriculture" while Haggblade, Tembo, and Donovan (2004) find yield gains anywhere from 0 to 1,645%, depending on the study and technique. Pretty and Hine (2001) find that for the category of "rainfed rice, wheat, maize, and legumes (uplands, dryland)" - the closest description of upland Liberian farming among their nine categorizations - increases in cereal production were typically 50-100%, with some projects achieving 200% increases. In our calculations, we conservatively estimate that farmers are able to achieve the same yield with no increase.

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[12] http://www.fao.org/ag/ca/1a.html
[13] "Soil Carbon Sequestration in Conservation Agriculture" http://www.fao.org/ag/ca/doc/CA_SSC_Overview.pdf

So it appears that with CA adoption, yield can, and does, increase. Profitability, on the other hand, depends on costs of inputs as well as yields and the alternative uses of the land. For the farmer, CA techniques are typically more labor-intensive than inorganic fertilizers (another option to intensify agriculture), but perhaps less labor-intensive than annual clearing and burning of farm bush. Farmers may have to spend many extra days per year preparing and distributing organic fertilizer and weeding, however they may also save labor that would have been required to till the soil. A summary of empirical evidence by HTD finds that profitability, or the return to labor, increases under CA, from 3% to 300% depending on the site. The authors caution, however, that there remains a "paucity of empirical evidence on financial viability of conservation agriculture technologies in Africa" and that there may be a possible "selection bias in favor of the best performers."

It is worth noting that adding an additional financial incentive for farmers, linked to the carbon sequestration that the CA will have enabled, would further increase the profitability to farmers – providing that a mechanism is implemented for carbon revenues to flow to individual farm households, rather than staying in central government. Since from all available evidence it appears profitability is not hurt from a long-term commitment to CA, the size of the incentive required is difficult to estimate, and because of the challenges of encouraging farmers to switch agricultural techniques, most likely take-up would not be anywhere near universal in any case.

With CA being potentially profitable for farmers, the government or some private agency would still need to take the lead in educating farmers and providing technical assistance. How much would such a program cost? The authors spoke with staff at CARE USA, which has experience implementing CA programs across Africa; they estimated that a realistic price tag for the GoL to consider would be $5 million spent over 6 years to convert 4,000 farmers to CA. The cost would include marketing, seed multiplication, finance mechanisms, irrigation, pest management, equipment, etc. After a number of those farmers met with success, the techniques could naturally spread - at very little cost - to other farmers. For instance, in Brazil, 30% of farmers have adopted zero-tillage agriculture (Pretty and Hine, 2001). Because of the scale of opportunity in Liberia (with an estimated 286,000 ha of upland rice – see Table 1), we consider a program six times this size – investing $30 million to convert a total of 24,000 farmers to CA agriculture over 6 years, with another 24,000 farmers following.

All that said, the challenges to implementing CA in Liberia on a broad scale are immense. It requires a total change in the mindset of the farmer; traditional modes of farming are essentially turned on their head. For Liberian farmers who have access to degraded land for extensive agriculture, who have a preferred way of farming that produces sufficient food for the family, and who have little training or formal education, the impetus to change would be small—especially when new manual labor is required. Moreover, even Ministry of Agriculture extension workers may have little enthusiasm for CA. It will require new advice, new research and demonstration plots, and they may not get the 'formula' correct on the first go. In fact, these techniques have long been in vogue amongst development practitioners, and yet there have been consistent challenges in implementing them in many settings. Subsistence farmers in general are found to be highly risk averse; in addition, credit constraints are often a major barrier to increased production.

To estimate the carbon savings, we note that 46 tons $CO_2$ per year may be saved for each hectare converted to CA. We assume that in years 3 through 6 6,000 farmers per year switch one hectare of farming each to CA, and in years 7 through 10 another 6,000 farmers per year switch on their own accord. This would result in a total savings of 9.9 million tons $CO_2$ over the first 10 years, increasing to **43 million tons $CO_2$ over 25 years**. This carbon would be saved at a cost of

**$1.44/ton**. In theory, all upland agriculture in Liberia could be converted to CA (with some inorganic fertilizer potentially necessary), thus freeing up the degraded land used in extensive agriculture to sequester carbon. In practice, however, CA conversion would likely require scaling up over a decade or more as farmers and extension workers gained the experience specific to the area.

CARE is already active in the CA field in Liberia. They are currently running a program in Bong County that is offering Farmer Field Schools to teach local farmers about CA, including demonstration plots; installing rice seed banks; establishing village-level financing mechanisms and CA associations; and training government workers. The program began in February 2009, so empirical evidence on costs, benefits, and adoption rates remain unknown.

### 3.2.2. Lowland Agricultural Development

Lowland, or 'swamp' agriculture, has produced the highest yields for rice production in Liberia. According to the 2008 Annual Report of the Ministry of Agriculture, upland rice had an average yield of 737 kg/ha, whereas irrigated swamp rice had a yield of 2567 kg/ha and rain-fed swamp rice had a yield of 815 kg/ha. While currently only a small fraction of available rain-fed lowland agriculture is under cultivation, it is believed that much more may be accessible—up to 600,000 ha, if extensive land conversion were completed.[14] Much of the current lowland agriculture is practiced in naturally occurring swamps, with uneven depth. There are barriers to farming low-land areas, including the presence of schistosomiasis and the need to wear rubber boots, as well as lack of proximity to oil palm groves which farmers can harvest in between tasks on grain or vegetable production.

Given the dramatic yield increases possible with lowland agriculture, attempting to tap into the vast potential of unutilized lowland farming may make a large impact in preventing future deforestation, not to mention improving food security and the country's trade balance. We conservatively assume that irrigated lowland agriculture can increase yields by one half, and use the same conservative estimate for CA agriculture that a farmer moves from a three-year fallow cycle to replanting on the same hectare. Thus, if six hectares of slash-and-burn agriculture or more are converted to one hectare of irrigated lowland agriculture, that could result in a $CO_2$ saving of 73 tons/year.

How much does it cost to achieve this? An IFPRI report for the World Bank on irrigation in Sub-Saharan Africa used an estimate of $600/hectare to initiate small-scale irrigation, plus $25/year in annual maintenance costs (You 2008). An FAO report used a value from $600-$1000/hectare to initiate small-scale irrigation using water harvesting on inland valley bottoms (Kay 2001). Each of these studies finds tremendous potential for irrigated land in the absence of carbon subsidies, relying solely on financial viability to the farmer. However, it is noteworthy that each of these studies also note that costs can be as high as $5,000 or $8,000 per hectare in situations where water pumps, tubewells, and water storage were required. The exact costs of implementation in Liberia will surely vary, and detailed studies would need to be undertaken to get exact figures for different areas of lowland agriculture.

As a representative number, we consider total costs of $1,250/hectare to develop one hectare of lowland agriculture. Besides providing the farmer with higher yields and profits, each 1ha of lowland agriculture will free 5 ha of land or more for forest recovery as assumed above, generating savings of 73 tons $CO_2$ per year. We consider a hypothetical program that develops

[14] Authors' communication with Ministry of Agriculture, November 2009.

30,000 ha of irrigated lowland farming over 25 years, with capital costs of $37.5 million and an additional program expenditure of $10 million or more, depending whether it could be implemented through existing institutions. If appropriate land-use policies were also in place, this would free up 150,000 ha of land for natural forestry regeneration. Such a program would save **41 million tons $CO_2$** over 25 years, at **$1.16/ton**. (Even if program expenditure were $30 million, the cost per ton $CO_2$ would still be only $1.65/ton).

Importantly, lowland rice farming increases methane emissions, another greenhouse gas that is around 21 times more potent than $CO_2$. Global methane emissions from rice farming are estimated at 20-100 million t/year (IPCC, 1992), or given global paddy rice area of 157 million ha (FAOSTAT), between 3-13t$CO_2$ equivalent per hectare. For this amount to be neutralized, an additional half hectare or so of land used in extensive agriculture would need to be freed up. We have assumed a 50% increase in yield relative to upland farming, whereas the data suggest a 300%+ increase is being attained in Liberia. If Liberia were required to offset the methane emissions with carbon sequestration, meeting the estimations above would only require the yield increase to be 62.5% instead of the assumed 50%.

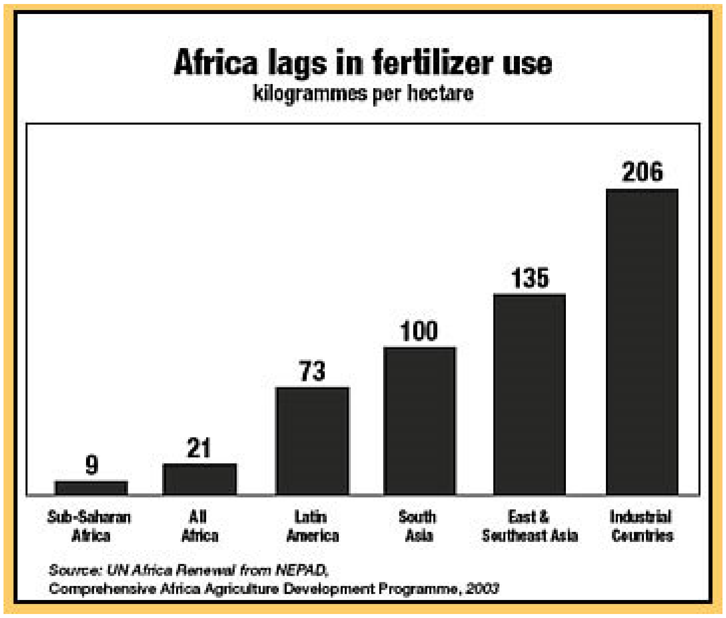
It is worth noting that these carbon savings will be hard to come by without significant external intervention. The barriers to a large-scale expansion of irrigated lowland farming are immense. Perhaps the largest barrier is access to land and land/water rights. The agricultural areas that individual farmers have may or may not include land appropriate for irrigation. Even if it does, they may not have access to the water that could irrigate it. Thus a high level of coordination would be required, within communities. This may be hard when land titles and tenure are uncertain or contested. Moreover, the start-up capital costs are immense and beyond the financial capacity of most farmers. Thus for a farmer who already has access to upland farming sufficient to feed his family, the risk and cost and land-use challenges associated with irrigated lowland farming may be too burdensome to convince him to transition. A mechanism would be required to use the revenue from carbon markets to overcome these barriers; some should be possible (e.g. support with start-up costs), but others may prove more difficult (e.g. land rights).

### 3.2.3. Targeted Fertilizer Subsidies

Many advocates of conservation agriculture or irrigation believe that inorganic fertilizer may play a supporting role in either of these strategies. Yet recent attention on the apparently successful example of subsidies in Malawi (e.g. New York Times, 2007) has brought a once criticized practice - offering direct subsidies on fertilizer to farmers - back into vogue. The reasons are quite simple, as a World Bank report noted (Crawford, Jayne, and Kelly 2004). Notably, fertilizer has a strong role to play in nutrient-poor soils, replacing negative nitrogen, phosphorous, and potash (NPK) balances. Wider fertilizer adoption could theoretically permit more intensive agricultural practice while freeing up other land for wider ecosystem services.

Fertilizer use in Liberia is currently minimal (Republic of Liberia, 2007). FAO reported negligible fertilizer use in Liberia. A survey in October 2006 found that 8% of rice farmers, 0% of root farmers, and 61% of vegetable farmers had bought any fertilizer, the latter spending just under $30 per year. These data portray a small group of relatively sophisticated farmers concentrating on high-value crops and investing in inputs, and a vast majority of subsistence farmers relying on traditional techniques. However, the presence of these vegetable farmers indicates that there is scope for adoption to spread using local knowledge.

**Figure 1: Fertilizer use in Liberia is low compared to the rest of Africa; Sub-Saharan Africa, meanwhile, uses the lowest amount of fertilizer in the world.**




When used correctly, fertilizer will increase the yield of an agricultural parcel. In Brazil, for example, upland rice yields were maximized at positive values of N, P, and K; extension services recommended 60-120kg N, 60-120kg P, and 30-90kg K per hectare (Barbosa Filho and Yamada, 2002). In Pakistani trials, upland rice yields reached their highest yield with 100 and 80kg/ha of N and P, respectively, although using 50 and 40 produced nearly as much grain (Ullah et al, 2009). The yield rose from 1.27 t/ha with no fertilizer to 2.30 and 2.24 t/ha with 100/80 and 50/40 kg/ha of N and P fertilizer. In Malawi, 55kg of fertilizer increased maize yields by 750kg/ha (Minde et al, 2008).

Whether fertilizer application is profitable for farmers will depend on the price of the fertilizer and the realized gain in productivity. Evidence from other countries suggests that it would be the case. In the absence of subsidies, fertilizer use in Kenya has been increasing, rising from 180,000 t/year in the 1980s to over 450,000 t/year in 2007 (Minde et al, 2008), indicating individual profitability. This is confirmed by Duflo, Kremer, and Robinson (2008) who find rates of return to Kenyan farmers for fertilizer at nearly 70% on an annualized basis.

Even with high financial returns to farmers, there still may be grounds for public intervention if farmers are too poor to afford fertilizer, if credit markets are too undeveloped to allow buying fertilizer on credit, or if there exist food security implications that necessitate higher domestic food production. In Malawi, in 2006-07, the government subsidized 72% of the cost of fertilizer as well as improved seed varieties for poor farm households; 175,000 tons of fertilizer and 4,500 tons of improved maize seed were distributed at a cost to government and donors of $91 million (Dorward et al, 2008, cited in Minde et al, 2008). A bumper harvest resulted, and many credited the fertilizer subsidies.

We consider a program that subsidizes fertilizer over 60,000 ha, together with appropriate land-use policies that would free up at least 120,000 ha of land for natural forest regeneration. This represents somewhere around one quarter of all upland rice in Liberia; the program could therefore be expanded in future if it proves to be successful.

Per hectare, consider fertilizer priced at $600/t; one 50kg bag would therefore cost $30. If the government subsidized the price of fertilizer by 72%, the cost per hectare would be $22, plus administrative expenses which could easily bring the cost up to $30. If this increased yield by 50% and enabled farming in the same site over several seasons, each 1ha with fertilizer applied could permanently free up two hectares or more from agricultural production, sequestering 29 tons $CO_2$ per year for over 25 years - or the time it would take for the farm bush to reach its maximum level of carbon per hectare.

To subsidize fertilizer use of 50kg/ha over 60,000ha in Liberia would require 3,000 tons of fertilizer, much less than was used in Malawi. Thus if prices remained, and Liberia were able to achieve the same cost per bag as Malawi, the program would cost $1.8 million. If implemented successfully, this could increase yields by half as well as allow more intensive use of land with less need for slash-and-burn agriculture. Thus it is could conceivably free up a million ha or more from agricultural use, generating immense carbon benefits.

At $30/ha/year, the annual cost would come to $1.8 million, and the $CO_2$ sequestered would reach 1.8 million tons per year.[15] Over 25 years, **44.1 million tons $CO_2$** could be saved at a cost of $45 million, or **$1.02/t$CO_2$.** Even if administrative expenses brought the cost up to $44/ha, the cost per ton $CO_2$ saved would be just $1.50/ha.

There are issues and challenges to note before implementing this policy:

i) Extensive agriculture practiced in much of Liberia is a substitute of sorts for fertilizer: as the fields lie fallow, the natural regeneration and subsequent burning of the farm bush replaces the nutrients lost in the soil from agricultural production. It is probably unlikely that Liberian farmers would significantly increase fertilizer use until population pressures (or carbon revenues combined with area-specific incentives) encouraged them to do so. That said, individual conversations between one of the authors and farmers in the Lake Piso area revealed enthusiasm for fertilizer if it could reduce the labor associated with clearing new parcels of bush for farming.

So what is the potential of fertilizer subsidies to actually reduce carbon emissions? The answer depends on how fertilizer affects land use practices. By increasing the yield, fertilizer subsidies could do one or more of:

- Increase food production and consumption
- Decrease area farmed
- Increase the fallow cycle

If fertilizer allowed a farmer who has 4 hectares of land, and who farms 1 hectare per year to farm the same hectare for 3 years before moving on to the next plot, then it would increase his fallow from 3 years to 9 years. However, it would have a minimal impact on carbon emissions in the long run since the slashing and burning that would occur after the long fallow would simply release more carbon into the atmosphere.[16] On the other hand, if he permanently allocated 2 hectares to carbon, and farmed each of the remaining 2 hectares for 3 years (keeping the 3-year

[15] There may be greenhouse gas emissions (nitrous oxide) associated with fertilizer use. Reliable estimates of the amount of emission that occur due to fertilizer application are not yet available. Should carbon credits require offsets for such emissions. further investigation would be needed to determine the extent.
[16] Shifting the fallow from 3 years to 9 years would increase carbon sequestration only to the extent that the average carbon per hectare of 9-year fallow is marginally higher than the average carbon per hectare of 3-year fallow.

fallow), then he would increase the amount of carbon sequestration. In other words, fertilizer subsidies can reduce carbon emissions only if they change actual land-use patterns.

(ii) The potential for political distortion of any subsidy remains a concern. While the Malawian example suggests the potential for a successful fertilizer subsidy program, there are as many or more examples of programs that have been derailed due to political influence. In Zambia, for example, the government has gone through at least five different subsidy programs since the 1990s (Minde et al, 2008). During the first four, fertilizer use actually declined. The fifth program has resulted in higher yields but has rewarded larger and better-connected farms, who were likely to purchase fertilizer even without a subsidy (Minde et al, 2008). Indeed, comparing national data for quantity disbursed with household survey data of subsidized fertilizer consumed suggested that only 29% of supposedly distributed fertilizer had reached its target beneficiaries. Much of the rest likely ended up being sold illegally to the private market and resold to farmers at market rates (CDFA 2008, cited in Minde et al, 2008).

In conclusion, fertilizer subsidies offer significant potential for creating the conditions for substantial emission reduction and carbon sequestration. However, subsidies alone would not be sufficient to generate these savings; institutional arrangements would be needed to ensure that land use patterns, and not simply the fallow cycle, changed. Moreover, very tight mechanisms would need to be created that protected the subsidy programs from graft and political influence.

### 3.2.4. Tree Crops located on degraded land rather than forest areas

Since the embargo on timber and diamonds, rubber has been the main export crop in Liberia. Other tree crops such as oil palm, cocoa, and coffee also form an important part of the local economy. With oil prices well above long-term trends, there has been further interest in oil palm as a bioenergy, with Sime Darby signing a recent concession with the GoL for 240,000 ha of oil palm (with only 5,000 ha developed annually through 2013, then gradually increasing to 22,000 ha per year in 2017). Recall from the discussion in Section 2.1 that there is 2.8 million ha of land in agricultural fallow periods, plus a further 1.0 million ha that is ‘unused’ (although not all of this would be suitable for plantations). Even if another several hundred thousand hectares were to come online over the next 15 years, this still represents a small fraction of the total underutilized land in Liberia. Moreover, since tree crops have a significant carbon content - far more than that of short-fallow agriculture - they do not pose a direct threat to Liberia’s carbon stock, *so long as tree crops do not replace primary or secondary forest*.

In order to better understand the carbon consequences of tree crops, we describe the carbon content in tree crops as compared with forest and agriculture. Specific measurements are not available for Liberia, so for extensive agriculture we use the percentage of carbon relative to forests from Cameroon data (Kotto-Same et al, 2001), applied to the FAO carbon content estimate for Liberian forests of 144 tons C/ha. We then use direct estimates from Cameroon for the carbon content of cocoa and oil palm. All figures represent the average carbon content, taking into account the regrowth/fallow cycles for the particular land use:

**Table 10: Above-ground carbon estimates for different land uses**

| | *t C / ha* |
|---|---|
| Secondary forest | 144 |
| Long fallow | 49 |
| 11-year fallow | 20 |
| 4-year fallow | 3 |
| Jungle cocoa | 61 |
| Oil palm | 30 |

We first compare the carbon revenue from allowing farm bush to return to forest as opposed to planting oil palm. Recall our estimate that farm bush left on its own will gain 14.7t $CO_2$ per year. Interestingly, oil palm accumulates carbon just as quickly as natural fallows (Kotto-Same et al, 2001), however it levels off at a lower amount after 7 years.

At this time, of course, the plantation is yielding economic benefits. A recent study by Grieg-Gran (2008) estimated the net present value (NPV) of economic benefits under a 10% discount rate of a hectare of oil palm or rubber in Cameroon to be $2,360/ha, equivalent to $236/ha when converted to annual flows. These numbers line up fairly closely to the profit and wages per hectare of existing rubber concessions in Liberia, as well as back-of-the-envelope calculations for smallholder rubber producers in Liberia.[17] Moreover, rubber and oil palm are employment-intensive and they provide revenue to the government as high as $200 per hectare per year, according to reports filed with the Ministry of Finance. Thus, a moderate amount of tree-crop plantations on degraded agricultural land, even in the presence of mid-priced carbon, seems to be a net benefit to Liberia.

That does not imply, however, that tree crops should replace mature forest. If one hectare of oil palm plantation were to replace one hectare of forest, 527 tons $CO_2$ would be emitted. The GoL, as a potential claimant of carbon revenue, could do better by discouraging tree crop concessions on land currently forested and instead seeking to generate carbon revenues from maintaining this forest.

Given the large area of land available for agriculture in Liberia, it would make economic sense to limit new concessions to degraded agricultural land that has a lower carbon content. There do not seem to be major limitations to doing so, given the current mode that land is awarded to concessionaires. If 100,000 ha of new tree-crop concessions were limited to degraded agricultural land instead of forest, nearly **53 million tons of $CO_2$** emissions would be avoided, at essentially **zero cost**.[18]

### 3.2.5. Energy and Charcoal/Firewood Production

Firewood and charcoal are the main source of domestic energy use for the vast majority of the population that does not rely on electricity, as well as an important cooking fuel for electrified households. As has been shown for other countries, charcoal production is a major use of forestry products. In Tanzania, for example, a World Bank study (2009) found that annual forest loss of

[17] Calculations available from the authors upon request.
[18] Assuming that production costs and productivity levels are equal in both cases.

100,000-125,000 ha could be attributed to the charcoal sector. In addition, forest will be lost due to the consumption of fuelwood that is not converted to charcoal, which is an equally important source of energy in rural areas.

Persson (1974) estimated 0.6 to 0.7 $m^3$ of wood per person per year for wood-based energy globally, while Openshaw (1974) estimated the figure for Tanzania, Gambia, and Thailand to be at least twice as high.[19] We use an intermediate figure of 1 $m^3$ per person per year, and assume that all Liberians use these energy sources. This amounts to 3.3 million $m^3$ of wood, a number far higher than the lumber that Liberia exported at the peak of the forestry sector output, reached in the early 2000s. Of course, firewood and charcoal can be made from wood that would be rejected for timber export, so the number should be put in context. Nevertheless, the potential impact of fuelwood demand as a driver of deforestation should not be ignored.

How much $CO_2$ does this involve? At 0.75 tons per $m^3$, and noting that approximately half of biomass is carbon, and up to half of fuelwood collected may be deadwood, 0.62 million tons C, or nearly 2.3 million tons $CO_2$, is released each year from fuelwood consumption. If Liberia's fuelwood sector could be made twice as efficient, then 1.14 million tons $CO_2$ could be saved each year. Over 25 years, this would amount to **28.5 million tons $CO_2$** emissions averted.
The fuelwood sector can be made more efficient at a variety of points, and it can also be regulated in order to increase efficiency. It is beyond the scope of this analysis to estimate the cost of effective regulation to increase the efficiency (and perhaps price) of the charcoal sector, but such a tactic could be part of an effective strategy to minimize carbon lost to fuelwood consumption. The Liberia National Energy Policy proposes the Rural Energy Master Plan, including the Rural and Renewable Energy Agency and the Rural Energy Fund to regulate and encourage the development of "economically viable, socially acceptable, and environmentally friendly" sources of energy in rural and peri-urban areas. This includes more efficient use of bio resources, the development of small-scale electricity generation, and more efficient stoves. The Energy Policy recognizes the potential for carbon revenue to help fund innovations and policy support.

**1.** One area where the fuelwood sector can be made more efficient with a relatively simple intervention is at the level of the **end user**. Energy-efficient stoves that use charcoal and fuelwood have been piloted in other African countries. So long as they are being used, they are contributing to carbon savings by reducing pressure on the forests.

A Kenyan company, Musaki Enterprises, manufactures such an energy-efficient stove for charcoal. For around $5, the stove can reduce energy use by around 40%; case studies suggest that each stove reduces $CO_2$ emissions by 1 to 1.5 tons per year, as well as saving the household money on charcoal.[20] By 1997, nearly 1,000,000 stoves were in use in Kenya.[21] Similar stoves have been developed that use wood. In Malawi, for example, the Mbaula stove is made of clay, produced locally by women's cooperatives, and retailed at the most for $4.[22] These stoves also reduce indoor air pollution and are generally produced locally, which has the added benefit of creating jobs and skills.

If an efficient charcoal stove could be produced in Liberia for $10 and would prevent the emission of 1.25 tons $CO_2$ per year for three years (the expected lifetime of the stove), then it could reduce emissions at a cost of **$2.67 per ton $CO_2$**. If an efficient wood stove could be

[19] Cited in Seiler and Crutzen, 1980.
[20] http://www.nowpublic.com/tech-biz/successful-fuel-efficient-cookers-show-way
[21] http://www.solutions-site.org/cat2_sol60.htm
[22] Malinski 2008.

produced in Liberia for $8 and would prevent the emission of 1.25 tons $CO_2$ per year for two years (the stoves can be made of clay and have a shorter expected lifespan), then it would reduce emissions at a cost of **$3.20 per ton $CO_2$**. Both of these figures are far less than the going price of $CO_2$ emissions reduction, even on the voluntary market. Moreover, they would contribute to the local economy by creating employment and skills, and some of the cost could be passed on to the consumer who would be saving money and time from fuelwood purchase or collection.

The actual program costs would be determined by the costs of setting up local businesses or cooperatives to manufacture and distribute the stoves, as well as the amount of subsidy involved to ensure near-universal take-up.

**2.** In addition, relatively simple kilns can be utilized in **the manufacture of charcoal** that improve efficiency. There are a range of kilns with different levels of efficiency and different prices. To understand how to reduce carbon emissions through the production of charcoal, further research on the Liberian context would be required.

These interventions would be relatively easy to implement. The production of the stoves and kilns might require some technical and financial support, and the stoves would most likely need to be subsidized and distributed widely for maximum carbon impact. A danger is that the carbon savings would "leak" across the border as subsidized stoves were smuggled into neighboring countries and sold at market prices. But if the supplier of these subsidies had in mind to reduce global emissions of $CO_2$ and not simply Liberian emissions, the consequences of such leakage could only be positive. Capturing the carbon value could occur in one of two ways: either the carbon savings could be imputed and sold on a voluntary market, as has occurred elsewhere, or Liberia could benefit from the reduced level of national deforestation through a nationally-compensated REDD program.

## 4. Other policies and issues - not quantified

### 4.1. Infrastructure: reduce deforestation alongside roads

Liberia is embarking on an expansion and upgrading of its road network, aiming to build or reconstruct 1,187 miles of primary roads and 400 miles of feeder roads during the PRS period (Republic of Liberia, 2008). These plans are considered to be essential to the country's development ambitions. However, this program poses a new threat of deforestation, as there is clear evidence from around the region and the world that deforestation rates increase rapidly when access to forest areas is improved through road building (Angelsen and Kaimowitz, 1999).

Given the strategic importance of these transportation networks, we assume that the expansion will go ahead as planned; we do not propose or consider any policies to reduce the extent of these plans. We also note that the bulk of the proposed road program is the refurbishment of existing roads and tracks; this implies that much of the plans will occur in areas that are already degraded, so the risk may in fact be lower than for brand new roads. We do, however, believe that there is value in implementing policies to reduce the intensity of the deforestation risk alongside new and upgraded roads.

This could include:

- Improved monitoring and enforcement of the at risk areas;
- Targeting programs aimed at limiting deforestation (see section 3) towards the at risk areas near to roads;
- Paying particular attention to access roads for mining, timber & agricultural concessions, which are more likely to go through primary forest: One option would be to create incentives for concessionaires to reduce deforestation within their areas, by encouraging them to bid for the rights to carbon credits in their areas (or conversely by penalizing concessionaires if deforestation exceeds a set target);
- Alternative road network configurations, encouraging roads to be routed away from blocks of primary public forest, redirecting this pressure onto already-degraded lands.

The first suggestion above would incur some additional costs; as this is well-targeted to at-risk areas, it is likely to be a cost-effective way to reduce deforestation (providing the enforcement is carried out successfully). The next two suggestions are likely to incur a minimal cost to Liberia. The final suggestion would incur an initial cost (both in planning and any additional construction cost), plus an ongoing economic and environmental cost if the alternative route results in longer journeys. It is not clear how practical this last suggestion is in Liberia; as a minimum, rules on environmental impact assessment could be applied more rigorously (and potentially strengthened).

### 4.2. Mangroves

Mangroves are a special type of forest; they provide a variety of services including protecting shorelines and acting as a nursery for commercial fish species, as well as being a source of charcoal and fuelwood (Sathirathai and Barbier, 2001). They are extensive in area, but their extent is declining over time; more data in needed on the precise extent and characteristics of mangroves in Liberia. There is also increasing evidence of the significance of carbon storage and sequestration in mangrove ecosystems. Mangroves sequester and bury an estimated 5.5 tons of $CO_2$ in organic substrates each year. Over time, this can add up to a massive store of carbon: each hectare of mangrove sediment might contain nearly 700 tons of carbon per each meter depth (Eong Ong, 2002) – disturbing these ecosystems can result in the release of these stores.

Mangroves face specific threats, such as the impact of fuelwood collection for fish smoking. As such, specific policies will be required to tackle these threats, including variations of the policies described for charcoal collection in section 3.12 (more efficient fish smoking houses; possibly the installation of ice-making facilities; education and awareness to encourage communities to source their wood from more sustainable sources); community-managed coastal areas; and national investment to protect these resources where they provide substantial ecosystem services and local management proves insufficient.

Without further primary research, we are not able to determine how cost-effective such measures would be from a purely carbon viewpoint. However, once other benefits of mangroves are factored in to the decision, these policies are likely to be economically beneficial to Liberia, if well designed and implemented.

## 4.3. Reducing uncontrolled burning caused by shifting agriculture

As well as the direct loss of forest from burning for shifting agriculture, occasionally the fires started for this purpose spread beyond the intended farm site and destroy a much larger area of forest (which may not then be put into immediate use).

Increased awareness and use of practices that reduce the risk of uncontrolled burns, such as setting firebreaks, and more careful planning of when and where to set fires, could reduce this deforestation threat at a relatively modest cost.

## 4.4. Bamboo and Eucalyptus

Bamboo and eucalyptus are both fast-growing, easily harvested, and can be used for many of the same applications as traditional lumber. Since many costs are not included in the price of wood in the current (pit-sawing) Liberian market – such as taxes and forestry concession bid premiums, not to mention carbon values - wood may be utilized in ways that do not make economic sense. For example, in most tropical developing countries, bamboo and not timber is used in scaffolding construction. Eucalyptus is often used in pulp manufacture and power generation. Both can be used to make homes, furniture, and flooring products.

Nurturing a viable private bamboo or eucalyptus industry could relieve pressures on the forest inasmuch as the production would replace wood products for those uses where wood itself is not necessary. Carbon savings would arise from less area being required to grow the bamboo and eucalyptus than the equivalent wood products, allowing the remaining land to be left to regenerate as natural forest. For example, in Costa Rica a 60-hectare bamboo plantation grows enough material for the construction of 1,000 houses; an equivalent wood plantation could require as much as 500 hectares. The exact quantity of bamboo or eucalyptus that the Liberian market could support, and the nature of an appropriate intervention, would require further analysis.

### 4.5. Carbon Plantations

If, due to effective implementation of intensive agricultural innovations like CA, irrigated lowland rice farming, and targeted fertilizer subsidies, Liberia were able to wean itself from dependence on extensive agriculture, its farmers could do one of three things with the freed-up land. One, they could simply allow the farm bush to return to forest. Two, they could use the land for some other purpose like ranching or small industry (this would obviously not generate any carbon savings, and could result in carbon emissions if farm bush or degraded forest were cleared for that activity – although it might generate revenue and jobs). Three, they could actively regenerate new forest to maximize carbon sequestration, by planting fast-growing trees.

Further study would be required to calculate the economics of active forest regeneration, through understanding the appropriate species and costs in Liberia. The forest would need to fit within the existing ecosystem of Liberia, including being able to support local fauna. Importantly, the carbon benefits would only comprise of the additional carbon sequestration above that which natural regrowth would produce. This study has estimated that natural regrowth could generate carbon savings on the order of 14.7 t. $CO_2$/year/ha. In comparison, eucalyptus or pine plantations, or agroforestry could generate carbon savings of around 36.7 tons $CO_2$/ha/year, or just over 20 tons $CO_2$/ha/year more than natural regrowth. However, while natural regrowth would continue to sequester carbon for 25+ years, eucalyptus is ready for harvesting in just 8-10 years, and its high rate of sequestration might wane after that period. Thus, the economics of this project would be determined by the carbon sequestration differential over time, as well as the cost of the plantation in Liberia.

### 4.6. Livestock policy

There is currently very little livestock in Liberia. A study conducted for the Ministry of Agriculture estimated that in 2005 there were 25,200 cows, 435,160 sheep/goats, 131,950 pigs, and 5.4 million chickens (CAAS 2008). Of those, the cows, sheep/goats, and most of the pigs were being raised in the traditional sector. The authors target an additional 182,000 hectares for conversion to productive pastureland. A number of abandoned ranches were identified, which could support approximately one cow per hectare. Other animals would require less space to raise. Liberia is a net meat-importing country, with over 14,000 tons imported in 2005.

If Liberia were to meet its meat demand domestically, it would be easy to imagine the livestock population could at least double. Currently, that would not produce a large pressure on the forest, given the quantity of degraded land available. However, if Liberia became a net meat exporter, there could be increasing pressure on the forests for the production of meat.

It is likely that any carbon/REDD policy that places additional value on preserving and re-growing forest in Liberia will provide the correct incentives for individual landowners to practice efficient livestock production. If the GoL were faced with a request for a livestock concession, it would do well to only award such a concession on degraded land, so as to maintain a low rate of deforestation and therefore maximize potential carbon revenues.

### 4.7. Mining

Given the significant contribution to economic growth anticipated from mining, and the relatively small direct footprint of mining operations, we do not propose or consider any policies to reduce the extent of the proposed mining expansion. Clearly mining should respect the boundaries of areas designated for other uses; existing rules on this subject should be enforced rigorously.

Additional regulation and oversight of mining prospecting and/ exploration could be useful in reducing the impact of this phase of operations.

Finally, we note the point made in section 4.1 about the impact of mining access roads; additionally, there is often a deforestation and degradation impact during the construction phase. Similar measure to those proposed in section 4.1 could help with this effect as well.

### 4.8. Bushmeat and biodiversity

The advent of REDD as a potential source of funding has both costs and benefits for the protection of habitat more broadly. When nations and/or landowners are rewarded for the quantity of carbon, and therefore biomass, on their land, they will generally respond by increasing the amount of biomass. Normally, this will have spillover benefits to other ecosystem services: soil erosion is prevented; watersheds are protected; and animal habitat is preserved.

However, with incentives so narrowly linked to carbon, and not other ecosystem services directly, the risk arises that landowners will develop "empty forests" that contain trees and little else. Yet the value of the other ecosystem services may be immense - Godoy, Lubowski, and Markandya (1993) survey a number of studies that find annual value per hectare of non-timber forest products (NTFPs) of anywhere from $1.06/ha/year in Cameroon to $50-150/hectare/year in the Amazon. An average of the values from Africa yields approximately $9/hectare/year.

In Liberia, according to a study undertaken for the Ministry of Agriculture, annual consumption of bushmeat was 4.4 kg/person/year - nearly the same quantity of meat per person as from livestock. If all policies focus on carbon at the expense of other forest services, overharvesting of these other items like bushmeat may result in fauna population declines or other long-term damaging outcomes.

For this reason, carbon projects in the voluntary market can attain a higher quality rating, and a higher price per ton of $CO_2$, when they include components to manage biodiversity and other ecosystem services. The Climate, Community and Biodiversity Alliance (CCBA) voluntary standards are an established way to design and identify land management activities that simultaneously minimize climate change, support sustainable development and conserve biodiversity. Liberia could examine the merits of following the CCBA standards, to conserve its valuable biodiversity, to ensure social equity in the transactions and to seek a price premium on the carbon credits generated.

Over the longer term, through the REDD+ process, social and environmental standards are being drawn up for REDD and other forest carbon programs that can be used by governments, NGOs, financing agencies and other stakeholders to design and implement programs that respect the rights of indigenous peoples and local communities and generate significant social and biodiversity co-benefits. These standards will learn from the existing CCBA experiences.

Liberia would do well, in the short run and certainly in the long run, to include an active biodiversity/ecosystem services component in any carbon policy, possibly based on the CCBA standards.

## 4.9. Land Tenure

Perhaps the largest barrier to an equitable national REDD policy is uncertainty in land tenure and ownership. Much of the land in Liberia faces competing, or overlapping, claims of ownership. To add to the complications, carbon ownership may be ambiguous within existing law. In a village inside a forestry concession, who is the claimant to any carbon revenues achieved? Is it the user of the land, the village government, the forester, or the national government? Such questions need to be clarified, in a manner that ensures the most ethical, equitable, and efficient distribution of carbon rights.

For carbon pricing to generate "efficient" outcomes, landholders must act in such a way that they clear forest if they can make more money from an economic activity than from carbon preservation, and they maintain forest or actively plant new forest if that activity is more profitable than any other. One way to achieve this is to offer direct compensation to landholders commensurate with the quantity of forest on their land. Of course, for this to occur, the distributing agent - whether the GoL or a development partner - must know whom to contract with. Massive uncertainty over land ownership makes it difficult to offer direct incentives to individual landowners. In fact, land claimants often face perverse incentives from a carbon standpoint: wanting to maintain a claim on a piece of land, they will seek to "improve" the land, which often means deforesting it and planting food or tree crops, so that no one else can lay claim to the land. This results in inefficient land clearing that is not able to take into account the potential carbon revenues.

This problem of how to allocate natural resource revenues has been faced before in Liberia, most notably with the forestry reform of 2006. The forestry reform process created a number of policy innovations, including a "community forestry" component. A recent Community Rights Law also specifies a number of ways, including a formal governance mechanism, by which a community may profit from its natural resources. These new mechanisms, while not designed explicitly for carbon, may prove to be a useful device to assist in creating the right incentives for reducing carbon emissions. Small investments in adapting existing land tenure to work with carbon, and larger investments in resolving land tenure uncertainty, may very well pay high dividends by enabling REDD finance to reach local actors.

## 4.10. Coordination between ministries and sectors

Cooperative working will be necessary, including establishment of a sustainable land planning strategy and a climate change steering committee. This is enabling policy for the other changes discussed above.

## 4.11. Alternative scenarios for Liberia's future

The projections made in this report do not take full account of several projected changes expected to affect Liberia's future. The impacts of these changes are as yet unknown.

- Climate change: This report considers ways to reduce global climate change. Nevertheless, a significant amount of climate change is projected to occur and to have effects on Liberian agriculture and natural ecosystems;
- Population growth: Liberia's population will grow naturally over time. This will result in increased pressure on natural resources, including agricultural land;

- Migration into rural areas: There is an ongoing movement of the population back into rural areas that were depopulated during the conflict period;
- Possible alternative options for land use within Liberia, such as growing more food or commercial crops for export.

## 5. Potential for Carbon Revenues

Given the shifting landscape of the carbon market, Liberia will need to make an informed but nevertheless uncertain decision on which mechanism to select to generate revenues for its available carbon stock. Several options are available. Considerations in choosing the appropriate strategy include the level of risk involved, the time frame for implementation and payment, start-up and transaction costs, and the potential revenues generated. The main options include:

### *1. Voluntary Carbon Markets*

At the moment, voluntary carbon markets provide a platform for reducing emissions from deforestation and degradation (REDD) by providing financial incentives to site-specific projects in developing countries for maintaining their carbon stocks. Currently these transactions are voluntary agreements in which the price per ton $CO_2$ is negotiated between the two parties. In 2007, over $330 million was traded on the voluntary carbon market, 15% of which was for forest-carbon credits. For example, Conservation International (CI) has existing experiences with schemes in several countries, such as in Madagascar, where an average price of around $7 per ton of $CO_2$ is being achieved. CI has also recently signed a deal with the Walt Disney Company to establish a scheme in the Democratic Republic of the Congo that will offset some of Disney's emissions; this will be one of the largest forest carbon projects in the world.

In the voluntary market, a project with forest resources pledges to reduce deforestation in exchange for a set price per ton $CO_2$ averted. Future deforestation rates are compared against a baseline deforestation rate and the project or sub-national activity is compensated for the amount of avoided deforestation. The carbon 'buyer' can be an NGO, an international agency or the private sector. Given the complexity in developing these agreements, a final contract requires significant time and technical capacity and often includes high start-up costs which necessitates a relatively large concession just to break even financially. However, this mechanism has a large advantage in that relatively little government intervention is required to allow a project to get off the ground, as the transactions are between private parties. Since the market is voluntary, there is nothing preventing the government from being the 'seller' in the transaction. The government may also tax any carbon revenues, but the more taxes imposed the harder it will be for transactions to occur.

Within the voluntary markets, the Climate, Community and Biodiversity Alliance (CCBA) voluntary standards enable the design and implementation of land management activities that simultaneously minimize climate change, support sustainable development and conserve biodiversity. Following CCBA standards should also generate a price premium on the carbon credits generated.

Liberia could consider encouraging or participating in individual carbon concessions through the voluntary market in the near future in order to develop experience in these schemes, to demonstrate the ability to generate valid carbon credits, and to initiate a stream of carbon revenues quickly. However, future buyers of carbon credits under the other options below will be unlikely to want to pay again for carbon that has been sold through this existing mechanism, so transactions here may imply foregone revenue under a different future scheme.

### *2. Clean Development Mechanism (CDM)*

The Clean Development Mechanism (CDM) was developed under the Kyoto Protocol to enable industrialized countries to reduce greenhouse emissions by investing in projects which reduce emissions in developing countries through afforestation or reforestation projects which sequester carbon from the atmosphere. Note that the CDM does not cover projects that reduce *deforestation* rates. Due to difficulties in achieving certification, to date only eight afforestation and reforestation projects have been approved under the CDM. The approval process for CDM forestry projects can take several years. Only one existing project is in Africa – the Nile River Basin Reforestation project in Uganda. This project will implement sustainable-harvest forest plantations on 2,100 ha of previously cleared, degraded grassland and is being financed through the World Bank's BioCarbon Fund.

That said, the CDM is the only existing institutionalized market for forest-based carbon sequestration currently in existence. This means that credits generated under the CDM can actually be used by polluters in European Annex I countries to offset excess pollution. As a result, the price of credits generated under the CDM is much higher. The GoL could consider encouraging the development of CDM projects depending on the outcome of the Copenhagen negotiations.

### *3. A REDD / REDD+ Mechanism post-2012*

The United Nations Framework Convention on Climate Change (UNFCCC) will be discussing REDD during the 15$^{th}$ Conference of Parties (COP15) in December 2009 in Copenhagen. If the COP establishes a framework for an international REDD financing mechanism, this could result in a major new market in carbon credits. Developing a strategy for implementing REDD in Liberia now, including determining the baseline deforestation rates, developing policies for equitably distributing REDD funds/incentives to the appropriate parties, and creating a monitoring, reporting and verification plan, would drastically speed up the process for implementing any national REDD strategy once the details get worked out at the international level.

If it is successful, a REDD finance mechanism would be part of a comprehensive global solution for avoiding deforestation and its associated emissions. Establishing a REDD strategy under the umbrella of an international compliance mechanism would take time (it would not come into force until 2012 at the earliest) and require increased technical capacity, but would provide the security of a compliant carbon market with strict oversight. If a market is successfully created, it could potentially offer a higher price for carbon, as the buyers would be motivated by binding targets enforced in Annex I countries.

An initiative under a REDD finance mechanism could either be implemented at the national scale or at the sub-national or project level. Sub-national activities (projects) could look like those currently possible through existing voluntary markets and the CDM, or they could be more flexible and allow smaller projects - at the level of the community or even landholder - to participate if they deemed it in their interest. The Government of Liberia is currently in the process of developing its readiness strategy (through the RPP process) and is a part of the World Bank's Forest Carbon Partnership Facility (FCPF) which supports developing countries in their efforts to reduce emissions from deforestation.

*More recent developments have resulted in a proposal for a* ***REDD+*** *mechanism – a refined version of the original REDD proposal.* As part of this process, social and environmental standards are being drawn up for REDD and other forest carbon programs, that can be used by to ensure that programs are designed and implemented to respect the rights of Indigenous Peoples and local communities, and to generate significant social and biodiversity co-benefits. These standards will learn from the existing experiences with the CCBA voluntary standards mentioned above.

In 2007 at the United Nations Climate Change Conference in Bali, there was agreement that while developing countries had a right to further economic growth, it was the global community's responsibility to find financing mechanisms to ensure that this growth would not come at the expense of the environment. This resulted in the concept of **Nationally Appropriate Mitigation Action (NAMA)** plans. NAMAs are voluntary actions supported by technological and capacity assistance from the developed world. The types of actions that will qualify in NAMAs are not yet confirmed; they could include renewable energy goals, cap-and-trade or carbon tax systems, or participation in emissions trading schemes such as the Clean Development Mechanism. It is also not yet clear how the monitoring, reporting and verification principles and oversight bodies will be implemented, or how the development and capacity assistance will be enabled. A low-carbon development strategy put forward by the GoL that builds on the evidence in this report would appear to be highly compatible with the concept of a NAMA for Liberia.

### *4. A National Strategy Today*

Given the uncertain nature of REDD progress at the international level, a handful of developed and developing nations are moving forward with their own strategies. In particular, Norway has taken the lead as the donor with the most enthusiasm for encouraging ad-hoc national REDD strategies. In the Norwegian vision, these country programs would be financed through bilateral and multilateral funds, and the funding and ad-hoc institutions devised would be agreed to be phased out once a more wide-reaching international solution is finalized. Below, we describe two of the leading such strategies, in Brazil and Guyana. Pursuing this alternative could provide Liberia with annual funding, contingent on specific objectives being met regarding rates of deforestation and degradation.

A pioneering Memorandum of Understanding between Guyana and Norway has been signed, where an investment fund will be established to channel funds to Guyana to implement Guyana's Low Carbon Development Strategy. The funds will be contingent on Guyana following REDD strategies, which will be independently monitored and evaluated throughout the life of the agreement. The mechanism will also ensure full national and international oversight of financial flows. Most details of the agreement have yet to be articulated. A timeline has been set up to define the building blocks of the agreement, including the finance vehicle itself and the monitoring and verification system. The fund will pay up to \$5/t$CO_2$ emissions avoided, assuming a constant level of 367t $CO_2$/ha, and relative to a baseline rate of 0.45% per year. For example, should the deforestation rate be measured at 0.30% per year, Guyana could receive up to \$41 million per year from Norway and from other donor sources.

A very different agreement is being developed in Brazil which would compensate actions in Brazil that lead to reductions in deforestation rates in the Amazonian states. The Brazilian government has unilaterally set up the Amazon Fund, and runs it through the Brazilian Development Bank. The Fund accepts donations (including a \$1 billion commitment from Norway) up to the reductions in deforestation that are achieved below Brazil's historical baseline. The Fund will compensate emissions reductions already made, and issue "certificates" to the fund donors. These certificates *cannot* be used as carbon credits to offset emissions elsewhere in the world.

In a sense, the fund has pay-for-performance properties like the Norway-Guyana agreement. In another sense, the fund acts more like an incubator, funding a variety of different projects that have some link to forest conservation.

The Amazon Fund may finance a wide variety of different projects, to encourage innovation and learning. It funds projects in the following areas: protected area management, sustainable production, science and technology development (to support sustainable use of biodiversity), and institutional development and control mechanisms.[23] One particularly interesting project run by an environmental NGO paid individual landholders to not cut down their trees, at a rate of $12/acre/year. The area is monitored by satellite, and farmers receive money at the end of each period commensurate with the amount of forest they keep standing (Rosenthal, 2009).

How could such a strategy be employed in Liberia? The GoL could, based on this and further economic analysis as well as political considerations, put together a plan of action that would reduce carbon emissions from deforestation and degradation. It could then seek financing from a bilateral/multilateral source (such as the Government of Norway), commensurate with the quantity of carbon emissions avoided. Since Liberia remains short on capital, the agreement could potentially specify that much of the up-front costs would be borne by the donors, while still retaining a pay-for-performance component to ensure that actors in Liberia remain incentivized to meet carbon targets. The contract could perhaps be structured such that if accessible higher-priced carbon credits become available, Liberia would be free to terminate the agreement.

## 5.1. Turning Liberia's strategy into carbon revenue

Identifying where carbon emissions can be reduced or sequestered, as has been the principal aim of this report, does not necessarily easily lead to carbon revenues. Besides achieving carbon-saving goals, which is in itself very complicated - there must also be a financing device to compensate the green activity, and a monitoring/verification system to identify how much carbon has been saved (and where this took place).

To add to the challenge, different policy options described above (voluntary markets, CDM, national strategy) may entail different schemes through which carbon savings are monetized. We describe two broad components of this process below.

1. **Valuing emissions reductions**. The first stage in the process is determining how carbon savings get translated into a marketable commodity. This report has identified potential elements of a Low-Carbon Economy, and estimated the amount of carbon that could be saved from each element. What it has ignored thus far is *how* those savings can be turned into a carbon credit. Ideally, one could simply monitor all the biomass across Liberia and value the savings at an agreed or market price of tons $CO_2$.In practice this is too labor-intensive to be a realistic option (for example, it could involve manually measuring the diameter of the trees in a given plot to calculate total biomass, then extrapolating to estimate the carbon content in an area; and each inventory costs between $500-$1,000).

Deforestation avoidance projects have therefore usually assumed a uniform level of tons $CO_2$/ha and simply monitored the area deforested, rather than measuring biomass. What counts as forested will follow international definitions, which include how to determine - based on satellite

[23] http://www.bndes.gov.br/SiteBNDES/bndes/bndes_en/Fundo_Amazonia/condicoes.html

data - whether a particular hectare is “forested” or not. The negotiated price per ton $CO_2$ is in actuality a price per hectare of forest that is not deforested. This has obvious advantages, most notably that it is easier to monitor.

However, some disadvantages of simply monitoring the number of forested hectares become clear once the Liberian context is examined in more detail. For example, the major potential source of carbon revenue in Liberia results from allowing degraded land to return to forest as agriculture becomes higher-yielding and more intensive. However, if farmers only get compensated once that hectare has been determined to be “forest”, then it may be a decade or more until the freed-up land is observed by the satellite data to have passed the threshold for biomass content and tree cover that counts as a forest.

Another potential policy, converting sustainable forestry to carbon concessions, may also not be picked up by this methodology: both sustainably-logged forest and unlogged forest would probably appear as “forest” to the satellite. For these reasons, the Norway-Guyana plan does contain a section on degradation (where the forest biomass may have been reduced through human activity). Thus, area samples will presumably be necessary, but the details have yet to be finalized.

In voluntary-market REDD projects, satellite observation is the dominant form of monitoring and verifying the progress made in combating deforestation. When projects have a component of reforestation, the project leader will need to establish growth curves of the species of trees being planted, and every five years site-based verification will occur to verify that the trees are sequestering carbon according to their predicted path. Compensation for the sequestered carbon would occur at the same interval as verification. This is largely the same for CDM forest regeneration projects.

Any eventual national policy, if it included reforestation in addition to reduced deforestation, would need to derive an appropriate mechanism to value the carbon sequestered by more efficient land use, that could be employed at an efficient price. Fortunately, the field of monitoring carbon stocks is progressing rapidly. There may be technological advances in satellite sensing to allow for more accurate measures of biomass accumulation.

2. **Creating emissions reductions**. The way in which emission reductions are valued will affect how successful a national REDD strategy will be in encouraging private and public actors to create those reductions. This encouragement will necessarily be multi-faceted, and may involve direct funding of programs as well as specific incentive approaches.

As an example, take what on the surface might seem like one of the least complicated policies: accelerated rollout of Protected Areas. How might a new Protected Area like the Kpo Mountains (currently scheduled for 2015 roll-out) be implemented in a way that earns carbon credits? Clearly, a successful program would need to benefit the local communities, create green jobs, and reduce deforestation. The reduction of deforestation might occur through a combination of enforcement, incentive-based payments or projects, and non-incentive-based projects. It could be managed by the FDA, the county, an NGO, or a carbon concessionaire. Who would get to keep the carbon revenues generated? Perhaps the project managing entity would manage this process, and in turn compensate local individuals and communities for their cooperation, as well as paying taxes to the government.

Distributional questions also come to the forefront in deciding how to manage emissions reductions and how to allocate carbon revenues. Consider a national plan that rewards Liberia for deforestation below a certain rate. In order to ensure that forestry concessions are not encroached by illegal logging or slash-and-burn agriculture, someone will need to monitor the concession for such activity. The forest concessionaire themselves might be the most effective at doing this, and therefore an argument could be made to grant the carbon rights to the forester. However, such a policy would grant a subsidy to one of the primary carbon emitters in the country! Carbon rights could also be distributed in a revenue-neutral fashion, through some form of auction for the right to earn revenue from the carbon saved.

All of these issues would need to be worked out for each element of the Low-Carbon Economy. Some policies, like preparing 30,000 hectares of lowland farming to benefit subsistence farmers, face particularly challenging issues; for some policies, although the carbon savings may be worth the amounts shown in Table A in theory, there may be obstacles to converting these into robust credits that can be sold.

Ideally, if a Low-Carbon Economy is to become a reality, a flexible mechanism would be designed that can fit a variety of different programs and policies. A variety of partners could be enlisted to help Liberia to experiment and learn which types of arrangements and managers are most successful at achieving carbon savings. Liberia can look to examples from around the world, and modify them to fit the political economy of Liberia.

## 6. Key Findings

### 6.1. Potential carbon revenues Liberia could receive from a low-carbon development strategy

Given the current prices in existing forest carbon projects (which average around $7/ton in Madagascar, for example), the bilateral agreement between Norway and Guyana ($5/ton), the proposed Amazon Fund and the potential prices under a post-2012 REDD finance mechanism (which could be higher), we estimate that Liberia could expect to obtain between $5 - $15 per ton of $CO_2$. The actual price will have a significant impact on the monetary benefits of each candidate policy, and the decision on which policies are beneficial to Liberia.

This section calculates the potential carbon revenues from the policies under a price of $5 per ton of $CO_2$. It then compares these revenues with the projected cost of each policy, to assess which policies would create a net benefit to Liberia.

The policies that are financially beneficial for Liberia at a price of $5 per ton $CO_2$, and are therefore included within the proposed low-carbon development strategy are:

- Plantations are located on degraded land rather than forest areas (100,000ha)
- Fertilizer subsidies to increase efficiency of shifting agriculture (across 60,000ha)
- Lowland rice promoted in place of shifting agriculture (30,000ha of lowland rice)
- Conservation agriculture promoted in place of shifting agriculture (48,000ha of CA)
- Accelerated creation of the Protected Area Network
- Increased efficiency of charcoal production and use
- No further Timber Sales Contracts

Together, this proposed low-carbon development strategy would save an estimated **11.7 million tons of $CO_2$** per year, generating revenues of **$58.7 million per year**. Total costs would sum to around **$22.0 million per year** (noting that costs would be higher than this in the early years), resulting in an estimated net benefit to Liberia of $36.7 million per year. There would also be additional costs of around $5 million per year for national coordinating and monitoring institutions (which could also coordinate climate-change adaptation policy). We also note that costs would not be spread evenly over the 25 years; costs would be significantly higher in the early years as programs are initiated and set-up costs incurred. Liberia can look for opportunities to partner with organizations prepared to fund these set-up costs.

Under a higher-end price of **$15 per ton of $CO_2$** (which is not achievable now, but could potentially be reached if carbon markets take off and the price rises in the future), revenues would be three times the amounts quoted here, and **all of the policies assessed would become beneficial to Liberia**.

On the other hand, if there are administrative cost overruns, or significant costs to set up and maintain the overall structure, the cost figure would be inflated, with commensurate reductions in the net benefits estimated.

Other policies in the forestry sector (no new FMCs are assigned; and community forest areas are managed as carbon concessions) could save an additional 4.0 million tons of $CO_2$ per year, generating additional revenues of \$19.1 million per year at \$5/t$CO_2$. However, these policies could cost between \$27.7 and \$51.6 million per year (mainly in foregone forestry revenues); hence this finding is dependent on the assumptions for yields and government revenues received from FMCs.

Increasing the efficiency of pitsawing could save a further 3.0 million tons of $CO_2$ per year, generating additional revenues of \$15.0 million per year at \$5/t$CO_2$. It has not been possible to estimate the costs of this policy.

The 11.7 million tons $CO_2$ that could be saved if Liberia successfully implemented the low-carbon development strategy proposed in this report is a sizeable amount of carbon. Annual deforestation rates in West Africa (excluding Liberia), according to the authors' calculations using World Bank data, averaged -1.14% from 1990-2008. For countries with GDP per capita in 2008 less than \$300 (measured in 2000 USD, also excluding Liberia), the average annual deforestation rate was -1.22%. Thus, if we take an even -1% annual deforestation rate as the appropriate reference scenario for Liberia, approximately 22.7 million tons $CO_2$ would be released. Implementing this low-carbon development strategy would reduce Liberia's carbon emissions resulting from land use choices by about half. This would help Liberia to achieve its goal to become carbon-neutral in energy by 2050, as outlined in the national energy policy.

The table and diagram overleaf summarize the key results by policy, as well as some of the key barriers to implementation, and other costs and benefits that were not considered in the financial calculations.

**Table 11: Key results by policy, including potential carbon revenues**

| Policy | Average CO2 saved per year (million tons) | Cost of carbon saved ($/tCO$_2$) | $5/ton: Carbon revenues per year ($ million) | $5/ton: Net benefit / cost per year ($ million) | Other benefits (above carbon revenues) | Other costs & barriers to implementation (not included in cost estimate) | Amenability to generating carbon revenues |
|---|---|---|---|---|---|---|---|
| 100,000ha of plantations are located on degraded land rather than forest areas | 2.1 | Very low | 10.6 | 10.6 | Biodiversity; Regulation of water flows; Non-timber forest products | Any impacts on productivity; Property rights need to be clarified; Existing claims by concessionaires. | Good |
| Fertilizer subsidies to increase efficiency of shifting agriculture | 1.8 | <2 | 8.8 | 7.1 | Increased agricultural productivity; Food security | Pollution from fertilizers; Capacity constraints. | Mechanism needs to be based on forest regeneration |
| Lowland rice promoted in place of shifting agriculture | 1.6 | <2 | 8.2 | 6.3 | Increased agricultural productivity; Employment generation for land preparation; Food security; Drought resistance | Reluctance to change practices; Property rights; Coordination required; Many landowners have no suitable land on their properties | Mechanism needs to be based on forest regeneration |
| Conservation agriculture promoted in place of shifting agriculture | 1.7 | <2 | 8.6 | 6.1 | Increased agricultural productivity; Food security; Soil conservation | Reluctance to change practices; Capacity constraints; Property rights | Mechanism needs to be based on forest regeneration |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Accelerated creation of Protected Area Network | 0.2 (0.8 over first 5 years, then zero after that) | <2 | 0.8 | 0.5 | Jobs created sooner (rangers etc.); Biodiversity; Regulation of water flows; Non-timber forest products | Costs incurred sooner; Capacity to implement and enforce; Need consultation process with local communities; Jobs displaced from reduction in illegal logging | Good |
| Increased efficiency of charcoal production & use | 1.1 | 2.67 - 3.20 | 5.7 | 2.1 | Increased efficiency of production; Health benefits from reducing cooking smoke; Jobs created in stove manufacture and distribution | Reluctance to change practices | Requires policy on receiving credits from avoided degradation, or direct marketing of credits from stoves |
| No further TSCs | 3.2 | 3.75 | 16.0 | 4.0 | Jobs created in carbon concessions; Biodiversity; Regulation of water flows (small areas are less valuable though); Non-timber forest products | Short-term jobs lost; Land not opened up for agriculture; Wood for Liberian market must come from another source; Requires change in established policy | Good |
| ***Sub-total for potential low-carbon development strategy*** | ***11.7*** | | ***58.7*** | ***36.7*** | | | |

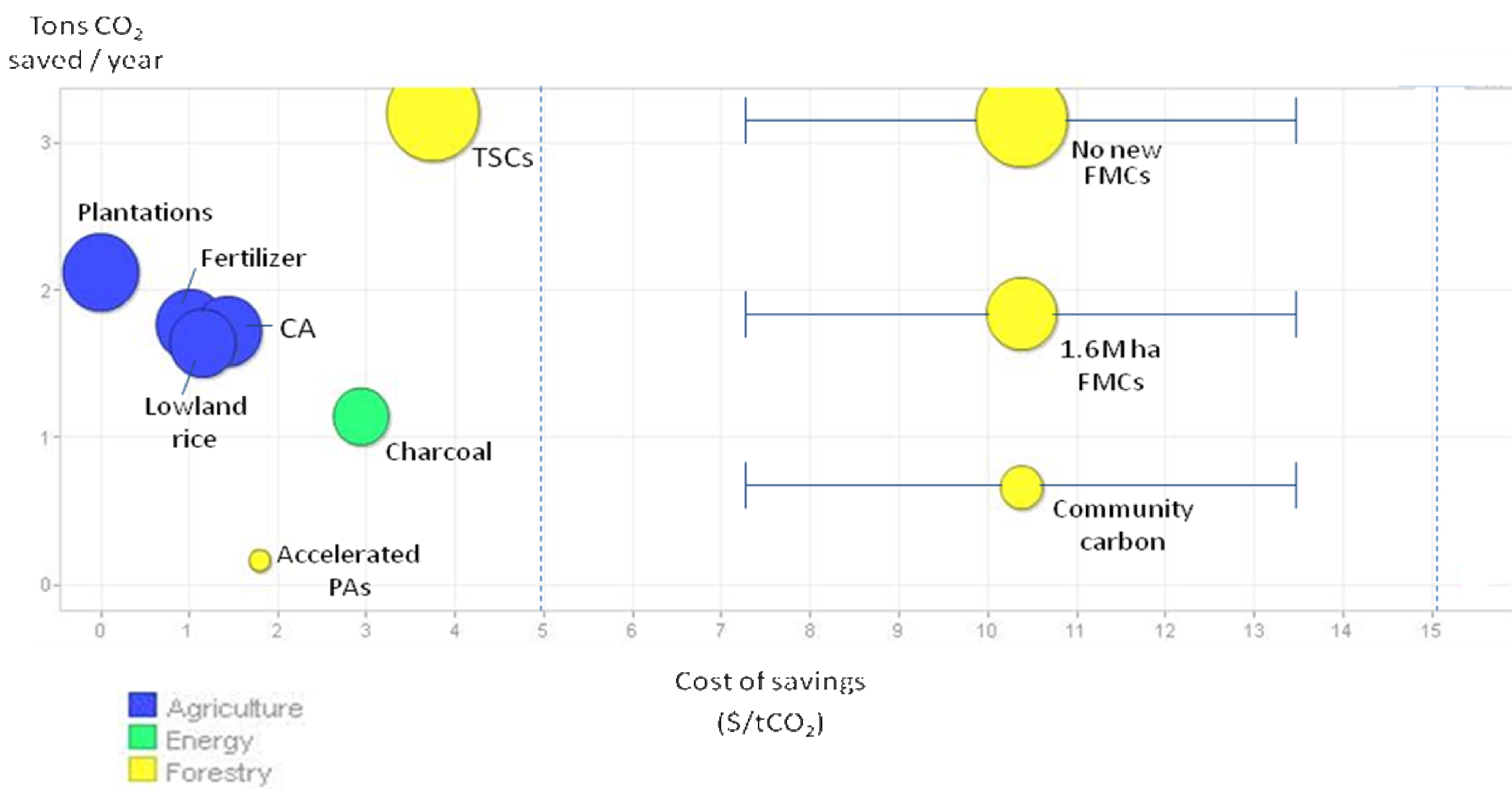
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Restrict FMCs to 1.6 million ha | 1.8 | 7.25 - 13.50 | 9.2 | -4.1 to - 15.6 | Jobs created in carbon concessions; Reduces risk of over-exploitative logging; Biodiversity; Regulation of water flows; Non-timber forest products | Jobs lost; Perception that forestry is important (but expansion of forest concessions has been slower than expected anyway) | Good; Possible monitoring issues with identifying logged forest vs. intact forest |
| No new FMCs | 3.2 | 7.25 - 13.50 | 15.8 | -7.1 to - 26.9 | Jobs created in carbon concessions; Reduces risk of over-exploitative logging; Biodiversity; Regulation of water flows; Non-timber forest products | Jobs lost; Requires rapid change in policy; Insufficient area to maintain chain of custody system | Good; Possible monitoring issues with identifying logged forest vs. intact forest |
| Community forest areas are managed as carbon concessions | 0.7 | 7.25 - 13.50 | 3.3 | -1.5 to -5.6 | Jobs created in carbon concessions; Reduces risk of over-exploitative logging; Biodiversity; Regulation of water flows; Non-timber forest products | Jobs not created in community forestry; Delays with rolling out the Community Rights Law | Good; Possible monitoring issues with identifying logged forest vs. intact forest |
| ***Sub-total for additional quantified strategies[24]*** | ***4.0*** | | ***19.1*** | ***-8.6 to -32.5*** | | | |

[24] excluding restricting FMCs to 1.6 million ha, as this would be double-counting with the 'no new FMCs' policy

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Two year moratorium on new concessions | Only temporary gains | n/a | n/a | n/a | Option value: Liberia can decide later whether to embrace carbon concessions or not, Can prove viability of sustainable forestry policy | Delay in job creation; Expansion of forest concessions has been slower than expected anyway | Only short-term revenues - requires different form of credits |
| Revoke existing forestry concessions that fail to meet terms of contract, replace with carbon concession | Unknown | n/a | n/a | n/a | Reduces risk of over-exploitative logging; Increases credibility of contract enforcement. | Potential legal hold-ups in annulling contracts. | Good; Possible monitoring issues with identifying logged forest vs. intact forest |
| Improved efficiency of pitsawing | 3 | n/a | 15.0 | n/a | Increased productivity for pitsawyers; Improved regulation would increase government revenues | Difficulty of changing an unregulated industry | Requires mechanism for generating carbon credits from degradation |

Figure 2 plots each policy on two axes: the x-axis shows the cost per ton of $CO_2$ saved; policies to the left of the first dotted line are beneficial to Liberia at a price of $5/ton $CO_2$, and are included in the proposed low-carbon development strategy. All policies lie to the left of the second line; they are all beneficial at $15/ton $CO_2$. Error bars indicate the level of uncertainty of the costs. The y-axis shows tons of $CO_2$ saved annually.

**Figure 2: Volume of $CO_2$ saved and cost of $CO_2$ savings for each quantified policy**



## 6.2. A New Industry

Much of the existing dialogue in the developing world sees a discrete tradeoff between "productive" activities (like forestry, farming, or ranching) and carbon finance, which is portrayed as getting paid to do nothing. This distinction misses a potentially very large opportunity. Carbon emissions reductions can be "produced" just like wood or rice; the difference is that the reductions do not have any intrinsic value to an individual; they cannot be used by anyone. However, these emissions reductions do have value to the world, insofar as reducing carbon emissions is the primary tool to prevent large-scale climate change. The market for emissions reductions through REDD has not even been created, but if and when it does the value of carbon emission reductions will be determined not by the value to the end-user, but instead by regulatory compromises, in countries far from Liberia. That said, once the market is created it can produce very real profit opportunities for entrepreneurs in Liberia and around the world.

As the nation best endowed with forest in West Africa, Liberia has the opportunity to be a market leader in the region in the production of emission reductions, a market that could easily be worth billions of dollars regionally. Reducing deforestation and returning degraded land to forest - in a biodiversity-preserving fashion - cannot be done by sitting around. Land must be divided up, monitored for illegal logging, and protected from forest fires. Agriculture must become more productive, and products and services like organic and inorganic fertilizer, irrigation, and grading will be procured, often locally. Databases must be created, new payment methods developed, and monitoring schemes perfected so as to remunerate landholders for their efforts. Extending the program to other ecosystem services provided to end-users such as plantation owners could result in payments for ecosystem services schemes where the service is monetized and produced professionally – for example, funding watershed protection programs And once Liberians have gained expertise in these areas, they can apply them in other economies in the Mano River Union and beyond.

Before the additional benefits related to carbon markets became apparent, Costa Rica began to structure its economy around its natural resource. The ecotourism and good governance that resulted have produced positive spillover effects for the rest of the economy. Liberia has the natural endowment to become the Costa Rica of West Africa, and REDD may provide the financing needed for that transition.

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