



# **An Assessment of Liberian Forest Area, Dynamics, FDA Concession Plans, and their Relevance to Revenue Projections**

**A report commissioned by Green Advocates, Monrovia, Liberia**

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*Photo Credit: P. H. Shearman. Clearance of logged forest within FMC "C", for rice and rubber cultivation, July, 2009.*

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*Washington DC*

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## 1

**JUST HOW MUCH FOREST IS THERE IN LIBERIA?**

*“The colonial powers, keen on conservation, established permanent forest estates in West Africa, as a result of the recognition of the destruction wrought in their own forests in medieval and more recent times. These controls were operated in various ways. The system of concessions applied to the forest certainly did not help to steer developments in the direction of sustained management and even managed to detach the local population from the forests they had originally made use of. The forest service, often powerful as far as the ordinary man was concerned, was powerless against big men going after the timber hoard, was unable to prevent the drama and was finally forced to watch the destruction of what they were meant to protect.”*

*(Adapted from: Parren and de Graaf, 1995)*

In the mid-1960s the German Forestry Mission to Liberia (Sachtler, 1968) conducted the only thorough inventory of the country’s forests to date. This coupled extensive and thorough volume surveys with mapping based on aerial photography in a competent examination of the subject. They concluded that in 1968, Liberia had 2.5 million ha of the land area covered with closed tropical forest. Half of the area was exploitable, the other part was found to either be too poor in merchantable timber or was inaccessible forest in rough terrain – with 90% of the exploitable forests in the south-east of the country (Parren and de Graaf, 1995).

If Liberia had 2.5 million hectares of closed forest (or 22% of the surface area of the country) in 1968, what is the basis for the Forestry Development Authority (FDA)’s statement that Liberia is either 59.5% ‘forested’ (FDA Annual Report 2007) or 45% forested (R-Pin, 2008<sup>3</sup>). The differences occur for two primary reasons. The 1960s survey only

examined large areas of forest where it believed there was commercial potential, so was clearly an underestimate of the total forest estate. In addition, and more importantly, the differences also occur due to the manner in which the results of the 2004 World Bank-sponsored area survey of Liberia’s forests (Bayol and Chevalier, 2004) are reproduced. Bayol and Chevalier (2004) used the interpretation of satellite imagery to divide Liberia into land-cover classes, a system that included 3 agricultural classes (2.1-2.3) and 3 forest classes (3.1-3.3). These classes and their respective areas are presented in Table 1.

The FDA arrived at the 55% forest cover figure by aggregating the three forest classes (3.1-3.3) with the forest supposedly contained in the agricultural class “2.3 Mixed agricultural and forest area”. This inclusion is erroneous – class 2.3 encloses populated regions under continuous agricultural rotations. The inclusion of these areas in the ‘forest

TABLE 1. LAND COVER CLASSES AND THEIR RESPECTIVE AREAS

Class	Surface area (ha)	%
2.1 Predominant rural agricultural domain	436,747	4.6
2.2 Agricultural area with small forest presence	3,042,091	31.7
2.3 Mixed agricultural and forest area	1,317,873	13.7
3.1 Agriculture degraded forest	949,615	9.9
3.2 Open dense forest	1,013,993	10.6
3.3 Closed dense forest	2,424,078	25.3

Bayol and Chevalier, 2004

estate' is confusing and misguided – especially since the “forest estate” category is the basis for allocating logging concessions to the commercial sector. The R-Pin Document, and most forest-related literature, include the three forest classes to suggest that the country is 45% forested. This is also open to debate for the reason that class 3.1 ‘Agriculture degraded forest’, often contains little forest and lots of people.

In the 1968 Inventory Sachtler stated that:

*“Not included in the forest land, obviously, are all populated areas undergoing permanent farming rotation, with respective intervals sometimes amounting to up to 80 years. The farming intervals in any case are so frequent that the forest can never regenerate up to High forest, and that the main portion of the stand - i.e. not individual emergent trees - never grows up to exploitable thickness, i.e. DBH of at least 50 cm. The forests do not serve any forest production, but are only auxiliary means for the regeneration of the soil serving for agricultural production. Minor residual High forest patches, too, are neither included in forest land, as due to their small size they cannot be utilized for an economical forest industry.”*

Sachtler (1968) was correct to not include areas that were under rotation or were essentially inhabited in their assessment of the commercial forest estate. In this regard, based on the work of Bayol and Chevalier (2004) it would be reasonable to say that Liberia has 3.4 million hectares of forest (35% of the land area) that could be considered for commercial (or conservation) purposes, of which 1 million hectares has already been logged (The difference between “open dense forest’ and ‘closed dense forest’ is that the ‘open forest’ was logged in the 10 years (or so) prior to 2004). In addition there are a further ≈900,000 hectares in which there is still some forest cover, which are also subject to extensive use by local people, and in varying states of degradation, from moderate to severe. The difference between the Sachtler (1968) assessment of the commercial forest estate (25% of the land area) and that of Bayol and Chevalier (2004) (35% of the land area) probably relates to the exclusion by Sachtler of small areas or those he deemed inaccessible, as well as generally less accurate mapping. While Bayol and Chevalier (2004) did not include an assessment of mapping error, conventional professional practice suggests that, given the techniques they employed, their figures would be within 10-15% of their correct values.

## 2

## HOW FAST IS LIBERIAN FOREST BEING LOST AND WHAT ARE THE DRIVERS OF THIS CHANGE?

There have been varying estimates of recent rates of forest loss in Liberia. Over the 25 years between 1980 and 2005, forest area has been reported as being reduced by 22%<sup>2</sup> (FAO, 2005), suggesting an average annual rate of deforestation of 0.9%. In addition, it is estimated that approximately 30% percent of Liberia's potentially commercial forests have been logged within that period (Bayol and Chevalier, 2004).

A 2008 forest change analysis in Liberia performed by a partnership between the Forestry Development Authority (FDA), Conservation International and South Dakota State University (SDSU) suggests the average deforestation rate increased from 0.2% in 1986-2000 (Christie *et al.* 2007) to 0.35% in 2000-2006 (R-Pin, 2008). These numbers are however, average rates – obtained by dividing the area of forest loss by the number of years encompassing the study. Average rates are somewhat confusing as they suggest that the same area is lost each year. Logically if that was occurring, then the rate of deforestation should be increasing as the area remaining is less each year. For this reason equations allowing for 'exponential decay' are often used in the calculation of deforestation rates<sup>3</sup>. Applying such an equation to the data generated by Christie *et al.* (2007) suggests that deforestation is occurring at an annualized rate of around 0.5% per year – approximately equal to the rate in much of the tropical World. In addition, large numbers of displaced people began moving back to their villages from Monrovia after 2003. This migration would be expected to be correlated with increased

subsistence-related deforestation, suggesting that recent rates of forest-loss are higher than they were at the beginning of the decade.

Three additional factors should also be noted in relation to the Christie *et al.* (2007) assessment. From the examination of imagery from circa-1990 it is possible that their classification process underestimated forest cover from this period, leading to an overall underestimation of change. Secondly, their recent coverage included lots of very small areas classified as 'forest'. While not commenting on whether or not these are predominantly correct classifications, their size means they are of limited commercial or conservation utility, and should probably have been separated in the final statistics. Lastly, their study does not examine degradation of the forest estate by the logging industry – an omission that could have led to its role as a key driver of deforestation being underestimated in recent literature on forest loss in Liberia. Logging of the intensity practiced in Liberia over 25-30% of the forested landscape is highly significant. It has undoubtedly been an important driver of deforestation and degradation. When these factors are taken into account it would not be surprising if recent rates of deforestation were in fact between 0.5-1% per annum<sup>4</sup>.

Historically, the main drivers of deforestation and degradation in Liberia have included:

1. conversion for slash and burn agriculture (especially dry rice cultivation);
2. small-scale chain saw operations for local markets and fuel wood production often termed - "pit-sawyers";

3. mining (both commercial and artisanal);
4. post-conflict population migrations, leading to additional clearing for agriculture;
5. extensive and excessive commercial logging which partially funded the purchase of armaments during the civil war period (R-Pin, 2008).

Historically, the interaction between commercial logging and the settlement and clearance of forested areas by migrants, and the use of logging roads by the pit-sawyers are major factors in the dynamics of deforestation. The synergistic interac-

tion between logging and these other drivers of deforestation will accelerate as soon as industrial logging begins again. Road construction, much of it associated with logging, has fragmented much of the remaining forests - four fifths of the forest is now within three kilometers of the road (ITTO, 2005). Future threats include the expansion of legal mining, expanding road infrastructure, and possibly conversion to industrial tree crop or oil palm plantations, as well as commercial logging (ITTO, 2005).

## 3

## THE RESURGENCE OF THE FOREST SECTOR

Prior to the collapse of the Taylor regime in 2003, the forestry sector was a significant economic contributor to the Liberian economy. Total log and timber production per annum peaked at 1-1.3 million cubic meters, with a value of approximately US\$100 million and generating government revenue of around \$20 million per annum. Forestry contributed approximately 50 percent of Liberian export earnings and about 20 percent of GDP, although at this time the mining sector was under sanctions and the rubber industry was below its current production capacity. The 2008 Poverty Reduction Strategy optimistically envisages the rebuilding of Liberia the infrastructure and economy to be partly underpinned by a resurgence of log exports to pre-2003 levels within a few years.

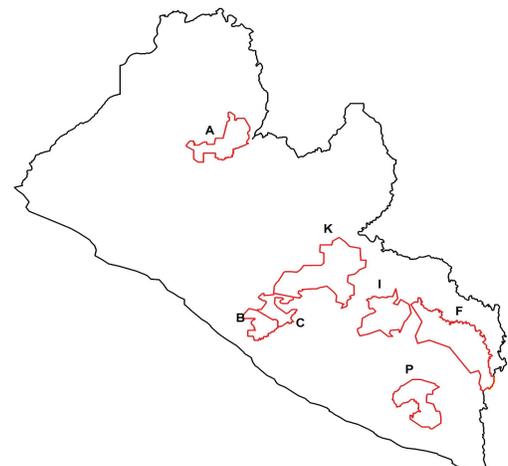
During the period 2003-2006 Liberia embarked on a forest reform process that has included the revocation of all previous timber concessions, a new forest policy, revised forest legislation and the issuing of supporting regulations. A chain of custody system governing all commercial log and wood export was put in place with funding from the World Bank.

Throughout the reform process, the Forestry Development Authority has been assisted by partners in the Liberia Forest Initiative (LFI). The LFI is a partnership of government, NGOs, and donor agencies collaborating to support the rehabilitation and reform of Liberia's forestry sector and enhance cooperation and coordination of activities for the promotion of sustainable forest management, improved conservation, and strengthened commu-

nity forestry practices. Some of the major partners include the US government (reform, commercial & community forestry), World Bank (reform & institutions), FAO (technical support), Conservation International (protected areas and communities) and Fauna & Flora International (protected areas and communities).

Progress within the FDA led to the United Nations Security Council (UNSC) lifting sanctions on commercial logging in Liberia in 2006. Since then, FDA efforts have focused on the development of new concessions and their allocation. As of July 2009, a total of 7 Forestry Management Concessions (FMCs) have formally been designated, and 3 awarded. The locations of these are presented in Figure 1. Felling operations are yet to commence.

FIGURE 1. CONCESSIONS (FMCs) CURRENTLY UNDER ALLOCATION



The FDA Development Strategy (FDA, 2007) for the resurgence of the commercial forest sector envisages that 2.5 million hectares will be allocated to concessionaires over the next 4-5 years, in which it suggests approximately 1.9 million hectares of harvestable forest exist (76% of the concession areas)<sup>5</sup>. Within the 7 concessions currently being allocated, 30% of the forests have already been logged. If this ratio is representative, and there is no reason to suggest that it is not, then 0.6 million ha of the total estate to be allocated has already been logged, with the remainder, 1.3 million ha unlogged<sup>6</sup>.

The following sections of this report examine the technical aspects of the data produced by the FDA from the perspective of assessing national capacity in the sustainable management of Liberia's forest estate. This examination naturally leads to a reappraisal of assumptions and estimates, particularly in regard to timber volume and area assessments. Finally, it allows some commentary on economic projections.

# 4

## ANALYSIS OF FDA JUSTIFICATION AND BID DOCUMENTS FOR NEW CONCESSIONS

The FDA is in the process of allocating seven concessions, containing 1.01 million hectares in large commercial concessions (Forestry Management Concessions or FMCs) – each of which is predominantly aimed at recommending the export of round logs. An integral part of the allocation process is the generation of a “Justification Document” that provides the inventory/area data and social information necessary for the FDA to deem the area ‘suitable for commercial forestry’. Following a satisfactory determination of suitability, the concession is competitively tendered on the basis of parameters in the “Bid Document”.

The documents associated with these allocations – assessments of area, forest condition, forest volume, site conditions and forestry prescriptions contain numerous scientifically and methodologically related flaws. In general the outcome of these flaws is the systematic overestimation of timber

volumes. The net outcome of this issue is the creation of a management regime that may encourage unsustainable logging to become the norm in Liberian forests.

The following analysis first examines the documents associated with Forest Management Concession (FMC) “C”, before summarising similar problems with the documentation for the other 6 concessions currently within the allocation process.

While FMC “C” is one of the smaller concessions in the allocation process, the documents associated with the project provide significantly more data on the methods of timber volume and area assessment than some of the larger, later concessions. For this reason it is instructive to look at the technical issues in these documents as an exemplar of the same problems in the wider allocation process.

### 4.1

#### ANALYSIS OF FOREST MANAGEMENT CONTRACT AREA “C”

This analysis is based on the Justification Document and the Bidding Documents for FMC “C” produced by the FDA in January 2008 and March 2008 respectively. The Justification Document, created under the New Forestry Reform Law (2006), sets out to assess the commercial viability and social acceptability of the proposed concession

though the generation and analysis of ‘baseline data’. The Bidding Documents incorporate much of the data provided in the Justification Documents, but aim to present sufficient information on timber volumes and constraints for concessionaires to competitively bid for the awarding of the area. This analysis does not aim to comment on social issues

related to the commercial logging of areas that are mostly under some form of customary usage.

### ASSESSMENTS OF AREA

FMC “C” is Located in River Cess County. The boundaries stipulated by the FDA enclose 59,322 hectares.

Several significant errors in the assessment of Area are:

- The document makes only passing mention of the fact that the overwhelming majority of the concession was logged, and logged as recently as 2003.

FMC “C” (and “B”) were completely within the previous concessions of Oriental Timber Corporation (OTC) which operated until timber sanctions were imposed in Liberia in 2003. OTC’s operations were some of the most intensive (and destructive) in the whole Liberian logging industry (ITTO, 2005). An independent assessment of 2008-2009 satellite imagery conducted by the author of this report suggests that of these ≈59,322 hectares, ≈52,040 hectares remain under forest cover. The remainder consists of cleared areas under subsistence cultivation, roads, or scrub/grassland. Of the forest area, 37,130 hectares (or 71%) have already been logged. If indeed the FDA is wishing to place the forests it manages under a 25 year rotation, areas that were logged as recently as 2003 should not be logged again for another 20 years. The intervening 5 years is a grossly insufficient time for significant regeneration to have occurred. The FDA has not considered this issue. It appears from comparison with the SRTM digital terrain model of the area that the forest areas that have not been logged are largely restricted to several hills, thus may not have been logged due to being inaccessible.

- There has been substantial clearance by local people who have used the roads made by previous logging efforts to gain access to the area. This is acknowledged in the FDA documents, but was not addressed in a reappraisal of their area assessment. These data could have been readily generated by the FDA and also could have been easily obtained using the data generated by Bayol and Chevalier

(2004), who under World Bank contract to the FDA, competently assessed the extent of forest cover and logging activity.

- The slopes that were measured in thirty-nine 0.045 hectare (ha) inventory plots were used to determine slope across the entire concession though extrapolation – resulting in the estimation that 1,414 hectares would be excluded from logging on the basis of slope<sup>7</sup>. This cannot reasonably be done. The plot data do not give a statistical insight to slopes across the concession. Slopes could easily have been mapped using a freely available 30m Digital Elevation Model (SRTM DEM), or even better, the 30m DEM provided by the US Government to the Liberian Government. These data could also have been obtained from the mapping of Bayol and Chevalier (2004). This error is of a fundamentally basic nature. It does suggest that capacity building within the FDA should be a priority before any further concessions are statistically described.

- The presence of water courses measured in these plots was also used to estimate the area of water courses and associated buffer zones throughout the entire concession. This cannot be done. Rather, primary and secondary rivers need to be mapped, and this is a straightforward exercise. The FDA use extrapolation of plot data to suggest that 32,514 ha of forest will be excluded from logging as it falls within river buffers. While this estimate is clearly wrong, if the FDA considered it to be true, this should have meant that the FMC was unsuitable for logging as the forest area was then less than the 50,000 ha mandated by the Forest Act (2006).

- The Bid Document states (p4) that while ‘*there are some small settlements in the area*’ it does not state what area they cover – simply stating ‘n.a’. It also states that areas of village use can be calculated by multiplying the estimated population of the settlements by 0.1 ha per person. No justification is given for this questionably small figure<sup>8</sup>. The examination of satellite imagery suggests that there are at least 7,200 hectares of settled land within the concession. It is of concern that the FDA could not determine this from its own imagery analysis.

- There has been logging activity on a large scale occurring within the concession as recently as late 2008 (-9° 11' 44.179 W; 5° 52' 41.321 N). This is not mentioned.

### ASSESSMENTS OF TIMBER VOLUMES

The analysis done by the FDA of relevance to forest management in FMC "C" is based upon inventory work done in 2007. A total of 42 plots<sup>9</sup> each 12.5 metres in radius were measured, and the results extrapolated to the whole area. This inventory was insufficient to generate a robust estimate of timber volumes. Examples of issues include:

- The number of plots was insufficient to reach a reasonable level of accuracy. In total they covered only 2.06 hectares – only 0.003% of the concession. The Justification Document states that they conducted a 3% inventory. On the basis of their data this is not factually correct. The stated coefficient of variation (133%) suggests that several hundred plots (>500) would be needed to obtain an error of 10%. It is likely that the error associated with the 42 samples is approximately 40% - not 10% as stated. It would be difficult for commercial decisions to be made on the basis of data with this level of statistical variation.
- The Justification Document states that based on the inventory, they determined that the area possessed a stocking of 235.35 m<sup>3</sup> per ha of trees over 50cm DBH (Diameter at Breast Height) – with the average Basal Area of 67.59m<sup>2</sup> per ha. These data have several major problems:

1. The 42 samples were stratified into three classes: 3 samples in Agriculture Degraded Forest, 4 in Open Dense Forest (Logged) and 35 in Closed Dense Forest (Unlogged). Unsurprisingly no trees over 50cm DBH were found in the Agriculture Degraded Forest, so will not be further considered here, although it really does mean that the FDA took 39 samples of actual forest, not 42. Samples should have been stratified according to the area of forest type. Given that 70 % of the FMC is Open Dense Forest (Logged), most of the samples should

have been obtained in those areas. Instead the majority of the samples were obtained in unlogged forest, which comprises only 29% of the forest area within the concession. This error could have been partially ameliorated if total volumes were estimated within each forest type as follows:

$$\text{Total Volume} = (\text{Volume in Open Forest (Logged)} \times \text{Area of Open Forest}) + (\text{Volume in Closed Forest (un-logged)} \times \text{Area of Closed Forest})$$

Instead, the FDA averaged all the samples and multiplied it by the TOTAL area of the concession – their calculation was:

$$\text{Total Volume} = \text{Average Volume in All 39 Samples} \times \text{Area of Concession.}$$

This was very wrong on two counts. It massively over-estimated volume across the concession, by applying unlogged volume data to logged areas. Further, this average volume was applied to the whole area, despite the fact that 15% of the area possess no forest. The FDA's own data suggests that unlogged forest has almost double the commercial volume as logged forest (49.1 vs 26.1 m<sup>3</sup> per ha) meaning that this error had massively inflated the estimated total log volumes.

- Determining how the FDA derived their estimate of 235.35 m<sup>3</sup> per ha of trees over 50cm DBH is difficult. They claim that on average there are 46.8 trees >50 cm DBH per hectare. In fact their own data shows that this number is only obtained by including the 40-50cm diameter class. In the >50 cm class there are, according to their data, 30.2 trees per hectare with a Basal Area (BA) of ≈10 m<sup>2</sup>. The 235 m<sup>3</sup> per ha appears to have been derived from multiplying this estimate by an average estimated log length. However this gets confusing as the new Logging Code of Practice stipulates that the minimum cutting

TABLE 2. COMPARISON OF FDA AND NEW ANALYSIS OF FMC AREA “C”

Parameter	FDA Analysis	New Analysis
Total area	59,374	59,322
Area of Gardens/grassland or scrub that is < 20 years in age	0	7,282
Total Forest (ha)	59,374	52,040
Logged Forest (ha)	Not quantified	37,130
Unlogged Forest (ha)	Not quantified	14,910
FDA Estimated Timber Volume (m <sup>3</sup> )	13,881,348	97,000 - 193,000
Likely Extraction vol per annum on 25 year rotation (m <sup>3</sup> )		3,900-7,700

DBH is 60cm – and for most tree species it is significantly greater than this. If the 60 cm limit is applied to the FDA data, there are only 16 trees per hectare (with a basal area of 6.6 m<sup>2</sup>) that are legally extractable, which on the basis of their data (assuming the same log length) would have a volume of 151 m<sup>3</sup> per ha. While these data all should be viewed with scepticism, they do suggest that total log volumes have been over-estimated by at least 50%. And that is before the issue that at least half the species recorded are non-merchantable is incorporated. Many of the species recorded are not generally sought for export (ITTO, 2005) – and this should be reflected in further reductions.

2. It is possible that these forests have a biomass of ≈235.35 tonnes per ha – but not an extractable timber volume. It is understood that the FDA has recently undertaken a country-wide assessment of forests for REDD preparation. This survey would have measured all trees, and determined biomass estimates. Is it possible that the FDA are using these data for the assessment of timber volumes? It might explain the order-of-magnitude discrepancy between these estimates and their likely true values.

To exemplify the consequences of these inaccuracies, a new area analysis was done by the author of this report using 2009 satellite imagery and regional and national timber volume estimates. The results of this analysis are compared with FDA figures in Table 2 and displayed pictorially in Annex 1. As can be seen, the deficiency in determining the actual forest area, or the area that has been logged, has a large implication on estimates of timber volumes. While it should be hoped that the FDA actually does not believe that their estimated volume of 235.35 m<sup>3</sup>/ha is equivalent to the extractable volume, Bid Documents for FMCs “A”, “B” and “C” state a total timber volume that is the result of multiplying a similar volume by the area of the concession. Given a likely maximum extraction rate of 8 m<sup>3</sup>/ha (perhaps up to 15 m<sup>3</sup>/ha if the laws are ignored), these documents imply a massive over-estimation of timber volumes. In other parts of the world, inaccuracies in such documents would be used quickly by winning concessionaires to argue for compensation, or the lenient application of logging standards.

It is generally accepted that a commercially viable forest exploitation activity in West Africa requires a critical production threshold on the order of 60,000 m<sup>3</sup>/year to outweigh the cost of a technical production site (Connolly, 2006). If this is applied to FMC “C”, it is highly unlikely that this threshold will be obtained unless the area is logged

## 4.2 PROBLEMS WITH OTHER FMC DOCUMENTS

within a period of 4-5 years, or if logging standards/DBH limits are significantly relaxed.

The presence of the same key problems described above for FMC “C”, were also found to a greater or lesser degree within the documents describing the other concessions. A summary of these issues are presented in Table 3. In addition, within the other 6 FMC documents, several further issues are worthy of mention. They are now discussed.

### FMC A

In the Justification Document the FDA states:

*“the minute lost (sic) of forest in the North Eastern part of the FMC area “A” has been caused by 2 factors:*

- 1) *Historically, subsistence agriculture - in particular upland rice, has been the most significant anthropogenic factor influencing forests*
- 2) *It has been the development of small roads, which also facilitate easier access for hunters and farmers. The connectivity of roads is clearly linked to forest change and fragmentation.”*

In actuality, a quick interpretation of the latest satellite imagery suggests that ≈25% (30,370ha) of this concession is NOT commercial forest: it is garden, grassland or scrub – hardly a minute amount. When this is excluded, the area of forest is reduced to ≈88,000 ha – which would be below the mandated 100,000 ha for the concession to be open to operators of a certain level of foreign ownership.

In the Bid Document it is stated that the total area should be reduced by 24,500 ha due to water-courses (17,200 ha) and settlements (5,000 ha). However, once again this was determined on the basis of the sampling, so these estimates are wrong. Nevertheless, this potentially should have reduced

the concession to the lower “100,000 ha” grouping. If true, this meant that the concessionaire was asked to pay US\$250,000 as performance bond, rather than the US\$100,000 that it should have paid if the actual area of forest was considered.

### FMCS F, I, K, AND P

In these four later concession documents, the FDA attempt to derive more realistic extraction volumes or ‘allowable cuts’. The documents are suggestive that the FDA is challenged as to how to do this, stating that the “FDA will restrict overall off-take to a maximum of 15% of RME<sup>20</sup> volume in each block,” - hence 15% of the total volume ≈150 m<sup>3</sup>/ha. This reduces the allowable cut to 9 - 21 m<sup>3</sup>/ha. While this is a more reasonable estimate than conducted for FMCA, B & C, there is no clear justification for a reduction of 15%<sup>21</sup>, and it is acknowledged that no reductions have been applied for marketability of species or defects.

An additional problem is the likelihood that total merchantable volume, even without accounting for marketability or defects, has been overestimated. The bidding documents indicate that the FDA estimated the merchantable volume as the “numbers of eligible trees, and their average and total volumes”. This indicates that the FDA calculated the average merchantable basal area (BA) of all trees above the statutory cutting limit in their survey plots, scaled it to m<sup>3</sup>/ha, then multiplied this value by the concession area to estimate total merchantable volume. However in FMC “F”, the average merchantable volume for Class A species is reported as 69.7 m<sup>3</sup>/ha, with a lower limit of 43 m<sup>3</sup>/ha. Even the lower limit of 43 m<sup>3</sup>/ha is an extremely high stocking rate for exportable round logs.

In an independent analysis conducted by this author using data from a comparable Papua New Guinean forest where all trees in one hectare had

TABLE 3. SUMMARY OF DEFICIENCIES IN THE FIRST SEVEN CONCESSIONS TO ENTER THE ALLOCATION PROCESS. THESE FOLLOW THE LAYOUT FROM THE TEXT DISCUSSION OF FMC 'C', AND ARE CATEGORISED INTO AREA, VOLUME AND COMMERCIAL VIABILITY CONSIDERATIONS

Concession	Area ha	Assessment of Area			
		Determination of area already logged	Determination of non-forest area	>50,000 ha of forest?	Proper assessment of constrained area (slope, water etc)
FMC A	119,169	No	Yes but incorrect	Yes	No
FMC B	56,839	Yes but incorrect	No	No	No
FMC C	59,322	No	No	Just - 50,482	No
FMC F	256,445	No	No	Yes	No
FMC I	131,307	No	No	Yes	No
FMC K	269,391	No	No	Yes	No
FMC P	119,524	N.A. (None Logged)	No	Yes	No
<b>Total Area</b>	<b>1,011,997</b>				

Concession	Area ha	Assessment of Volume			
		Area surveyed (%)	No. Samples (0.045ha) in Open or Closed Forest	Actual Error (%) on the mean estimate <sup>12</sup>	Stratification of samples to land-cover classes in final volume estimation
FMC A	119,169	0.002%	69	33	No
FMC B	56,839	0.003%	42	44	No
FMC C	59,322	0.003%	39	40	No
FMC F	256,445	0.002%	110	26	No
FMC I	131,307	0.002%	70	29	No
FMC K	269,391	0.002%	135	?	No
FMC P	119,524	0.003%	78	?	No
<b>Total Area</b>	<b>1,011,997</b>				

Concession	Area ha	Commercial Viability				
		Stated Total Extractible Volume m <sup>3</sup>	Likely Max. Total Extractible Volume <sup>13</sup> (m <sup>3</sup> )	Extent of over-estimation (times)	Estimated Annual Max Cut on 25 year rotation m <sup>3</sup>	Economically Viable <sup>14</sup> on 25 year rotation m <sup>3</sup>
FMC A	119,169	Not stated but suggests 1200 cubes per ha.	672,552	?	26,902	No
FMC B	56,839	11,022,405	187,294	59	7,492	No
FMC C	59,322	13,881,348	193,540	72	7,742	No
FMC F	256,445	4,948,290	1,431,916	3	57,277	Yes
FMC I	131,307	2,114,620	732,944	3	29,318	No
FMC K	269,391	6,218,033	1,479,092	4	59,164	Yes
FMC P	119,524	1,911,415	803,608	2	32,144	No
<b>Total Area</b>	<b>1,011,997</b>	<b>15,192,358</b>	<b>4,447,560</b>		<b>220,038</b>	

been measured, it was found that including or excluding just two large (> 100 cm dbh) trees changed the estimated merchantable volume in m<sup>3</sup>/ha by more than 50%. The fact that the FDA used very small sample areas means that their technique is very sensitive to the presence of large trees. In addition, if plot locations were not randomly selected, but were located in patches of high quality forest, then merchantable volumes are likely to be further overestimated.

In conclusion, there appears to be an overestimation of total merchantable volume in areas F, I, P and K, in addition to a failure to account for marketability and defect, which combine to result in a high likelihood that an overly large allowable cut will be applied to these concessions. This is further discussed in the following section on Liberian timber volumes.

## 5

## A DISCUSSION OF LIBERIAN TIMBER VOLUMES

The validity of the previously discussed documents depends primarily on reliable estimates of extractable timber volumes. Indeed these data are vital to underpin revenue prognoses. Given the difficulties with the FDA numbers in the Justification and Bid Documents, the following discussion aims to derive more reasonable estimates.

In 1968, Sachtler conducted an inventory of Liberian forests to assess timber resources. This study found that the minimum reliable estimate of merchantable volume of all species > 60 cm across all High (closed) forest ranged from 55-90 m<sup>3</sup>/ha. This is lower than the FDA's minimum reliable estimate (RME) for FMCs F, I, P and K, 60.9-138.6 m<sup>3</sup>/ha, which the FDA intended to be conservative. Additionally, the FDA's RME estimate is based upon a cut limit of >60 cm for a number of species, and yet is still higher than volumes found in the 1968 inventory. On the basis of this comparison, it seems likely that the FDA has overestimated volume. As previously stated, this may have occurred as a result of their small sample sizes.

In a more detailed study of selected timber areas, the 1968 inventory identified that only 9-25.9 m<sup>3</sup>/ha of trees > 40 cm DBH, or 5-15.5 m<sup>3</sup>/ha for trees > 60 cm DBH, was potentially exportable timber (Sachtler, 1968). Thus exportable timber made up only 6-28% bole volume of all trees > 60cm DBH. However, since 1968 a number of other species have become exportable so consequently, 5-15.5 m<sup>3</sup>/ha may be conservative.

Since this inventory was conducted in 1968, a proportion of Liberia's forests have been harvested

– generating real extraction data. The wall-to-wall distribution of pre-2003 concessions is displayed in Annex 2. Bayol & Chevalier (2004) cite official FDA figures showing an average harvest yield from logging operations in Liberia of 3-5 m<sup>3</sup>/ha. The ITTO also cites FDA figures of 3-5 m<sup>3</sup>/ha, but also state that the harvest volumes under the latter years of Taylor in OTC concessions may have been as high as 15 m<sup>3</sup>/ha (ITTO 2005). Bayer & Chevalier (2004) argue that a harvest volume of 3-5 m<sup>3</sup>/ha is achievable, based upon their assessment of road density and canopy disturbance apparent in high to moderate (10-30 m) resolution satellite imagery covering a sample of logging operations. However, Bayol & Chevalier (2004) noted that in other locations in Liberia, heavier logging with more canopy damage and higher road density existed (Bayol & Chevalier 2004), indicating that higher yields might be extracted from more damaging and intensive harvesting practices. These studies support the official government estimate of 3-5 m<sup>3</sup>/ha, for the less intensive Liberian harvesting operations, with an upper estimate of 15 m<sup>3</sup>/ha in the more intensively logged concessions, which almost certainly extracted logs of a DBH lower than 60cm. These data are comparable to actual reported extraction rates from Gabon (4-5 m<sup>3</sup>/ha), Ghana (8-10 m<sup>3</sup>/ha) (Ze Meka, 2006) and the Democratic Republic of Congo (11 m<sup>3</sup>/ha) (Brown, 2004).

Accordingly, accepting the official FDA figures cited by Bayol & Chevalier (2004) that the forests inventoried in 1968 on average yielded a harvest of 3-5 m<sup>3</sup>/ha, then only 3-9% of the volume of all spe-

TABLE 4. LIKELY EXTRACTABLE VOLUMES (M<sup>3</sup>/HA)

FMC	Average Harvesting		Destructive Harvesting	
	Min (3%)	Max (9%)	Min (17%)	Max (27%)
F	4.6	12.6	23.1	37.8
I	2.0	5.5	10.2	16.6
P	3.9	10.7	19.6	32.0
K	3.8	10.4	19.0	31.1

Based on estimates of Satchler (1968).

cies > 60 cm (55-90 m<sup>3</sup>/ha) was actually harvested (or 17-27% using the upper limit of 15 m<sup>3</sup>/ha). Applying this finding to the FDA's minimum reliable estimate of all species above the statutory cutting limit (60 cm for most of the primary harvested species), then location "F", with a surveyed volume for all species and all trees above the statutory cutting limit of RME 138.6 m<sup>3</sup>/ha, could be expected to yield a harvest of 4.6 – 12.6 m<sup>3</sup>/ha on average, or 23 - 38 m<sup>3</sup>/ha using a high density road network and a high degree of canopy damage, and probably extracting trees < 60 cm DBH. The average harvest yield of 4.6 – 12.6 m<sup>3</sup>/ha is much lower than the 21 m<sup>3</sup>/ha currently permitted for FMC "F" in the tendering process. Indeed, only the most damaging and intensive logging practices would produce a harvest volume of 21 m<sup>3</sup>/ha. As it is likely the FDA volumes are overestimates, even this may be optimistic. Applying the same screening process to the FDA data from FMC "I", "K" and "P", similar results are found (Table 4).

It seems likely that the arbitrary 15% of the total volume above the statutory cutting limits used by the FDA to assign allowable cut is too large, and the FDA estimate of volume too great. Indeed, the FDA has assigned an allowable cut based on the volume of all classes (A, B & C). Yet the primary extractable species are those in class A. The ITTO estimated that in past years 65% of Liberia's timber trade was based upon export of round logs in class

A. This suggests that the allowable cut has been generated using a volume of trees unlikely to be harvested, meaning that the volume of harvestable timber per hectare has been overestimated.

By applying the FDA's arbitrary limit of 15% to the volume above the statutory cutting limits for species A only, then the allowable cut for FMC F should be 6.5 m<sup>3</sup>/ha. This 6.5 m<sup>3</sup>/ha is comparable to the extractable volume of 4.6-12.6 m<sup>3</sup>/ha predicted by the 1968 inventory (Sachtler, 1968) and others (Bayol and Chevalier, 2004; Ze Meka, 2006; ITTO, 2005). Applying the same screening process to FDA data, FMCs I, K and P showed similar results. In all four FMCs, the FDA's allowable cut is greater than the likely extractable volume, except in the most damaging and destructive harvesting scenario.

If the Liberian Government allows an annual harvest volume for the FMCs "F", "I", "P" and "K" to be based upon the current FDA estimates, then the only way such an annual volume could be obtained is for operators to log a greater area than 1/25<sup>th</sup> of the concession each year. Alternatively, logging operators will have to employ far more intensive and damaging harvesting practices, resulting in greater collateral damage, soil disturbance, canopy damage and destruction of residual trees. The outcome for Liberian forests of the application of current bidding documents can be seen by visiting the former OTC concessions.

## 6

**SUSTAINABILITY AND THE 25 YEAR CUTTING CYCLE**

*“the low number of potential crop trees (in Liberia) indicates that after the next felling cycle in 25 years, the stock will not be sufficient to guarantee a sustained yield for these species”*

*(Parren and de Graaf, 1995)*

In Liberia the forest resource is supposed to be managed under a simple system of control where in theory, a concession is granted for a 25 year period, with the concessionaire cutting 1/25<sup>th</sup> of the area each year and only removing stems over a specified diameter at breast height (DBH) for certain species.

The notion that Liberian forests could be logged on a sustained yield basis<sup>35</sup> on a 25 year rotation seems to have been sourced from the inventory work of Woll (1981). However, and importantly, the manner in which Woll interpreted his own data has been called into question as he appears not to have included defensible growth data, or more critically, realistic assessments of the damage caused by logging to the residual forest (Parren and de Graaf, 1995).

In his study of timber volumes in Liberian forest, Jordan (1985) calculated that after logging 20% of the commercial trees were damaged, and another 25% were lost during logging. Nearly half of the trees below the felling limit were destroyed or damaged, especially within the smaller diameter classes. More than half of all the commercial trees in the 10-20 cm DBH classes were destroyed during logging and 90% of all losses refer to trees of a DBH class below 40 cm. In a comparable study, Weingart

(1990) found that felling damage occurred in 33% of the forest area and resulted in a 13% loss of potential regeneration surface to skid tracks, loading bays and logging roads.

These studies are comparable with recent global estimates of the damage done by selective logging operations. Houghton (1999) compiled most of the logging damage studies ever conducted, and found between 20 and 80 percent of biomass is removed during selective logging (ie through felling/skidding, collateral damage and harvest). Recent studies in lowland Bolivia have shown that commercial trees grow at lower rates than assumed by policy makers when the currently designated cutting cycles were applied. Consequently, it is estimated that only 3–38% of the volume harvested during the first commercial timber harvest will recover in time for the next planned harvest, i.e., at the end of the second cycle (Pena-Carlos et al. 2008).

The sustainability of timber management in Brazil using “Reduced Impact Logging” techniques (RIL) was evaluated by Sist & Ferreira (2007) through the calculation of the recovery level of commercial trees in three different scenarios. In the most optimistic scenario (growth rate of 5 mm/

year and 1% annual mortality), they predicted that after 30 years, only 50% of the commercial stand would recover, provoking a drastic reduction of the harvesting intensity at the second felling cycle. Within a 30-year felling cycle (i.e. the legal felling cycle duration in the Brazilian Amazon) and even under RIL systems, the present logging intensity occurring in the study area (6 trees/ha) is not compatible with sustainable yield production on a long-term basis.

Given these global comparisons and on the basis of growth increment data and a realistic assessment of log damage, Parren and Graaf (1995) suggests that if one wishes to manage Liberia forests on a sustained yield basis, then a felling cycle of 50 years, and reduced harvests in the second and third harvest is clearly more realistic than the 25 year cycle. The proposed 25 year cycle is certainly not sustainable, from either a yield or environmental perspective.

## 7

## AN ANALYSIS OF REVENUE PROJECTIONS FROM THE FORESTRY SECTOR

As can be seen from Table 5, the FDA has been predicting significant revenue from the export of logs for a number of years. In reality, this revenue has not been forthcoming. While this has largely been a consequence of justifiable delays in the allocation procedures, the question of paramount importance is just how much these projections are overestimates, having been based on over-inflated area and volume data. Given that the Poverty Reduction Strategy (2008) has accepted these projections to support 5-6% of activities between 2008-09, rising to 9% in 2010-11, their veracity is important.

The parameters that have been used for recent FDA predictions can be determined from the FDA Annual Report of 2007 projections for 2008/09. In 2008/09, the estimated Government revenue of US\$16 million is based on a projected area of forest under harvest of 843,655 ha<sup>26</sup>, estimated to produce in that year 536,031 m<sup>3</sup>, which after accounting for wastage and defects (a reasonable 15%) results

in an export of 455,627 m<sup>3</sup>, worth on average about US\$245 per m<sup>3</sup>, resulting in an FOB value of US\$111,662,770. The US\$16 million estimate is a result of an average taxation rate of 14.5%<sup>27</sup>. While the estimates of wastage, FOB price and taxation are all reasonable, the timber volumes are not – unless the logging code of practice, the 25 year rotation and the DBH limits are discarded.

These FDA numbers seemingly do not factor in the Area Fees which are assumed to be \$2.50/ha/yr, or the Land Rental Fees which range from \$5-10/ha/yr. On the basis of these figures, these fees would generate an additional US\$7.8-13 million per annum<sup>28</sup>.

In 2008, it was disclosed that many of the FMCS had been advertised with the Area Fees reformulated as a once off payment rather than an annual fee, with the one off payment still at the level of the annual payment (UN Panel of Experts report, 12 December 2008). While this was not permitted to

TABLE 5. PROJECTED AND ACTUAL GOP REVENUE FROM THE EXPORT OF LOGS AND TIMBER FROM FMCS

Source	2007/08	2008/09	2009/10	2010/11
Poverty Reduction Strategy 2008	526,000	24,283,000	36,686,000	46,110,000
FDA 2007 Annual Report	1,771,015	16,194,915	26,238,564	35,399,434
FDA 2008 Annual Report			11,352,886	
<b>Actual</b>	<b>0</b>	<b>0</b>	<b>?</b>	<b>?</b>

All monetary values are in US Dollars.

occur, one has to wonder if the apparent absence of the annual payments in the FDA revenue predictions is an indicator of the probability that they will be collected.

More recently the UN Panel of experts (June 2009) has called into question revenue predictions:

*“...the management of FDA continues to provide a very optimistic, though arguably unrealistic, picture of the revenue possi-*

*bilities for the timber sector. For example, the management report section of the 26 February 2009 FDA Board of Director meeting minutes states that if the four forest management contracts were approved by May 2009, revenue intake in combination with the other three contracts would be around \$10 million. This scenario is impossible given the timing of the bid evaluation and due diligence processes”*

## 8

## AN ALTERNATIVE ANALYSIS OF TIMBER VOLUMES

In light of these uncertainties is it possible to make more realistic estimates of revenue? Perhaps. However it is certainly possible to make more realistic predictions of extractible timber volumes on the basis of refined area estimates and reasonable timber volumes. Extractible timber volumes are the basis of the timber industry – if they are incorrect, then all the estimates based on them will also be flawed.

The following analysis examined the first 7 FMCs to be awarded or advertised, which correspond to the million hectares that the FDA believed it would have under concession in its 2008 figures. Area assessments were made using 2009 satellite imagery which was classified into non-forest (village areas, gardens and water), logged closed forest and unlogged closed forest. This followed the same procedure as Bayol and Chevalier (2004) in their analysis of Liberian forests. It relied upon color enhancement of 15 m resolution Landsat ETM+ imagery and onscreen digitisation of easily discernable forest boundaries, roads and rivers<sup>19</sup>. Forest was deemed to have been logged if it occurred within 1 km of a logging road<sup>20</sup>.

Two scenarios (High and Low) of extractible timber volumes were assessed. These were based on the previous analyses, estimated extraction volumes from the 1990-2003 period (ITTO, 2005) and the estimates of Sachtler (1968) and Bayer & Chevalier (2004). Within unlogged forests a low extraction scenario of 4m<sup>3</sup>/ha and a high extraction scenario of 8m<sup>3</sup>/ha was applied. These figures are probably erring on the side of generosity in that no reduc-

tions for buffers, slopes or other inaccessible areas have been applied. While higher extraction volumes, ~15 m<sup>3</sup>/ha, were obtained pre-2003, these are reported to have occurred in OTC areas where felling trees < 60 cm DBH was common practise (ITTO, 2005). If the statutory cutting limit for the primary harvestable species as outlined in “Liberia Code of Forest Harvesting Practices” is to be enforced (> 60 cm for most species), average extraction volumes of this magnitude are unlikely.

The likely residual stock of merchantable trees in logged forest is difficult to estimate. What is certain is that if the majority of trees >50cm were removed from these forests, there has not been enough time for there to have been sufficient regeneration to support a second cut at all. Considering that these forests have been re-worked repeatedly by pit-sawyers using the access provided by the logging roads, it is likely that extractible volumes will be very low. In this regard, for this analysis estimated volumes have been set at 1 m<sup>3</sup>/ha and 3 m<sup>3</sup>/ha for the low and high scenarios respectively. This too is generous.

The results of this analysis (presented in Table 6) are strikingly different from FDA predictions. It suggests that with the 7 concessions in full operation, but operating on a 25 year rotation, log export volumes would be between 110,000 - 220,000 m<sup>3</sup> per annum. At maximum, this is approximately 50% of the projected export volume – at minimum about 25%. Why is this so low? Apart from the inclusion of realistic stocking volumes, it takes into account the large area that has been logged. While overall in

these 7 areas, 30% of the forest area has been logged, in some concessions (“B” and “C”) 70% of the forests have already been logged. If none of the areas

had been previously logged, maximum log export volumes would be closer to 290,000 m<sup>3</sup> per annum – potentially about 65 % of the FDA prediction.

# 9

## CONCLUSIONS

The overestimation of extractible timber volumes and forest areas have several significant implications for the management of the commercial forestry sector. These potentially include:

1. Revenue from FOB-based taxation is likely to be half, or less, of what is currently projected.
2. It is possible that concessionaires could argue that bid on inaccurate and inflated data, and therefore require modifications to contractual conditions. These would almost certainly involve shortening the 25 year rotation (to export more timber) or reductions in area-based taxation. This could occur via concessionaires arguing for reductions in the size of their concessions, an eventuality that would have bearing on community relations as well as the sustainability of the operations.
3. While it could be argued that revenue from area-based taxes are immune to timber volumes, it is rather improbable that the logging companies will see it that way. It is possible that efforts to reduce the annual payments, to a single payment in the first year reflect this issue.
4. In other parts of the world where concessionaires have been provided with inflated log volumes, the outcome has often been the lowering of forestry standards and rotation periods. This is driven just as much by the companies wishing to extract the maximum volume in the shortest time, as Governments, who in their need to raise revenues, are willing to make compromises. The outcome has been timber operations operating unsustainably.
5. It is apparent on the basis of these revised figures, that several of the seven concessions analysed are unlikely to be commercially viable on a 25 year rotation. If this is taken into account, log export predictions could be dramatically lower than suggested in this analysis.
6. At least 30% of concession-bound forests have already been logged, some as recently as 2003. If these forests are ever to regenerate they should not be logged again in such a short period. They should not be included in new forestry concessions.
7. It is important to note that the 30% of the total forest estate that has already been logged was the most accessible and commercially attractive forest in the country. Those areas that were not logged are in comparatively more rugged and remote regions. This factor has not been incorporated within economic modelling, either that of the FDA or this study, of these concessions and their likely output.

Finally it is important to point out that the 25-year rotation period will not provide a sustained yield of timber into the future. It is too short. Aside from the inherent improbability of commercially significant forest regeneration within this period, it does not reflect the reality that logging roads will again open up the forests to pit-sawyers and

provide access to settlers, both of which will act synergistically to increase the rate of conversion of Liberia's remaining forest cover.

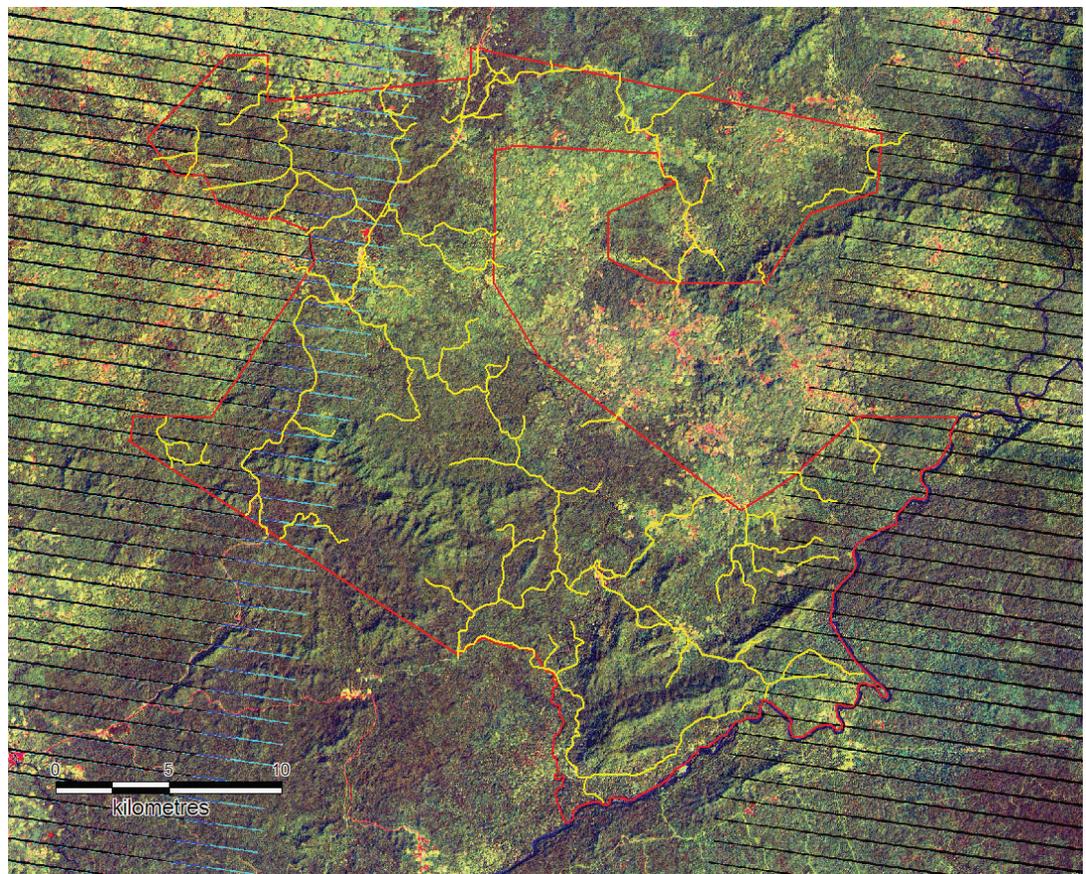
TABLE 6. RESULTS OF REVISED AREA AND VOLUME ANALYSIS

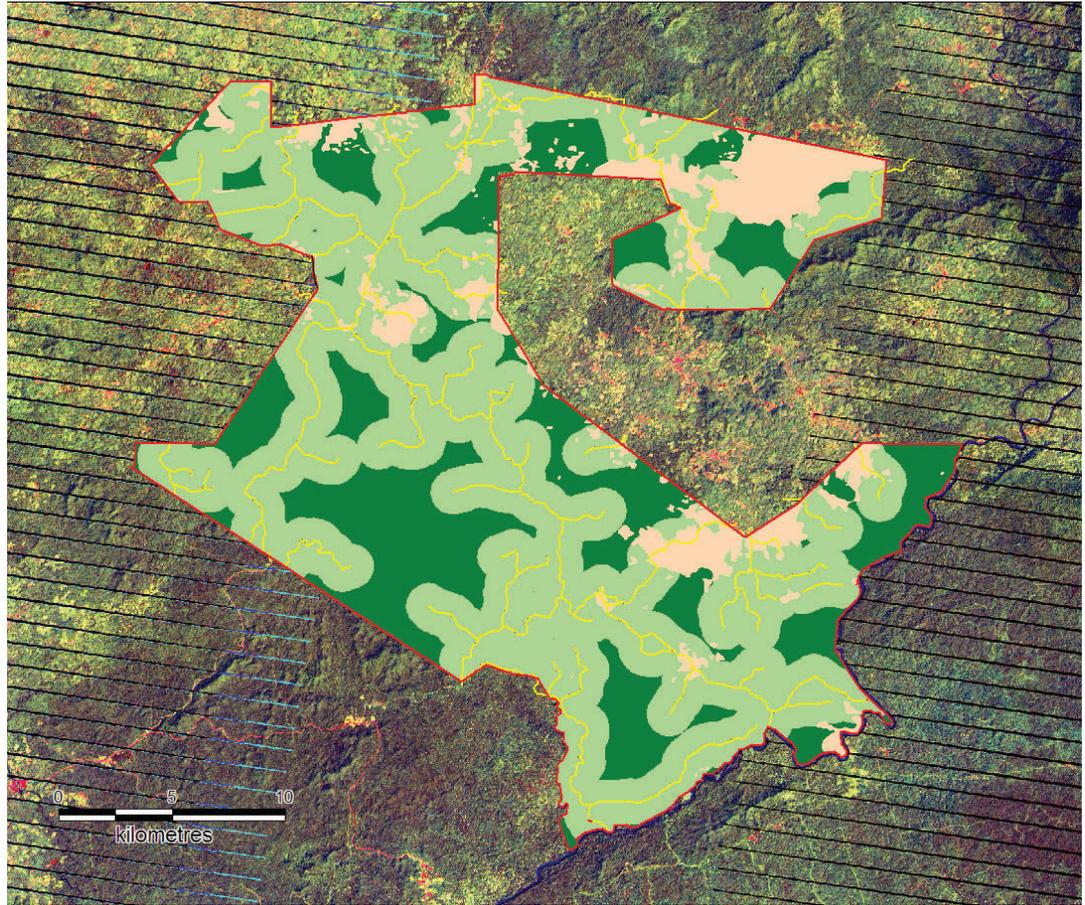
Concession	Area (ha)	Non Forest Area (ha)	Forest Area		Logged ha (%)		Unlogged ha (%)	
			ha	(%)				
FMC A	119,169	30,377	88,792	(75)	6,296	(7)	82,495	(93)
FMC B	56,839	8,312	48,527	(85)	33,487	(69)	15,040	(31)
FMC C	59,322	7,282	52,040	(88)	37,130	(71)	14,910	(29)
FMC F	256,445	14,358	242,087	(94)	84,130	(35)	157,957	(65)
FMC I	131,307	15,644	115,663	(88)	32,060	(28)	83,603	(72)
FMC K	269,391	26,312	243,079	(90)	77,590	(32)	165,489	(68)
FMC P	119,524	19,072	100,451	(84)	0	0	100,451	(100)
Total Area	1,011,997	121,357	890,639	(88)	270,693	(30)	619,945	(70)

Concession	Low Scenario (Low = 1 High = 4 m <sup>3</sup> /ha )				High Scenario (Low = 2 High = 8 m <sup>3</sup> /ha )			
	Timber Vol Logged	Timber Vol Un-logged	Total Timber Vol	Annual cut (1/25th)	Timber Vol Logged	Timber Vol Un-logged	Total Timber Vol	Annual cut (1/25th)
FMC A	6,296	329,980	336,276	13,451	12,592	659,960	672,552	26,902
FMC B	33,487	60,160	93,647	3,746	66,974	120,320	187,294	7,492
FMC C	37,130	59,640	96,770	3,871	74,260	119,280	193,540	7,742
FMC F	84,130	631,828	715,958	28,638	168,260	1,263,656	1,431,916	57,277
FMC I	32,060	334,412	366,472	14,659	64,120	668,824	732,944	29,318
FMC K	77,590	661,956	739,546	29,582	155,180	1,323,912	1,479,092	59,164
FMC P	0	401,804	401,804	16,072	0	803,608	803,608	32,144
Total Area	270,693	2,479,780	2,750,473	110,019	541,386	4,959,560	5,500,946	220,038

## ANNEX 1

Landsat ETM+ Imagery from early 2009 was used to determine basic landcover classes, which were manually digitised. This followed the classification and techniques employed by Bayol and Chevalier (2004), except at a higher resolution. These images show the process for FMC “C”. In the upper image, the concession is bounded by a red line while yellow lines demarcate logging roads. In the lower image, logged forest (buffered from roads by 1km) is colored light green, unlogged forest in dark green, and non-forest areas (scrub, gardens or cleared areas) in faun.







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## ENDNOTES

- <sup>1</sup> The first step in REDD preparedness via the World Bank Forest Carbon Partnership Facility (FCPF) is the creation of a Readiness Plan Idea Note (an "R-Pin"). Once that is accepted, it leads to the funding of an R-Plan.
- <sup>2</sup> The FAO suggests that in 1990 there was 4.06 million ha and in 2005, 3.15 million ha. This was derived from Bayol and Chevalier, (2004), who compared 2001-2004 data with the results of an interpretation of 1979 aerial photography. The FAO use a series of estimates and algorithms to translate these figures to 1990 and 2005 data.
- <sup>3</sup>  $r = (1/(t_2-t_1)) * (\ln(A_1/A_2))$ ; where A<sub>1</sub> is forest area at time 1 (t<sub>1</sub>) and A<sub>2</sub> is forest area at time 2 (t<sub>2</sub>)
- <sup>4</sup> Christie et al (2007) suggest that 'a key significant technical challenge in measuring Liberia's carbon dioxide emissions from deforestation and degradation is the fact that Liberia's recent low relative deforestation and degradation emissions do not accurately predict expected future higher emissions'. Given the issues highlighted here it is possible that over the last 10 years, rates have actually been consistently quite high. Future studies will be needed to accurately determine what they were - and the data to do this does exist.
- <sup>5</sup> As shall be discussed below, within the 7 concessions analysed here, in total 12% was not actually forest – so when slopes and watercourse etc are included as constraints, a 24% reduction seems reasonable.
- <sup>6</sup> It should be noted that these 1.3 million hectares of unlogged forest are likely to be of a lower timber volume, and more inaccessible than the million hectares that were logged between 1990 and 2003. This should be factored into output projections – but has not.
- <sup>7</sup> While the FDA used 30% slope as a cut-off for timber harvest suitability, the consensus among LFI partners was that a 25% slope should be the upper limit for commercial logging, and this would be consistent with the draft (November 2005) Liberia Code of Forest Practices. Slope suitability could be weighted according to their relative suitability for preservation (steeper equates to more suitable), or a single threshold (e.g. 25%) could be established as an automatic "yes/no" suitability factor.
- <sup>8</sup> This amounts to only 31 m<sup>2</sup> per person – hardly a sufficient area for gardening purposes.
- <sup>9</sup> The Justification document states that 69 plots were used, but the attached statistics states that there were 42.
- <sup>10</sup> Reliable Minimum Estimate.
- <sup>11</sup> Why 15%? It does seem as though the volumes were arbitrarily reduced, just so as to appear reasonable.
- <sup>12</sup> In the FDA reports, the Standard Deviation is described in %. For this reason it is more likely to be the coefficient of variation, although this too is unclear. Assuming it is the coefficient of variation, the utilisation of the FDA sample data allowed determination of the actual error in the mean estimates of their samples. This is reported here.
- <sup>13</sup> Based on assessment of area of forest, area logged and likely extraction rates. See Table 6.
- <sup>14</sup> This is based on the work of Connolly (2006) who assessed that a stand-alone operation generally requires an annual output of over 60,000 m<sup>3</sup> for commercial viability.
- <sup>15</sup> Not to be confused with environmentally or ecologically sustainable forestry, 'sustained yield' forestry aims to manage the forest such that the same yield can be obtained over a specified rotation period. In Liberia this has been set at 25 years – although in other countries it is significantly longer – in Papua New Guinea it is 35 years. However in PNG all of the available data suggests that this is an insufficient period even for biomass regeneration, but this is largely irrelevant as the average concession life has been only 11 years.
- <sup>16</sup> Within a total area of 1,059,569 ha.
- <sup>17</sup> This has apparently been derived from some assessment of the relative proportions of Category A and B species in the Stumpage and Log Export Fees.
- <sup>18</sup> This may be where the difference between the Poverty Reduction Strategy and FDA Annual Report figures occurs – in the inclusion of Area and Bid fees?
- <sup>19</sup> This was based on the product of a Tasseled Cap and Brovey transformation (Kauth & Thomas 1976) applied to 2009 Landsat ETM+ imagery.
- <sup>20</sup> Note that Bayol and Chevalier (2004) used 1.2 km for this buffer exercise. The use of 1km in this current study meant that our estimates of logged forest areas are more conservative.



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