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Carbon Stock Assessment Report for Plantation Socfinac Ghana Limited (PSGL)

Subri Concession, Western Region

15 May 2017




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About Proforest

Proforest is an independent organisation working with natural resource management and specialising in practical approaches to sustainability. Our expertise covers all aspects of the natural resources sector, from sustainable forestry and agricultural commodities production to responsible sourcing, supply chain management and investment.

Proforest works to transform commodity supply chains and sectors through developing **awareness** about sustainability, helping to generate **commitment** to better practice, supporting **implementation** of these commitments in practice and working with the wider community to increase the positive **impact**.

Proforest Ghana leads on delivery of Proforest activities in West and Central Africa including direct support to companies implementing responsible production, sourcing and investment for agricultural and forest commodities together with long-term programmes to support capacity building and multi-stakeholder initiatives in the region. Proforest also has offices in Brazil, Malaysia and the UK.

Our team comprises specialists in forest management, agricultural commodities such as palm oil, conservation and sustainability initiatives and certification. We have extensive experience in Africa and internationally and can work in English, French and Portuguese.

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Proforest Ghana is a company registered in Ghana as Proforest Limited (Company Number CS115042012).

Executive Summary

About 1% sampling rate was used to assess the aboveground and belowground carbon stock in the PSGL's Subri concession located near Daboase in the Wassa East District of the Western Region of Ghana. The assessment area of 4,996 ha is composed of three Blocks: Gmelina plantation (Block 1), salvage forest area (Block 2), and conversion area (Block 3). Forty-nine plots of 1 ha each, subdivided into 25 square quadrats of 0.04 ha, were used. The diameter and estimated height of all the living trees with diameter at breast height (dbh) of 10 cm and above were recorded. The vegetation type of each quadrat was recorded and the collected field data were processed with Microsoft Excel, QGIS, and ArcGIS. Six mains vegetation types which are: Agricultural Commodities Plantations, Cleared or Open Land, Natural Forest, Moasic of Shrubland and Cropland, Timber Plantation (*Gmelina arborea*), and Water Bodies were identified in the landscape of the concession. The assessment area was dominated at 98.55% by natural forest and Gmelina plantation. Tree density and the average of diameter and height were higher in the natural forest than the Gmelina plantation. Accordingly, the estimated total carbon stock was 208.3 tC/ha for the natural forest and 27.9 tC/ha for the Gmelina plantation. For the entire area of the concessions, the total carbon stock obtained was 981,080.74 tC (196.37 tC/ha). An area of 4,515 ha that includes the entire conversion area (Block 3) and 73.5% of the salvage forest area (Block 2) were identified as significant carbon sink to be set aside. Based on the results obtained from the assessments (HCV and CS) management and monitoring recommendations were made to ensure that, the establishment and management of oil palm or rubber plantations in the concession are environmentally friendly.

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1 Introduction

1.1 About Plantations Socfinac Ghana Limited (PSGL)

Plantations SOCFINAF Ghana Limited (PSGL) is a subsidiary of the SOCFIN Group, which is an agro-industrial group of companies with headquarters in Luxembourg. The SOCFIN Group is an Ordinary Member of RSPO which is a large-scale producer of palm oil and natural rubber and is currently operating in over 10 countries in Asia and Africa, including Cambodia, Indonesia, Congo DR, Liberia, Cameroon, Sierra Leone, Cote d'Ivoire, Nigeria, Sao Tome and Principe, and Ghana. It also has interests in plantation companies in Guinea and Kenya. These interests usually involve a majority shareholding and are managed by the group through Socfinco SA based in Brussels.

PSGL was registered as a business entity in Ghana under the Ghana Companies' Code on the 25th September 2012. The company acquired the assets of the defunct Subri Industrial Plantations Limited (SIPL) in 2013 as part of the Government of Ghana's Divestiture Implementation Programme for the purpose of establishing oil palm and rubber plantations on the erstwhile SIPL estates within the Subri River Forest Reserve.

1.2 History of the Subri concession acquisition by PSGL

The entire PSG concession (about 17,937.80 ha) was originally acquired by the Government of Ghana through an Executive Instrument (EI 7) in February 1990. This was subsequently given out on a 50-year lease to the Subri Industrial Plantation Limited (SIPL) in August 1991 for the establishment of *Gmelina arborea* plantations to feed an intended pulp and paper mill. However, the original objective of installing a pulp and paper manufacturing plant could not be executed due to some challenges, including inadequate funding and raw material supply base capable of sustaining a functioning pulp and paper mill. As a result, SIPL was listed in the Government of Ghana's Divestiture Implementation Programme in December 2002 with an initial objective to obtain a potential joint ventureship for pulp and paper production. However, no suitable partners were found. Due to lack of additional investment, the company (SIPL) focussed on sawmilling the indigenous trees which could not sustain the company financially. This compelled the Divestiture Implementation Committee (DIC) to re-advertise the company for investors in 2008 and again in 2010, this time with a broad objective of finding an investor to take over the company's assets for sustainable use. SOCFIN applied to acquire SIPL and was granted a right of entry to the site in December 2012. SIPL's assets at the time included an existing plantation of about 5,000 hectares of *Gmelina arborea*, and 13,000 hectares of forest reserve land.

1.3 Context and objectives of the assessment

As RSPO member, SOCFIN is committed to demonstrating sound environmental management in all its operations. This requires that the company should identify all areas necessary for the protection of biodiversity and minimise the impacts of their operations on the environment and on society.

An essential part of the RSPO certification compliance management requirements prior to land conversion is the New Planting Procedure (NPP). The RSPO requires an oil palm company that intends to certify its plantations to identify social and environmental impacts of the proposed operations and any HCVs and significant carbon sinks contained in the concession prior to land conversion.

As part of this commitment, PSGL has asked Proforest to conduct a detailed and independent Carbon Stock Assessment of its Subri concession in the Western Region of Ghana.

The main objectives of the assessment were to:

- Estimate the total carbon stock contained in the vegetation of the concession;
- Identify and map out any significant carbon sinks present within the concession;
- Provide management and monitoring recommendations for ensuing that establishment and management of oil palm and rubber plantations in the concession are environmentally friendly.

This report describes the methodology used, team composition, findings and management and monitoring recommendations for the PSGL's Subri concession.

2 Description of the assessment areas

2.1 National and regional context

Ghana is situated on the West coast of Africa with a total area of 238,540 square kilometres. The country has a North-South extent of about 670 km and a maximum East-West extent of about 560 km. It shares borders with Côte d'Ivoire to the West, Burkina Faso to the North, and Togo to the East. To the South are the Gulf of Guinea and the Atlantic Ocean[1]. The country is divided into 10 administrative regions (Figure 1).

Ghana has a warm and humid climate. The mean annual temperatures range from 26.1 °C near the coast to 28.9 °C in the extreme North. The mean annual rainfall of the country is estimated at 1,187 mm with an annual potential open water evaporation ranging between 1,350 mm in the South to about 2,000 mm in the North.

There are six agro-ecological zones defined on the basis of climate, reflected by the natural vegetation and influenced by the soils that characterize the country (Rhebergen *et al.*, 2016). These agro-ecological zones are the following: Rain forest, Deciduous forest, Transition zone, Guinea savannah, Sudan savannah, and Coastal savannah (Figure 1).

[1] Source: http://www.fao.org/nr/water/aquastat/data/query/index.html

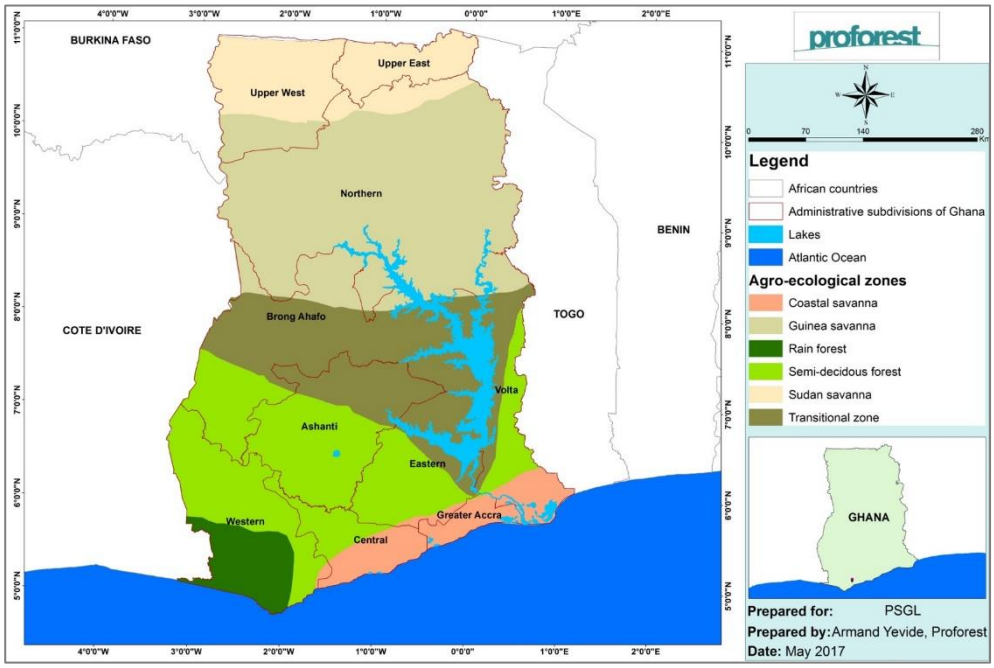

Figure 1: Regional boundaries and agroecological zones of Ghana.

PSGL is located in the Western Region which covers an area of approximately 23,921 square kilometres, which is about 10 per cent of Ghana's total land area. It is bordered on the East by the Central Region, to the West by Côte d'Ivoire, to the North by Ashanti and Brong-Ahafo Regions, and to the South by the Gulf of Guinea.

The Western Region lies in the equatorial climatic zone that is characterised by moderate temperatures, ranging from 22°C at nightfall to 34°C during the day. The Region is the wettest part of Ghana, with a double maxima rainfall pattern averaging 1,600 mm per annum. The two rainfall peaks fall between May-July and September/October. In addition to the two major rainy seasons, the region also experiences intermittent minor rains all the year round. This high rainfall regime creates much moisture culminating in high relative humidity, ranging from 70 to 90 per cent in most parts of the region.

The Western Region has about 75 per cent of its vegetation within the high forest zone of Ghana. The South-Western areas of the region are noted for their rain forest, interspersed with patches of mangrove forest along the coast and coastal wetlands, while a large expanse of high tropical forest and semi-deciduous forest is also found in the Northern part of the region. The Western Region has 24 forest reserves, which account for about 40 per cent of the forest reserves in the country.

2.2 Description of the assessment site in PSGL's Subri concession

The assessment site is located within PSGL's concession in the Subri River Forest Reserve near Daboase in the Wassa East District of the Western Region of Ghana. It is comprised of three (3) Blocks (Figure 2) covering a total area of 4,996 hectares of the PSG concession; Block 1 is located in the area previously planted with Gmelina by SIPL and covers 330 ha, Block 2 covers 570 hectares in the Salvage Forest Area, and Block 3 covers the entire 4,096 ha of the Conversion Forest Area.

Block 1 consists largely of old *Gmelina arborea* plantation at an advanced stage of growth. It is surrounded by young oil palm and rubber plantations, and some cleared areas which were earmarked for planting in 2016.

Block 2 has been under salvage logging where timber of economic value is removed prior to land clearing sanctioned by the Forestry Commission. It is bounded in the East, South, and South-West by cleared areas which were earmarked for planting in 2016 and some areas planted with oil palm and rubber; and in the North-West by the Conversion Area (i.e. Block 3). The vegetation bears semblance to a highly-disturbed forest with trees at various successional stages of growth.

Block 3 has been selectively logged and has been earmarked for conversion to plantations by the Government of Ghana. The forest is moderately degraded. The Block shares its Western boundary with a Globally Significant Biodiversity Area (GSBA), the Northern and eastern boundaries with Timber Utilization Contract (TUC) areas which are under selective logging, and the Southern boundary with Block 2 and young oil palm and rubber fields.

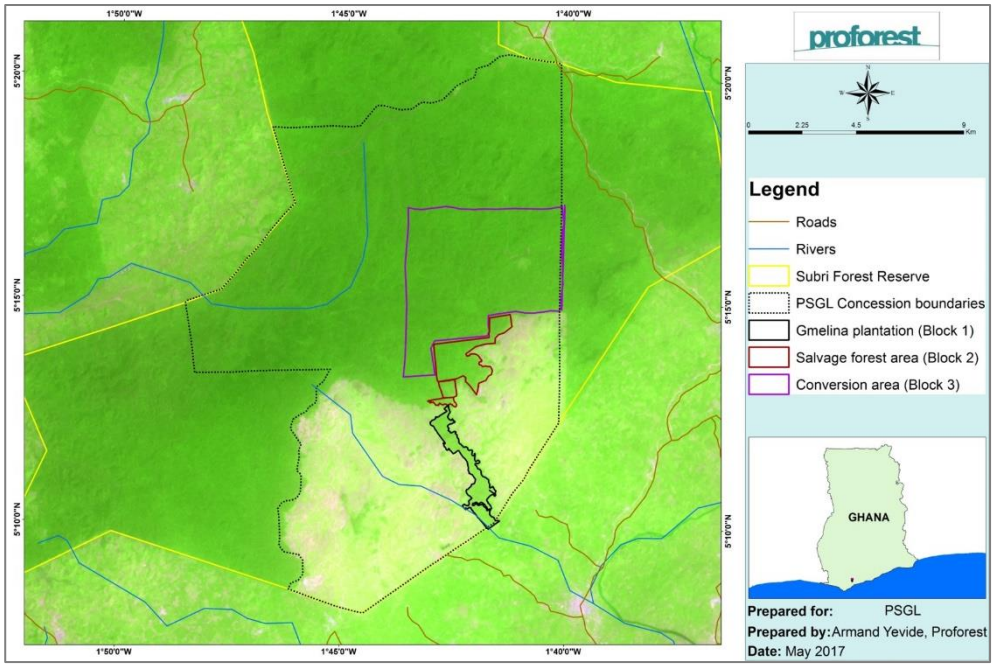

Figure 2: Geographic location of PSGL's concession and the assessment site.

NB: The satellite image in the background is a 30 metres resolution satellite image acquired from the EarthExplorer webpage of the United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/) for the year 2016 (Scene Identifier: LC81940562016030LGN00 acquired on the 30th January 2016).

3 Assessment process and methods

3.1 Assessors and their credentials

In conducting this carbon stock assessment for PSGL's Subri concession near Daboase in the Western Region, Proforest has drawn on its internal capacity from the regional office in Accra, Ghana and local consultants in the same country. The

team involved in the assessment are therefore highly competent in the field of natural resources management, botany, forest survey and data processing.

Table 1: List of the assessors and their qualification.

Name	Organisation/company	Role in the assessment
Abraham Baffoe	Proforest	Assessment oversight and Ecology/landuse planning
Elikplim Agbitor	Proforest	Assessment team leader
Armand Yevide	Proforest	Flora survey coordination plus GIS and mapping
Benjamin Campion	Faculty of Renewable Natural Resources/Kwame Nkrumah University of Science and Technology (KNUST)	Natural Resources Manager/Flora survey

The team members had collective expertise in Botany, Agriculture, Forestry, Environmental Science. Together, they possess several years of experience working on plant identification, tree measurement techniques, forest survey, carbon stock assessment, vegetation dynamic study, big data treatment and processing, ArcGIS and remote sensing. Below are brief summaries of the Proforest team members' experience:

Abraham Baffoe, Assessment oversight

Abraham has more than 18 years' experience working on natural resource management, specialising in sustainable forest management, certification and forest policy. His experience involves managing community forestry projects, developing and implementing forest certification programmes and providing support to sustainability standard setting and policy implementation. As the Forest Programme Leader at the WWF West Africa Forest Office, he coordinated several forestry projects and provided technical support to the Forest Law Enforcement, Governance and Trade (FLEGT)/Voluntary Partnership Agreement (VPA) process. He has also provided training and technical support to companies on forest certification for the Global Forest and Trade Network.

Abraham has led several HCV and baseline assessments for forestry, rubber, coffee and palm oil operations. These include new plantation developments in several countries in Africa including Cameroon, Cote d'Ivoire, Ethiopia, Gabon, Ghana, Liberia, Nigeria, Tanzania and Zambia. Abraham is an RSPO approved team leader for HVC assessment.

Elikplim Agbitor, Assessment team leader

Eli has a background in natural resources management, forestry and the environment. He has worked on a diverse range of projects for organisations including UNDP, GIZ, ITTO and FSC, and has extensive experience working with the public sector, private sector, civil society organisations, research institutions and communities.

Eli is a certified FSC and RSPO lead auditor and has been involved in a number of second and third party audits in the forestry and agriculture sectors. He has

hands-on experience with issues such as climate change, ecosystem services management and participatory resources management, as well as knowledge and experience with international best practice in sustainability. He holds Masters degrees in Forestry and Environmental Science (Bangor University, UK; University of Padua, Italy) and a BSc in Natural Resources Management (KNUST, Ghana).

Eli is based in our Africa Office where he leads Social Impact Assessments and stakeholder engagement, and provides technical support to palm oil and forestry enterprises to help them meet certification requirements.

Armand Yevide, Flora survey coordination plus GIS and mapping

Armand's background is in agronomy, natural resources management especially ecology, forestry and agroforestry, in species distribution modelling under climate change scenarios, in long-term ecosystem monitoring, and in social network analysis. He has worked as consultant for the "Institut National de la Statistique et de l'Analyse Economique (INSAE)" on the dynamic of cash crop chains (Cashew, Sugar cane, Pineapple and Tabaco) in Benin. Additionally, he has more than 5 years of experience teaching undergraduate students in many private and public universities in Benin.

Armand holds a PhD in Natural Resources Management and spent about 2 years as post doctor at the Institute of Remote Sensing and Digital Earth (RADI) working for the United Nations Environment Programme-International Ecosystem Management Partnership (UNEP-IEMP) under the Chinese Academy of Science's International Young Scientist Programme. He has a number of scientific publication on the ecology, dynamic, productivity and tree growth modelling of natural and man-made forests, ethnobotany, biodiversity and ecosystem monitoring network with a special focus on Africa. Armand is fluent in French and English, and has basic communication skill in Chinese. He is currently a Project Manager in the Proforest Africa regional office and has been involved in several audits against various standards including RSPO, FSC and OECD.

Benjamin Campion, Natural Resources Manager/Flora survey

Dr Benjamin Betey Campion is a lecturer in the Faculty of Renewable Natural Resources. He has a very diverse academic upbringing traversing botany, aquatic ecology, resources management to climate and vegetation geography. He has been working on the characterisation of water and soil resources (quantity and quality); effects of land use and climate change on groundwater recharge, quality of ground and surface waters; soil degradation and sustainable managements of soils; ecological and cultural sustainability of urban environments; biofuels and the effects of large scale land acquisition to the sub-region.

3.2 Flora survey methodology

3.2.1 Desk-based literature review

A desk review of documents including paper and cadastral maps provided by PSGL was carried out prior to the field assessment. The objective of the desk review was to identify the key landscape level concerns that are relevant for the assessment area and to also have a better understanding of the geo-physical characteristics of the landscape.

3.2.2 Planimetrics and coarse land cover identification

PSGL provided maps and shapefiles of their concessions at Daboase in the Western Region. In planning for the assessment, a combination of satellite images of the wider landscape was used. This included publicly available Google Earth imagery which were used in the initial planning for the assessment. Satellite imageries were thereafter used to aid the assessment of the study area and to have a sense of the coarse land cover classes in the area. This was crucial to inform the distribution of the flora survey transects and sampling plots.

3.2.3 Sampling and experimental design

An approximately 1% sampling rate was used to determine the sample size for the estimation of the total carbon stock for the proposed concession. 49 sampling plots were laid across the proposed concession. These plots were distributed along 13 transect lines oriented North South and, which were at least, a distance of 500 m from each other (Figure 3).

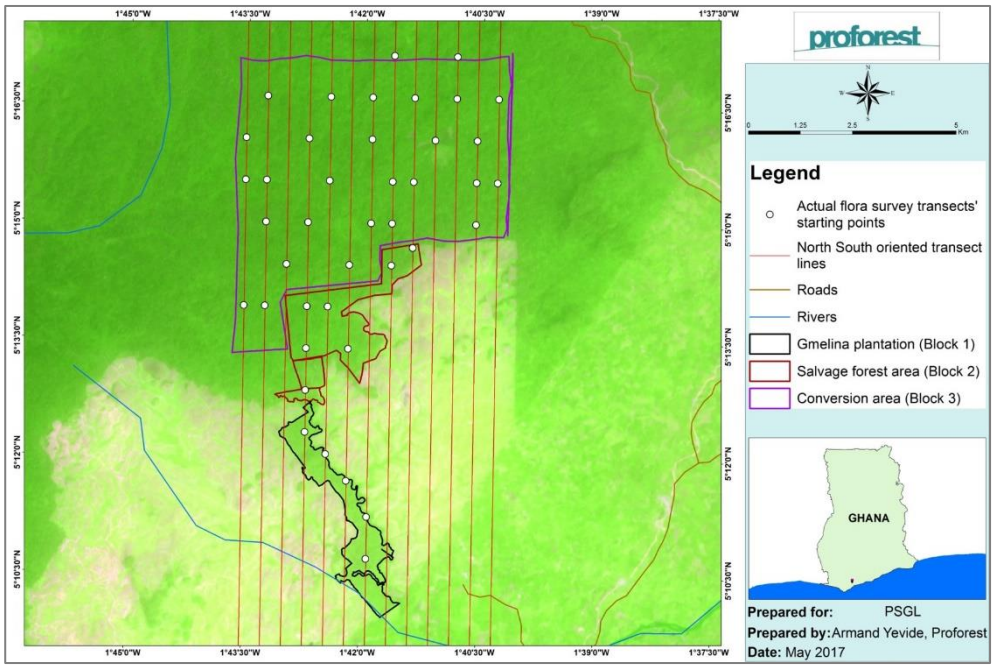

Figure 3: Distribution of sampling plots along transect lines across the three Blocks.

NB: The satellite image in the background is a 30 metres resolution satellite image acquired from the EarthExplorer webpage of the United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/) for the year 2016 (Scene Identifier: LC81940562016030LGN00 acquired on the 30th January 2016).

Photo 1: Flora team members laying a transect and keeping the South bearing with the compass.

Each plot was a rectangle of 1 ha (length 500 m and width 20 m) which was subdivided into 25 quadrats of 20x20 m (400 m^2) each (Figure 4). At the starting points of each plots, a bearing was taken with a compass when surveying the quadrats to keeping the South direction fixed and effectively walk along the transect line. Data collected from the plots included the name of the species, diameter at breast height, and observation on the individual tree (whether it was diseased, fruiting, etc). Only live trees and lianas with trunk diameter at breast height (dbh) ≥10 cm were measured, using a diameter tape. In addition to the dbh

Photo 2: Assessors measuring and recording the diameter at breast height of trees.

measurements, the height of each individual tree was estimated visually. Each quadrat within the plot was assigned to a one of the vegetation types obtained after the land use and land cover classification. The number of quadrats in each vegetation type was used to estimate its area within the entire proposed concession.

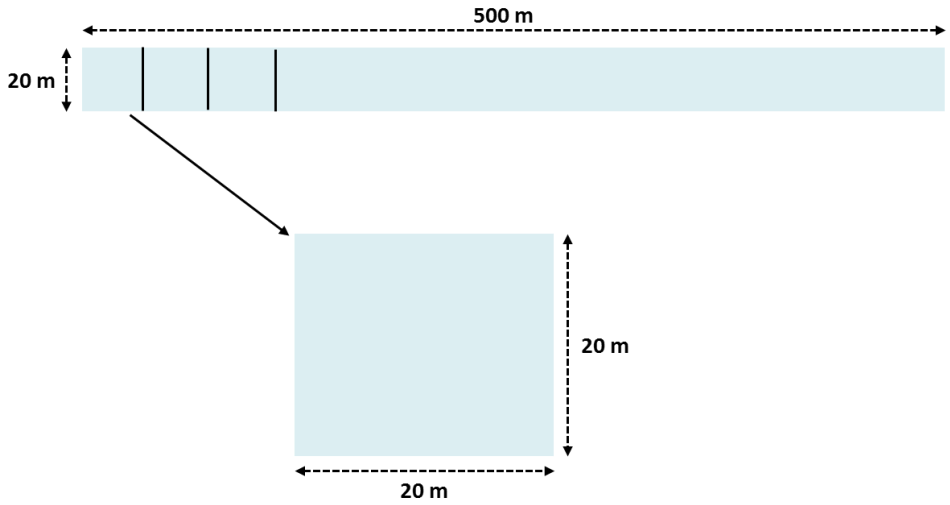

Figure 4: Length and width of the botanical survey plot and quadrats.

3.3 Land use and land cover classification

A Landsat 8 satellite imagery was downloaded from the EarthExplorer webpage (http://earthexplorer.usgs.gov/) of the United States Geological Survey (USGS) that provides free access to several remote sensing products of various dates.

Landsat 8 carries an Operational Land Imager (OLI) and a Thermal Infrared Sensor (TIRS) instrument on board. Landsat OLI image data consists of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and Band 9. The resolution of Band 8 (panchromatic) is 15 meters. Landsat 8 provides a new data source for monitoring land cover, which has the potential to significantly improve the characterization of the earth's surface.
The acquisition date of the downloaded satellite image (Scene Identifier: LC81940562016030LGN00) was the 30th January 2016. The acquired image was pre-processed and classified.

Photo 3: Assessors estimating visually tree heights in the natural forest.

PSGL's Subri concessions in Daboase are mostly contained within Landsat path 194, rows 56. A clear and almost cloud-free image were selected for the land use classification. The downloaded data was pre-processed by atmospheric correction, i.e. the removal of atmospheric distortions in the imagery due to differences in aerosols, water vapour, haze, and illumination effects. This was done with Quantum GIS (QGIS) version 2.14.3. The output data was converted into surface reflectance. The image was procured in Level 1T preprocessing format, which means that geometric correction including orthorectification has already been applied by USGS. The image had a very good geometric matching for land use change analysis. The land use and land cover features were mapped using a false colour composite image (FCC, bands 6, 5 and 7) at various scales.
The land use or land cover classification was done with ArcGIS version 10.3 which uses an object based image classification method. During the flora survey, conducted in from November 2016 to February 2017, ground truthing data were

collected and used as training sample through the maximum likelihood algorithm to classify the vegetation of the Subri concessions landscape for the year 2016 into seven classes with an overall accuracy of 99.4% and a Kappa coefficient of 99.2%. Eventually, a visual screening of the classification results was conducted in order to reduce mis-classifications and improve classification accuracy. The table below shows the description of the land use classes.

Photo 4: Assessor collecting data in the Gmelina plantation.

Table 2: Description of the land use or land cover categories used for the classification.

Land use classes	Description
Agricultural Commodities Plantations	Oil palm and rubber plantations
Cleared or Open Land	Area cleared or having a minor vegetation cover or roads
Natural Forest	Natural vegetation of the Subri Forest Reserve which is a high-density forest where some logging activities have been conducted in the past
Moasic of Shrubland and Cropland	Abandoned land recolonised by natural vegetation and land dedicated to annual or biannual crop production
Timber Plantation (*Gmelina arborea*)	Artificial plantation of *Gmelina arborea*
Urban	Cities and settlements that are characterised by buildings and other infrastructures
Water Bodies	Natural water bodies and artificial water bodies - lakes, reservoirs, and rivers. Can be either fresh or salt-water bodies.

3.4 Carbon stock estimation

Various approaches have been developed and used to estimate the total above ground biomass of individual trees or of a particular ecosystem. The destructive approach which consists in felling trees has contributed to the establishment of models and has led to the non-destructive approach which uses field data collected on alive or dead trees and models already built to estimate the biomass they contain.

Numerous models have been developed over the course of time. Some of them are solely diameter-based allometric models while others are diameter and height-based models.

For the current carbon stock estimation, the above ground biomass was estimated using the latest improved allometric model of Chave *et al*. (2014) which

uses tree height, stem diameter and wood density as covariates. To deduce carbon content from the biomass, we used the assumption that carbon concentration is about half (47.5%) of the biomass (Whittaker & Likens, 1973; Brown, 1997; Losi *et al*., 2003; Nasi *et al*., 2009). The biomass was estimated for each individual tree (including all stems for multi-stemmed trees) using the equation below:

$$AGB = 0.0673 \times \left(\rho D^2 H\right)^{0.976}$$

Where ***AGB*** is aboveground dry biomass (in kg); ***ρ*** is wood density (in g/cm^3) ***D*** is diameter at breast height (in cm) and ***H*** is the height (in m).

The underground or belowground biomass (BGB) was deduced using the assumption that, for each individual tree, the belowground biomass represents 20.5% of the aboveground biomass (Mokany *et al*., 2006). Therefore, the total biomass was equal to 1.205 * AGB.

Wood density was compiled from the Global Wood Density Database (Chave *et al*., 2009; Zanne *et al*., 2009), and from the African Wood Density Database (Carsan *et al*., 2012). Of the 205 species recorded in the inventory of the concession, wood density was available for 112 species (54.6%). For the remaining species not reported in these databases, we used the mean wood density of the matching genus (64 species) or matching family (27 species) or matching order (2 species).

Microsoft Excel, QGIS version 2.14.3 and ArcGIS version 10.2 were the three main programmes used to process the data collected.

4 Carbon stock assessment findings

4.1 Biodiversity and vegetation cover dominant species

A total of 12,990 living trees belonging to 205 species, 143 genera and 52 families were recorded within the surveyed plots across the assessment site. The top five most abundant species were *Drypetes aylmeri* (589 individuals), *Funtumia africana* (526 individuals), *Diospyros sanza-minika* (480 individuals), *Afrostyrax lepidophyllus* (475 individuals), and *Carapa procera* (468 individuals). Compared to the natural forest, the biodiversity of the Gmelina plantation is very low. Only 600 living trees were encountered in the surveyed plots. They belong to 52 species, 41 genera and 24 families. All the species encountered in the Gmelina plantation were also found in the natural forest. The top five species observed in the Gmelina plantation were *Funtumia africana* (46 individuals), *Drypetes aylmeri* (35 individuals), *Maesobotrya barteri* (34 individuals), *Gmelina arborea* (32 individuals), and *Carapa procera* (24 individuals). The five dominants species at the Subri concession level were the same for the natural forest and three of them were also among the most abundant species in the Gmelina plantation. This situation reveals that, the Gmelina plantation has been neglected and has not been well managed. It also shows that, over the course of the years, lot of the Gmelina trees has been felled reducing *de facto* their population and allowing natural vegetation to take over.

Photo 5: Natural forests alongside a road in the conversion area (Block 3).

The table below presents the list of the IUCN Red List species alongside with their family and number of individual observed. They represent about 5.4% of the species recorded within the surveyed plots across the concession. One of them (*Afrostyrax lepidophyllus*, 475 individuals) happened to be one of the dominant species of the natural forest and a black star species. Based on the collected data, the density of the IUCN Red List species in the natural forest is more than 13 trees/ha. This shows that the natural forest is a habitat for a large population of vulnerable species that requires conservation measures.

Table 3: Species recorded on the IUCN red list.

IUCN Status	Species	Family	Number
Vulnerable	*Afrostyrax lepidophyllus*	Huaceae	475
	Berlinia occidentalis	Caesalpiniaceae	6
	Cassipourea hiotou	Rhizophoraceae	65
	Cola umbratilis	Sterculiaceae	6
	Cussonia bancoensis	Araliaceae	4
	Gilbertiodendron splendidum	Caesalpiniaceae	10
	Piptostigma fugax	Annonaceae	7
	Schumanniophyton problematicum	Rubiaceae	2
	Synsepalum aubrevillei	Sapotaceae	21
Endangered	*Tieghemella heckelii*	Sapotaceae	5
Lower Risk or near threatened	*Irvingia gabonensis*	Irvingiaceae	52

4.2 Land use distribution in the concession landscape

The figure 5 below shows the land use classes of the landscape of the three Blocks which constitutes the assessment area. It reveals that the assessment area landscape is predominantly covered by natural forest (90.90%) followed by a man-made forest which is the Gmelina plantation (7.65%). The table 4 presents the area covered by each type of land use and their proportion.

Table 4: Size of land use types of the assessment site in PSGL's Subri concession.

Land use classes	Total area covered (ha)	Proportion (%)
Agricultural Commodities Plantations	32.8	0.66
Cleared or Open Land	0.01	0.00
Natural Forest	4541.6	90.90
Moasic of Shrubland and Cropland	39.2	0.78
Timber Plantation (*Gmelina arborea*)	382.3	7.65
Water Bodies	0.1	0.00
Total	**4996.0**	**100.00**

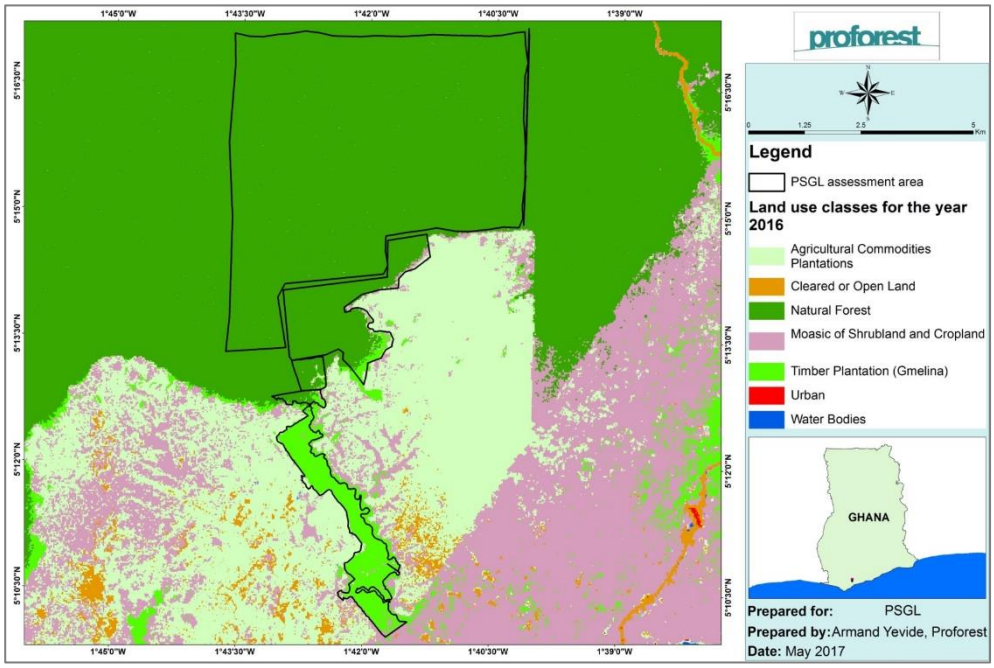

Figure 5: Land use distribution in the PSGL's Subri concession landscape.

NB: The land cover classification was based on a 30 metres resolution satellite image acquired from the EarthExplorer webpage of the United States Geological Survey (USGS) (http://earthexplorer.usgs.gov/) for the year 2016 (Scene Identifier: LC81940562016030LGN00 acquired on the 30th January 2016).

4.3 Results of the carbon stock assessment

4.3.1 Total carbon stock distribution across the concessions

The figure 6 below shows the distribution of carbon stock across the landscape of the assessment area.

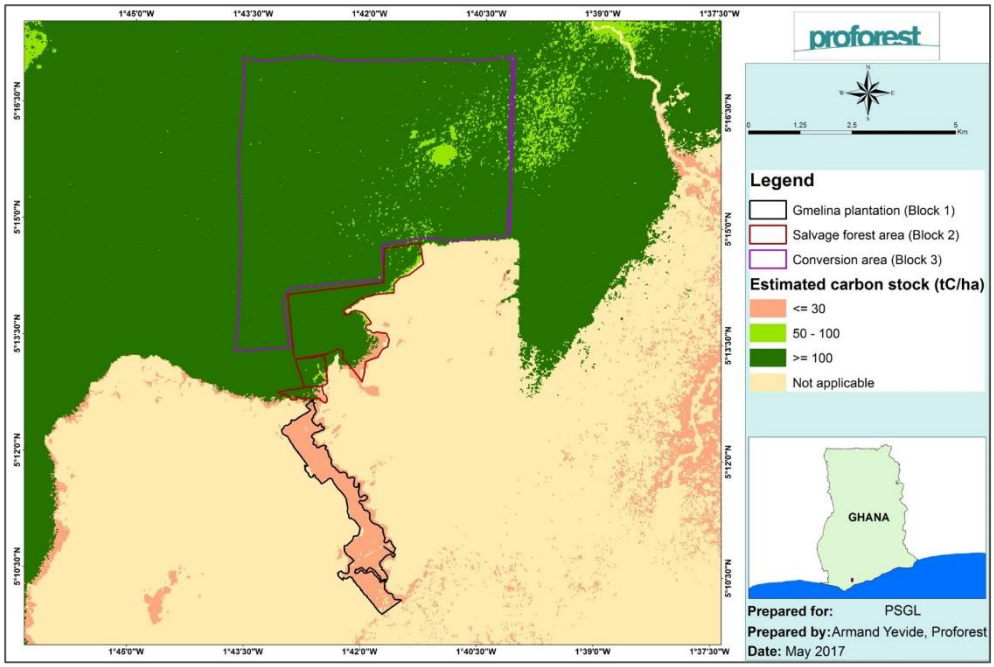

Figure 6: Distribution of carbon stock estimated for PSGL's Subri concession.

The estimated carbon stock varies from 27.92 tC/ha for the Gmelina plantation to 208.29 tC/ha for the natural forest. The estimated carbon stock for the sampled plots was 9,664.96 tC and averaged 197.24 tC/ha. Extrapolated to the size of the three sites, the total carbon stock was 981,080.74 tC (Table 5).

Table 5: Total carbon stock estimated in the different vegetation types of PSGL's Subri concession.

	Sampled area			**Total concession**	
Vegetation types	Sampled area (ha)	Total carbon (tC)	Carbon (tC/ha)	Total area (ha)	Total carbon (tC)
Natural Forest	46	9581.21	208.29	4666.00	971868.24
Timber Plantation (*Gmelina arborea*)	3	83.75	27.92	330.00	9212.50
Total	**49**	**9664.96**	**197.24***	**4996.00**	**981080.74**

* this value is equal to the total carbon obtained for the sampled area (9664.96 tC) divided by the total sampled area (49 ha).

Based on the estimated carbon stock for the two different vegetation types, the area covered by the natural forest has been identified as significant carbon sink of the PSGL's Subri concession (Figure 7). Given the carbon potential of the natural forest and the density of species of conservation concerns, the identified significant carbon area has to be set aside and manage in a way to conserve and enhance the biodiversity present and ecosystem services the area is already providing.

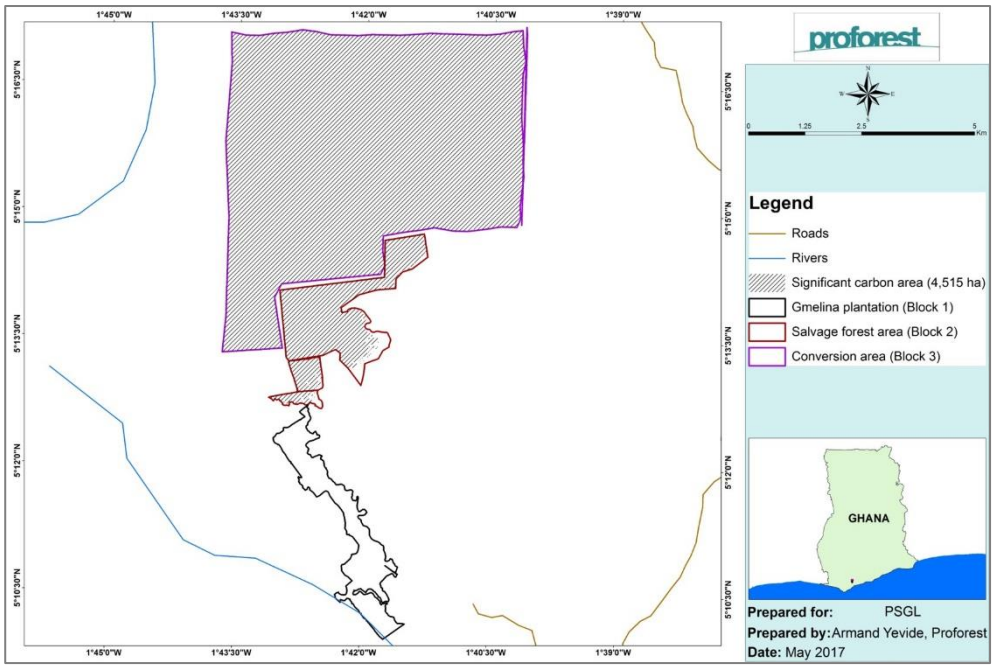

Figure 7: Location of the significant carbon areas in PSGL's Subri concession.

The areas having a carbon stock greater or equal to 35 tC/ha are considered here as significant carbon areas and should be set aside. Therefore, the significant

carbon area covers the entire conversion area (Block 3) and 73.5% of the salvage forest area (Block 2). There represents about 90.4% of the PSGL's Subri concession. The top 5 species encountered in the area include one IUCN Red List species which is also a black star species (*Afrostyrax lepidophyllus*).

4.3.2 Description of the vegetation types across the two sites

The table below presents the dendrometric characteristics of trees in the natural forest and the timber plantation (*Gmelina arborea*). Tree density is higher in the natural forest than the Gmelina plantation. Trees height stretches from 4 to 70 m irrespective of the vegetation type and the average diameter was 28.31 ± 21.14 cm and 19.08 ± 10.69 cm for the natural forest and Gmelina plantation respectively.

Table 6: Dendrometric characteristics of trees in the different vegetation types.

		Natural Forest	Timber Plantation
Area (ha)		46	3
Total number of trees		12,390	600
Density (trees/ha)		269.3	200.0
Diameter (cm)	Min	5.13	7.96
	Max	145.0	105.0
	Average	28.31	19.08
	Standard deviation	21.14	10.69
Height (m)	Min	4.0	5.1
	Max	70	45
	Average	20.51	13.66
	Standard deviation	10.65	5.91

The figure 8 below shows the distribution of the number of trees as function of the diameter classes for the two vegetation types. It reveals that 90.8% and 99.3% of the trees measured less than 50 cm at breast height in the natural forest and Gmelina plantation respectively. Regardless of the vegetation type, 87.3% of the trees has a diameter comprises between 10 to 40 cm. Also, it has been noticed that, there is 5 times more big trees (diameter greater or equal to 50 cm) in the natural forest than the Gmelina plantation.

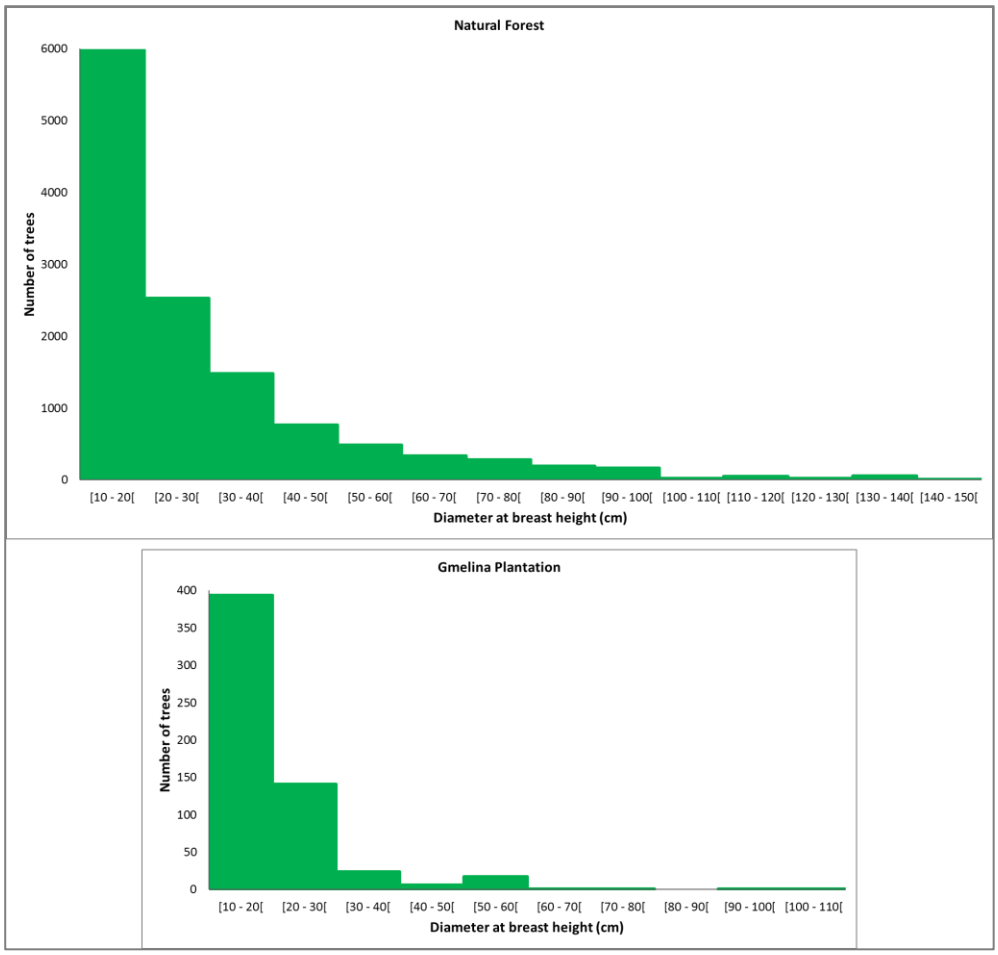

Figure 8: Pooled dbh-distribution of trees in the vegetation types.

Regardless of the vegetation type, *Petersianthus macrocarpus*, *Piptadeniastrum africanum*, and *Dialium aubrevillei* were the species with the highest total carbon stock. None of the top five abundant species were present among the top 10 species that contributed for 45.4% of the estimated carbon (Figure 9). *Sacoglottis gabonensis*, *Parinari excelsa*, and *Anopyxis klaineana* happened to have the highest carbon stock per tree (20.02 tC/tree, 13.13 tC/tree, and 11.27 tC/tree respectively). However, none of them were among the dominant species nor the top 10 high carbon species.

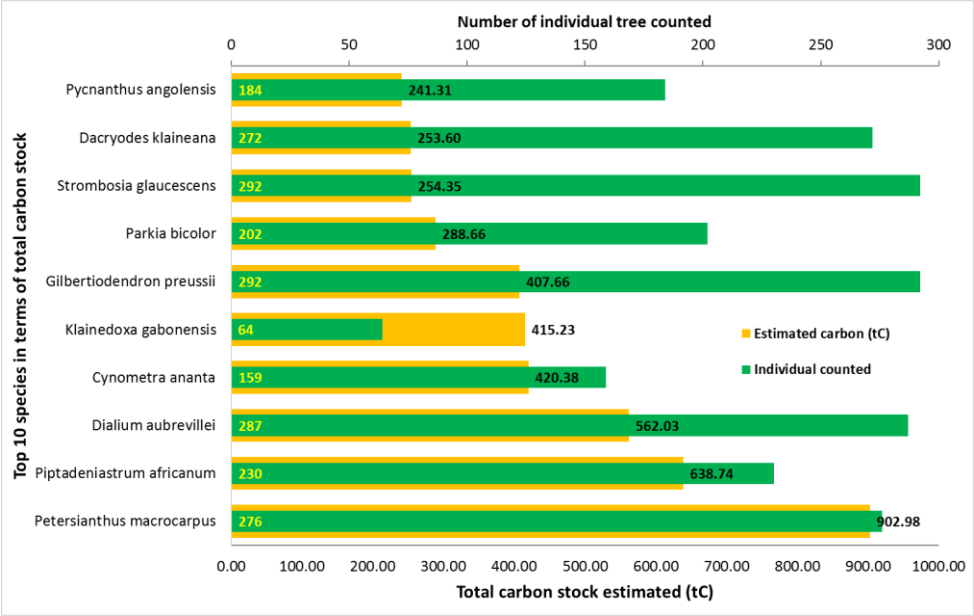

Figure 9: Top ten tree species in terms of total carbon stock with their abundance.

5 Management and monitoring recommendations

The assessment conducted has revealed that the dominant land use forms in the concession were natural forest and Gmelina plantation. These land cover types represent 98.6% of the assessment area. Apart from the Gmelina plantation, the carbon sequestration potential of the natural forest is very high compare to the carbon sequestration potential of an oil palm plantation. Though, a recent study conducted in the Eastern Region of Ghana has revealed that rubber plantations have the highest carbon content and can sequester carbon at an equal or higher level than natural forests in the area (Kongsager *et al*., 2013), converting the identified carbon sink covered by the natural forest would lead to the destruction of several species of conservation concern. Also, it would take more than 40 years for a rubber plantation to sequester 214 tC/ha (Kongsager *et al*., 2013). Therefore, we recommend that the entire Block 3 and the 73.5% of natural forest in the Block 2 be set aside for biodiversity conservation and ecosystem services provision. The entire Gmelina plantation and the remaining part of the salvage forest area (Block 2) which has been highly degraded and was no longer covered by the natural forest can be converted into oil palm or rubber plantation (Figure 10).

However, the current land use forms conversion into oil palm or rubber plantations and the management of the plantations should be mindful of the conservation of the identified HCVs and carbon sinks as well as the mitigation of greenhouse gas (GHG) emission throughout operations management.

The HCV assessment conducted has come up with numbers of management and monitoring recommendations for the identified HCVs conservation. In addition to those, the table below presents other additional management and monitoring recommendations for both biodiversity conservation and GHG emission mitigation.

Table 7: Management and monitoring recommendations for the purposes of biodiversity conservation and GHG emission mitigation.

Purpose	Management recommendations	Monitoring recommendations
Conservation of the identified HCVs	All identified HCVs should be managed as recommended in the HCV assessment report.	Ensure the monitoring of the identified HCVs in accordance with the recommendation made in the HCV assessment report.
Protection and conservation of the habitats of the black star and IUCN red list species of plants	The carbon sink identified should be clearly mapped and delimited on the ground to avoid accidental conversion. Identify and avoid the felling of the black star and IUCN Red List species. Ensure that no illegal loggings happen in the area.	Ensure that the boundaries of the set aside carbon sink remain intact and that no illegal loggings are conducted in the premises.
Protection and conservation of the black star and IUCN red list species of plants		Periodic (bi-annual) assessment of habitat quality and presence of the species of conservation concern
GHG emission mitigation during land clearing and land preparation	Avoid biomass burning practices during land clearing and land preparation process.	Ensure through periodic unexpected visits to the field during land clearing and land preparation.
	Use a combination of mechanic and manual methods for land clearing and land preparation to minimise GHG emission.	
GHG emission mitigation through fertilizer utilisation	All forms of fertiliser use shall be justified following periodic soil and tissue sampling, and shall be applied by trained staff with supervision from management.	Ensure periodic soil and tissue analysis conducted by an accredited laboratory.

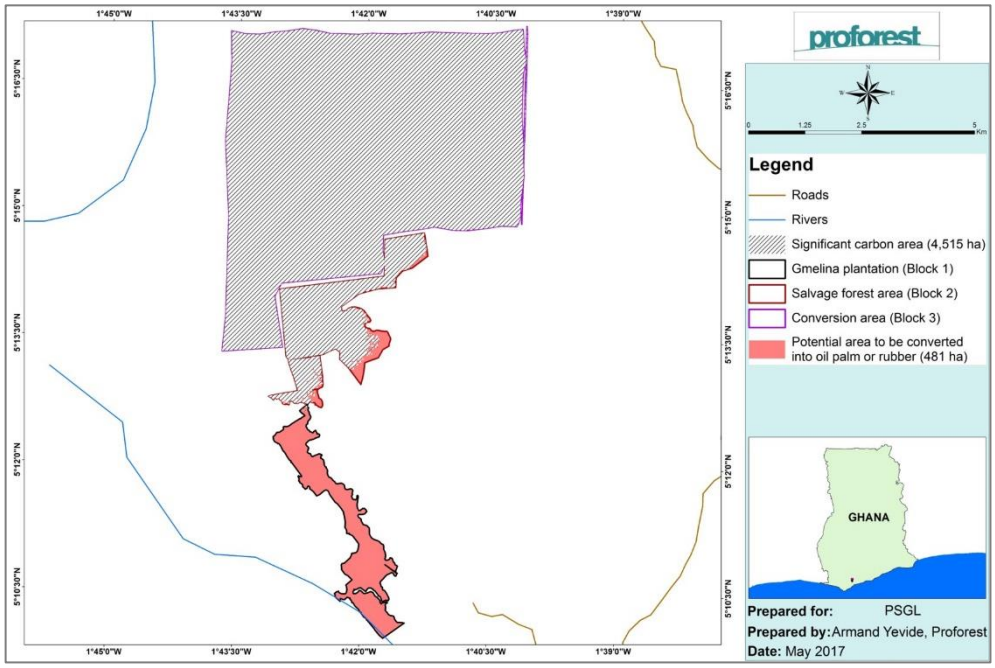

Figure 10: Significant carbon area set aside and area to be developed into oil palm or rubber plantations.

6 Internal responsibility

Signing off by Carbon Stocks Assessor

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Acknowledgement of internal responsibility by PSGL.

I, the undersigned being the legal representative of the assessed company agree with the content of this report

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Name:

Position:

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Appendix: Tree density and carbon stock in the assessed plots.

Plots	Tree density (trees/ha)	Carbon stock (Mg/ha)
TR 1	505.0	126.61
TR 2	307.0	159.85
TR 3	287.0	39.16
TR 4	505.0	234.06
TR 5	281.0	31.75
TR 6	110.0	10.62
TR 7	198.0	54.09
TR 8	140.0	20.59
TR 9	153.0	53.88
TR 10	315.0	52.38
TR 11	315.0	128.48
TR 12	306.0	54.33
TR 13	418.0	89.48
TR 14	161.0	50.43
TR 15	190.0	142.28
TR 16	168.0	76.46
TR 17	196.0	116.02
TR 18	196.0	164.31
TR 19	272.0	326.73
TR 20	243.0	199.66
TR 21	216.0	468.32
TR 22	216.0	186.28
TR 23	150.0	122.88
TR 24	101.0	68.64
TR 25	252.0	210.93
TR 26	252.0	330.16
TR 27	252.0	136.50
TR 28	158.0	149.11
TR 29	414.0	182.26
TR 30	414.0	584.11
TR 31	399.0	518.25
TR 32	397.0	417.15
TR 33	291.0	217.72
TR 34	180.0	196.89
TR 35	172.0	137.74
TR 36	234.0	82.74
TR 37	255.0	269.00

TR 38	340.0	399.75
TR 39	500.0	362.62
TR 40	216.0	280.32
TR 41	295.0	459.56
TR 42	252.0	524.48
TR 43	304.0	304.91
TR 44	256.0	140.01
TR 45	216.0	67.10
TR 46	256.0	275.13
TR 47	329.0	345.78
TR 48	198.0	54.09
TR 49	209.0	41.38

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