Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 5, No. 6, p. 289-301, 2014
http://www.innspub.net

RESEARCH PAPER | OPEN ACCESS

Evaluating respect of felling restrictions on harvestable diameters and logging methods at the forest management units (FMUs) in South Western Cameroon with decision support systems (DSS)

Kato Samuel Namuene[1,2], Egbe Enow Andrew[2], William S. Shu[2]

[1]*Program for the sustainable management of natural resources (PSMNR), Buea, South West Region, Cameroon*

[2]*Faculty of Science, Department of Botany and Plant Physiology, University of Buea, South West Region, Cameroon*

Article published on December 14, 2014

Key words: *Biodiversity, FMU, logging, deforestation, decision support system.*

Abstract

The high biodiversity of tropical rainforests including numerous species in the IUCN Red list is being threatened by numerous anthropogenic activities carried out in the forest by various stakeholders. Logging in tropical rainforests improves the economy of tropical countries, but, this is accompanied by high forest deforestation and degradation. If logging continues in the present pace unmonitored, tropical rainforests may soon be replaced by a disproportionate and unbalanced ecosystem, especially as loggers hardly respect their logging limits. Because there are no set methods and standards to truly measure logging in Cameroon, loggers are not monitored, so may log indiscriminately beyond their logging limits. Except a system to monitor their logging activities, loggers will always derail from their logging limits in the management plan for both unprotected and protected species. Decision support systems (DSS) will help forest officials take vital decisions with respect to forest exploitation by loggers, and control their logging activities with the click of a mouse button. KatLog Pro DSS has components to monitor concession holders' respect of logging diameter limits in the management plan, respect of protected species cutting limits, and also the fate of non-commercial species. KatLog Pro found that Concession holders do respect cutting limits of unprotected species, but they cut protected species like Iroko (*Milicia excelsa* (Welw.) C.C Berg) below their management diameters. Also, much Azobé (*Lophira alata* Banks ex Gaertn) was cut but abandoned by loggers, while mostly *Desbordesia glaucescens* (Engl.) Tiegh was used for road construction.

***Corresponding Author:** Kato Samuel Namuene ✉ kato2025@yahoo.ca

Introduction

Tropical forest ecosystems host at least two-thirds of the Earth's biodiversity and provide significant local, regional and global human benefits through the provision of economic goods and ecosystem services (Gardner *et al*., 2009; Lewis, 2011), and also sequester large amounts of carbon and regulate global climate (Brady and De Wasseige, 2010; Talbot, 2010). Cameroon forests fall within the high biodiversity Congo Basin forest which is the world's second largest tropical forest (Brady and De Wasseige, 2010). This high biodiversity is threatened by deforestation, degradation and fragmentation (Gardner *et al*., 2009; Goodman, 2010, Talbot, 2010) which has raised considerable international interest as much of the forest continues to disappear, significantly affecting people who depend on the forest for their livelihoods, mainly due to agricultural expansion, logging, overgrazing, fuelwood gathering, and urbanization (Hussin *et al*., 1996; Oldfield, 1998; Gardner *et al*., 2009; Achard *et al*., 2002; Lewis, 2011).

Deforestation contributes 20% of global CO_2 emissions (Goodman, 2010), contributing significantly to global warming and atmospheric change (Laurance, 2007). Commercial logging for timber is one factor in the clearance and disruption of forest ecosystems, the timber extracted being either for local consumption or international trade. Virtually all the tropical timber entering the world market is from natural forests, harvested on an unsustainable basis, and there is therefore a very real possibility of the economic potential of forests being destroyed through the over-exploitation of timber species (Oldfield, 1998). Trees extracted from tropical forests for the international market are either selected on a species basis to meet specific demands for example in the construction industry or felled to supply general and non-specific wood products (Oldfield, 1998).

The development of the RIL methods have been proposed for minimizing deforestation, and for contributing to Sustainable Forest Management (SFM) in the tropics. Meanwhile, in the unsustainable conventional harvesting methods (CH) there is little operational planning; the decision over trees to be cut, the skid trails and road design are taken by the logging contractors, and thus the results are associated with high damage to the residual stand, the ground area affected, higher soil compaction, low efficiency operations, damage to future crop trees (FCTs), coupled with the increased likelihood of invasion by lianas and other light-demanding weeds, and loggers suffer even higher fatality plus injury rates and lack of achievements of SFM as a consequence (Pereira *et al*., 2002).

RIL involves preparation of topography maps, identification of individual cutting units (blocks), inventory of the trees per cutting block, layout of a detailed transportation and extraction system, climber cutting, seed trees identification, felling patterns etc. (Boscolo and Vincent, 2000; Van Der Hout and Van Leersun, 2000). But these have not been implemented in RIL plans in Cameroon (Van Der Hout and Van Leersun, 2000). The cost-benefit is better than CH and RIL can reduce canopy and ground damage. E.g. in Suriname RIL resulted in canopy loss of 6.5 to 7.4%, while conventional logging opened 11.4 to 16-5% (Pereira *et al*., 2001). The machines employed in logging tropical forest are the bulldozers for CH and rubber tire skidders for RIL (Boscolo and Vincent, 2000; Pereira *et al*., 2002). Forest exploitation including all forms of land use and timber production should be guided by long term objectives based on careful land use planning. If the present trend of deforestation continues, all of tropical Africa's forests are expected to be depleted within nine decades (Boahene, 1998), which will have a great impact on our environment.

However, current exploitation levels are mostly unsustainable, with more than 50% of trees being felled illegally without a license (Reynolds and Peres, 2006). Local forestry officials who depend on logging companies for transport into the field do not have sufficient resources to enforce existing regulations. Villagers generally know when illegal logging is taking place and could apprehend suspects, but they have no incentive to do so because all hardwood timbers remain the exclusive property of the government (Reynolds and Peres, 2006). Other villagers allow unlicensed operators to log in their areas without notifying authorities in exchange for cash, jobs or both (Reyes, 2003). An international debate focusing on illegal logging and related trade resulted in the Forest Law Enforcement, Governance and Trade (FLEGT) Action Plan, initiated by EU in 2003, fostering a Voluntary Partnership Agreement (VPA) with important timber producing and trading countries, with aim to eliminate trade in illegally produced timber from partner countries (Van Oijen and Wiersum, 2010).

It is therefore clear that the future of much of tropical forest biodiversity depends more than ever on the effective management of human actors (Perfecto and Vandermeer, 2008; Wittemyer *et al*., 2008). Considerable disagreement remains, however, about whether economic activity and the maintenance of tropical biodiversity can be reconciled (Lewis, 2011). The complexity of making coherent, integrated, and interdependent timber exploitation monitoring decisions challenges human capabilities. The monitoring of deforestation and illegal logging operations will reduce tax losses, bringing with it long term positive consequences for the entire national economies (ITTO, 2009), and also resolve conflicts between stakeholders (Mowrer, 1997; Varma *et al*., 2000). Over the past three decades decision support systems (DSS) have been used to integrate decision maker's own insights with computer's information processing capabilities for improving the quality of decision making (Varma *et al*., 2000). DSS have evolved to encompass multicomponent systems that include various combinations of simulation modeling, user interface components (Mowrer, 1997), and associated databases for calibration and execution (Mowrer, 1997; Varma *et al*., 2000). In 2009, the International Tropical Timber Organization (ITTO) sponsored development of a forest management system (FMS) which consists of a set of tools designed to monitor and evaluate forest companies logging activities (Olegário *et al*., 2009). The effect of logging on timber trees has received surprisingly little attention and information on the conservation status of valuable tropical timber is difficult to come by, which represents a major area of weakness in planning for the rational utilization and conservation of tropical forests as world demand for timber and wood products continues to increase (Oldfield, 1998). KatLog Pro is a DSS app that has a component for monitoring the respect of harvestable diameters and protected species in tropical rainforests. This forest informatics solution is very important as it will enable the merging of human knowledge of the tropical rainforest with the computational power of information systems to curb the lapses of manual monitoring.

This study was conducted in Mamfe-Cameroon. In this study a global timber monitoring tool which is a Decision Support System (DSS) was developed. This tool can be used by stakeholders to effectively monitor the activities of concession holders and timber suppliers, and hence influence decisions that favour sustainable forest management (SFM).

Materials and methods

Study Sites

The study was carried out in Manyu Division of Southwestern Cameroon. Manyu Division lies at the northwestern end of the region, bordered by Universal Transverse Mercator (UTM) coordinates 48234, 629115 m to the West, 597372, 615667 m to the East, 572470, 722248 m to the North and 522168, 586781 m to the South (all UTM values based on the N32, World Geodetic System (WGS) 24 base datum) (Egbe and Tabot, 2011). It covers a surface area of about 945720.6 ha (Egbe and Tabot, 2011). It is a low plateau with undulating topography and an altitude of 135 to 1000 m (Egbe and Tabot, 2011).

There are two seasons, a dry season from November to March, and a wet season from April to November, peaking in July and August with a second peak in

September (Wanji, 2001; James and Sunderland, 2003; Egbe and Tabot, 2011). From November to April, the climate is mainly dry; some months, usually January and February, may receive no rain at all (James and Sunderland, 2003). Mean annual rainfall of 2000-2500 mm is recorded, with a mean annual temperature range of 26 to 35 ºC (James and Sunderland, 2003; Egbe and Tabot, 2011; Protus *et al.*, 2012).

The natural vegetation is the lowland equatorial rainforest, interspersed with secondary regrowth as a result of agricultural practices and logging of timber in some areas (Wanji, 2001; Egbe and Tabot, 2011). Its forests have a higher diverse flora, richer in species than any other African rainforest for which comparable data are available (Egbe and Tabot, 2011). The soils are acidic and predominantly sandy-loam which are heavily leached as a result of low water retention capacity and frequent heavy rainfall (Egbe and Tabot, 2011).

Agriculture is the main economic activity, with previously large expanses of vegetation replaced by agroforestry schemes ranging from subsistence farms and smallholder schemes to private plantations (Egbe and Tabot, 2011; Protus *et al*, 2012). (Fig. 1)

Table 1. RIL classification parameters characteristics and scoring.

RIL Parameter	Characteristics	Score
Skid trail and road preparation	No skidder trails	0
	Created during logging	1
	Created before logging starts	2
Skidder type	Chained tires	0
	Chained and rubber tires	1
	Rubber tires	2
Preparation of logging map	No logging map	0
	Partial logging map where cut and transported logs are not represented	1
	Complete logging map	2
Climber cutting	No climber cutting	0
	Cutting of climbers near the ground	1
	Complete climber cutting	2
Systematic identification and marking of exploitable timber	No identification nor marking	0
	Identification and marking during logging	1
	Identification and marking before logging starts	2
Systematic identification and mapping of seed trees and other important species	No identification nor marking	0
	Identification and marking during cutting	1
	Identification and marking before logging starts	2

Description of the KatLog Pro level of exploitation tools

Microsoft Visual Basic 2010 Programming language and Microsoft SQL Server 2012 (Microsoft Corporation, 2010) was used to develop the KatLog Pro timber monitoring package, using Beginner's All-purpose Symbolic Instruction Code (BASIC), Structured Query Language (SQL) and Language Integrated Query (LINQ) as development tools. Microsoft Visual Basic 2010 was used to develop the front end of the package that includes data entry forms, query results and charts, while Microsoft SQL Server 2012 is the database at the back end.

Prior to logging in an FMU, forestry officials carry out an inventory of all exploitable tree species. The management and minimum cutting diameters of all harvestable timber are measured and recorded in the management plan, so that concession holders will know the diameter limits for each tree they will harvest in their respective allocated FMUs. When a tree is cut, loggers measure the big end diameter (BE), small end diameter (SE), length, X and Y GPS coordinates and then estimate the volume, and record them in the field register, one log per line. The status of each cut timber is also recorded in the field register, where a tree can fall in three categories; commercial, left behind, or construction.

Commercial trees are those that are fit to be sold, while trees that have holes and other defects are either abandoned or used for road and other constructions. The data is then sent to the Regional Delegation for Forestry and Wildlife in hard copy by concession holders. Data from 2003 to 2012 at this delegation was used to develop and test the KatLog Pro package.

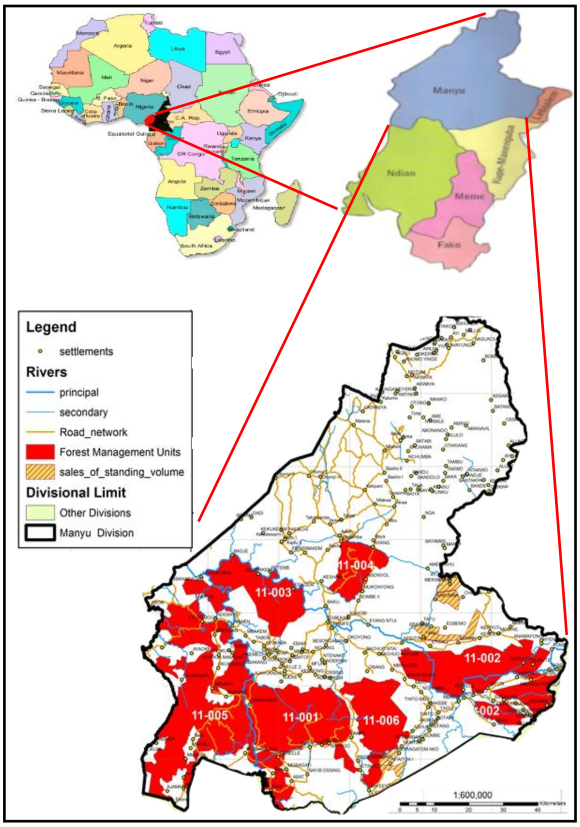

Fig. 1. Location of FMUs in the South-western Cameroon (Source: reconstructed map from PSMNR-SWR, Buea).

KatLog Pro is a multipurpose app package with various components including monitoring tools. Diameter limits for protected and non-protected species are entered in the management plan data entry form (fig. 2). The management cutting diameter of protected species are very high to limit their exploitation. Logging data from the field register is entered in the data entry form for field register (fig. 3) within the package. Algorithms were developed to compare cut diameters with management diameters, to identify the species that are logged below their supposed management diameters, as well as protected species that are logged below their high management diameters. Other algorithms query the database for the fate of non-commercial timber.

Table 2. RIL Classification with total scores.

Total Score	RIL Classification
Less than 8/12	Conventional Harvesting
8/12	Beginning RIL
9/12	Level one RIL
10/12	Level two RIL
11/12	Level three RIL
12/12	Complete RIL

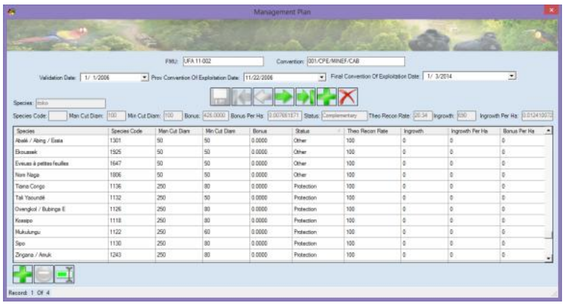

Fig. 2. Screen shot of the KatLog Pro management plan data entry form.

Assessing concession holders' respect of management diameters

The cutting diameter limits for each exploitable timber is specified in the Management plan. A data analysis form with SQL and LINQ queries in the back end was created with algorithms to check if concession holders respect their diameter limits or if they are cutting trees bellow their specified limits (Fig. 4). Diameter controls were also created with algorithms to warn the administrator if the concession holder is logging below the diameter limits. If the concession holder is cutting logs within or above the limits, the control message is "Cut Diameter OK" and if below the limits, the message is "Cut Diameter Excess". Total diameter cut, the total diameter to cut as per the management plan, the diameter difference, the number of trees cut in excess and the number of protected species cut were also calculated as fig. 4 illustrates. The administrator can also choose from two analysis criteria; display all records or display records per FMU per ACA, per

FMU per species and per FMU per wood status. One way ANOVA with Tukey honestly significant difference (HSD) was used to test significant difference between the management cut diameters and the concession holders' cut diameters for unprotected species with Minitab 16 for Windows.

Table 3. Totals of comparison of diameters for cut trees and their specified limits in the management plan (this is a sample of the trees cut).

Species	Cut Diameter (cm)	Management Cut Diameter (cm)
Piptadeniastrum africanum (Hook.f.)	148^{a}	160^{b}
Pycnanthus angolensis (Welw.)Warb.	54^{a}	60^{b}
Erythrophleum ivorense A. Chev	60^{a}	70^{b}
Lophira alata Banks ex Gaertn	11050^{a}	11730^{b}
Totals	11312	12020

Analysis of means separated through Tukey's test.

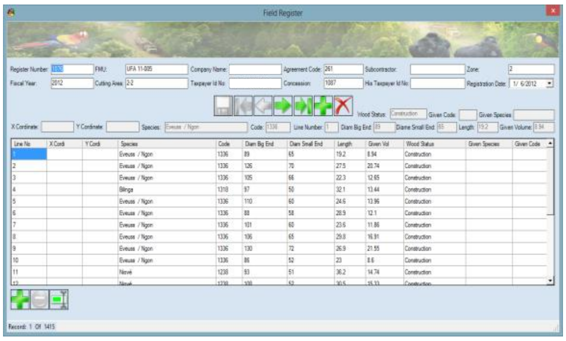

Fig. 3. Screen shot of the KatLog Pro field register data entry form.

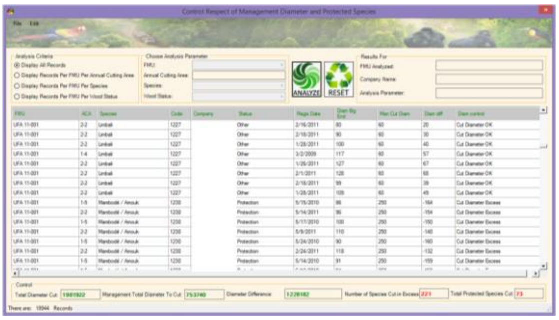

Fig. 4. Screen shot of the KatLog Pro Control Respect of Management Diameter and Protected Species data analysis form.

KatLog Pro also manages the exploitation of protected species by concession holders. The logging limits for protected species is also specified in the management plan as they are easy recognized by their high management diameter which limits their exploitation. The control respect of management diameter and protected species (fig. 4) data analysis form also contain algorithms to evaluate exploitation of protected species, including estimation of the total number of protected species exploited per FMU. One way ANOVA with Fisher's least significant difference (LSD) was used to test significant difference between the protected species cut diameters in the field with their management diameter limits in the management plan with Minitab 16 for Windows

Ascertaining the fate of non-commercial timber

Some trees that are cut and recorded in the field register may have a hollow interior and other defects that may force the concession holder to reject them and abandon them in the forest. Some other logs are used for construction of roads in the FMU and neighboring areas in favour of the concession holders' exploitation. To control these construction and abandoned wood Microsoft SQL Server and Lync queries were created to estimate the total number of logs that were used for construction, those that were left over, and then compute the total number of non-commercial logs by subtracting the total number of logs cut from the number of logs sold. Also, this is important so that if such a tree is found in the supply chain, the concession holder will be held responsible for illegal logging. The abundance of species used for construction and those that were abandoned were estimated.

Management can also monitor non-commercial trees per FMU per ACA, as fig. 5 illustrates.

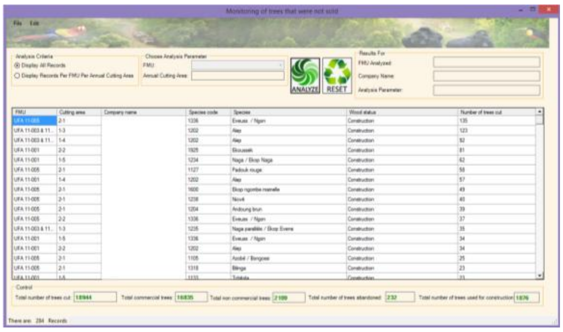

Fig. 5. Screen shot of the KatLog Pro Monitoring of Trees that were not sold data analysis form.

Reduced Impact Logging Classification

Seven RIL parameters were used to classify each FMU, with respect to how they apply the parameters based on various characteristics. The parameters used were; skid trail and road preparation, skidder type, preparation of logging map, climber cutting, systematic identification and marking of exploitable timber, systematic identification and mapping of seed trees and other important species. Each parameters was further classified and scored as follows;

FMU 11-005, FMU 11-006 and FMU 11-003 & 004 enabled firsthand experience on how logging activities are carried out. Skid trails and skidders were checked, and climbers in areas where logs had been cut were checked to see if they were cut before logging. Standing trees were also checked if they were marked for cutting or as seed or other important species. Site managers were questioned on how they carry out logging activities in the FMUs, and their responses were combined with observations in the field to fill the logging index table above. Each FMU can score a maximum of 12 points, so the total score for each FMU was then classified as follows;

Results

Assessing concession holders' respect of management diameters

KatLog Pro found that most unprotected trees cut have diameters higher than its minimum and management cutting diameters in the management plan. Table 3 illustrates a sample of some of the trees that have been cut as KatLog Pro compares them to their diameter limits in the management plan. One way ANOVA with Tukey honestly significant difference (HSD) shows that there is a significant difference between the cut diameters and the management cut diameters. However, some trees, especially *Lophira alata* Banks ex Gaertn has been exploited bellow diameter where a total of 11050 cm has been exploited, instead of 11730 cm in the management plan.

Table 4. Totals of protected trees that have been exploited below their diameter limits in the management plan.

Species	Cut diameter (cm)	Management cut diameter (cm)
Khaya anthotheca Welv.	110^{a}	250^{b}
Detarium macrocarpum Harms	5258^{a}	13500^{b}
Brachystegia mildbraedii Harms.	114^{a}	250^{b}
Milicia excelsa (Welw.) C.C. Berg	1060^{a}	2250^{b}
Entandrophragma candollei Harms	754^{a}	1750^{b}
Entandrophragma congoense Pierre & De Wild.	130^{a}	250^{b}
Total	7426	18250

Analysis of means separated through Fisher's test.

Some protected species with diameters below their limits in the management plan have been cut as fig. 6 and table 4 illustrates. One way ANOVA with Fisher's least significant difference (LSD) shows that there is a significant difference between the cut diameters in the field and their management diameter limits in the management plan. *Detarium macrocarpum* Harms and *Milicia excelsa* (Welw.) C.C. Berg., have been most exploited bellow diameter. A total diameter of 5258 cm has been exploited, instead of 13500 cm in the management plan for *D. macrocarpum* Harms., while A total diameter of 1060 cm has been exploited, instead of

2250 cm in the management plan for *M. excelsa* (Welw.) C.C. Berg.

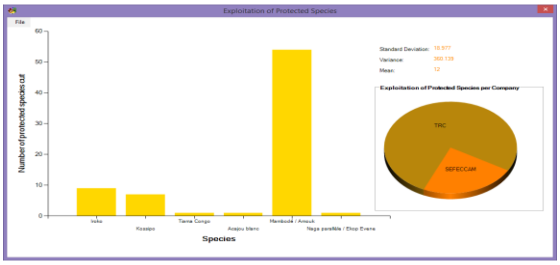

Fig. 6. KatLog Pro exploitation of protected species data analysis form.

Ascertaining the fate of non-commercial timber

Some cut trees were either left behind or used for construction of roads and other infrastructures that will favour timber exploitation and the forest communities. Table 5 illustrates the frequency and relative abundance of non-commercial logs, where the Lophira alata Banks ex Gaertn is the species that was abandoned the most with a relative abundance of 21.03, and Desbordesia glaucescens (Engl.) Tiegh was the most used for construction with a relative abundance of 18.45.

Table 5. Non-commercial trees that were used for construction or abandoned.

Cut log status / Species	Construction		Abandoned	
	Frequency	Abundance	Frequency	Abundance
Khaya anthotheca Welv	0	0.00	1	0.43
*Khaya ivorensis*A. Chev.	6	0.32	3	1.29
Canarium schweinfurthii Engl.	14	0.75	3	1.29
Ongokea gore (Hua) Pierre	10	0.53	1	0.43
Aningeria robusta A.Chev.	0	0.00	1	0.43
Maranthes glabra (Oliv.) Prance	5	0.27	0	0.00
Anopyxis klaineana (Pierre) Engl.	4	0.21	0	0.00
Guarea cedrata (A Chev.) Pellegr	7	0.37	1	0.43
Lovoa trichilioides Harms	2	0.11	0	0.00
Berlinia grandiflora (J.Vahl) Hutch.	1	0.05	0	0.00
Tetraberlinia bifoliolata (Harms) Hauman	8	0.43	0	0.00
Plagiosiphon longitubus (Harms) J. Léonard	1	0.05	0	0.00
Librevillea klainei (Pierre ex Harms) Hoyle	2	0.11	0	0.00
Toubaouate brevipaniculata (J. Léonard) Aubrév. & Pellegr	8	0.43	0	0.00
Alstonia boonei De Wild	3	0.16	0	0.00
Ricinodendron heudelotii Bail.	5	0.27	0	0.00
Stemonocoleus micranthus Harms.	3	0.16	0	0.00
Pachyelasma tessmannii (Harms) Harms	1	0.05	1	0.43
Dialium zenkeri Harms	9	0.48	0	0.00
Daniellia ogea L.	4	0.21	1	0.43
Terminalia superba Engler & Diels	10	0.53	3	1.29
Ceiba pentandra (L.) Gaertn.	3	0.16	0	0.00
Didelotia letouzeyi Pellegr.	11	0.59	0	0.00
Albizia ferruginea (Guill. & Perr.) Benth.	0	0.00	2	0.86
Milicia excelsa (Welw.) C.C.Berg	0	0.00	1	0.43
Rhodognaphalon brevicuspe (Sprague) Roberty	2	0.11	0	0.00
Entandrophragma candollei Harms	0	0.00	1	0.43
Amphimas pterocarpoides Harms	13	0.69	0	0.00
Gilbertiodendron dewevrei (De Wild) J.Léonard	21	1.12	1	0.43
Detarium macrocarpum Harms	19	1.01	0	0.00
Baillonella toxisperma Pierre	1	0.05	2	0.86
Distemonanthus benthamianus Baill.	13	0.69	0	0.00
Mammea africana Sabine	13	0.69	0	0.00
Zanthoxylum heitzii (Aubr. et Pell.) Waterman	1	0.05	0	0.00
Antrocaryon klaineanum Pierre	9	0.48	0	0.00
Poga oleosa Pierre	8	0.43	0	0.00
Afzelia pachyloba Harms	6	0.32	1	0.43
Swartzia fistuloides Harms	1	0.05	0	0.00
Entandrophragma utile (Dawe & Sprague) Sprague	3	0.16	1	0.43
Parinari excelsa Sab.	26	1.39	0	0.00

Cut log status / Species	Construction		Abandoned	
	Frequency	Abundance	Frequency	Abundance
Entandrophragma angolense Welw.	0	0.00	1	0.43
Desbordesia glaucescens (Engl.) Tiegh.	346	18.45	0	0.00
Klainedoxa gabonensis Pierre Ex Engl	218	11.63	5	2.15
Gilbertiodendron brachystegioides (Harms) J. Léonard	87	4.64	0	0.00
Brachystegia cynometroides Harms.	123	6.56	10	4.29
Didelotia unifoliolata De Wild. & T. Durand	71	3.79	6	2.58
Pterocarpus soyauxii Taub.	126	6.72	21	9.01
Lophira alata Banks ex Gaertn	64	3.41	49	21.03
Staudtia kamerunensis Warb.	78	4.16	7	3.00
Monopetalanthus microphyllus Harms.	47	2.51	3	1.29
Brachystegia mildbraedii Harms.	35	1.87	6	2.58
Nauclea diderrichii De Wild.	36	1.92	3	1.29
Oxystigma oxyphyllum (Harms) J. Léonard	38	2.03	0	0.00
Paraberlinia bifoliolata Pellegr.	40	2.13	0	0.00
Anthonotha fragrans (Baker f.) Exell & Hillc.	31	1.65	0	0.00
Piptadeniastrum africanum (Hook.f.) Brenan	49	2.61	4	1.72
Terminalia ivorensis A. Chev.	37	1.97	13	5.58
Petersianthus macrocarpus (P.Beauv.) Liben	46	2.45	0	0.00
Erythrophleum ivorense A. Chev	41	2.19	38	16.31
Cylicodiscus gabunensis Harms.	20	1.07	21	9.01
Berlinia bracteosa Benth.	20	1.07	6	2.58
Eribroma oblongum Pierre ex A. Chev.	23	1.23	9	3.86
Pterygota macrocarpa K Schum.	7	0.37	3	1.29
Pycnanthus angolensis (Welw.)Warb.	39	2.08	4	1.72
Total	**1875**		**233**	

Table 1. Classification of FMUs in South Western Cameroon based on RIL Classification.

RIL Parameter	Scores per FMU		
	FMU 11-002	FMU 11-005	FMU 11-006
Skid trail and road preparation	1	1	1
Skidder type	0	1	0
Preparation of logging map	2	2	2
Climber cutting	1	0	1
Systematic identification and marking of exploitable timber	2	2	2
Systematic identification and mapping of seed trees and other important species	1	2	1
Total	7	8	7
RIL Classification	Conventional Harvesting	Beginning RIL	Conventional Harvesting

Reduced Impact Logging Classification Index

At the moment, timber exploitation is carried out only in FMU 11-002, FMU 11-005 and FMU 11-006, where the RIL classification index was tested as illustrated in Table 6. RIL is not carried out in FMU 11-002 and FMU 11-006 where CH is the norm, while the concession holders of FMU 11-005 are at the beginning level of RIL.

Discussion

KatLog Pro's proof of concession holders' respect of harvestable diameter limits for unprotected trees in the management plan is good news to forestry officials, as there is a significant difference between the cut diameter and the diameter limits in the management plan. The diameters of cut trees in the various FMUs were generally higher than the management cutting diameter in the management plan, even though some trees, especially *Lophira alata* Banks ex Gaertn has been exploited bellow diameter. Concession holders avoid harvesting trees with small diameters because the market value of the harvested logs is less than the sum of variable logging costs and royalties; variable cost of felling a tree and transporting it from the forest to the market point (a mill or port), and also to meet up with fixed and variable logging costs and the felling taxes (Boscolo and Vincent, 2000). Heavy penalties are also levied on concession holders who do not comply with the set diameter limits (Boscolo and Vincent, 2000) and some have been fined for cutting protected species without authorization and for cutting undersized trees (Greenpeace, 2002).

Two protected species; *Detarium macrocarpum* Harms and *Milicia excelsa* (Welw.) C.C. Berg. have been significantly cut below their management cutting diameters. *D. macrocarpum* is a medium sized to very large tree up to 60m tall, bole branches for up to 20m, usually straight, cylindrical, up to 150 to 200 cm in diameter, with small buttresses, alternate compound leaves with fruits that usually ripen during the dry season (Lemmens *et al.*, 2011). Their main seed dispersers are elephants, while gorillas, chimpanzees and pigs instead eat the seed (Lemmens *et al.*, 2011). It often occurs scattered and in low densities in the forest; in southwestern Cameroon the average density of boles of more than 60 cm in diameter is 0.07 per ha, with an average wood volume of 0.73 m^3 per ha (Lemmens *et al.*, 2011). The low densities of this tree and the exhaustive hunting of its disperser (elephants) which are themselves endangered shows that it is important to halt its exploitation before it becomes extinct. Silviculture methodologies to foster its propagation in and ex situ may also increase the population. Saka *et al.* found in 2013 that the number of *D. macrocarpum* trees in the Girei forest reserve of Adamawa state in Nigeria have greatly reduced because of overexploitation.

D. macrocarpum is traded as ‘amouk’ from Cameroon and is used for flooring, joinery, interior paneling, stairs, furniture, cabinet work, turnery, sliced veneer and the bark is an ingredient of hunting poison in Cameroon (Lemmens *et al.*, 2011).

Milicia excelsa (Welw.) C.C Berg. is a deciduous tree usually up to 30m high but can grow up to 50m with a straight clear bole with high crown that is umbrella-like and growing from a few thick branches (Jøker, 2005; Babalola *et al.*, 2013; Kenya Forestry Research Institute, 2013; Nzekwe *et al.*, 2013). Bark is ash-grey, later brown to nearly black, exuding milky sap when cut. The tree produces clusters of finger-like fruits between November and April that contain numerous very tiny seeds that are surrounded by sticky oil substance (Jøker, 2005; Kenya Forestry Research Institute, 2013; Nzekwe *et al.*, 2013). Mature fruits are food for Bats, the species main dispersal agent (Nzekwe *et al.*, 2013). *M. excelsa* wood has; a density of 550 to 750 kg/m^2 at 12% moisture content, shrinkage rates from green to oven dry are; 1.7 to 4.1 (-56%) radial and 2.4 to 6.3 (-9.3%) tangential, and the wood dries well in open air and kilns with little degrade (Nzekwe *et al.*, 2013). Because of its durability and its resistance to termite and marine borers (Jøker, 2005; Kenya Forestry Research Institute, 2013) it is used for timber, for construction, furniture, cabinetwork, paneling, ship-building, marine carpentry, railway sleepers, sluice gates, cabinet works, pulp and paper, frames, floors, fuelwood etc. (Jøker, 2005; Kenya Forestry Research Institute, 2013; Nzekwe *et al.*, 2013). Other uses include mulch, shade and wind break, and used in local medicine to treat various ailments (Jøker, 2005; Kenya Forestry Research Institute, 2013; Nzekwe *et al.*, 2013). *M. excelsa* formerly is commercially known as Iroko. It is a threatened tree with typically low density (approximately 10 adults/km^2) (Babalola *et al.*, 2013). In the International Union for Conservation of Nature (IUCN) Red List *M. excelsa* was considered close to qualifying for ‘vulnerable’ (Jøker, 2005) and later as “near threatened” (Babalola *et al.*, 2013).

Currently, the species is categorized as one of the endangered valuable timber species under the IUCN Red Data List (Babalola *et al.*, 2013). Some of the threats to the species include heavy exploitation, iroko gall (*Phytolyma fusca*) attacks especially at early growing stage, and the ease of loss of viability by the seeds (Louppe *et al.*, 2008; Babalola *et al.*, 2013). A number of countries have formulated policies toward its protection. For instance, it is protected by legislation in Ghana, Ivory Coast and Mozambique, while in Kenya, a Presidential ban on logging of indigenous timber was implemented in 1986 (Louppe *et al*., 2008; Babalola *et al*., 2013). Since West Africa continues to export large quantities of Iroko (Jøker, 2005), such legislation should also be passed in Cameroon where it already it is subject to a log export ban (Louppe *et al*., 2008). At present exploitation of *M excelsa* is not sustainable in most countries. It requires protection and exploitation has to be limited if it is to become sustainable. Silviculture methodologies may foster its propagation in situ and ex situ though they are limited by pests (Louppe *et al*., 2008).

Some cut logs are left behind for construction in villages, logging camps, bridges etc., but, though logs used for construction are to be regulated (African Timber Organization and International Tropical Timber Organization, 2003), concession holders still cut large number of *D glaucescens* which is a managed species. More controls have to be put in place such that logs that have been recorded for construction should not be found circulating in the market, and heavy fines should be imposed upon defaulters. Much *L. alata* have been recorded as left behind or abandoned by concession holders. Controls should also be put in place to ensure that logs that have been recorded as left behind are not found circulating in the market, and these should also be accompanied by heavy fines.

Conventional harvesting is the de facto logging method in the FMUs in south western Cameroon with a higher domino effect on surrounding trees, where more trees are snapped and uprooted during CH. This is in line with Van Der Hout and Van Leersun (2000) who found that RIL is poorly practiced in Cameroon. This implies that logging in south western Cameroon greatly damages the forests as CH has higher ground damage, opens the canopy more, has a higher domino effect on surrounding species and highly damages future crop trees, coupled with the increased likelihood of invasion by lianas and other light-demanding weeds, and loggers suffer even higher fatality and injury rates as compared to RIL (Putz *et al., 2008)*. In Suriname RIL resulted in canopy loss of 6.5 to 7.4%, while CH opened 11.4 to 16-5% (Pereira *et al*., 2001). Loggers implementing RIL practices frequently must adopt new ways of working, invest in new equipment and safety gear, re-train their crews, and hire technically qualified supervisors to plan and oversee the work, making it more expensive to implement thatn CH, but, RIL operations have been shown to be clearly more favorable financially than CH perations, due in large part to a reduction in wastage of merchantable timber where RIL is applied (Putz *et al.,* 2008).

Logging in tropical rainforests should be controlled to reduce exploitation of protected and managed species, as well as control respect of diameter limits, and also the fate of non-commercial logs. KatLog Pro was able to detect disrespect of cutting diameters for protected species, though it also detected that the diameters of unprotected species were respected. It also clarified the fate of non-commercial logs that are left for construction or completely abandoned in the forest. If adopted by forestry officials, this tool will go a long way to help them take vital decisions concerning concession holders as a decision support system with respect to cutting diameter limits and protected species, plus management of non-commercial logs.

Acknowledgements

This research was carried out with grant from the International Tropical Timber Organization (ITTO). I am very grateful for this support. Many thanks to the Regional Delegation for Forestry and Wildlife for the South West Region, Buea for allowing access to raw data that was used to test the DSS. Mr. Pascal Deschere was very instrumental in the initial idea for the development of the queries and tables.

References

Achard F, Stibig HJ, Eva H and Mayaux P. 2002. Tropical forest cover monitoring in the humid tropics – TREES project. Tropical Ecology **43,** 9-20.

African Timber Organization and International Tropical Timber Organization 2003. ATO/ITTO principles, criteria and indicators for the sustainable management of African natural tropical forests. ITTO Policy Development Series, 20- 21

Babalola FD, Borokini TI, Onefeli AO. 2013. Socio-Economic Benefits of Iroko Trees (Milicia excelsa Welw C.C. Berg) in Ibadan Metropolis, Oyo State, Nigeria. International Journal of African and Asian Studies - An Open Access International Journal **1**, 11- 17

Boahene K. 1998. The challenge of deforestation in tropical africa: reflections on its principal causes, consequenses and solutions. Land Degradation And Development **9**, 247- 258

Boscolo M, Vincent JR. 2000. Promoting better logging practices in tropical forests: A simulation analysis of alternative regulations. Harvard Institute for International Development, Cambridge U.S.A., 1- 3

Brady M, De Wasseige C. 2010. Monitoring forest carbon stocks and fluxes in the Congo basin. Conference International Conference report, 10- 18

Ebbe EA and Tabot PT. 2011. Carbon sequestration in eight woody non-timber forest species and their economic potentials in Southwestern Cameroon. Applied Ecology and Environmental Research **9**, 369-385

Gardner TA, Barlow J, Chazdon R, Ewers RM, Harvey C. A., Peres CA, Sodhi NS. 2009. Prospects for tropical forest biodiversity in a human-modified world. Ecology Letters **12**, 1- 22

Goodman C. 2010. Bunjil – a social network for proactive monitoring of tropical rainforests. Telecommunications journal of Australia **60**, 1- 16

Greenpeace. 2002. Cameroon's Forest of the Great Apes. Forest crime files, 1- 4

Hussin YA, Shaker SR, Pantimena L. 1996. The use of remote sensing and GIS in monitoring tropical rain forest. International archives of photogrammetry and remote sensing **31**, 315- 320

International Tropical Timber Organization (ITTO) 2009. Monitoring deforestation, logging and land use change in the pan Amazonian forest – panamazon II. ITTO thematic programme on Reducing Deforestation and Forest Degradation and Enhancing Environmental Services (REDDES), 22- 24

James AC and Sunderland TCH. 2003. Takamanda: the biodiversity of an African Rainforest. Smithsonian Institution, 4- 5

Jøker D. 2005. Seed leaflet: Milicia escelsa (Welw.) C.C. Berg. Forest and landscape Denmark **63**, 1- 2

Kenya Forestry Research Institute. 2013. Tree Seed Information Leaflet No. 15: *Milicia excelsa*, 1- 4.

Laurance WF. 2007. A New Initiative to Use Carbon Trading for Tropical Forest Conservation. BIOTROPICA **39**, 20- 24

Lemmens RHMJ, Louppe D, Oteng-Amaoko AA. 2012. Ressources végétales de l'Afrique tropicale 7(2): Bois d'œvre 2. Fondation PROTA, Wegeningen, 319-322

Louppe D, Oteng-Amaoko AA, Brink M. 2008. Plant resources of tropical Africa 7(1): Timbers/Bois d'oeuvre 1. PROTA, Wegeningen, 363- 366

Mowrer HT. 1997. Decision Support Systems for Ecosystem Management: An Evaluation of Existing

Systems. Rocky Mountain Research Station Fort Collins, Colorado, 5- 10

Nzekwe U, Ubani CS and Ajuziogu GC. 2013. Effects of seed pre-treatment and media on seed germination and seedling growth of Iroko, Milicia excelsa (We/w.) C.C. Berg moraceae, Syn. Chlorophora excelsa. African Journal of Agricultural Research **18**, 2057- 2062

Oldfield S. 1988. Rare tropical timber. IUCN, Gland, Switzerland and Cambridge, UK, 6- 22

Olegário J, De Carvalho P, Silva JNM, Pokorny B, Sabogal C and Zweede J. 2009. Systems for SFM. ITTO Tropical Forest Update **18**, 9-11

Pereira JR, Zweede J, Asner G and Keller M. 2002. Forest canopy damage and recovery in reduced-impact and conventional selective logging in Eastern Pará, Brazil. Forest Ecology and Management, 77- 89

Perfecto I. and Vandermeer J. 2008. Biodiversity conservation in tropical agroecosystems. Annals of the New York Academy of Sciences **1134**, 173–200

Protus A, Faith AO, Gabriel AA, Nolé T, Anastasia NG and Geoffrey MR. 2012. Indigenous Knowledge and folk use of a polyherbal antimalarial by the Bayang Community, South West Region of Cameroon. Journal of Natural Product and Plant Resources **2**, 372-380

Putz FE, Sist P, Fredericksen T and Dykstra D. 2008. Reduced-impact logging: Challenges and opportunities. Forest Ecology and Management **256**, 1427–1433

Reyes D. 2003. An Evaluation of Commercial Logging in Mozambique. Collaborative for Development Action (CDA), USA, 7-24.

Reynolds JD and Peres CA 2006. Overexploitation. Sinauer Associates Inc. 256-267

Saka MG, Jatau DF and Olaniyi WA. 2013. Status of indigenous tree species in Girei forest reserve of Adamawa state. Journal of research in forestry, wildlife and environmental **5**, 28-40

Talbot JD. 2010. Carbon and biodiversity relationships in tropical forests. Multiple Benefits Series 4. Prepared on behalf of the UN-REDD Programme. 4-5

Van Der Hout P and Van Leersun GJR. 2000. Reduced impact logging: a global panacea? Comparison of two logging studies. In: Jonkers WBJ, ed. Logging, Damage and Efficiency: A Study on the Feasibility of Reduced Impact Logging in Cameroon. Tropenbos-Cameroon Programme. 8-24

Van Oijen DCC and Wiersum KF. 2010. Timber legality, livelihoods and social safeguards in Ghana. TROPENBOS International – Ghana program. 4-5

Varma VK, Ferguson I and Wild I. 2000. Decision support system for the sustainable forest management. ELSEVIER Forest Ecology and Management **128**, 49-55

Wanji S. 2001. Rapid Assessment Procedures for Loiasis. UNDP/World Bank/WHO Special Programme for Research and Training in Tropical Diseases (TDR), 11-12

Wittemyer G, Elsen P, Bean WT, Burton CO and Brashares JS. 2008. Accelerated human population growth at protected area edges. Science **321**, 123–126.