2019

ANNUAL REPORT

CSIR-FORESTRY RESEARCH INSTITUTE OF GHANA

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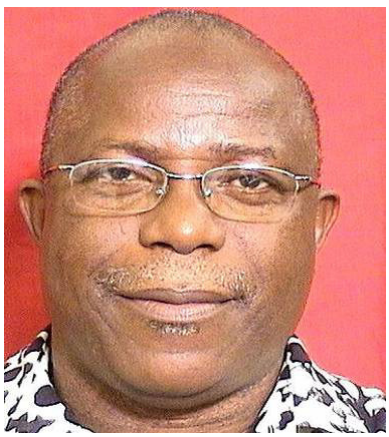
FOREWORD

CSIR-Forestry Research Institute of Ghana (CSIR-FORIG) is one of the 13 institutions of CSIR, mandated to undertake forest, forest products and related research and to disseminate and commercialize research outputs and services in Ghana. For CSIR-FORIG to be able to accomplish this mandate, the institute undertakes demand-driven research, builds capacity and promotes the application of technologies for the sustainable management of Ghana's forest resources for the benefit of society. This report shows the research outputs and outcomes for the year 2019 grouped under four (4) broad research themes namely: Food Security & Poverty Reduction, Climate Change, Environmental Management & Green Technology, Material Science and Manufacturing and Science and People.

With the high dedication of its research staff, its culture of interdisciplinary and multidisciplinary co-operation and its strength in applied research, CSIR-FORIG is strategically placed to remain as one of the top research institutes of the CSIR in Ghana. On behalf of CSIR-FORIG management, I applaud and acknowledge the contribution of all staff to this high performance of the Institute.

Prof. Daniel A. Ofori,
Director, CSIR-FORIG



Prof. Robert Clement Abaidoo,
BOARD CHAIRMAN

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LIST OF ABBREVIATIONS AND ACRONYMS

AAC	Annual Allowable Cut
ABCECG	Association of Building and Civil Engineering Contractors of Ghana
AGI	Association of Ghana Industries
BA	Basal Area.
BAE	Basal Area for Exotic species
BAI	Basal Area for Indigenous Species
CCST	CSIR-College of Science and Technology
CHED	Cocoa Health and Extension Division
CHRAJ	Commission on Human Rights and Administrative Justice.
CIOB	Chartered Institute of Building
COCOBOD	Ghana Cocoa Board
CREMA	
CSIR-FORIG	Council for Scientific and Industrial Research -Forestry Research Institute of Ghana
CSIR-PGRR	Council for Scientific and Industrial Research-Plant Genetic Resources Research Institute
CSZ	Coastal Savanna Zone
DBH	Diameter at Breast Height,
DfID	Department for International Development
DOLTA	Domestic Lumber Traders Association
DOTIC	Domestic Timber Certificate
DTM	Domestic Timber Market
ESD	Education for Sustainable Development
EU	European Union
FAO	Food and Agriculture Organization
FC	Forestry Commission
FCCD	Forest and Climate Change Division
FGMC	Forest Governance, Market and Climate
FIP	Forest Investment Project
FIPD	Forest Improvement and Productivity Division
FLEGT	Forest Legality, Governance and Trade
FSD	Forestry Service Division

GDP	Gross Domestic Product
GEM	Global Environmental Monitoring
GIFMIS	Ghana Integrated Financial Management Information System
GIS	Geographical Information Systems
GNA	Ghana News Agency
GOG	Government of Ghana
GPS	Global Positioning System
GREDA	Ghana Real Estates Developers' Association.
GSA	Ghana Standards Authority
HVTC	High Volume Timber Consumers
IGF	Internally Generated Funds
IMC	Internal Management Committee
ISO	International Organization for Standardization
IVI	Intravenous Infusion
KSNR	Kogyae Strict Nature Reserve
KWC	Kumasi Wood Cluster
LA	Leaf Area
LAI	Leaf area index
LDMC	Leaf Dry Matter Content
LKS	Lesser Known Species
LUS	Lesser Used Species
MC	Moisture Content
MOE	Ministry of Education
MOE	Modulus of Elasticity
MOFA	Ministry of Food and Agriculture
MOR	Modulus of Rupture
MOU	Memorandum of Understanding
MRI	Multi Resource Inventory
MSDFZ	Moist
NDF	Nature and Development Foundation
NGO	Non
NGRL	Newmont Golden Ridge Limited
nPA	Non
NTFP	Non
PA	Protected Area

PAU	Protected Area Unburnt
PVC	Polyvinyl Chloride
PPP	Public Private Partnership
PPP	Public Procurement Policy
R&D	Research and Development
RCBD	Randomized Complete Block Design
REDD+	Reduced Emissions of Deforestation and Forest Degradation
RGR	Relative Growth Rate
RMSC	Resource Management Service Center
SAFORGEN	Forest Genetic Resources in Sub
SDF	Skills Development Fund
SDG	Sustainable Development Goals
SECO	State Secretariat for Economic Cooperation (Affairs?) ,
SLA	Specific Leaf Area
SMFE	Small and Medium Forest Enterp
SOP	Schools' Outreach Programme
SPSS	Statistical Package for Social Scientists
TAPPI	Technical Association of the Pulp and Paper Industry
TEV	Total Economic Value
TU	Technically Unknown
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organization
UTM	Universal Testing Machine
VPA	Voluntary Partnership Agreement
WFTC	Wood and Furniture Testing Center
WIUD	Wood Industry and Utilization Division
WRI	World Resources Institute
WTP	Willingness of farm households and local communities to Plant Trees

COMPOSITION OF CSIR-FORIG MANAGEMENT BOARD

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Mr. Lawrence K. Mensah *Head of Administration, CSIR-FORIG*	Secretary

EXECUTIVE SUMMARY

During the period under review, a total of twenty (20) projects were implemented comprising thirteen (13) pure research projects and seven (7) service-oriented activities. Eleven (11) of the research projects were undertaken in collaboration with other national and international institutions. The projects were linked to four (4) of the seven (7) CSIR Thematic Research Areas and these are; (a) Food Security and Poverty Reduction; (b) Climate Change, Environmental Management and Green Technology (CCEM&GT); (c) Material Science and Manufacturing; and (d) Science and People.

Under the Food Security and Poverty Reduction programme, the seedlings of two varieties of Pomegranate (*Punica granatum*) planted in four different ecological zones were monitored for their growth, development and survival during the year. Data collection on the growth performance parameters such as plant growth height, the diameter of the stems and the number of shoots developed by the pomegranate plants indicated that growth performance at Abofour was the best. On comparative studies on growth and yield of *Volvariella volvacea* (oil palm mushroom) on agricultural and composted *Ceiba pentandra* wood wastes, results indicated that it would be profitable to cultivate oil palm mushroom using dry plantain leaves, mixtures of dry plantain leaves and yam peels and rice straw with supplements.

Under the Climate Change, Environmental Management and Green Technology Programme, a total area of 3,131.60 hectares of forest plantations of both indigenous and exotic tree species has been established. The plantation sites are being maintained by weeding and fire rides construction to protect them from fires. There was an increase in the number of species recorded for amphibians, birds and bats but a decrease in mammals recorded under the research project involving the monitoring of vegetation, fauna and soil erodibility of reclaimed mining sites in Ahafo. In the Akyem mine (Newmont Golden Ridge Limited) Wildlife Monitoring Programme, results revealed that, there was an increase in reptiles, birds and mammals whilst there was a decrease in the number of amphibians within the remnant forest during the survey.

On the study of phytoremediation potential of exotic and indigenous tree species for the rehabilitation of mining sites, it was also observed that, *T. superba* among other species had a high potential for the uptake of Cd and Pb from the study. The National Tree Seed Centre (NTSC) produced an average of **2,862,710** seeds within 2019 and the seeds were estimated to produce about four hundred and fifty thousand **(450,000)** seedlings. The seedlings produced can plant a total of **2, 544** ha per year. Seed orchards of 2 ha *Gmelina arborea* species as well as plantations of 2 ha *Eucalyptus* species were established with genetically superior planting stocks. Conservation plot of an endemic species (*Talbotiella genti)*, was established and maintenance continued earnestly.

UNIDO sponsored tests for furniture products were completed and this generated enough data for use by external assessors to assess the testing centre for international accreditation. An executive Composite Swivel Chair manufactured by the Institute passed the internation testing system.

Under the Science and People programme, CSIR-FORIG is committed to ensuring that environmental education is brought to the doorsteps of children in Ghana under its programme of creating awareness among basic schools on climate change sensitization and outreach programmes all in an effort to mitigate and adapt to climate change. CSIR-FORIG organised twenty-two (22) workshops and a total of five hundred and fifteen (515) particitants were trained in mushroom production, snail production and beekeeing in 2019. The MSc. and MPhil programmes in Climate Change and Integrated Natural Resources Management continued to run smoothly with eleven (11) new students admitted.

1.0 FOOD SECURITY & POVERTY REDUCTION (FSPR)

1.1 Background and Highlights of Research Achievements under FSPR research theme

In 2019, CSIR-FORIG engaged with other national and international research institutions on research covering key agricultural and forestry issues under the following thematic areas:

Forest, trees and plant resources (natural products)

- Soil, mechanization and agro food processing
- Biotechnology (Germplasm collection, conservation, bio-processing) under the Biomedical and Public Health research theme of CSIR, Ghana.

Under these themes, food-related research was accomplished to meet the challenges of providing Ghana's growing population with access to safe, modest and nutritious food, using sustainable land use practices.

OUTPUT 1.2 POMEGRANATE (*PUNICA GRANATUM*) SPECIES TRIAL IN GHANA

Research Team: *D. A. Ofori; A. Antwi-Wiredu and P. P. Bosu*
Donor: *Northstone Investment Ltd*

CSIR-FORIG during the year under review seeks to locally domesticate and assess the capacity, growth and yield of two pomegranates fruits namely Hicaz and Wonderful in Ghana. In collaboration with Blue Skies two (2) pomegranate fruits from Turky and South Africa were brought to CSIR-FORIG for trials in four (4) sites (Mpraeso, Yenku, Abofour, and Mesewam). In July and August 2018, the seedlings of pomegranate were planted on the fields.

In March and September of 2019, the growth performance assessment of pomegranates was carried out from the four sites while considering plant growth height, the diameter of the stems and the number of shoots developed.

The relative growth rate (RGR) of height (cm^{-1}) over 6 months interval, and growth in height of pomegranates one year after planting were determined. The highest relative growth rate for Hicaz was produced at Yenku (1.91cm), followed by Mesewam (1.74cm), Mpraeso (1.64cm) and Abofour (1.56 cm) (Figure 1). But for Wonderful, it was slightly higher at Abofour (2.19cm) than Yenku (2.18cm), Mesewam (1.72cm), and Mpraeso (1.32cm) (Figure 1).

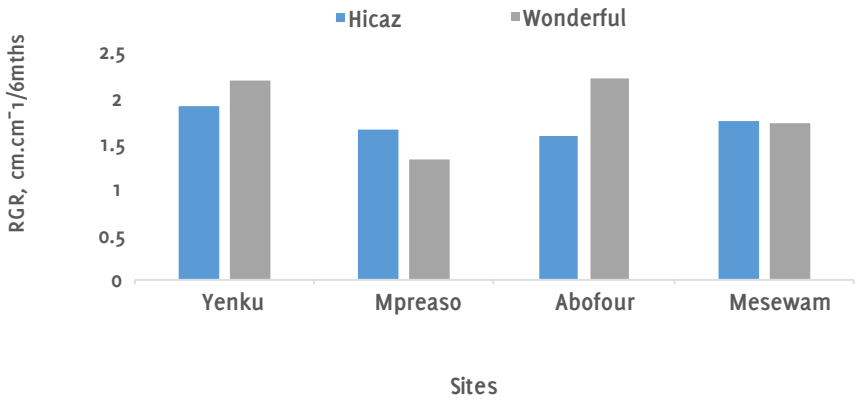

Figure 1: RGR of pomegranate seedlings at the four sites

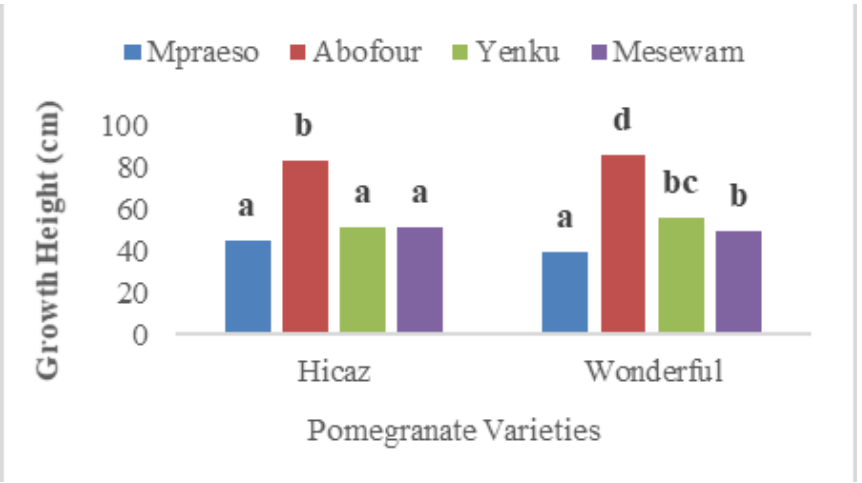

Figure 2: Growth of pomegranate varieties at the four sites

The highest growth in height for Hicaz was recorded at Abofour (Figure 2). There was a significant growth height difference (P,0.05) between Abofour and the rest of the sites. Mean growth height was as follows; Abofour = 83.30cm, followed by Mesewam = 51.37cm, Yenku = 51.24cm and Mpraeso = 45.02cm (Figure 2). Again, Abofour (85.67cm) being the highest was significantly different from Yenku (55.59cm), Mesewam (48.99cm) and Mpraeso (39.52cm) for Wonderful pomegranate varieties (Figure 2).

The development of shoots for both varieties was highest at Abofour followed by Yenku, and the rest of the sites. The plants at Abofour outperformed exceedingly by recording the highest diameter of girth for both pomegranate varieties than others. Yenku falls within the Coastal Savannah, Abofour in the Dry Semi-Deciduous, Mpraeso and Mesewam in the Moist Semi-Deciduous ecological zones. The performance of the plant supports the fact that pomegranate is light-loving and prefers dry zones compared to moist zones.

Finally, Abofour showed the highest growth and development performance for both Hicaz and Wonderful pomegranate varieties (Plate 1) as compared to the other sites.

Plate 1: Wonderful Pomegranate shrub growing at Abofour.

OUTPUT 1.3 COMPARATIVE STUDIES ON GROWTH AND YIELD OF VOLVARIELLA VOLVACEA (OIL PALM MUSHROOM) ON AGRICULTURAL AND COMPOSTED *CEIBA PENTANDRA* WOOD WASTES

Research Team: *M. M. Apetorgbor; A. K. Apetorgbor; M. Adablah; D. E. Nyarko and A. Asante.*
Donor: *CSIR-FORIG*

Volvariella. volvacea (oil palm mushroom) grows on cellulosic agricultural residues and industrial and decaying wood wastes. Wood waste has been used to cultivate some edible mushrooms (*Pleurotus* spp., *Auricularia* sp., *Ganoderma* spp., etc.) with success. However, growth of *V. volvacea* on wood waste has only been partially successful.

Locally available agricultural lignocellulose wastes such as rice straw, banana/plantain leaves and root tuber peelings have been used to cultivate *V. volvacea*, but yields have been low and inconsistent. This study sought to determine the optimum composting period for wood waste and develop the best agricultural substrate media and supplements which would produce maximum growth and yield of *V. volvacea* to improve cultivation practices.

Oil palm mushroom was cultivated on low beds using dry plantain leaves, rice straw, dry yam peels and *Ceiba pentandra* sawdust. Substrates were used singly and variously mixed with dry leucaena leaves, rice husk and lime ($CaCO_3$) as supplements.

Yam peels (50%) supplemented with plantain leaves (50%) gave the best yield (152.92g/kg substrate) with pinheads appearing in 8 days followed by rice straw supplemented with lime (129.08g/kg substrate) and plantain leaves supplemented with lime (125.13g/kg substrate). Plantain leaves supplemented with lime induced early formation of pinheads followed by mixture of plantain leaves and yam peels and rice straw supplemented with lime. For sawdust, composting for four weeks and supplementing with wheat bran and lime gave the best yield (89.38g/kg substrate) followed by composting for 6 weeks with mixtures of wheat bran, rice husk and lime (51.18g/kg substrate). The sawdust substrates were heavily contaminated with

Trichoderma species and this might have affected the growth and yield of the mushroom. It will be profitable to cultivate oil palm mushroom using dry plantain leaves, mixtures of dry plantain leaves and yam peels and rice straw with supplements.

Plate 2: Yam peels supplemented

Plate 3: Rice straw supplemented with plantain leaves with lime

Plate 4: Sawdust supplemented with wheat bran and lime

2.0 CLIMATE CHANGE, ENVIRONMENTAL MANAGEMENT & GREEN TECHNOLOGY (CCEMGT)

2.1 Background and Highlights of Research Achievements under CCEMGT

CSIR-FORIG's research under the climate change, environmental conservation and green technologies theme improves our knowledge of the health and environment effects of climate change and provides sustainable solutions for communities to effectively manage and reduce the impacts of a changing climate. In 2019, the research activities under the theme were related to the following:

- Soil, Water and Biodiversity Conservation
- Climate Change Mitigation (Including REDD+)
- Climate Change Adaptation and Social Development
- Green Technologies for Sustainable Development

OUTPUT 2.2 ESTABLISHMENT OF FOREST PLANTATIONS TO SUPPORT REFORESTATION OF GHANA'S FORESTS

Research Team: *R.T. Guuroh; S. Adu-Bredu; F. Asuming-Baffour; A. Asamoah; G. Djagbletey; D. A. Ofori and E. G. Foli.*

Donor: *Forestry Commission/Industry Fund Board*

CSIR-Forestry Research Institute of Ghana (FORIG) was tasked to establish best practices for the establishment of plantation of fast growing indigenous and exotic commercial species at various locations in the country with support from the FC/Industry. The plantations were established in the Research Working Circles of CSIR-FORIG in Pra-Anum, Opro/Afram Headwaters and Asenanyo Forest Reserves, and in degraded Forest Reserves at Mankrang, Essen-Apam and Pamu Berekum.

Efforts towards reforestation of Ghana's forest estate via plantation development continued during the year under review under the Government of Ghana's plantation development programme.So far, an area of 3,131.60 ha has been planted with indigenous species including Ofram (*Terminalia superba*), Kusia (*Nuclea diderrichii*), Onyina (*Ceiba pentandra*), Wawa (*Triplochiton scleroxylon*), Mahogany (*Khaya ivorensis*), Otie (*Pycnantus angolense*). The exotic species are Cedrela (*Cedrela odorata*), Teak (*Tectona grandis*) and Paulownia species (*P. elongata* and *P. fortunei*). Operations from the month of January to end of November 2019 centered on maintenance of plantations in the form of weeding, fire rides construction and maintenance; patrolling for detection of bush fire threat and illegal encroachments; fire-fighting and fire preventive education; nursery management; peg cutting, line pegging, beating up and carrying out of census in some permanent sample plots established in the already established plantations.The target of establishing **384 ha** in 2019 was achieved and the progress of work was satisfactory. The plantation presents an opportunity

to implement different research components that would lead to a better understanding of plantation establishment in Ghana and this opportunity should be vigorously explored. Scientists are encouraged to make use of the sites for their research activities.

Plate 5: One-year old *Tectona grandis* at Pamu Berekum Forest Reserve

Plate 6: Four-year old *Terminalia superba* plantation at Asenanyo

Plate 7: Seven years old *Cedrela odorata* stand at Pra Anum

OUTPUT 2.3 AKYEM MINE WILDLIFE MONITORING PROGRAMME

Research Team: *B.O. Kankam and C. Ofori-Boateng*
Donor: *Newmont Golden Ridge Limited*

Newmont Golden Ridge Limited (NGRL) is monitoring wildlife which is a major component of not losing any additional biodiversity in their operations going forward since surface mining is destructive to biodiversity.

This monitoring activity is focused on the assignment relating to biodiversity monitoring targets relevant to Akyem mine. Researchers' specifically surveyed and determined the trend in the number of wildlife (especially species of global concerns) observed in forest fragments and 60-ha reforestation plot, and assessed the presence and distribution of Hooded vulture (*Necrosyrtes monachus*) in and around NGRL mine boundary. The objective of this study was to provide information for adaptive management, such as identifying areas requiring improvements to wildlife management and the effectiveness of mitigation efforts, aimed at reducing potential mortality risks. It would also contribute to understanding the human impacts on vultures and mammal assemblages in and around the mining community.

Fauna survey on avifauna, large mammals including bats, reptiles, and amphibians were conducted within Akyem mine concession area by the research team. Also, the use of camera traps was key to this survey, especially for information on illusive species. Information on the presence and distribution of vultures is being gathered by visiting the waste-dump sites where Newmont and the communities surrounding the Akyem mine dump their non-toxic waste materials.

Results revealed that the number of amphibians decreased in this survey but increased for reptiles, birds and mammals within the remnant forest. The species diversity decreased for amphibians but increased slightly for reptiles, birds and mammals. In the reforested plantation, the species diversity increased for reptiles, birds and mammals but decreased for amphibians. Ten birds, and 3 mammals recorded for this survey were completely protected as per Ghana's wildlife laws. Chao 2 estimator of species richness revealed that we had recovered 94% of amphibians,

80.3% of birds and 89.6% of the mammals present within the remnant forest, indicating that our sampling procedure was adequate, except for reptiles (68.3%). In the reforested plantation area, the Chao 2 estimator of species richness showed that we had recovered 91.4% of amphibians, 93.4% of reptiles, 83.9% of birds, 99.2% of mammals and 89.7% of butterflies. The multivariate regression showed that overall species richness declined with disturbance and was statistically significant (Wilks' lambda=0.02, $P<0.05$). From the camera traps analysis, the total trap success was 3.25% and 0.61% respectively before and after a barbed wire fence was established at the forest buffer. There are resident vulture population at the Akyem Mine Inert waste dump site, and New Abirem, but temporarily absent in the surrounding communities. Wildlife species of 'special concern' (species of concern) at the site include *Necrosyrtes monachus* (Plate 8: Critically Endangered), *Hipposideros jonesi* (Plate 9: Near-threatened) and *Phataginus tricuspis* (Plate 10: Vulnerable). It is recommended that consistent biodiversity monitoring and evaluation should be integrated into the Akyem mine project overall Environmental and Social Management System Plan and linked to management actions.

Plate 8: *Necrosyrtes monachus*

Plate 9: *Hipposideros jonesi*

Plate 10: *Phataginus tricuspis*

OUTPUT 2.4 VEGETATION AND SOIL ERODIBILITY MONITORING OF RECLAIMED SITES, AHAFO GOLD OPERATIONS

Research Team: *P.P. Bosu; B.O. Kankam; L. Amissah; G. Djagbletey; G. Quansah; E. O. Adjei and E. Gaisie.*

Donor: *Newmont Ghana Gold Limited*

Newmont Ghana Gold Limited (NGGL) is reclaiming its degraded lands within the operational sites to bring it up to a level where its ecological integrity and/or socioeconomic relevance will be enhanced in compliance with statutory obligations outlined in the Environmental Assessment Regulations,1999 (L.I.1652) and Minerals and Mining (Health, Safety and Technical) Regulations, 2012 (L.I.2182) of Ghana. As part of this obligation, a 70ha waste rock surface was reclaimed at the operational area using indigenous and exotic tree species from 2009 to 2015 to mitigate the environmental impacts of its operation. The main objective of this assignment was to monitor the process of restoration of the 70ha reclaimed site at the NGGL at Ahafo Kenyase, based on selected biophysical properties (vegetation, fauna and soil).

This report represents a broad range of study efforts and goals. The study included a variety of research efforts, such as vegetation cover assessment, soil erodibility studies of reclaimed sites, fauna survey, Leaf Area Index assessment and invertebrate assessment.

Apensu site exhibited the highest (7.60 cm^2 ha^{-1}) for the overall basal area (BA) of both the indigenous and the exotic species in the different sites while Subika East recorded the least with the value of 1.77 cm^2 ha^{-1}. Considering basal areas separately i.e. basal area for indigenous species (BAI) and basal area for exotic species (BAE), Amoma site recorded the highest BAI (4.23 cm^2 ha^{-1}), while Subika West recorded the highest BAE with the value of 5.91cm^2 ha^{-1}. Species richness was 16, 15, 9 and 7 for Amoma, Apensu, Subika East and Subika West site respectively. *Trema orientalis* exhibited the highest IVI of 67.63, in the Amoma site, *Gmelina arborea* recorded the highest IVI of 65.92 in the Apensu site, *Gmelina arborea* exhibited the highest IVI of 117.76 in Subika West, while *Solanum erianthum* exhibited the highest IVI of 117.55 in Subika East. Subika East recorded the highest (88.89%) and the least (11.11%) of indigenous and exotic species population, respectively. The least percentage of indigenous species population (42.86 %) was recorded in Subika West site.

Soil texture were loam, clay loam and silt clay loam, whilst bulk density range of 1.2 -1.5 gcm^{-3} falls within the ideal range for efficient plant growth and water infiltration. Soil erodibility ranged from 0.38 to 0.47 which is considered highly susceptible to erosion. Soil loss on the study plots ranged from 0.42 Mg $ha^{-1}y^{-1}$ to 4.50 Mg $ha^{-1}y^{-1}$ and rated as very low indicating that erosion control strategies adopted by the Company in their reclamation programme is effective.

There was an increase in the number of species recorded for amphibians, birds and bats but decrease in mammals (small mammal and medium to large mammals). There was also a decrease in the number of species for reptiles. Six families, 6 genera and 8 species of amphibians were recorded as compared to 3 families, 3 genera and 3 species of amphibians in 1999/2000. For birds, 31 families, 55 genera and 85 species were recorded for this survey; whereas 24 families, 52 genera and 62 species were recorded in 1999/2000. A bird, *Necrosyrtes monachus* is listed as Critically Endangered. A new species of forest robin in the genus *Stiphrornis* (*Stiphrornis inexpectatus*) was recorded at the Apensu North reclaimed site. The Shannon-wiener diversity for bats was relatively high (H'= 1.64) for this survey than the baseline survey (H'=1.25) in 1999/2000 in the Boskumese and Amama Forest Reserves, which lie on the periphery of Ahafo mining lease area. However, for small mammals (rodents), Shannon diversity was high for the baseline survey in 1999/2000 (H'=1.53) than the current survey (H'=0.56). Most of the animals were recorded at the Apensu North reclaimed site. Five medium-to-large sized mammals were detected by the camera traps. Giant pouched rat (*Cricetomys gambianus*) was the most recorded species (n=20; 2.50 detections/ 100 camera trap days) followed by Striped ground squirrel (*Xerus erythropus*) (n=5; 0.83 detections/ 100 camera trap days).

Leaf area index (LAI) differed significantly among the various sites assessed. Measured LAI values obtained in most of the sites sampled were generally within the range (1.2-12.94) obtained in tropical forests.

Major taxonomic groups of insects collected from pitfall traps and baited butterfly traps show clear trends towards recovery of arthropod population within the sites following the reclamation and rehabilitation of the sites. Butterflies and various species of ants, which are well-known bioindicators of ecosystem health were recorded in nearly all the reclaimed sites.

From the results it can be concluded that:

1. Though Apensu site exhibited the highest Basal area (BA) (7.60 cm^2ha^{-1}), it is still low, compared to a typical tropical forest, suggesting that, there is potential for full recovery barring any external perturbation. The extraordinarily low percentage (11.11%) exotic species composition at the Subika East site, low percentage (20%) exotic species composition at Apensu and low percentage (42.86%) indigenous species composition at Subika West may be due to species failure.
2. Soil texture and bulk density of reclaimed plots allow for higher infiltration and could reduce soil erosion through runoff.
3. Soil erodibility (K) levels on the reclaimed plots were high indicating that the reclaimed plots are inherently susceptible to erosion. However, soil loss on the study plots were within tolerable soil loss range (<6.7) as a result of effective vegetative cover.
4. Soil erosion control measures deployed on reclaimed sites were therefore evaluated as effective.
5. The number of families, genera and species of amphibians has increased than the previous baseline survey in 1999/2000. Wildlife is returning to the disturbed 70ha waste rock surface that was reclaimed at the Ahafo South mine.
6. The capture of five new species at the site and the loss of three species within 17/18 years suggest there is ongoing species turnover.
7. Results from the Leaf area index (LAI) suggests that the foliar cover of most of the restored sites assessed is adequate to aid ecological processes and therefore ecosystem functioning and provision of ecosystem services such as climate regulation.
8. LAI values for 75% (6 out of 8) of the restored sites measured were below $4m^2\ m^{-2}$ and therefore represent a medium shade canopy. The other 25% (2 of 8 sites) represent a close canopy similar to a moist semi-deciduous forest in Ghana.
9. Across 34 plots, measured LAI values obtained in most of the locations sampled are generally within the range obtained in tropical forests.
10. The foliar cover of most of the restored site assessed has adequate canopy cover to aid ecological processes and therefore ecosystem functioning and provision of ecosystem services such as climate regulation similar to a secondary forest.

OUTPUT 2.5 NEWMONT GOLDEN RIDGE LIMITED WILDLIFE MONITORING PLAN

Research Team: *B.O. Kankam and L. Amissah,*
Donor: *Newmont Golden Ridge Limited*

Mine-related activities impact negatively on biodiversity. Surface mining activities largely affect the plants, wildlife, soils and rivers in many ways within an ecosystem. The monitoring goal of Newmont is to obtain a "healthy ecosystem" so that there would be "no additional loss" of wildlife/biodiversity at Newmont's operating sites. Recent bird mortality at Newmont Goldcorp Akyem Mine remains unclear due to the good practices adopted for sustainable mining by the

company. Research has established that cyanide and some heavy metals are harmful to wildlife when they are potentially exposed to them and therefore need to be assessed. Monitoring of wildlife by Newmont Goldcorp Akyem Mine is a vital component of not losing any additional biodiversity in their operations going forward.

The objective of this study is to 1) Survey and monitor the distribution of wildlife in forest fragments within the Newmont Goldcorp mine boundary; 2) Survey and monitor the distribution of wildlife in the 60ha established plantation within the Newmont Goldcorp mine boundary; 3) Assess wildlife interaction with the gold processing plant facility and the tailings system ponds in Newmont Goldcorp; 4) Determine bird mortality through the use of toxicological studies to assess the presence or absence of - Cyanide, Mercury, Lead, Cadmium and Arsenic or mortality causation agent(s). The wildlife monitoring programme helps to continually assess how well different wildlife respond to the changing mining environment. This research will also provide information for adaptive management, such as identifying areas requiring improvements to wildlife management and the effectiveness of mitigation efforts aimed at reducing potential mortality risks.

Fauna survey on avifauna, large mammals including bats, reptiles and amphibians were conducted within Akyem Mine concession area by the research team. Also, camera traps were installed to gather information on illusive species. The eight dead pied crows (*Corvus albus*) retrieved from the survey area were sent to the Chemistry Department and School of Veterinary Medicine, University of Ghana, Legon, Accra for laboratory examination (post-mortem) to determine the possible causes of death.

Preliminary toxicology results showed the mean concentrations (mg kg−1 wet weight) of Cyanide (CN), Mercury (Hg), Lead (Pb), Cadmium (Cd) and Arsenic (As) from samples of dead pied crows' tissues/organs (brain, liver, heart, lungs, kidney, intestine, gizzard). The cyanide and heavy metal concentrations in the dead pied crows at the Akyem mine varied among tissues. The highest mean cyanide concentration of 75.41 mg/kg (range: 29.28–120.46) was found in the liver. Regarding mercury, the gizzard had the highest mean concentrations of 26.63 mg/kg (range: 5.89–43.81). Similarly, gizzard recorded the highest mean concentrations for arsenic [54.27 mg/kg (range: 12.78–94.00)]. The highest concentrations of cadmium was in the brain 5.49 mg/kg (range: 1.84–9.14), whereas lead was only found in trace amounts (<0.01 mg/kg: Below Detection Limit) in the examined organs.

Data collection began in November 2019. Data will be collected as scheduled to obtain all information necessary to address the specific objectives.

OUTPUT 2.6 ASSESSMENT OF THE SUITABILITY OF PLANTATION-GROWN *EUCALYPTUS* SPECIES AS UTILITY POLE MATERIAL IN GHANA

Research Team: *F. W. Owusu; E. Ebanyenle; J. Korang; M. Apetorgbor; H. Seidu; J. Govina; B. Brentuo; M. Mensah and F. Boakye.*

Donor: *CSIR-FORIG*

In Ghana, there has been over-reliance on *Tectona grandis* for the manufacture of utility poles. Close to a decade now, wooden poles from pines are imported into the country. In effect, Ofori, (2001) investigated the suitability of some Ghanaian wood species to be considered as alternatives.

Inarguably, the growth rate of these indigenous species is slow. MIRO Forestry Company Limited located at Asante Akyem Agogo has for the past 5 years been growing various trees species including eucalyptus on large-scale plantations. Due to the availability of the species in Ghana coupled with its utilisation in other countries as electricity poles, Asuboa wood treatment limited collaborated with CSIR-FORIG to investigate the suitability of the eucalyptus hybrid from MIRO (Ghana) Forestry and other established plantations in Ghana for use as electricity poles. The main objective of the study is to increase the timber resource base in the wood industry through the introduction and utilization of a new wood species (Eucalyptus spp) as a utility pole material in Ghana thereby contributing to sustainable resource management, climate change mitigation and livelihood improvement. The specific objective is to determine the suitability of plantation - grown Eucalyptus tree species as electric power transmission pole in Ghana.

Six (6) trees of Eucalyptus (three from each ecological zone) have been extracted from Pra-Anum forest reserve (Moist semi-deciduous forest zone) at Amantia in the Eastern region, for CSIR-FORIG) and Yenku forest reserve (Coastal savannah forest zone) at Winneba in the Central region and transported to CSIR-FORIG. These were processed into lumber and stacked for air drying. Disc samples of thickness 2cm were taken from axial positions (base, middle, top) and labelled. From each disc, samples were taken from both heartwood and sapwood portions to represent radial positions. Sampling from all positions is to capture any variability within each tree.

Morphological features such as sapwood width, diameter at breast height (dbh), log length, bottom, mid-length and top circumference were measured using linear tape, diameter tape etc. Match-stick size wood samples were prepared and macerated to dissolve lignin that hold individual wood tissues together. The maceration process follows a procedure described by Franklin (1923) and it enhances access to individual fibres, vessels and parenchyma. The dimensions of the fibres were measured using a National Compound Digital microscope and its associated Motic Image Plus software. Only straight and unbroken fibres were measured. Regarding tissue proportion investigation, 2cm cube samples were prepared and soaked in water over 21 days. Afterwards, cube samples were placed in 1:1 solution of ethanol and glycerol for another 21 days. When wood samples were adequately softened, thin (20-25 µm) wood sections were cut using a sledge microtome from the cross-sectional plane. The thin sections were stained in Safranin O and dehydrated in ethanol. They were then mounted permanently on specimen slides and oven dried at 60°C for 24 hours. Images of the cross-sectional surface were captured using the National Compound Digital microscopic. Wood tissues (fibres, vessels and parenchyma) were counted per mm^2 on cross-sectional surface using ImageJ software.

Again, discs of 50cm thick were cut from three and five trees of Eucalyptus species from Pra-Anum forest reserve (Amantia) and Yenku forest reserve (Winneba) respectively, and samples were initially prepared as shown in Plate 4 for the physical studies. The 2.5cm thickness strips were extracted and planed to 2cm thick. The 2 x 2cm square sections were then crosscut to 2cm cubes for moisture content and basic density determination according to standard procedure (BS 373). The moisture content (MC) and basic density were calculated from the formulae:

MC, % = ((Initial weight - Oven-dried mass) X 100% / Oven-dried mass)

Basic density (kg/m^3) = Oven-dried mass (kg) / Volume of water displaced by swollen specimen (m^3)

The method developed by Terazawa (1965) was adopted to estimate drying time, sensitivity to drying defects and ultimately kiln schedules by observing drying time and characterizing

the various kinds of defects (initial checks, cross-sectional deformation and honeycomb) that developed.

Samples were taken from wood blocks of size 14mm^3 obtained from sapwood, outer heartwood and inner heartwood of the butt, middle and top sections, serially numbered and oven dried at 103±2°C for 24 hours. Four test blocks from each section selected at random were weighed and tested against the white rot fungus, *Coriolopsis polyzona*. Soil block decay chambers (Kohl bottles) were half filled with field soil of 70% water-holding capacity after sieving through a 2mm wire mesh. Feeder strips of sizes 3mm x 15mm x 50mm were obtained from *Triplochiton scleroxylon*, soaked overnight and placed on the soil in bottles and sterilized at 15psi at 121°C for thirty minutes. Two discs (5mm diameter) from fresh cultures of *Coriolopsis polyzona*, the test fungus grown on 2% Malt Agar medium were placed at the edge of each feeder strip. The bottles were then incubated at 28± 2°C and relative humidity of 80%. When the feeder strips were fully covered by the mycelium of the test fungus, the four test blocks, which have been sterilized at 15psi at 121°C were placed aseptically on each feeder strip with their cross-surface face in contact with the mycelium and incubated at 28±2°C for 12 weeks after which they were oven dried at 103±2ćC and weighed. Quantitative assessment of percentage weight loss of the test blocks was determined using the following formula:

$$\%WL = \frac{\text{Initial dry weight-Final dry weight}}{\text{Initial dry weight}} \times 100$$

All the chemical tests were conducted according to TAPPI standards (2002) except for alcohol–benzene solubility, where instead of alcohol–benzene, acetone was used. Sample preparation for the 2nd phase of the MIRO/Asuboa Eucalyptus project has been done using planer and cross-cutting machines. These were conditioned in a chamber before mechanical strength tests. Plate 5 shows the prepared samples for mechanical strength test. Sapwood and heartwood samples of E*ucalyptus* wood spp. was taken from breast, mid and/or top height and sawn into strips. Wood blocks (14mm^3) representing each wood sample was selected for test against the test fungus *C. polyzona*, using the accelerated laboratory test (soil-wood block method) for 12 weeks.

For the purposes of easy identification for the mechanical strength tests, the trees were assigned unique identification codes as AM1, AM2, AM3 representing trees from Pra-Anum forest reserve at Amantia while WE2, WE3, WE4 representing those from Yenku forest reserve at Winneba.

Modulus of Elasticity (MOE) and Modulus of Rupture (MOR) had their samples prepared and tested based on British Standard BS 373-1957. All the trees were sectioned into Butt (B), Middle (M) and Top (T) with 10 specimens for each of the sections. The samples were tested using a Universal Testing Machine, UTM (Instron, model no. 4482) as shown in Plate 6. The results of the test were stored in an output folder by the Instron software. Test results were extracted into Microsoft Excel format and finally analyzed using the Origin Lab Software, version 9.0. The analysis was done comparing the means of the various sections within trees and that of tree-to-tree.

The mean values for the quantitative anatomical features investigated include fibre length, fibre diameter, fibre lumen width, fibre double wall thickness and proportion of fibre, parenchyma and vessels in mm^2. These variables investigated are known to influence, among others, basic wood density, treatability of wood, tensile strength, natural durability. Plates 7A and 7B show the photomicrographic images of a transverse section of Eucalyptus species from Winneba and Amantia respectively while Table 1 indicates the comparison of sapwood portion for the

Eucalyptus species from the two localities. The mean values recorded for sapwood width, both top and bottom were similar. However, the percentage of sapwood volume for Amantia materials was about 12%, lower than mean value recorded for Winneba materials. This observation is because the top circumference for Winneba samples was lower than Amantia materials. For the Eucalyptus trees extracted from the two different localities, overall mean values for fibre characteristics and wood tissue portions were comparable. However, Amantia materials are likely to be denser, exhibit superior tensile strength, and would be naturally durable than Winneba materials. The prediction is as a result of the longer and higher proportion of fibre in Amantia materials. Materials from Winneba would need effective preservative treatment to enhance its service life. In all, this anatomical study should complement other mechanical, physical, chemical, pathological, and treatability studies to deeply understand the wood of Eucalyptus grown in Ghana, and test its suitability for utilisation as utility pole in Ghana.

Table 1: Comparison of sapwood portion for Eucalyptus species from two localities in Ghana

Variable	Amantia			Winneba		
	Min	Max	Mean	Min	Max	Mean
Sapwood width at Butt (mm)	26.00	30.50	28.25	27.50	32.50	30.00
Sapwood width at top (mm)	18.50	33.50	26.00	27.50	29.00	28.25
% sapwood volume	8.00	15.00	11.50	26.20	32.40	29.30

The green moisture content for the *Eucalyptus alba* from Yenku forest reserve ranged from 20.13% to 113.27% with a mean moisture content of 45.64% at a standard deviation of 9.85. The analysis of variance indicated that differences between the mean moisture content of the trees were highly significant (df = 4, 639; f = 44.5; p = 0.000). The moisture contents were also different at the three different height positions. The highest mean moisture content was recorded at the bottom section (46.1%) and the lowest (43.36%) at the top sections of the trees. The moisture content values declined from the bottom section to the top. Mean basic density was also ranged from 642.25 kg/m^3 to 804.6 kg/m^3 and the mean density was 727.02 kg/m^3 (Std: 86.63). Mean basic density also varied at different stem positions of the trees and increased from the bottom (718.37 kg/m^3) towards the tops (741.53 kg/m^3).

Eucalyptus robusta from Pra-Anum forest reserve at Amantia had a mean moisture content value of 44.08%, which ranged from of 23.53 to 80.34%. Mean moisture content within trees along the stem height was lower in the middle (43.82%) than at the bottom (44.42%). The mean moisture content within sections of the trees was 44.08% from a range of 23.53 to 80.34. The results also revealed a mean basic density of 733.55 kg/m^3 (Stdev: 150) from a range of 461.59 –1520.43 kg/m^3. The mean basic density of the trees was 733.55 kg/m^3 (std: 150.46), which ranged from 461.59 to 1520.43 kg/m^3.

Generally, the mean basic density of *Eucalyptus alba* from Yenku (727.02 kg/m^3) was comparatively lower than that recorded for *E. robusta* (733.55 kg/m^3) while deviation in moisture content of the species was not significant. The proposed drying schedules correspond to Madison schedules as T8-B4/T10-B4 and T8-B5 for species from Pra-Anum forest reserve, Amantia and Yenku forest reserve at Winneba respectively.

The outer heartwood and inner heartwood of *E. robusta* trees felled from the Moist-Semi Deciduous Forest Zone (MSDFZ) were highly resistant (5.42% and 6.99% respectively) while the sapwood was moderately resistant (32.42%) to *C. polyzona*. The sapwood of *E. alba* trees from the Coastal Savannah Zone (CSZ) was equally moderately resistant (41.21%) to *C. polyzona* attack, while the outer heartwood was resistant (20.79%) followed by the inner heartwood which is rated highly resistant (3.17%). The percentage resistance of each of the species from the two ecological zones was obtained according to the standard ASTM D2017-05. Sapwood of *Eucalyptus robusta* and *E. alba* trees from both ecological zones (MSDFZ and CSZ) were found to be moderately resistant to the white rot fungus, *Coriolopsis polyzona* based on the standard procedures of ASTM D2017-05. Both timber species can be used for indoor application but for outdoor application, treatment with preservatives may be considered to enhance its service life.

Table 2 shows the mean chemical composition of *Eucalyptus robusta* extracted from the Pra-Anum forest reserve in the Moist Semi-Deciduous Forest Zone.

Table 2: Chemical composition of 3 trees of *Eucalyptus robusta* from Pra-Anum forest reserve

Composition	Percentage on tree basis			%
	Tree 1	Tree 2	Tree 3	
Moisture content	12.6	11.6	11.1	11.8
Cold water extract	19.6	17.3	19.5	18.8
Hot water solubility	24.1	21.2	23.7	23.0
Acetone extract	7.3	7.0	7.2	7.2
Ethanol extract	3.8	3.6	6.2	4.5
Holocellulose	44.0	52.6	46.2	47.6
Lignin	24.5	22.7	25.2	24.1
Cellulose	28.8	26.4	40.3	31.8
Hemicellulose	71.2	73.6	59.7	68.2

Table 3 compares the level of significance at the 0.05 level among the trees of each location of extraction, that is Amantia (Pra-Anum forest reserve - Moist semi-deciduous forest zone) and Winneba (Yenku forest reserve - Coastal savannah zone).

The longitudinal (sectional) comparison of the individual trees suggests uniform distribution of strength (MOE) along the tree height from bottom to the top for the trees extracted from Amantia and largely for that of Winneba.

Inter tree comparison suggests strength properties differ from each other for Eucalyptus from Amantia. Eucalyptus from Winneba, however, largely suggest uniform distribution of strength among the trees.

The location comparison, however, suggests significant differences among their MOEs with the Eucalyptus from Winneba recording a higher MOE. However, their MORs remain insignificant.

This strongly suggests that in the first instance, there is significant difference in the Tukey analysis of the means. The p-value of 0.03 also means there were significant differences between the two (Table 2).

Table 3: MOE/MOR at Moisture Content of 9.4% determined for individual trees

Tree ID	MOE (Nmm^{-2})		MOR (Nmm^{-2})	
	Mean	St. Dev.	Mean	St. Dev.
AM1	12,590	1,495.00	98.30	23.23
AM2	16,680	1,903.15	116.57	16.67
AM3	18,020	2,385.60	117.14	25.94
WE 2	16,905	2,311.07	103.56	24.02
WE3	15,601	2,031.64	95.16	26.53
WE4	16,482	1,502.07	104.47	13.32

Considering the MORs, the Tukey results from the ANOVA indicates that AM1-AM2 and AM1-AM3 had a p-value ‹ 0.05 suggesting significant difference among the two. However, AM2-AM3 had a p-value › 0.05 which suggests strongly that the difference of their mean MORs was insignificant. The ANOVA conducted on WE2, WE3 and WE4 indicated that WE2-WE3 at p-value ‹0.05 has a significant difference between their means. However, WE2-WE3 and WE3-WE4 displayed a p-values ›0.05 which suggests their differences were insignificant.

Table 4 shows the comparison of MOE and MOR between Eucalyptus extracted from Amantia and those from Yenku, Winneba.

Table 4: Comparison of strength properties for Eucalyptus from Amantia and Winneba at MC of 9.4%

Eucalyptus Source	MOE Nmm^{-2}	Standard Deviation	MOR Nmm^{-2}	Standard Deviation
Amantia (AM)	15,763	3,026.23	110.67	23.73
Winneba (WE)	16,329	2,029.56	101.06	22.20
One-Way ANOVA				
p-value	0.142		0.01	

P-value › 0.05 indicates insignificant difference and p-value ‹ 0.05 indicates significant difference

The one –way ANOVA (Tukey) results indicate that the modulus of elasticity among the two groups of Eucalyptus gave a *p-value* of 0.142 › 0.05. This strongly suggests that the MOEs of the two groups are not significantly different. However, the *p-value* of the Modulus of Rupture of the two groups was 0.01 ‹ 0.05 which strongly suggest they are significantly different.

The overall mean values of the Eucalyptus species from two different localities for fibre characteristics and wood tissue portions were comparable. Nevertheless, due to the longer and higher proportion of fibre in Amantia materials, the species is likely to be denser, exhibit superior tensile strength, and would be naturally durable than Winneba materials. Materials from Winneba would need effective preservative treatment to enhance its service life.

The mean basic density of *Eucalyptus alba* from Yenku and *E. robusta* from Pra-Anum forest reserves are 727.02 kg/m^3 and 733.55 kg/m^3 respectively. Again, the mean tangential and radial shrinkage values (over 5.5) and (over 3.0) respectively indicate that shrinkage from green to 12% moisture content is large. The ratio of tangential shrinkage to radial shrinkage (T/R) used as an index of dimensional stability is low. Early checks were mild and there was no honeycombing and deformation. The proposed drying kiln schedules for the species developed (T8-B4/T10-B4 for Pra-Anum forest reserve at Amantia and T8-B5 for Yenku forest reserve at Winneba), which correspond to Madison schedules, indicate that the wood can withstand high temperatures.

Sapwood of *Eucalyptus robusta* and *E. alba* trees from both ecological zones (MSDFZ and CSZ) were found to be moderately resistant to the white rot fungus, *Coriolopsis polyzona* based on the standard procedures of ASTM D2017-05. Both timber species can be used for indoor application but for outdoor application, treatment with preservatives may be considered to enhance its service life.

There were significant differences between the MOEs from Pra-Anum and eucalyptus species from Yenku forest in Winneba recorded higher MOE while their MORs remain insignificant.

Plate 11: Flitched billets of *Eucalyptus alba/robusta* from Yenku and Amantia

Plate 12: *Eucalyptus alba/robusta* lumber stacked for air drying

Plate 13: Sample discs for morphological and anatomical studies

Plate 14: Eucalyptus samples being prepared for physical tests

Plate 15A & B: Prepared specimens from *Eucalyptus* species for mechanical strength tests

Plate 16: Mechanical strength testing of prepared specimens from *Eucalyptus* species

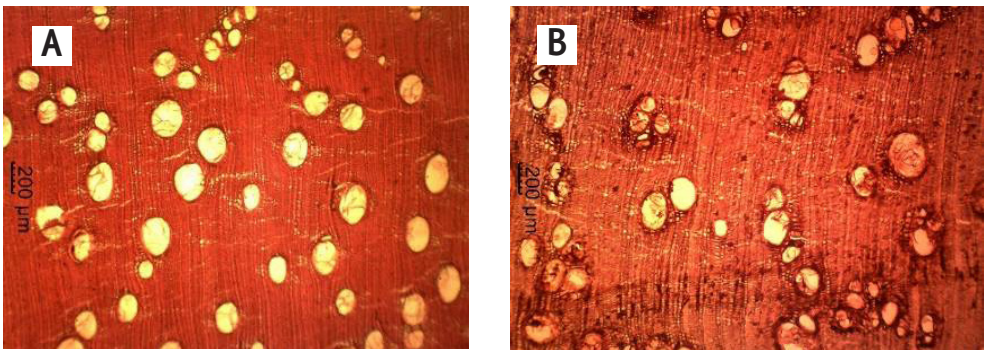

Plate 17: Photomicrographic images a transverse section of Eucalyptus species. Image labelled A represent Winneba samples, B for Amantia

OUTPUT 2.7 ESTABLISHING A LAND RESTORATION RESEARCH AND DEMONSTRATION AREA WITHIN DEGRADED MINING SITES IN THE BIBIANI AREAS, GHANA

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Donor: *CSIR-FORIG*

Forest ecosystem services are crucial in supporting human wellbeing. However, forest resources are under immense pressure from several forest sector illegal activities causing deforestation and forest degradation in Ghana's forest zone. Illegal surface mining (galamsey) is increasingly becoming a major cause of deforestation in Ghana with associated negative environmental consequences, including loss of numerous forest ecosystem functions and associated benefits. Conservation efforts to tackle degraded galamsey sites have so far been limited to fragmented initiatives with little or very low impact. This is partly due to the lack of comprehensive information on the galamsey value chain at the local level as well as limited understanding of the local perceptions and perceived economic values for forest ecosystem services and their role in supporting rural livelihoods. This study sought to contribute information on perceived

impact of galamsey activities on forest ecosystem services and rural livelihoods. Furthermore, it explored the indirect and non-use values of non-market forest ecosystem services from restored galamsey sites within the context of value orientations to inform policy directions in developing an integrated conservation mechanism for restoration activities.

The findings of this study revealed that, illegal mining activities are often initiated by foreign nationals in recent times, particularly Chinese with local collaborations. This was reported by about 66% of respondents. Land for mining activities were mainly offered by individual landowners either through outright purchase (63% leasing purposely for mining (25%) or mining on own family land. The findings further show the galamsey value chain was characterized by multiple actors including chiefs, landowners, youth groups, women, children as well as foreign nationals and non-native Ghanaian nationals. Profitability from land sales ranged between GHS8000.00 per acre to GHS40,000.00 depending on the land's richness in mineral deposits as identified during prospecting and the landowners' negotiation skills. Daily earnings from typical galamsey activities such as excavation, washing, soil gathering, food vending could range between GHS80.00 to GHS2000.00 per month depending on the type of activity and the vibrancy of the galamsey in the community. More than half of respondents reported that at least 1 to 3 known members of their households were involved in galamsey. Majority of respondents acknowledged the important role of forests in ecosystem services provision. Forest role in protecting rivers and streams from drying up (73.8%) and maintaining clean air quality and regulation of temperature (73.3%) received the highest percentages of responses with respect to perceived importance of forest functions. Nevertheless, the findings revealed respondents were extremely concerned about the tremendous negative impact of galamsey activities on forest ecosystem services including NTFPs and on rural livelihoods.

A similar trend of perceived negative impact was noted for NTFPs with majority of respondents reiterating current scarcity relative to abundance of NTFP'\s prior to galamsey activities in the communities. In spite of the reported short-term economic gains and other associated positive impacts of galamsey on livelihoods, reported negative impacts included prevalence of teenage pregnancy, increase in school dropouts, excessive use of alcohol and drug abuse. The temporary ban on galamsey was perceived to have brought both positive and negative consequences to forest resources and livelihoods. The most reported positive and negative impacts were improved water quality and increased economic hardships respectively.

OUTPUT 2.8 EVALUATION OF THE PHYTOREMEDIATION POTENTIAL OF SELECTED INDIGENOUS AND EXOTIC TREE SPECIES IN GHANA

Research Team: *A. Duah-Gyamfi; L. Amissah; J. K. Korang; R. T. Guuroh; S. A. Owusu and K. O. A. Agyemang*

Donor: *CSIR-FORIG*

Small scale mining is an important economic activity in Ghana. However, it is also a source of land degradation. A major environmental problem associated with small scale mining in Ghana and throughout the world, is heavy metal pollution of soils. In Ghana, soils of forests degraded by activities of small-scale mining have been rendered infertile and impoverished. These metal polluted soils are toxic for humans, animals, microorganisms and plants. Plants that survive on these soils may grow poorly and for food crops their products may not be fit for consumption.

Among the methods used to decontaminate degraded mine soils, phytoremediation has received increasing attention owing to its sustainability, low cost and easy large-scale applicability. The strategy employs plants to remove contaminants from degraded soils. In Ghana the potential of species to remediated heavy metal polluted sites is little understood. Therefore, the goal of this research is to determine the phytoremediation potential of selected indigenous and exotic tree species in Ghana.

Soil samples were randomly collected from a depth of 0-20cm from degraded mine portions of Atewa Range Forest Reserve and from mined sites at Bibiani. Seeds of selected species including *Tighemella heckelii, Termialia superba, Milicia excelsa, Nauclea didderichii, Cassia ssp, Tectona grandis, Cedrela odorata,* among others, were sown in bowls filled with soils collected from Atewa. Germinated seedlings were transplanted into Polyvinyl chloride (PVC) pipes filled with soils collected from the study sites. To assess growth performance and phytoremediation potential of the species, five replicates of each species were selected and monitored for growth performance in a completely randomized design manner in a greenhouse.

Relative height growth rate ranged between 0.004±0.001 cm cm^{-1} wk^{-1} and 0.048±0.010 cm cm^{-1} wk^{-1} for the mined soil from Atewa whereas relative height growth rate for the control ranged between 0.007±0.002 cm cm^{-1} wk^{-1} and 0.069±0.009 cm cm^{-1} wk^{-1} (Figure 4). *Nauclea diderrichii* recorded the highest relative growth rate in the mined soil followed by *Milicia excelsa*, *Terminalia superba* and *Tieghemella heckelli* with relative growth rates 0.039±0.010 cm cm^{-1} wk^{-1}, 0.022±0.004 cm cm^{-1} wk^{-1} and 0.004±0.001 cm cm^{-1} wk^{-1}, respectively. However, in the control *M. excelsa* recorded the highest relative growth rate followed by *N. diderrichii*, *T. superba* and *T. heckelli* with relative growth rates 0.056±0.015 cm cm^{-1} wk^{-1}, 0.028±0.003 cm cm^{-1} wk^{-1} and 0.007±0.002 cm cm^{-1} wk^{-1}, respectively. The results concur with similar studies that reported faster growth in controls compared with mined soils.

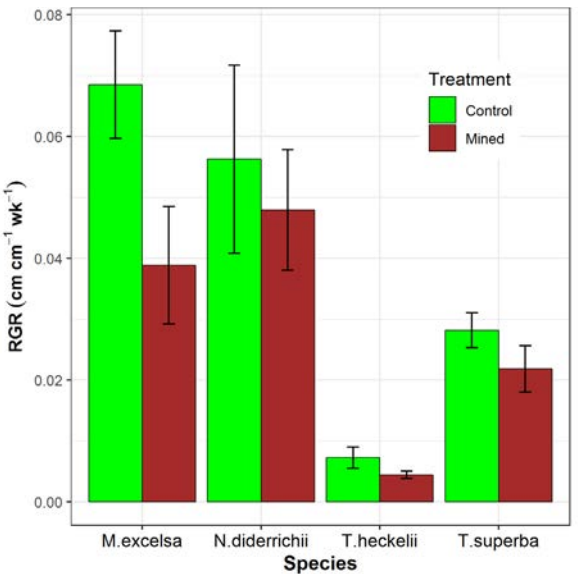

Figure 3: Relative height growth rate of *M. excelsa, N. diderrichii, T. heckelii and T. superba* in mined soil from Atewa Range Forest Reserve and unmined soil (control)

The slow growth in mined soil is attributable to accumulation of toxic metals in tissues of plants, which impairs physiological processes in plants and consequently hinders growth rate.

Generally, the plants showed potential for removal of heavy metals from the mined soils, particularly Cd and Pb (Figure 3). Total concentration of Cd was highest in *M. excelsa* (11.476 mg kg^{-1}) followed by *T. superba* (9.400 mg kg^{-1}), *N. diderrhichii* (9.338 mg kg^{-1}) and *T. heckelii* (7.619 mg kg^{-1}). Similarly, *M. excelsa* recorded the highest concentration of Pb in total (9.561 mg kg^{-1}) followed by *N. diderrhichii* (8.733 mg kg^{-1}), *T. superba* (6.912 mg kg^{-1}), and *T. heckelii* (5.424 mg kg^{-1}) (Figure 4).

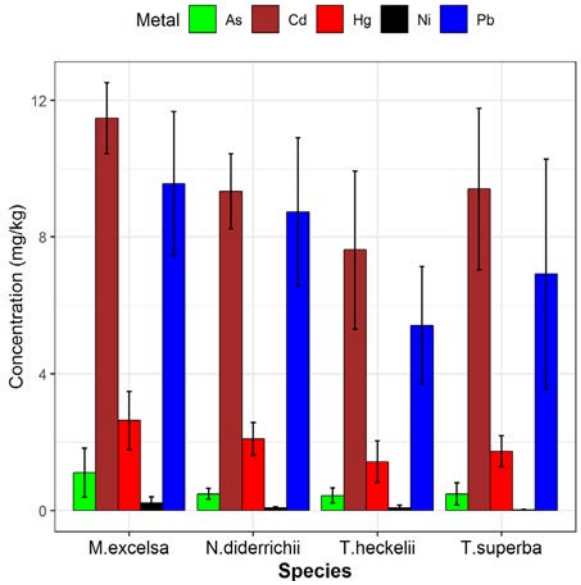

Figure 4: Concentration of heavy metal in *M. excelsa, N. diderrichii, T. heckelii* and T. *superba*

The high concentration of Cd and Pb observed concurs with a similar study on the phytoremediation potential of plants on rehabilitated sites at AngloGold Ashanti (Iduapriem) mine, Obuasi, Ghana (Bansah and Addo, 2016). It was observed that *T. superba* among other species (e.g. *Theobroma cacao*) had a high potential for the uptake of Cd and Pb (Bansah and Addo, 2016). The high Cd and Pb uptake by the plants may indicate appropriate mechanisms for the absorption of Cd and Pb by the plants.

OUTPUT 2.9 DEVELOP PROTOCOLS FOR MASS PRODUCTION OF SELECTED GENETICALLY SUPERIOR PLANTING MATERIALS OF SELECTED TREE SPECIES

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Donor: *World Bank*

There are inadequate seed sources to produce planting materials to meet the increasing demand to rehabilitate large tracts of degraded forest areas. This is because of irregular fruiting of some species as well as reduction in stocking levels of other species within the natural forest. Though vegetative propagation has been found to be a viable solution to this challenge, there are no protocols for vegetative propagation of many preferred species. The project therefore focused on developing protocols for vegetative propagation of selected indigenous species. The specific objective was to determine the rooting success, shoot formation and survival of stem and root cuttings of selected species.

The rooting success of two indigenous species; *Terminalia ivorensis* and *Entandrophragma candollei* was tested using stem cuttings of plants (*Terminalia ivorensis*) growing in a hedge garden at CSIR-FORIG and root cuttings of roots sampled from *Entandrophragma candollei* stand near CSIR-FORIG. Stem cuttings of 10cm long with two leaves were used. The cuttings were treated with hormone (Hormodin) of two different concentrations (0.1% and 0.3%) hereafter referred to as treatments. For each treatment, there were three replicates with 30 cuttings per replicate. The control (i.e. cuttings with no hormone added) had similar replicates with 30 individual cuttings per replicate. Similar design was used for the root cuttings. The root cuttings were planted vertically with the distal end down in the propagator. The root cuttings were planted in the propagators (Plate 18) **on 3rd July 2019**. In the case of *Terminalia ivorensis,* the stem cuttings were planted in the propagator (Plate 18) on 17th July 2019.

Rooting success of *Entandrophragma candollei* was tested using stem cuttings from seedlings produced from wildlings collected from Birim South Forest Reserve. No hormones were applied to the cuttings. There were insufficient seedlings to allow for replication and also for testing the impact of hormones on rooting. This was a preliminary study due to insufficient seedlings at the nursery; the few mature *Entandrophragma candollei* trees in the Birim South Forest Reserve have not been in fruit for the past three years that the trees have been monitored.

Plate 18A & B: Stem cuttings of *Terminalia ivorensis* planted in the propagator

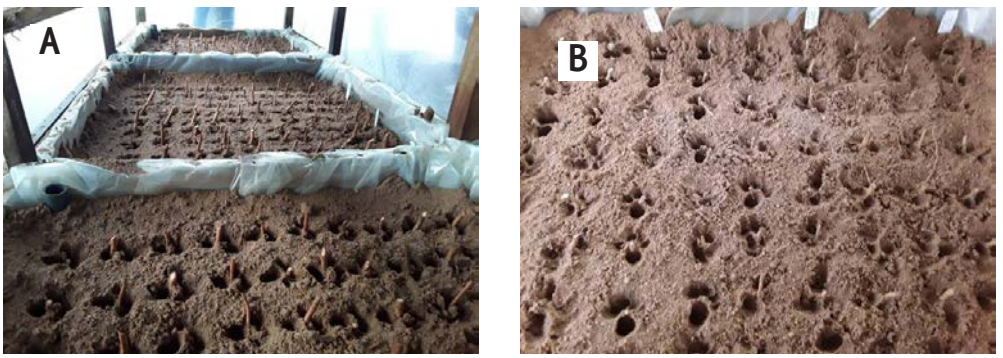

Plate 19A & B: *Entandrophragma candollei* root cuttings planted in a propagator

Vegetative propagation experiment conducted using stem and root cuttings of *Entandrophragma candollei* and *Terminalia ivorensis* did not yield good rooting success, an indication that the species may not be propagated using stem and root cuttings.

Rooting success of *Entandrophragma candollei* tested using stem cuttings of seedlings produced from wildlings collected from Birim South Forest Reserve and without hormone application produced 90% rooting success (Plate 19). This suggests that *Entandrophragma candollei* can be propagated using seedlings. However, this is only a preliminary result as few seedlings were used for the experiment due to the scarcity of seed sources and natural regeneration of the species. The experiment should therefore be repeated using more replicates and different hormone levels to confirm the results obtained in this initial experiment.

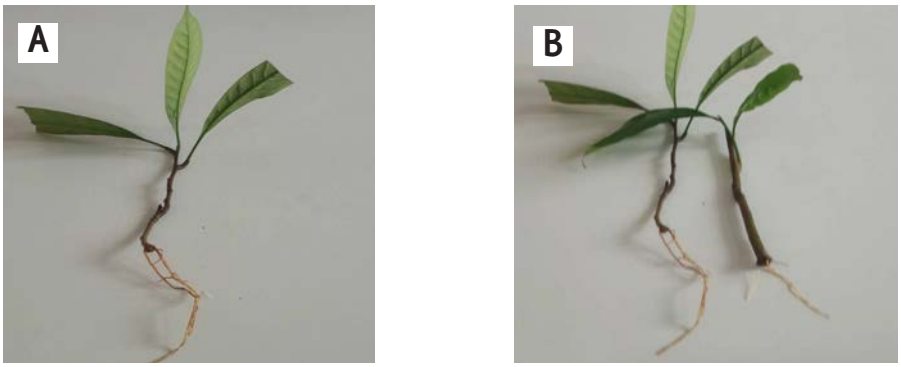

Plate 20A & B: Rooted cuttings of *Entandrophragma candollei*

The experiment on the vegetative propagation of *Entandrophragma candollei* should be repeated using more replicates and different hormone levels to confirm the results obtained in the initial experiment. Additional indigenous species whose seed sources are dwindling may also be included in the experiment.

OUTPUT 2.10 PRODUCTION OF GENETICALLY SUPERIOR PLANTING STOCKS OF SELECTED TREE SPECIES THROUGH THE ESTABLISHMENT OF SEED ORCHARDS

Research Team: *L. Amissah; J. Mireku Asomaning; E. G. Foli; S. Owusu and E. Manu.*

Donor: *World Bank*

Deforestation and forest degradation have continued over the past decade in many tropical areas including Ghana despite efforts at global and national levels to curb the menace. This has brought much focus on the need for restoration of these deforested and degraded areas as well as the development of commercial plantations, which is expected to reduce pressure on natural forests in the near future. However, there are currently inadequate seed sources for production of high-quality seedlings to facilitate such forest restoration and commercial plantation development efforts due to irregular fruiting of some species, low stock of seed trees attributable to overexploitation that has characterised production of wood for export and the local timber market as well as rampant wildfires. The objective of the project was to establish seed orchards using seedlings or clones produced from seeds or scion materials collected from superior trees to produce seeds of superior genetic quality compared to those obtained from unimproved stands.

Periodic monitoring and maintenance of all seedlings and clonal seed orchards established from 2016 to 2018 was carried out. These included 2-ha seedling seed orchard at Bia Tano Forest

Reserve at Gambia No. 1 (Plate 21), 6-ha clonal seed orchard at Asenayo Forest Reserve at Akota, 8-ha seedling seed orchard at Subri Forest Reserve at Benso (Plate 22), 15-ha seedling seed orchard at Pra Anum Forest Reserve at Amantia and 17-ha seedling seed orchard at Afram Headwaters Forest Reserve at Abofour. An assessment of orchards established in 2017 and 2018 was carried to ensure sufficient preparation was made to enable the replacement (beating up) of dead seedlings in the stands.

Land was prepared at Afram Headwaters (2-ha) at Abofour and Asenayo Forest Reserve (2-ha) at Akota for the establishment of seedling seed orchards using seedlings produced from seeds of *Gmelina arborea* and *Eucalyptus* provenances imported from Tanzania. Three *Eucalyptus* provenances were planted with spacing of 6m by 6m. In Afram Headwaters Forest Reserve, seedlings of 6 provenances of *Gmelina arborea* were used. Metal sign posts were made for all seed orchards established from 2016-2019.

Maintenance and monitoring were carried for 44ha seedling and clonal seed orchards established from 2016-2018. The orchards comprised 2-ha (1-ha *Pericopsis elata*, 1-ha; *Triplochiton scleroxylon,* Plate 20) at Bia Tano, 4-ha grafted *Khaya ivorensis* and 2-ha of grafted *Pericopsis elata* (Plate 24) at Asenayo Forest Reserve, 4- ha *Nauclea diderrichii* (Plate 23a) and 2-ha *Tieghemella heckelii* (Plate 23b), 15-ha *Gmelina arborea* planted at Pra Anum Forest Reserve, 17-ha *Gmelina arborea* and 4-ha *Tectona grandis* at Afram Headwaters Forest Reserve.

In 2019, an additional 2-ha *Gmelina arborea* seedling seed orchard was established at Afram Headwaters Forest Reserve and 2-ha *Eucalyptus* seedling seed orchard established at Asenayo Forest Reserve. Beating up was carried out in the 6-ha seedling seed orchard (*Nauclea diderrichii*, *Tieghemella* heckelii) established at Subri Forest Reserve, Benso in 2017 (beating up could not be done in 2018 due to unavailability of seedlings, and 32 ha seedling seed orchards comprising (*Gmelina arborea* and *Tectona grandis*) established at Afram Headwaters and Pra Annum forest reserves in 2018.

All seed orchards established in 2016, 2017 and 2018 were monitored to assess the trees for the need to pollard. Signposts (Plate 25) were mounted at the sites where seedling and clonal orchards have been established.

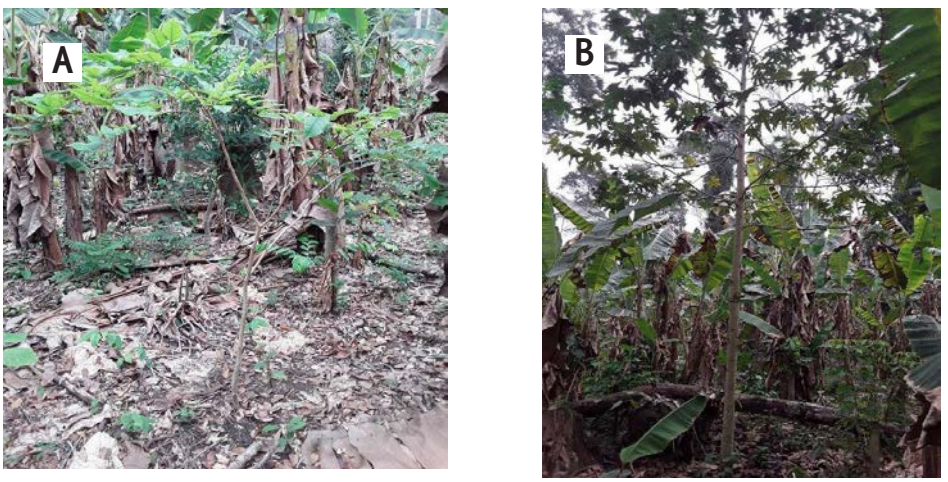

Plate 21A & B: Saplings growing in seedling seed orchards established in 2016 at Bia Tano Forest Reserve at Gambia No 1. (a) *Pericopsis elata*) and (b) *Triplochiton scleroxylon*.

Plate 22A & B: Measurement of clones in seed orchards established in 2017 at Asenayo Forest Reserve

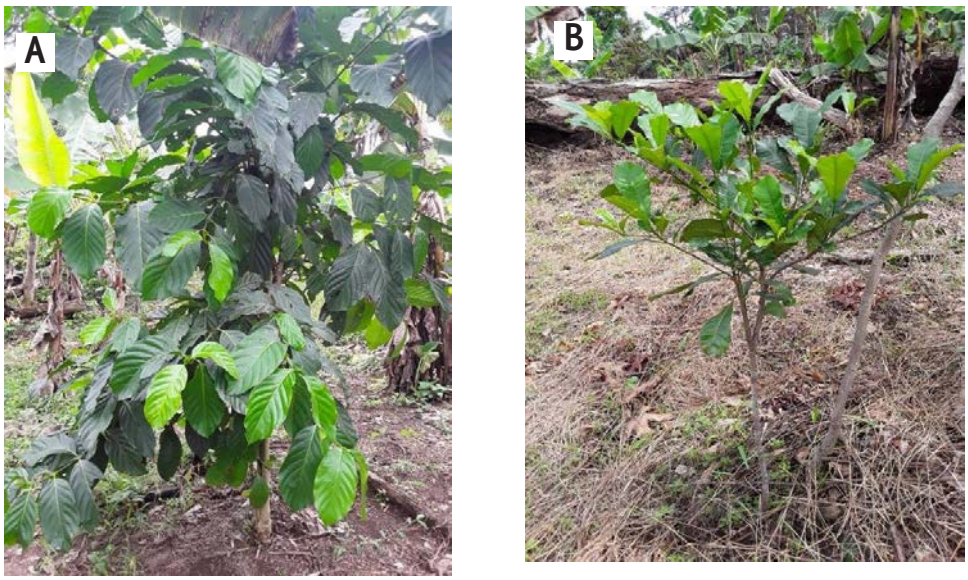

Plate 23A & B: Saplings growing in seedling seed orchards established in 2017 at Subri Forest Reserve at Benso (a) *Nauclea diderrichii* and (b) *Tieghemella heckelii*

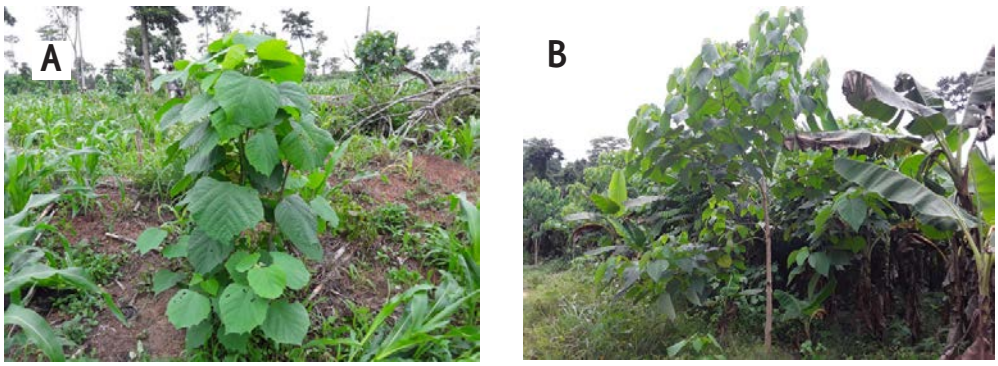

Plate 24A & B: Saplings of *Gmelina arborea* growing in orchards established in 2018 at a) Afram Headwaters Forest Reserve and (b) Pra Anum Forest Reserve.

Plate 25A & B: Metal sign post mounted at Subri and Pra Anum Forest Reserves Maintenance of the orchards established in 2016, 2017, 2018, and 2019 will be continued. The saplings will be pollarded to enhance lateral branching.

OUTPUT 2.11 EX SITU CONSERVATION OF *TALBOTIELLA GENTII* IN TAIN II FOREST RESERVE

Research Team: *L. Amissah, D. Ofori, D. Dompreh, S. Owusu*
Donor: *FORM International*

In Ghana, *Talbotiella gentii* is one of the few endemic tree species and is a priority for conservation (Hawthorne & Abu-Juam, 1995). Threats to *Talbotiella gentii* include wildfires, exploitation for charcoal, firewood and farming activities (Amissah, 2005). *Talbotiella gentii* has been found to experience high rates of fruit abortion, low fruit and seed set, low germination capacity and low seedling survival. These problems could reduce gene flow between populations leading to inbreeding and loss of diversity rendering the species less capable of surviving changing environmental conditions. To prevent loss of genetically distinct population, there is the need to implement both in situ and ex situ conservation measures.

This project is aimed at conserving *Talbotiella gentii* populations by *ex situ* method at Afram Headwaters and Asenayo Forest Reserves. The specific objectives are:

1. To collect seed samples from the existing *Talbotiella gentii* populations in Ghana
2. To raise planting materials for ex situ conservation plots establishment
3. To study the suitability of the selected planting sites for survival and growth of the species with respect to climate and soil conditions
4. To establish ex situ conservation plots of *T. gentii*

Seedlings (6,500, Plate 26) were produced from seeds collected from Bandai Hill Forest Reserve and wildlings collected from Yongwa Forest Reserve. Seeds from Bandai Hills were collected from eight accessions (trees). Two-hectare ex-situ conservation plots were established at Afram Headwaters Forest Reserve, which is a dry semi deciduous forest type (Plate 27) and Asenayo Forest Reserve (Plate 28), which is a moist semi deciduous forest type. In each site, four 50m by 50m plots were established and seedlings planted using a spacing of 3m by 3m in a completely randomized design. The planted seedlings are being monitored at an interval of six months for their performance (survival and growth). The plots double as ex-situ conservation and experimental plots which are being used to determine the performance of the species outside its home natural range. Two measurements (height, diameter and number of leaves) and survival

assessment of the planted seedlings were completed. Two measurements (height, diameter and number of leaves) were also done in the 1-ha ex situ plots established in 2018.

Plate 26A & B: Seedlings of *Talbotiella gentii* growing at CSIR-FORIG nursery

Plate 27A & B: Planting of *Talbotiella gentii* seedlings on a plot at Afram Headwaters Forest Reserve

Plate 28A & B: Diameter and height measurement of *Talbotiella gentii* seedlings growing in the field at Asenayo Forest Reserve

Preliminary analysis of performance showed 82% seedling survival in the moist forest (Asenayo Forest Reserve) and 70% survival in the dry forest (Afram Headwaters Forest Reserve). So far, a total of 2000 seedlings are still growing at the CSIR-FORIG Nursery and will be planted during the 2020 growing season.

OUTPUT 2.12 FOREST INVESTMENT PROGRAMME (FIP): SOCIO-ECONOMIC AND AGRO-ECOLOGICAL STUDIES

Research Team: *B. Darko Obiri; E. A. Obeng; K. A. Oduro; L. Damnyag; L. Anglaare; J. Korang; S. Pentsil; E. G. Foli; R. Adjei; K. Asumadu and K. Sarfo Bonsu*

Donor: *World Bank/GoG*

Extensive deforestation and forest degradation in forest–agricultural landscapes especially in Brong Ahafo and Western Region cocoa landscapes threaten crop productivity and increases the vulnerability of the cocoa economy and livelihoods to climate change. The FIP socio-economic and agro-ecological studies have been executed under activity 3.4.1 of the Forest Investment Project-ENFALP. It has been designed to cover the period 2016-2020. This report covers the progress of activities from January-December 2019 as well as a brief on the overall objectives to clarify the context and status of achievement from inception of the research to date.

The overall objective of the FIP socio-economic and agro-ecological studies is to describe the context and analyse factors including tree crop management and potential integration into forest-agricultural landscape in FIP areas. This is to guide research, promotion and adoption of Climate Smart Interventions planned under the FIP. The specific objectives are as follows: 1) Analyse crop land management strategies including trees on farm lands, tenurial issues, agro-chemical usage to guide tree integration on farmlands. 2) Identify determinants of tree integration through Willingness to pay methodology/perceived economic values to inform policy. 3) Analyse land use conflicts including tenure regimes challenging sustainability of forest-cocoa landscape. 4) Assess cocoa intensification especially the use of a wide range of agro-chemicals for weed, pest and disease control as well as fertility management and effects on agro-bio-diversity/food security to inform design of suitable agroforestry techniques for cocoa and food production on sustainable basis.

Plate 29A - D: A meeting with local communities and relevant institutions including the FSD, Traditional authorities, CHRAJ, Security Services, NGOs, COCOBOD

The FIP socio-economic and agro-ecological studies have from 2016-2019 been conducted across over 60 communities (admitted farms, fringe communities and CREMAs) distributed across 21 administrative districts and involved over 1000 respondents in the Brong Ahafo and Western Regions where the Forest Investment Programme activities are being executed. The distribution of the study communities cut across 16 forest reserves in 10 forest districts.

A mix of qualitative and quantitative social and economic research methods have been used including key informant interviews, focus group discussions and questionnaire surveys to engage local communities and relevant institutions including the FSD, Traditional authorities, CHRAJ, Security Services, NGOs, COCOBOD, etc. for the collection of data.

Using coded questionnaire, data was collected from 340 farmers in 10 cocoa farming communities in three forest districts (Asankragua, Juaboso and Enchi) in the Western North Region of Ghana where FIP activities are being executed. The data was analysed descriptively and quantitatively.

Approximately 30% of the respondents were female, and the average age of the sample was about 48 years with 63% above 45 years. More than half (54.3%) were natives of their communities while temporal migrants and permanent settlers made up 10.8% and 34.9% respectively. Average household size was 7 with a minimum of 1 and maximum of 21 members respectively. More than half (54.3%) of respondents had formal education. Out of this, majority (64.3%) had middle school/junior high certificate, 18.5% had primary/basic level education, 11.6% had secondary/ senior high education while 5.6% had post-secondary education including vocational, technical or tertiary level education. The mean monthly income for households was about GHS 847.02. Cocoa farming was the primary occupation for almost all respondents (97.6%) with minority 2.4 % engaged in other non-farm based primary occupation but have cocoa farming as a secondary occupation. Approximately 35% had additional secondary occupation besides farming. Majority of farmers (71.7 %) had their land ownership arrangement as family land, 2.2% had rented farm lands, 8.5% had purchased lands whiles 7.8% and 26.7% had government land and land acquisition through sharecropping arrangement respectively. The average cumulative farm size of respondents was 2.6 acres.

The attitude of farmers towards trees on farms and the forests' role in providing different ecosystem services was assessed. Figure 5 shows reported means for level of familiarity with the concepts of trees providing non-market ecosystem services. In general, respondents were more familiar with five of the six non-market forest ecosystem services provided by trees on farms having a mean of above 4 which denote "I am very knowledgeable about this role". Culture and spiritual significance of trees on farms/forest was the service less familiar to respondents relative to the other five. Nevertheless, the mean level of familiarity was 3.55 which denoted moderate knowledge on the 5-point Likert scale.

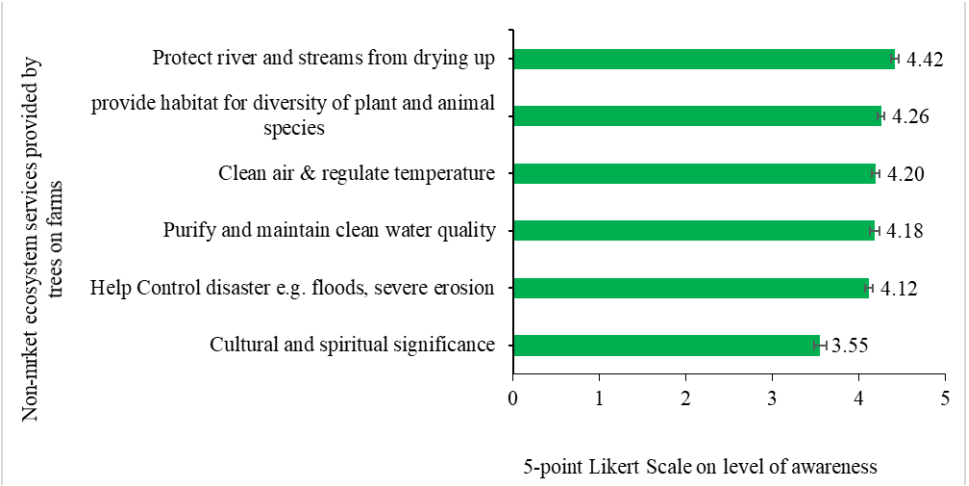

Figure 5: Respondents' level of awareness of non-market ecosystems services provided by trees on farms assessed on a 5-point Likert scale. (1 = I have no idea and have never heard of this role, 2 = I have slight knowledge of this role, 3 = I have moderate knowledge about it, 4 = I am very knowledgeable about this role, 5 = I am extremely knowledgeable about this role).

With regards to on-farm tree integration, 60 trees species were reported to be either planted or as naturally occurring trees which are tendered for on farms. Overall, about 83% of respondents had either retained naturally occurring trees or intentionally planted trees on their farms. Diversity of on-farm tree species reported by respondents is presented in Figure 6. Majority of the species are also economic timber species. The first 3 i.e. Ofram, Emire and Mahogany that are most planted are noted to be very fast growing and are among the best companion shade species.

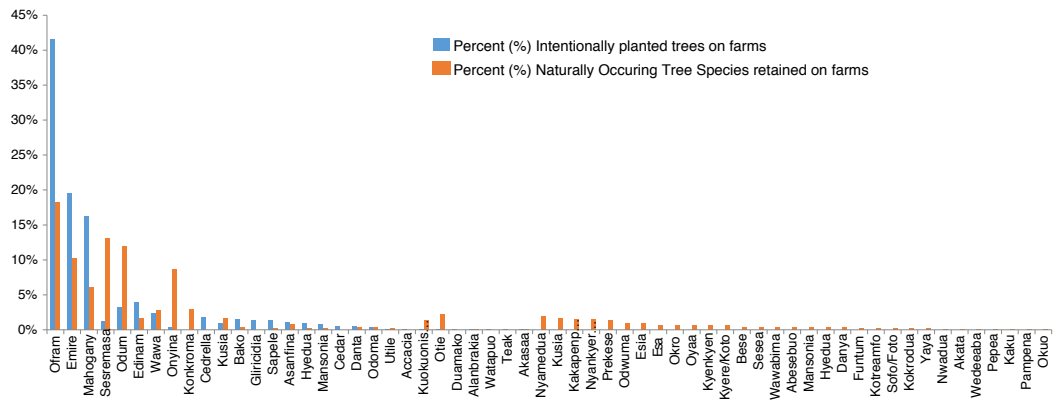

Figure 6: Tree species planted and intentionally retained on cocoa farms in study communities

Farmers keep trees on cocoa farms for 7 main reasons including shade provision for crops, medicinal purposes, environmental benefits and serving as collateral for accessing financial credits (Figure 7). Shade provision for crops was ranked by majority of respondents (85.2%) as the most important reason (Rank 1) for keeping trees on farms. This was followed by personal access to timber for wood products including furniture which was ranked 2 by almost half of respondents (47.4%). Similarly, approximately 37% and 34% of respondents ranked medicinal purposes and environmental benefits as the second most important reason for keeping trees on farms respectively.

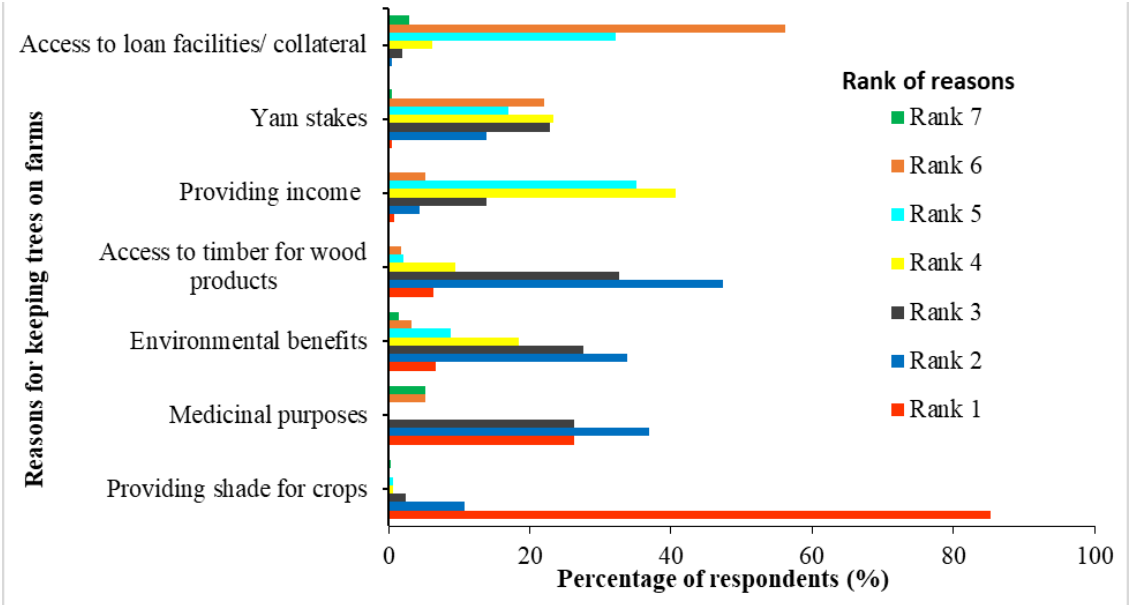

Figure 7: Percentage distribution of respondents ranking of reasons for keeping trees on farms (Ranking is based on 7-point scale of most important reason with 1 being the most important and 7 being least important)

Trees are also kept on farms and forests in general for various value motivation reasons based on the total economic value (TEV) framework across the three forest districts. All mean values were higher than 3 which suggest either greater than moderate level of importance attached to different values of forest ecosystem services i.e. use, bequest and existence values. Overall, conserving forest for its continuous existence was rated as the most important value motivation why farmers would want to engage in conservation initiatives with a mean of 4.6. This denotes "important" on the 6-point Likert scale and was statistically significantly different from 5 which denotes "very important" (test showed statistically significant difference between 4.6 and 5.0; p-value = 0.001). A Pearson chi-square test also shows a statistically significant difference ($P < 0.001$) in how respondents from the three forest districts ranked their level of importance attached to the existence value of forest. The next value motivation in respect of protecting forests is bequest values with a mean of 3.2, denoting "moderate importance". There is also statistically significant differences ($P = 0.08$) in how respondents from the three (3) forest districts perceive the bequest values of forest ecosystem services. Personal use values were the least rated value motivation with a mean of 3.1 denoting moderately important. However, respondents from Juaboso forest district rated this forest ecosystem values relatively higher (3.5) than the overall mean of the use values. A Pearson chi-square test shows a statistically significant difference ($P < 0.02$) in the ratings specific to personal use values by respondents in the three forest districts.

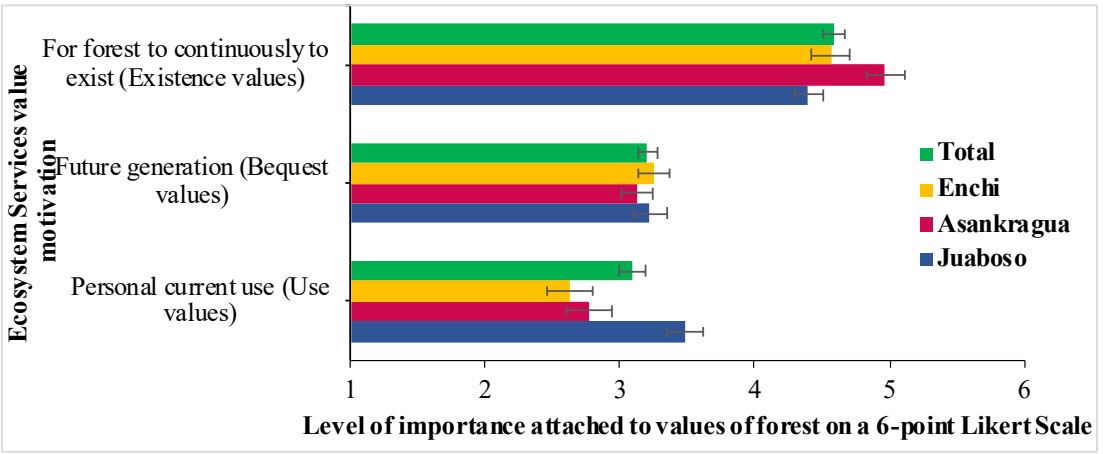

Figure 8: Respondents ratings of their Value motivation for forest protection based on the TEV framework. (6-point scale: 1 = Not at all important, 2= not important, 3= Moderately important 4= Important, 5=Very important, 6 = Extremely important)

The estimated economic values from the interval regression models (mean WTP and respective confidence intervals) are presented in **Table 5**. The mean WTP provides information on farmers economic values associated with supporting **ecosystem services provided by on-farm trees in cocoa landscapes.** The bundled supporting non-market ecosystem services of focus include providing habitat for pollinating insects – essential in cocoa cultivation, nutrient cycling and soil formation, carbon sequestration, watershed management that improves agriculture productivity. The overall monetary estimates using the sampled population ranged between GHS788.04 and GHS887.13 per household per year.

Table 5: Mean WTP for tropical rainforest watershed.

	Mean WTP estimates	95% confidence intervals† (GHS per household per year)	
Whole Sample	837.59***	788.04	887.13
Juaboso	855.63***	762.60	948.65
Enchi	815.7***	740.91	890.53
Asankragua	835.2***	754.4464	915.91

Statistical significance * = p < 0.1; ** = p < 0.05; *** p < 0.001;
†95% confidence intervals computed using parametric bootstrapping (1000 reps).

The mean WTP estimate considering the entire sample was computed as GHS 837.59 per household per year. Implicitly, a respondent on average would be willing to enroll in on-farm tree integration programme and pay approximately GHS837.59 per household per year for the provision of enhanced bundled supporting ecosystem services. Furthermore, cocoa farmers in Juaboso had relatively higher mean economic values than Enchi and Asankragua. Generally, this suggests that farmers have economic values for the supporting role provided by trees on their cocoa farms for the provision of supporting ecosystem services and are willing to pay for them through donation of cocoa beans during the harvesting and buying season even though most

of these supporting services are typically non-marketed with non-rivalry and non-excludability characteristics.

Results from the four major studies being executed under the socio-economic and agro-ecological aspects of the FIP research will ultimately lead to the determinants for adoption of the FIP Climate Smart interventions in greening the forest-agricultural landscape to reduce its vulnerability to climate variability. The willingness of farm households and local communities to plant trees (WTP) to restore and maintain the forest agriculture mosaic is critical. Hence, the identification of key factors that influence household decisions in participation in environmental programmes and adoption of the Climate Smart interventions in forest-agricultural landscapes, will serve as a useful guide for pro-poor environmental policies as well as in designing action-oriented research and development interventions, for reducing vulnerability of farm households to climate variability. It is suggested that considerations must be given to payments to compensate for the adoption of Climate Smart landscape strategies by local communities. Also, results from the assessment of effects of cocoa intensification practices on the status and magnitude of availability of NTFP and agro-biodiversity, will assist in designing policy options for food security and sustainable forest-agricultural landscape planning.

OUTPUT 2.13 CLIMATE AND LAND USE EFFECTS ON PLANT DIVERSITY IN GHANA

Research Team: *R.T. Guuroh; G. K. Adeyiga, and A. Duah-Gyamfi*
Donor: *British Ecological Society*

In Ghana, people tend to depend heavily on natural ecosystems for their survival thus making them highly vulnerable to environmental changes that have negative consequences on ecosystems .

The objective of this project was to contribute to an improved understanding on how land use and climate interactively affect vegetation composition, aboveground biomass production, as well as the taxonomic and functional diversity of woody and herbaceous vegetation in Ghana.

The project was conducted in three ecological zones in Ghana namely; the Forest-savannah Transition zone, the Guinea savannah zone and the Sudan savannah zone. In each zone, three land use types – protected areas with and without controlled fires and surrounding non-protected areas under communal use – were selected to study the differentiation in vegetation. A nested plot design was used for sampling data on the woody and herbaceous vegetation. One protected area (PA) and one non-protected area (nPA) were selected per ecological zone. In each PA, an unburnt area (PAU) and a burnt area subject to regular controlled fires (PAF) were identified with help of PA management.

The GPS coordinates of the 0.1 ha sample plots were recorded. Adult trees and shrubs with a stem diameter . 5cm at 1.3m (diameter at breast height, dbh) were recorded on the 0.1ha plots. Their species identity was recorded; their dbh was measured to the nearest centimetre and their canopy height to the nearest decimeter (see Ouédraogo et al., 2015). Juvenile woody plants (dbh ‹ 5cm) were recorded on the 180 subplots (25m^2). Their species identity was recorded and their canopy height was measured to the nearest decimeter. The identity, ground cover, phenological stage and height of all herbaceous species were recorded on the 180 sampling quadrats (1m^2). On 90 of the 1m^2 plots – where species identities, vegetative heights, ground cover and phenological stages have been recorded – the plant biomass were harvested at stubble

height (ca. 3cm) and separated into species, discarding moribund material (Guuroh, 2016). The samples were oven-dried (60°C, 48 hours) and weighed. We measured plant functional traits for five individuals of all woody species occurring on our plots. Besides height (see above), we assessed leaf area (LA), leaf dry matter content (LDMC) and specific leaf area (SLA), using standard protocols (Pérez-Harguindeguy *et al*., 2013). We additionally assembled plant functional traits from taxonomic literature for both woody and herbaceous vegetation. These included life history, life form, photosynthetic pathway, and growth habit. For woody species, we also compiled data on specific wood density. Historical climate data (over 30 years) was downloaded from WorldClim database online.

We used species richness and Shannon-Wiener Index of Diversity as response variables. Linear mixed-effect models and model selection were used to test the relationships between multiple environmental variables and the response variables. We found clear differences in species composition between land-use types across the climatic gradient for both the tree and herbaceous layers. We found differential responses of the herbaceous and tree layers to environmental drivers (Figures 9 to 12). Grazing pressure was an important predictor of all response variables (Figures 11 and 13). Climatic aridity and fire were only directly important for herbaceous vegetation (Figure 13) but not the tree layer (Figure 10) although their indirect effects on the tree layer cannot be discounted. For soil properties, organic matter was important for both vegetation layers (Figures 10 and 12). Magnesium and base saturation were only important for the tree layer (Figure 10) while sodium, organic matter and pH were important for the herbaceous layer (Figure 12). The marked differences in species composition for various land-uses along the climatic gradient imply that climate change will indeed have an effect on vegetation. The observed importance of grazing for all response variables implies that land-use could override climate effects and that appropriate land management strategies could mitigate potential negative effects of climate change.

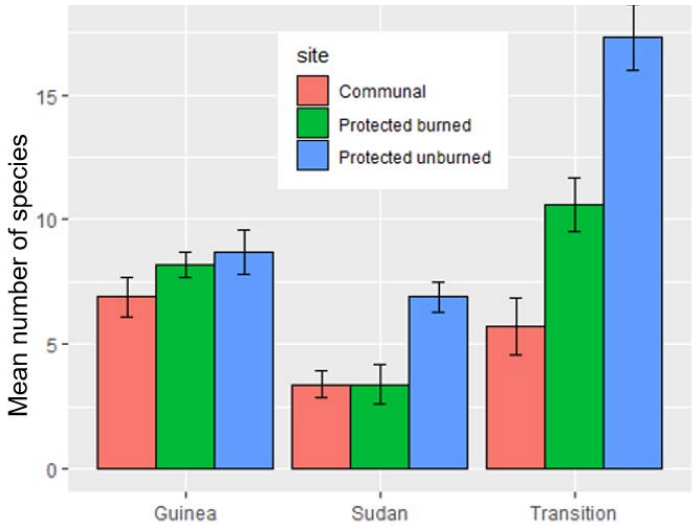

Figure 9: Mean tree species richness across ecological zones differentiated into land-use types.

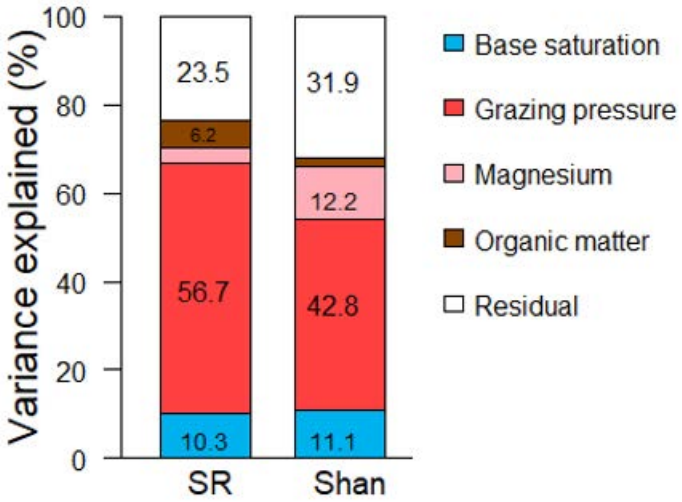

Figure 10: Variance explained by climate, soil and land-use predictors in linear mixed-effect model for woody layer. For each response variable, bars denote the proportion of variance explained by significant predictors, calculated as classical eta squared. Unexplained variances is included as residual. SR = Species richness, Shan = Shannon-Wiener Diversity Index.

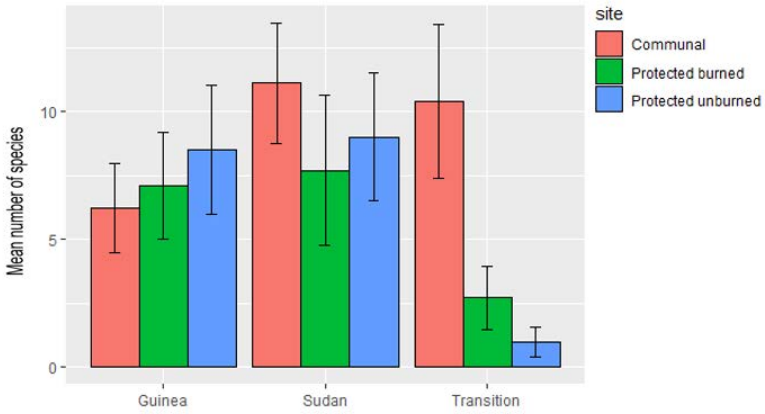

Figure 11: Mean herbaceous species richness across ecological zones differentiated into land-use types

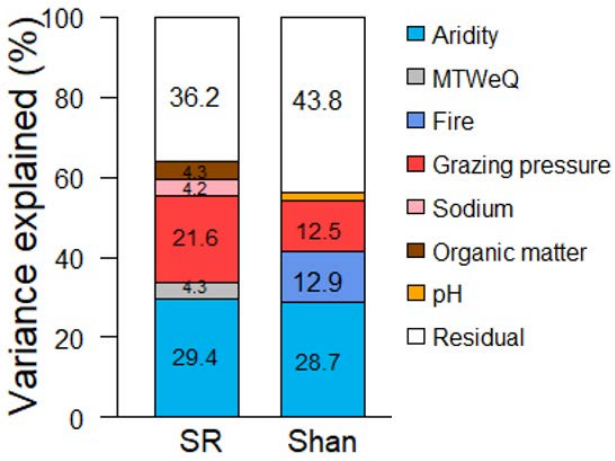

Figure 12: Variance explained by climate, soil and land-use predictors in linear mixed-effect model for the herbaceous layer. For each response variable, bars denote the proportion of variance explained by significant predictors, calculated as classical eta squared. Unexplained variances is included as residual. SR = Species richness, Shan = Shannon-Wiener Diversity Index.

OUTPUT 2.14 AGROFORESTRY FOR FOOD AND NUTRITION SECURITY, SUSTAINABLE LIVELIHOODS AND ENVIRONMENTAL SUSTAINABILITY IN GHANA

Research Team: *D. A. Ofori; L. Anglaaere; L. Amissah; L. Damnyag and J. Twintoh.*

Donor: *Modernizing Agriculture in Ghana (MAG)*

Land degradation, and more recently climate change, pose a challenge to the quest to increase agricultural productivity and therefore, the achievement of food and nutrition security in most developing countries especially in sub-Saharan Africa including Ghana. In Ghana, agriculture is the bedrock of its economy and contributes 19% of the Gross Domestic Product and accounts for over 43% of national employment, with smallholder farmers contributing up to 80% of all agriculture production in Ghana (MOFA, 2017a). However, in recent years agricultural productivity has consistently declined. Recent trends in production of major food crops such as maize, rice and sorghum have been found to show on-farm productivity stagnation (MOFA, 2017b). Many factors have contributed to this decline. Notable among them are soil fertility decline due to improper practices such as over cropping, over use of inorganic fertilizers and use of fires for land preparation. The use of inorganic fertilizer and other subsidy program may increase productivity for some crop but these are short-term fixes, which turn out to be unsustainable, environmentally as well as economically, because continuous cropping with inorganic fertilizers does not improve soil structure and texture but rather contributes further to environmental degradation and soil fertility decline. Agroforestry provides a safe and environmentally sound approach to solve these challenges. Agroforestry, which is the integration of trees with annual crop cultivation, livestock production and other farm activities, is a land management approache practised by more than 1.2 billion people worldwide (Steffan-Dewenter et al. 2007). Integration increases farm productivity when the various components and their associations are managed effectively.

Agroforestry systems offer a variety of products and services that are significant locally, nationally and globally (Garrity 2004). In addition to direct provision of edible products, agroforestry trees support food production by a range of other means, including provision of shade and support for crops that need it, supporting animal production and improving soil fertility and providing varied and nutritionally balanced diets (Susila *et al.* 2012). The system also promotes ecological and social resilience to change because the various components of a system and the interactions between them will respond differently to disturbances.

This report focuses on the agroforestry components of the MAG project being implemented by CSIR-FORIG and details progress and key achievements over the year. It is focused on activities that address the three objectives of the project. Activities implemented included, creating awareness on benefits of agricultural biodiversity, consultation with farmers to determine preferred tree species, farm selection and collection of baseline data on selected farms, identification of compatible tree crops, germplasm collection, training on nursery establishment and tree propagation and building capacity of farmers and supporting them to integrate trees in farming systems. The main objective of the project is to reduce vulnerability to climate change, improve food security, and livelihoods of the rural poor smallholder farmers sustainably.

CSIR-FORIG organised an inception workshop (Plate 30) with the aim of bringing all the stakeholders of the project together. The stakeholders comprised representatives of Ghana Cocoa

Board (COCOBOD) represented by the Cocoa Health and Extension Division (CHED), Ministry of Food and Agriculture (MOFA) District Director and extension staff, District Forest Manager and Range Supervisor of Forest Services Division, the District Veterinary Officer, District Development Planning Officer, the District Chief Executive and the District Coordinating Director (Fanteakwa South District), chiefs, opinion leaders and farmers. The purpose of the inception meeting was to introduce the project to all major stakeholders, outline roles and responsibilities, and elicit their support and cooperation for the successful implementation of the project. It was also to raise awareness on the need to incorporate agroforestry into cocoa and food crop production and the accrued benefits. Furthermore, the inception meeting was meant to interact with farmers, hold discussions with them in focus groups, to agree on tree species preferences and other relevant issues necessary for the successful implementation of the project.

Stakeholders were briefed on the general issues of land degradation in Ghana and its negative impacts on agricultural productivity and the need to address it if farmers' livelihoods were to be sustained. Stakeholders were informed that the project was being implemented to contribute to the reversal of agricultural decline and address continuous deforestation in the landscape through the use of agroforestry approaches. Additionally, the project contributes to government's agricultural programmes and policies on modernizing agriculture and planting for food and jobs.

The discussions after the introduction of the project to stakeholders focused on a number of issues including; selection of desirable tree species of farmers to be integrated on farmlands, the management of existing old trees on farms and effective collaboration of stakeholders (MOFA, FSD and CHED) and the project team in the implementation of the project activities.

On the desirable tree selection, the project would guide farmers to select the appropriate species for integration in food crop and cocoa farms based on farmers' preferences and technologies developed at CSIR-FORIG. On the question of removal of already existing old trees, farmers were sensitised on the benefits of trees on-farm and the need to maintain existing trees as well as integrate additional trees based on the current population of trees on farms. On the issue of collaboration, it was emphasised that MOFA, FSD and CHED representatives would actively participate in implementation of all project activities and have the role and responsibility to assist in the identification and selection of farmers and farms where the agroforestry options would be installed. MOFA staff would identify food crop farms and farmers and CHED would assist in the identification and selection of cocoa farms for tree integration. FSD representatives would assist in collection of germplasm and assist production of planting materials.

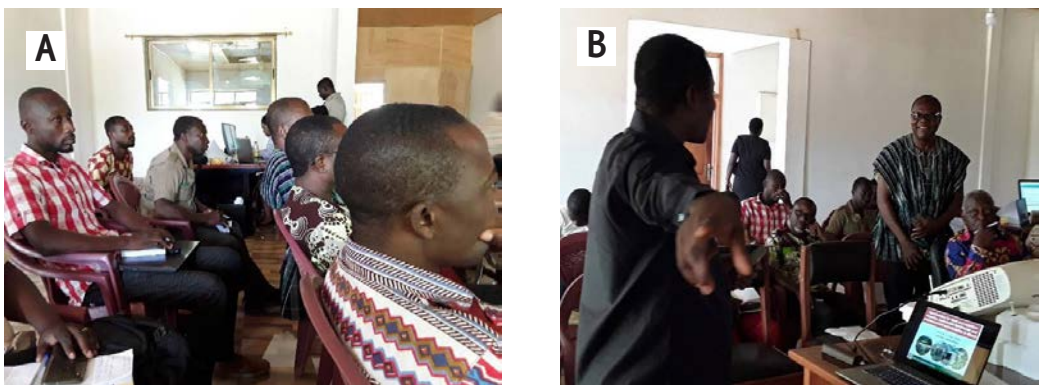

Plate 30A and B: Inception meeting with project collaborators and major stakeholders. Prof. D. Ofori taking participants through project overview, objectives, activities and intended outputs and outcomes.

Participants mentioned that, they had observed a significant change in the landscape over the past ten years. They recalled the presence of dense forest and abundance of forest products including mushrooms, snails and cool climate in the past compared to the present. They mentioned that the present landscape was degraded with less fertile soils due to increased use of chemicals in land preparation and management.

Farmers indicated that the current challenges with farming were low productivity, low soil fertility, illegal mining, irregular rainfall and less trees on farmlands. The other challenges mentioned were pressure on land because of population increase, application of chemicals leading to low cocoa yield, change in weather affecting cocoa trees and insects attack on cocoa trees.

Measures for addressing insects/pest and diseased farms that were suggested included; i) regular removal of weeds on farms; regularly pruning of cocoa trees, ii) avoiding cross border effect through regular weeding of farms that share boundaries with others, iii) removal of trees like 'okuro' and 'waterpuo' that attract insects into farms. Aside these measures, swollen-shoot disease and parasitic plants on cocoa trees are more difficult for farmers to address. Insects attack on food crops such as maize is also difficult for farmers to address. The agricultural extension officer present advised farmers to practice crop rotation to minimize insect infestation on food crops.

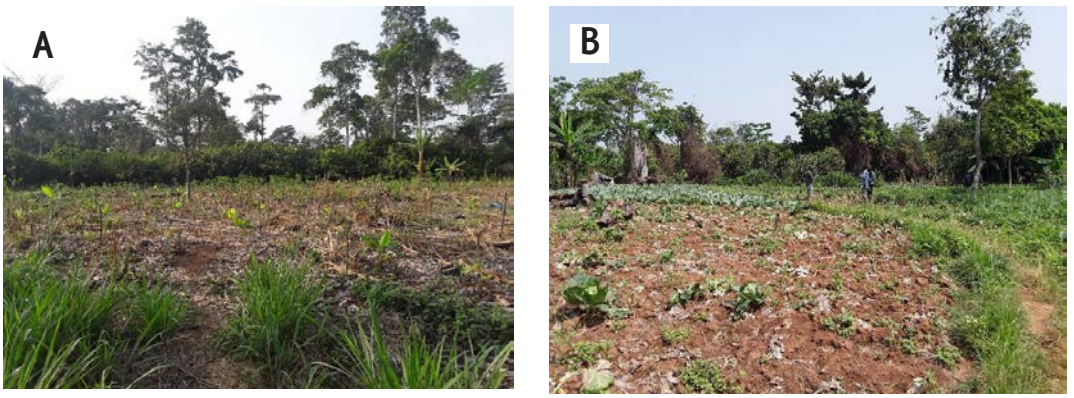

Plate 31: Newly cleared farm at Osino ready to be planted with (A) cocoa seedlings and (B) vegetables

Farmers identified diverse roles of trees on farm. The beneficial roles identified include; i) protection of crops from effect of severe sun light, ii) carbon sequestration and regulation of climate and provision of oxygen for animal and human life, iii) protection of crops against wind storm, iv) improvement of soil fertility through leaf drop, v) regulation of ground water flow, vi) crop improvement through better management of trees on farms, and vii) provision of fruits, food and income. Trees that provide food include oranges, coconuts, pears and mangoes. Other non-timber forest products mentioned included pawpaw, jack fruit or bread fruit (d-ball), ataa bean (*Pentaclethra macrophylla*), cola (*Cola nitida*), adosoa (*Chrysophyllum albidum*), 'krobonko' (*Teffaria occidentalis*)

Farmers mentioned a number of timber tree species that they were generally familiar with, which included; *Tieghemella heckilii* (Abako), *Holarrhena floribunda* (Asese), *Terminalia ivorensis* (Emire), *Cedrela odorata* (Cedrela), *Khaya spp.* (Mahogany), *Entandrophragma cylindricum* (Sapele), *Pycnanthus angolense* (Otie), *Piptadeniastrum africanum* (Dahoma), *Garcinia cola* (Tweapea).

To get an idea of farmers' preferred tree species on farms, farmers were asked to mention the trees they would prefer to plant on cocoa and food crop farms. The timber tree species mentioned included; *Terminalia ivorensis* (Emire), *Terminalia superba* (Ofram), *Khaya species.* (Mahogany) and *Triplochiton scleroxylon* (Wawa). Farmers were advised that *Triplochiton scleroxylon* though preferred is not a good tree to plant on cocoa farm despite its high economic value.

Forty-five (45) farmers were initially selected for implementation of various agroforestry options. The communities in which the farms are located are Osino, Abompe, Hemang, Nsutam, Abodobi, Bosuso, Ayaso, Subrimaa and Saamang. In the first quarter of the project cycle, fields of 25 farmers were visited and assessed (Plates 31, 32 and 33). Baseline information (i.e. farmer personal records, farm size, ownership of the land, intended food crop choice, preferred tree species on farm and current tree population) on each farm was obtained. Majority of the farms visited were new farms with few or no trees. Others have trees with very narrow crown that might not provide the proper shade for cocoa. On a few farms, the trees were concentrated on one side of the farm. Based on this information, the project team developed the appropriate design for the integration of trees on each farm. Results of one on one interviews with farmers during field visits showed that farmers preferred one or two of ten species: *Terminalia superba* (Ofram), *Terminalia ivorensis* (Emire), Khaya spp (mahogany), *Triplochiton scleroxylon* (Wawa), *Milicia excelsa* (Odum), *Antiaris toxicaria* (kyenkyen), *Entandrophragma cylindricum* (Sapele), *Pouteria aningeri* (Asanfena), *Cedrela odorata* (Cedrela), and *Tetrapleura tetraptera* (Prekese)) due to various benefits. The preferred species overlap with the list of species obtained during focus group discussion at the project inception phase. Majority of the farmers indicated shade quality was the reason they preferred the selected species. Other attributes mentioned were soil fertility, and provision of goods such as good timber and other non-timber forest products (NTFP).

Plate 32A and B: Assessment of baseline information of selected farms

Plate 33A and B: Project team having a discussion during field visits as part of farm selection process.

Seeds of some of the preferred species which included *Terminalia ivorensis* (Emire), *Terminalia superba* (Ofram) and *Cedrela odorata* (Cedrela) were collected and seedlings produced at the CSIR-FORIG nursery and supplied to farmers based on individual farm agroforestry design. In addition, seedlings of indigenous fruit trees were acquired from Plant Genetic Resources Research Institute (CSIR-PGRRI). Fruit trees acquired were *Monodora myristica* (Wedieaba), Prekese, Sweet apple, Black pepper, Xylopia (Hwentea), Africa star apple (Alasa), Soursop (Aluguintuguin), Atoo (Volta mango), Guava and Miracle berry (Asaa).

Forty-one (41) farmers and 10 extension officers from MOFA and COCOBOD-Cocoa Health and Extension Division (CHED) were trained in nursery establishment and tree propagation (Plate 34). The training focused on methods of seed collection, processing and storage techniques and factors to consider when establishing a nursery. Additional areas of the training focused on site selection; characteristics of quality seeds, and plus trees. Farmers were trained to be able to assess the needed characteristics to ensure high-quality seeds were collected for the production of high-quality seedlings.

Plate 34A and B: A section of farmers and extension officers from MOFA and COCOBOD-CHED at the training on nursery establishment and tree propagation, Bunso.

Farmers and extension officers were trained in various methods of vegetative propagation (Plate 35). Methods demonstrated to farmers included grafting, budding and marcotting. Grafting was explained as a process of fusion between two different plants. It is used for plants, especially

woody plants and certain fruit trees, which cannot be easily propagated by division or cuttings. In the grafting process, stem cuttings (scion) from a tree with superior characteristics are grafted onto stock plants. In the budding process, a bud is taken from one plant and grown on another. The new organism continues to be attached to its parent organism as it slowly grows and only detaches or separates from the parent when it becomes mature, leaving behind a scar tissue.

Farmers were also introduced to marcotting (air layering). In layering methods, roots are induced to form on the part of the plant while it remains aerial (aboveground), hence the term air layering. It is practiced on many types of fruits. These include jackfruit, guava, avocado, mango, cashew, and citrus.

Plate 35A, B, C, D: Farmers being trained in vegetative propagation methods.

Timber trees *(Terminalia ivorensis* (Emire), *Terminalia superba* (Ofram) and Mahogany)) seedlings produced by CSIR-FORIG and indigenous fruit trees (*Monodora myristica* (Wedieaba), Xylopia (Hwentea), *Chrysophyllum albidum* (Alasa) produced by Plant Genetic Resources Research Institute (CSIR-PGRRI) were distributed to farmers (Plate 36). The team from CSIR-FORIG gave a demonstration to farmers on the planting designs and spacing (Plate 37). The CSIR-FORIG team, the MOFA and CHED extension staff assisted farmers with planting of the supplied seedlings. Trees integrated on cocoa farms were planted at a spacing of 24m by 24m with a mix of the 3 timber tree species and 3 fruit trees. For food and vegetable farms, tree and fruit-trees seedlings were planted randomly with a minimum spacing of 24m by 24m.

Plate 36A, B, C, D: Loading of seedlings and distribution to farmers in communities in the Fanteakwa South District

Plate 37A - D: Project team (a and b) explaining the planting design to farmers on their farms at Osino in the Fanteakwa South District. Farmer (d) planting supplied seedlings on his Cocoa farm after brief training.

A total of 29 farms located in Hemang, Osino, Abodobi, Nsutam, Ehiamakyene, Bosuso and Ewento were visited (Plates 38 and 39). During the monitoring, the number of seedlings planted were checked against total number of seedlings supplied to each farmer. In addition, old or existing trees on the farms before the introduction of trees under the project were also identified and recorded. On average 85% of the seedlings planted in all 29 farms survived. Most farmers (76%) had adhered to the planting design and the recommended spacing. The few farmers that failed to follow the recommended design for planting and also planted more seedlings than was appropriate were advised to thin out some of the seedlings.

Five sites in five communities (Ehiamakyene, Hemang, Bososu, Nsutam and Abodobi) were visited to assess their suitability for the establishment of community nurseries. The expectation of the project is that the farmers will produce seedlings and distribute/sell to other farmers in the communities' who have expressed interest to grow trees on their farms. This is because during the inception phase of the project many farmers expressed interest to join the project but most of them could not be included in the project due to budgetary constraints. The community nurseries will help to increase production of tree seedlings and upscale tree integration on food and cash crop farms.

Plate 38A - B: Seedlings of fruit trees and timber trees growing on farms

Plate 39A - B: Farmers assessing tree survival on their farms

Three (3) communities' nurseries are being established in Ehiamankyene, Abodobi and Ankaase. Land preparation and construction of germination beds have begun. Nursery inputs such as polypots, cutlasses, shovel, spade, wheelbarrows, water barrels, watering cans, mattock and rakes have been purchased and have been supplied to the communities.

The implementation of project activities progressed smoothly. All project activities planned for the year have been successfully implemented in close collaboration with staff of MOFA and COCOBOD-CHED. The project outputs have been achieved as the capacity of farmers and MOFA and COCOBOD staff has improved in tree nursery production, integration of trees on farm using tested designs. In addition, awareness on the benefits of trees in crop production systems has increased. Farmer interest in the project remains high. There is the need to upscale the agroforestry component of the project in areas that have suffered intense land degradation. This is because increased tree cover within the landscape would enhance farm productivity and enhance resilience as well as mitigate the impact of climate change.

OUTPUT 215 NUTRIENT RESORPTION AND STOICHIOMETRIC PATTERNS ALONG A RAINFALL GRADIENT IN GHANA

Research Team: *S. D. Addo-Danso and S. Adu-Bredu*
Donor: *Royal Society, UK*

The removal of nutrients from senescing tissues, nutrient resorption, is an important physiological process for nutrient retention in forest ecosystems, especially in nutrient-poor sites. In addition, the functional significance of tissue and soil stoichiometric ratios (e.g. leaf N:P ratio) as indicators of nutrient status is widely recognized. Nutrient resorption and stoichiometric constraints strongly influence critical ecosystem processes and functions, including elemental cycling and net primary productivity. Most studies in tropical forests have focused on leaf resorption and stoichiometry, but high proportion of nutrients could be resorbed from stem and fine roots into ecosystems. Understanding the patterns and driving factors of nutrient resorption and stoichiometry in tropical forests is hampered by the lack of data, particularly in tropical African forests, which have been understudied. The lack of data poses a challenge to our understanding of global nutrient cycles, and our ability to predict total ecosystem nutrient uptake of key nutrients in the tropical forest biome. The objectives for this project are: 1) Determine how nutrient concentrations, nutrient resorption and stoichiometry vary along a rainfall gradient. 2) Evaluate seasonal variation in nutrient concentrations, nutrient resorption and stoichiometry. 3) Evaluate relationships between nutrient concentrations, and nutrient resorption and stoichiometric ratios in plant tissues and soil, and 4) Integrate the resorption data with existing net primary productivity data to quantify total ecosystem demand or uptake of key nutrients.

During the period under review, focal tree species, which together composed › 50 % of the total basal area were identified and selected. Tissue (leaf, stem and root) samples were collected on tree species (three replicates per species). In addition, soil samples have been collected under each focal tree. Collected samples were transferred into labelled sealed plastic bags and sent to the laboratory for further processing. The processed samples were sent to the laboratory for nutrient analysis.

Preliminary results showed that during the wet season leaf N and P concentrations and C/N ratio did not vary much among the focal species in the Bobiri Forest Reserve. For instance, N and P concentrations varied 2-fold (from 2.4-4.1% for N concentration) and (from 0.15-0.26% for P concentration). At the species level, leaves of *Turraeanthus africanus* contained more N (4.1%) but *Albizia zygia*, which is a nitrogen-fixing species, had the least N concentration (2.4%). When the species were grouped into functional groups, leaves of shade bearers contained more N (3.41%) than that of the pioneers (2.92%) and non-pioneer light demanders (2.7%). Phosphorus concentration also followed the same pattern. However, leaf C/N ratio was highest in the non-pioneer light demanders (22.22), followed by pioneers (18.89) and shade bearers (16.53).

Overall, some progress has been made in the reporting period. In fact, wet season data collection was completed and the samples processed. Currently, the samples are being analyzed to determine their nutrient concentrations. Activities planned for the dry season is expected to start in February 2020.

OUTPUT 216 THE MULTI-YEAR IMPACTS OF THE 2015/2016 EL NIÑO ON THE CARBON CYCLE OF TROPICAL FORESTS (EL NINO)

Research Team: *S. Adu-Bredu; G. Djagbletey; A. Duah-Gyamfi and S. D. Addo-Danso*
Donor: *Natural Environment Research Council (U.K)*

In recent times the threat of climate change has been the focus of international, regional and national debates. In Ghana and West Africa, predictions of climate change models indicate that the climate is expected to become drier. Changes in drier conditions are likely to influence species composition and distribution in the long term. In the light of this, this study was conducted in a dry forest-savannah transition zone of Ghana to assess changes in some stand attributes of two ecotones in the Kogyae Strict Nature Reserve (KSNR) between 2012 and 2018. The period examined takes into account the El Nino event experienced in Ghana around 2015-2016.

In this study, a savannah and a forest plot at KSNR that form part of the Global Environmental Monitoring (GEM) network of plots across the tropics were assessed for changes in species composition, diversity and distribution of tree stems between 2012 and 2018. One-hectare plot, divided into 25 subplots, were established in each site in 2011 and trees with *dbh* › 10 cm have been inventoried annually since 2012.

Generally, the number of trees per hectare declined in the two sites between 2012 and 2018. The stocking density of trees in the savannah decreased from 193 in 2012 to 147 in 2018, a decrease of 23.8 %, whereas the density in the forest decreased by 8.7 % during the same period. The dominant species in the savannah in 2012 were *Bridelia ferruginea* (26.4 %) and *Pterocarpus erinaceus* (12.4 %). The same species were still the most abundant species in 2018: *Bridelia ferruginea* (24.4 %) and *Pterocarpus erinaceus* (15.6 %). In contrast, *Cola gigantea* and *Sterculia tragacantha* were the dominant species in the forest site in 2012 (*C. gigantea*, 10.8 %; *S. tragacantha*, 10.8 %) and 2018 (*C. gigantea*, 11.9%; *S. tragacantha*, 9.0 %).

Table 6: Changes in stand characteristics between a savannah and forest stand of the Kogyae Strict Nature Reserve

	2012		2015		2018	
Stand characteristics	**Savannah**	**Forest**	**Savannah**	**Forest**	**Savannah**	**Forest**
Stems per ha	193	194	181	180	147	177
Basal area (m^2/ha)	11.9	20.5	12.4	18.5	11.7	22.0
Species richness / ha	32	49	32	45	28	49
Shannon-Wiener index	2.72	3.33	2.76	3.31	2.67	3.38

Species richness and the Shannon diversity index did not differ significantly even though there were slight declines in both measures for the savannah and increase in Shannon diversity for the forest site. The consistency in the dominance of some species and presence of rare species may account for the observed trend for species richness and diversity. Basal area did not change much for the savannah but slightly increased for the forest site. The significant (x^2 = 51.9, *df* = 18, p <0.05) recruitment of stems into larger diameter classes in the forest site (Figure 15) may account for the increase in basal area.

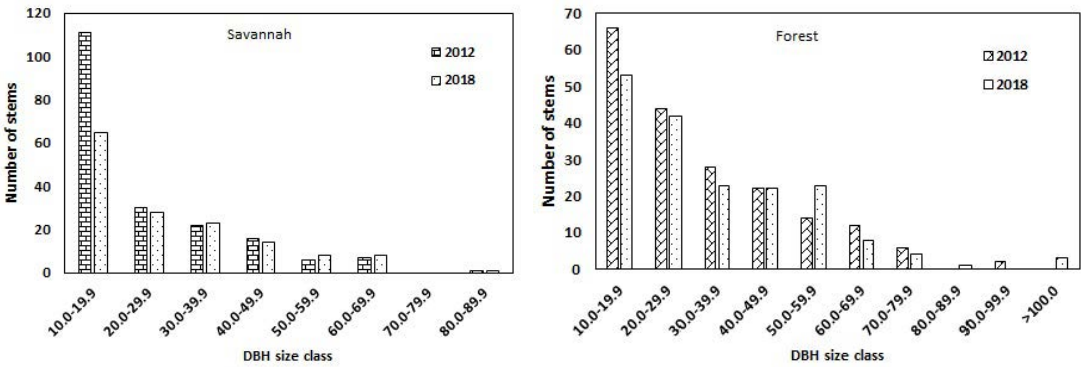

Figure 13: Diameter at breast height size class distribution for 2012 and 2018 in a savannah and forest site at KSNR

The studies have so far revealed a significant decline in tree stems especially within the savannah zone of KSNR. Annual fire is common at the KSNR and may play a role in the gradual decline of tree species in the savannah. This may have implications for ecosystem functioning such as carbon storage. Although the decline in tree stems did not affect tree diversity during the period examined, long-term declines in tree stem might affect species richness of KSNR.

OUTPUT 217 LIGHTNING: AN INVISIBLE DRIVER OF TREE MORTALITY IN TROPICAL FORESTS ELECTRICAL RESISTANCE OF LIVING TREES TO SOIL SURFACE LAYER (GROUND)

Research Team: *S. Adu-Bredu; A. Duah-Gyamfi and S. D. Addo-Danso*

Donor: *Natural Environment Research Council, U.K.*

Electrical resistivity is a non-destructive geophysical method that allows measurements of the distribution of resistivity across the soil surface. Measurements are based on the difference in resistivity of soil layers, rock formations, etc. It is an approach used in the exploration of deeper geological structures. However, its use in ecological research is becoming popular. Despite this recognition, the electrical resistance of living trees to soil subsurface is little studied yet potentially important considering the interaction between trees and lightning discharges.

The comparison of the electrical resistance of trees in different seasons may provide information about the behaviour and/or response of specific trees to different environmental conditions such as soil water content, water content of living tissues (roots, stems). For instance, trees can soak tissues with available water in the soil with a lower electrical resistance to the ground. Therefore, the phenomena of soaking tissues with water particularly in the wet season can be useful for a better understanding of the interaction of trees resistance and environmental factors.

In this study, measurements for the resistance of trees of *Pentadesma butyracea* for both the dry (March 2019) and wet (September 2019) seasons in the Ankasa Conservation Area located at Elubo, near the border with La Cote d'Ivoire, are presented. Five trees of *Pentadesma butyracea*, with diameter at breast height, *d*bh in the range $10 < dbh < 100$ were randomly selected in a 50-ha plot established to study lightning impacts on tree mortality. Using a Digital Earth Tester MEGGER® *DET2/2*, a portable instrument designed to measure earth electrode resistance, the ground resistance of the selected trees was measured. Tree resistance was measured on two points along the stem of each tree, at 1.4m and 0.7m above the ground. For each level of measure, the terminals of the *DET2* were connected and resistance measured at a distance of 20, 30, 40, 50, 60, 70 and 80m from each tree.

The results indicate that *P. butyracea* shows a similar trend in resistance at different points along the stem (Figure 14 & 15). However, differences in resistance between the points was more pronounced in the dry season compared to the wet season. This low resistance in the wet season may be attributable to availability of water/moisture minimizing resistance to the soil surface or ground layer. Despite the slight difference, a repetition of the same trend for both seasons may be due to inherent characteristics of *P. butyracea*. It may be related to nature of water conduction in the species that could be linked to reduced crown size, or fewer roots or both. Further, a morphological feature or characteristic peculiar to the tree, bending on one side, could also present a structural problem that may explain the trend in resistance to the ground observed here.

The results presented here provide an opportunity to conduct detailed studies to understand other factors (e.g. soil texture) that might influence resistance of trees to soil surface or ground.

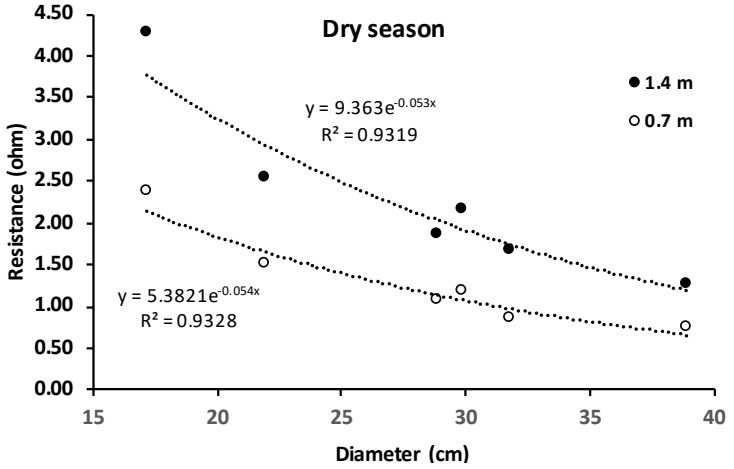

Figure 14: Resistance to soil surface of selected *dbh* sizes of *P. butyracea* in the dry seasons at the Ankasa Conservation Area

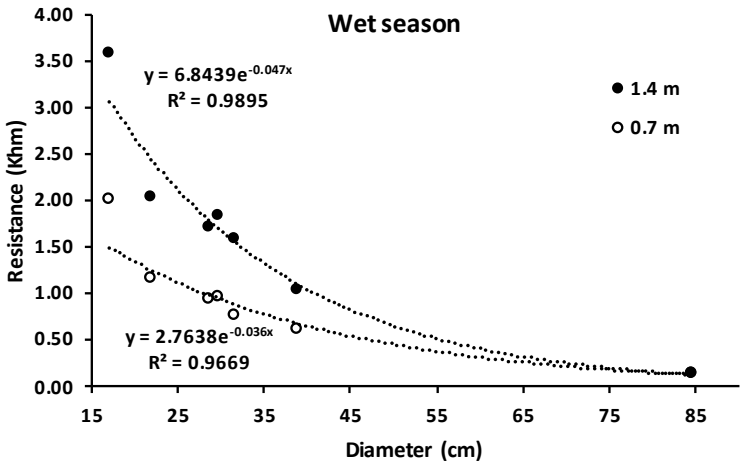

Figure 15: Resistance to soil surface of selected *dbh* sizes of *P. butyracea* in the wet seasons at the Ankasa Conservation Area

OUTPUT 218 UNRAVELLING THE ROLE OF ANIMALS IN AFRICAN SOILS ECOLOGY (SOFIA): TERMITE ABUNDANCE AND DIVERSITY IN COCOA LANDSCAPES

Research Team: *S. Adu-Bredu and G. W. Quansah*

Donor: *Royal Society-DFID African Capacity Building Initiative, UK*

Cocoa is an important crop to Ghana's economy contributing 25% GDP. The crop, however, is mainly cultivated on forest soils and is a major cause of land-use change. Soil research has traditionally focused on the abiotic drivers, while the role of faunal communities in soil ecology has received far less attention. In Africa, the wealth and dominance of soil fauna and large mammal herbivores begs the question: to what extent are African soils created by and maintained by fauna, such as termites? Termites are an important biological component of tropical ecosystems providing numerous ecosystem services. Previous studies have indicated termites are sensitive to disturbance and decrease in richness and abundance across land-

use intensification gradients, with consequences for the essential services they provide. Native shade trees are often used to improve cocoa cultivation and may reduce the detrimental effects of land-use change on biodiversity. The aim of this study was therefore to explore how termites respond to cocoa cultivation along a shade-tree gradient. It is predicted that termite richness and abundance would decrease with decreasing shade cover.

Termites were sampled along a forest-cocoa shade gradient at locations varying from 27 to 80% shade cover in the Kakum National Park of Ghana and surrounding cocoa farms. Using a standardized transect method approach, termites were sampled at nine locations along the shade gradient.

A total of 1,112 termite encounters were recorded from the nine termites transects, and consisted of 29 species from 23 genera. The highest number of encounters was observed on cocoa agroforest plot of 43% shade-cover, followed by forest (edge) plot of 80% shade-cover with 203 and 193 encounters, respectively. The least was observed on 27% shade-cover cocoa agroforest plot with 59 encounters (Figure 16). The most frequently found species were *Ancistrotermes spB* (94), *Pseudacanthotermes spa* (88) and *Nasutitermes latifrons* (81) on 59 % shade-cover cocoa agroforest, 80 % shade-cover forest (edge) and 43 % shade cover cocoa agroforest plots, respectively. These are species that are commonly found in disturbed areas, and feed on a wide range of food sources (Inward *et al*., 2007). The larger abundance of the *Ancistrotermes spB* and *Pseudacanthotermes spA* species observed on forest (edge) plot may be due to edge effect, a condition that is likely to introduce non-indigenous species or may cause species extinction. It was therefore not surprising to observe the intrusion of species that are commonly associated with disturbance within the forest (edge) plot. Termite abundance, however, did not show any pattern along the shade gradient. In the case for termite richness, the number of species did not show any pattern along the shade gradient, though in the case of forest habitat the number of species increased with increasing distance away from the edge of the forest into deeper forest (Figure 17).

Thus, species richness and abundance showed no particular trends across the land-use gradient, and composition did not alter significantly indicating that despite a change in the dominant vegetation type, termite communities were robust to the disturbance. In contrast to our prediction, termite richness and abundance did not change along the shade.

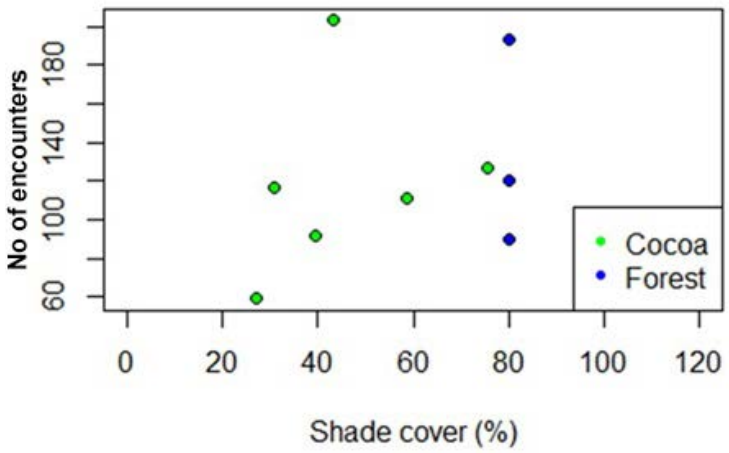

Figure 16: Scatter plot of number of encounters against percentage shade-cover

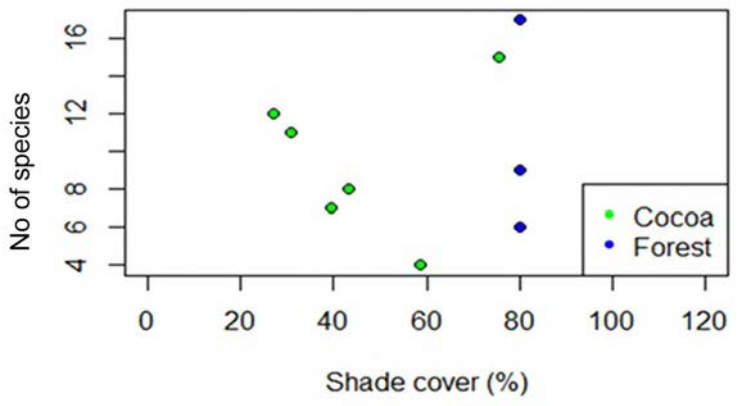

Figure 17: Scatter plot of the number of species against percentage shade-cover.

OUTPUT 219 EFFECTS OF PRE-SOWING SOAKING IN TAP WATER ON GERMINATION AND EARLY GROWTH RESPONSE OF *PTEROCARPUS ERINACEUS* (ROSEWOOD) SEEDLINGS TO BOTTLE DRIP IRRIGATION AND MULCHING

Research Team: *S. E. Akpalu and G. K. Adeyiga*
Donor: *CSIR-FORIG*

Pterocarpus erinaceus (African rosewood tree) is a deciduous tree, 12 to 15m tall and occurs in semi-arid to sub-humid tree savannah and is capable of surviving annual bushfires. It produces flowers and fruits in the dry season, usually before coming into leaf at the beginning of the rainy season. It is found in open forest and wooded savannah. It is believed to be among the remnants of the former dense Sudanian forest (Orwa et al., 2009). It is native to Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Cote d'Ivoire, Gabon, Gambia, Ghana, Guinea-Bissau, Mali, Niger, Nigeria, Senegal, Sierra Leone, Sudan and Togo.

The leafy branches are browsed by livestock and are especially important towards the end of the dry season when fodder is generally scarce, making it a very useful fodder plant in the Sudan savanna zone. Its wood produces good quality charcoal, and the inflorescence is also a source of quality nectar in apiculture. Its timber has a beautiful fine-grained appearance and, once seasoned, it maintains its shape very well. It is used for external construction, furniture, door and window frames, decorative panelling, and parquet flooring.

The tree species has become very important in Ghana of late due to the discovery of its excellent timber quality, leading to its overexploitation.

The need for the establishment of plantations of the African rosewood towards reversing or restoring its populations cannot be overemphasised. A major constraint to its propagation has been the erratic nature of the germination of its seeds. In response to this difficulty, the Savannah Research Centre of CSIR-FORIG is undertaking a study to identify simple, cheap, easy-to-adopt methods to improve its germination at the nursery, and its growth on the field after transplanting.

The study is being undertaken at the Nursery site at the Guesthouse of CSIR-FORIG in Bolgatanga.

The objectives of the study were: 1) To identify simple, cheap, and easy-to-adopt pre-sowing treatment methods to improve germination of the African rosewood seed and 2) To study the response of transplanted seedlings to some agronomic practices such as mulching and bottle drip irrigation.

Whole pods (seeds not extracted from pods) were soaked in tap water for 0, 18, 20, 24 and 48 hours (labelled as To, T18, T20, T24 and T48 respectively) and sown in drills on 26th March 2019. The treatments were replicated on three sub plots and each treatment was made up of 100 seeds. Data was collected on the number of seeds that germinated on daily basis until seed germination ceased.

Some of the seedlings were then transplanted on the Guesthouse compound for the early growth studies. The experimental design was a split-split plot design. The treatments were; (i) mulching + irrigation, (ii) mulching, no irrigation (iii) irrigation, no mulching, and (iv) no mulching, no irrigation. Data being collected include; Height, number of leaves and collar girth.

Germination started by the 9th day after sowing, and number of seeds germinating increased steadily up to 30 days after sowing. There were however, some mortalities between the 30th day after sowing and 48 days after sowing (during potting) (Figure 18). Among the treatments, sowing seeds without soaking in tap water (To) and soaking seeds in tap water for 48 hours (T48) exhibited superior germination percentages than the other treatments at 30 days after sowing. By the time of potting (48 DAS), however, To and T24 seeds showed the best germination percentages (Figure 20).

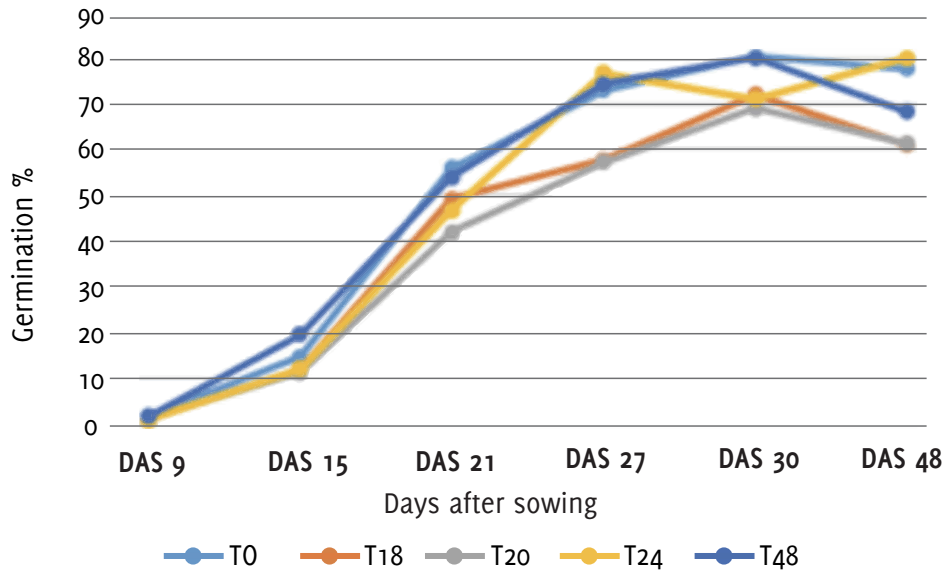

Figure 18: Germination percentage of *Pterocarpus erinaceus* seeds soaked in tap water for different durations

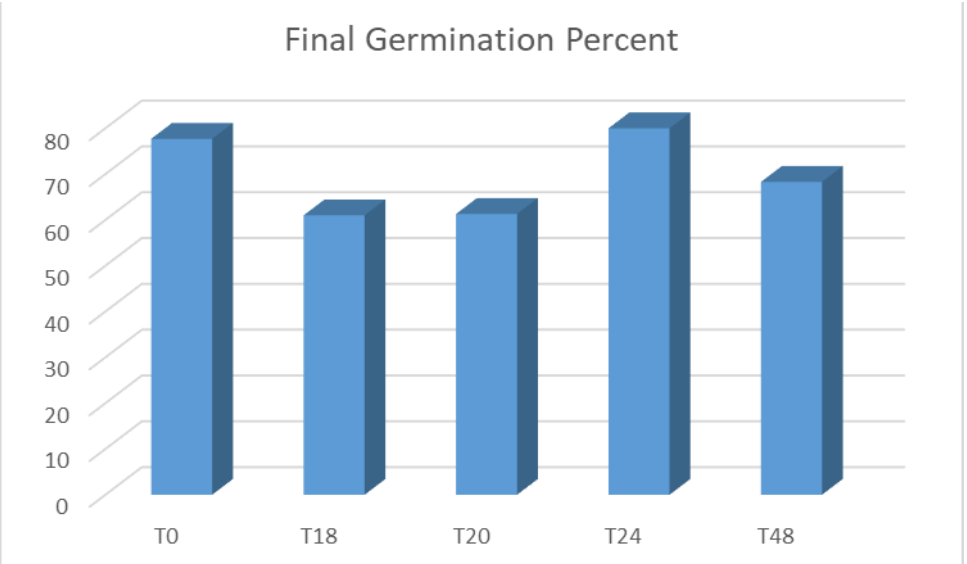

Figure 19: Final Germination Percentages of *Pterocarpus erinaceus* seeds soaked in tap water for different durations

These preliminary results point to the fact that it is possible to have satisfactorily high germination percentages for *Pterocarpus erinaceus* when the pods are either sown directly or soaked in tap water for between 24 and 48 hours before sowing.

3.0 MATERIAL SCIENCE AND MANUFACTURING (MSM)

3.1 Background and Highlights of Research Achievements under MSM

CSIR-FORIG's research under this theme helps to improve competitiveness of industry by developing materials, which are preferred by Ghanaian industries. This year, the focus of the research was centred on two main programmes, namely;

- Material Science (Wood, Integrated Materials)
- Industrial Products (Bio-Resources)

OUTPUT 3.2 EVALUATION OF TIMBER SPECIES ON THE DOMESTIC MARKETS IN THE ASHANTI REGION OF GHANA

Research Team: *F. W. Owusu; L. Damnyag; J. Korang; B. Darko Obiri; E. Ebanyenle; K. Antwi Oduro; S. Pentsil; J. Govina; H. Seidu; E. Asiedu Opoku; and B. Brentuo*

Donor: *Forestry Commission / CSIR-FORIG*

Supplying legal timber to the domestic market of Ghana is increasingly recognised as a critical policy intervention for the sustainability of forest resources and good forest governance in Ghana. This is because the domestic market is flooded with volumes of chainsaw lumber of various wood species, which are illegally extracted from both the forests and farmlands. This policy intervention has virtually failed to meet the desired objectives. This has led to the upsurge or proliferation of the production and marketing of illegal chainsaw lumber in the country despite government's relentless efforts and investments in curtailing the practice. Over 70% of wood stocked on the market is from illegal chainsaw lumbering (Marfo *et al*., 2017; Obiri *et al*., 2009 and Odoom, 2005). In 2009, the number of wood species that were identified on the domestic markets in Ghana was 66 (Obiri *et al*., 2009). This figure was raised to 94 out of which the sawmill sector was processing 54 (Owusu *et al*., 2014). Therefore, most timber species on the domestic market are reported to be underutilised because new species are continuously introduced *(Owusu et al., 2014)*. Some of these new/emerging timber species need to be identified and researched into in order to promote their utilisation. Ashanti region being the most dominant region for the supply of chainsaw lumber in Ghana with Sokoban as the second largest domestic timber market in the country was selected for the study. In the 2014 domestic timber market survey study, the region recorded a monthly stock volume of 35,173.47m^3. The objectives of the study were to: a) Identify and document the emerging lesser-known and technologically-unknown timber species on the domestic timber market in the Ashanti region of Ghana. b) To determine the wood qualities of the emerging lesser-known and technologically-unknown timber species in the domestic timber markets.

The timber market study consisted of a survey of wood merchants or suppliers at the domestic timber markets across the Ashanti region. To ensure an effective survey, the selected study

areas were divided into two zones based on the study by Owusu *et al.* (2014). Each of the survey team comprised four enumerators, who collected data within the same period of 6 days simultaneously across the region. According to earlier studies by Hansen *et al.* (2012) and Obiri *et al.* (2009), the peak period for timber market is whereby large volumes of timber of different species are conveyed to the market centers, which is due to the ease of felling trees and conveyance of timber from forest areas while the lean season is the reverse. These periods are the dry and rainy seasons respectively. Due to limited resources, the study was undertaken during the peak period.

A structured questionnaire amidst personal interviews (Plate 40) was used to collect data on inflows and outflows of lumber, as well as the types of species supplied to the domestic timber markets, dimensions of the timber products, their prices and the types or sources of the products. To facilitate co-operation of the timber merchants in collecting the requisite data, discussions between the research team and the leaders of the Domestic Lumber Traders Association (DOLTA) were held to enable them understand the objectives of the study thereby sensitizing their members of the exercise prior to data collection. The data has been cleaned and analyzed descriptively and are summarized appropriately for the final report.

- 23 domestic timber markets were enumerated in the Ashanti region
- The total number of timber species, in product form, that were available at the domestic timber markets surveyed was 56 as shown in Table 7
- 28 emerging timber species (Table 8) were identified out of a total of 56 available at the 23 domestic timber markets
- The first ten dominant timber species, in terms of volume stocked per month, which ranged from 4,127 m^3 (Onyina) to 1,082 m^3 (Watapuo/wobre) are Ceiba/Onyina, Wawa, Senya, Dahoma, Ofram, Esa, Mahogany/Dubene, Essia, Nyamedua and Watapuo/Wobre (Table 9).
- The cost per cubic meter of all the 56 timber species ranged from Ghs1,607 (sintia) to Ghs 387 (Apotwere) as shown in Table 9 while the emerging timber species ranged from Ghs 1,455 (Kumanini) to Ghs387 (Apotwere).
- The major timber products identified were beams, boards and lumber of which 15%, 28% and 56% by volume were estimated from the 56 species (Figure 20) while 12% (beams), 12% (boards) and 76% (lumber) in the same order were recorded for emerging species (Figure 21) but comparatively with lower percentage volumes.
- Stocked and sales volumes and values for lumber continue to be the highest among the three wood products.
- Beam product continues to be supplied to the domestic market but most were eventually reconverted into lumber for sale using either wood-mizer, bush-mill or bench saw.
- As shown in Table 10, the minimum and maximum percentage volumes of the three wood products identified and their sources with respect to the emerging timber species are 30% (boards from sawmills) and 53% (lumber from bush cut) respectively.
- The sources of supply of the timber products from the total volumes stocked in the markets were 83% and 17% from chainsaw/bush-cut and sawmill respectively (Figure

22). With respect to the emerging timber species, estimated records indicated 93% and 7% (Figure 22) in the same order of arrangement.

- Ninety-two (92) different dimensions with respect to thickness, width and length were identified during the survey in the Ashanti region, which is comparatively lower than that of 2014 but higher than 2009 (Figure 24).
- A total of 96 dimensions of the three wood products were recorded in the study comprising 14 (beams), 33 (boards) and 49 (lumber).
- Projected annual stock and sales volumes of the emerging timber species (28) were estimated as 0.273 million m^3 and 0.149 million m^3 respectively while those of the total wood species (56) surveyed were determined as 1.237 million m^3 and 0.79 million m^3 respectively.

Table 7: Fifty-six timber species surveyed at the domestic timber markets in Ashanti region

	Local name	Scientific name
1	Esa	*Celtis spp*
2	Essia	*Petersianthus macrocarpus*
3	Watapuo/wobre	*Cola gigantea*
4	Ceiba/Onyina	*Ceiba pentandra*
5	Akonkodie / Akata	*Rhodognaphalon buonopozense*
6	Nyamedua / Sinduro	*Alstonia boonei*
7	Yaya	*Amphimas pterocarpoides*
8	Okoro	*Albizia zygia*
9	Wonton	*Morus mesozygia*
10	Tweneboa	*Cordia millenii*
11	Nokwa / Nakwa	*Holoptelea grandis*
12	Konkroma	*Morinda lucida*
13	Okuo / Oyaa	*Zanthoxylum gilletii*
14	Kumanini	*Lannea welwitschii*
15	Wama	*Ricinodendron heudelotii*
16	Kotreamfo	*Ficus sur*
17	Ngo ne Nkyene	*Cleistopholis patens*
18	Dawadawa-dua	*Parkia bicolor*
19	Katawani	*Pseudospondia macrocarpa*
20	Opam	*Macaranga spp*
21	Akuakuoninsuo	*Spathodea campanulata*
22	Dahoma	*Piptadeniastrum africanum*
23	Senya	*Daniellia oliveri*

	Local name	Scientific name
24	Bonsamdua	*Distemonnanthus benthamianus*
25	Ofram	*Terminalia superba*
26	Otie	*Pycnanthus angolensis*
27	Wawabima	*Sterculia rhinopetala*
28	Kyenkyen	*Antiaris toxicaria*
29	Danta / Apro	*Nesogordonia papaverifera*
30	Asanfina	*Aningeria altissima*
31	Denya	*Cylicodiscus gabunensis*
32	Bediwonua	*Canarium schweinfurthii*
33	Hyedua	*Guibourtia ehie*
34	Kwabohoro	*Guarea cedrata*
35	Avodire Apapaye	*Turraeanthus africanus*
36	Akasa	*Chrysophyllum subnudum*
37	Edinam (Tamatama)	*Entandrophragma angolense*
38	Koto	*Pterygota macrocarpa*
39	Aprokuma	*Antrocaryon micraster*
40	Onyina-Koben	*Rhodognaphalon buonopozense*
41	Sapele	*Entandrophragma cylindricum*
42	Walnut / Dubenebiri	*Lovoa trichilioides*
43	Papao	*Afzelia africana*
44	Mahogany / Dubene	*Khaya spp.*
45	Wawa	*Triplochiton scleroxylon*
46	Emire	*Terminalia ivorensis*
47	Odum	*Milicia excelsa*
48	Awiemfosamina	*Albizia ferruginea*
49	Kusia	*Nauclea diderrichii*
50	Mansonia	*Mansonia altissima*
51	Efoobrodedwo	*Entandrophragma utile*
52	Abako / Baku	*Tieghemella heckelii*
53	Apotrewa	*Maesobotrya barteri*
54	Sintia	*New spp identified*
55	Cedrela / Dua-gyeene	*Cedrela odorata*
56	Gmelina	*Gmelina arborea*

Chainsaw/bush-cut lumber continue to be supplied to the domestic market, of which the volumes far exceed that of sawmills, hence the need to intensify the education on the illegal use of the

product and monitoring. Dimensions of timber products should be seriously monitored for easy management of the trade and sustainability of the resource. Some new timber species were identified in addition to those without any scientific information for their efficient utilisation. The properties of these species need to be established for their better promotion.

Table 8: Emerging timber species identified at the domestic timber markets in Ashanti region

S/no.	Local name	Scientific name
1	Watapuo/wobre	*Cola gigantea*
2	Akonkodie / Akata	*Rhodognaphalon buonopozense*
3	Yaya	*Amphimas pterocarpoides*
4	Okoro	*Albizia zygia*
5	Wonton	*Morus mesozygia*
6	Tweneboa	*Cordia millenii*
7	Nokwa / Nakwa	*Holoptelea grandis*
8	Konkroma	*Morinda lucida*
9	Okuo / Oyaa	*Zanthoxylum gilletii*
10	Kumanini	*Lannea welwitschii*
11	Wama	*Ricinodendron heudelotii*
12	Kotreamfo	*Ficus sur*
13	Ngo ne Nkyene	*Cleistopholis patens*
14	Dawadawa-dua	*Parkia bicolor*
15	Katawani	*Pseudospondia macrocarpa*
16	Opam	*Macaranga spp*
17	Akuakuoninsuo	*Spathodea campanulata*
18	Senya	*Daniellia oliveri*
19	Bonsamdua	*Distemonnanthus benthamianus*
20	Otie	*Pycnanthus angolensis*
21	Wawabima	*Sterculia rhinopetala*
22	Bediwonua	*Canarium schweinfurthii*
23	Aprokuma	*Antrocaryon micraster*
24	Onyina-Kobene	*Rhodognaphalon buonopozense*
25	Apotrewa	*Maesobotrya barteri*
26	Sintia	*New spp identified*
27	Cedrela / Dua-gyeene	*Cedrela odorata*
28	Gmelina	*Gmelina arborea*

Table 9: Volumes and values of 56 timber species surveyed at the DTMs in the Ashanti region

No.	Timber species	Volume stocked m^3	Volume sold m^3	Value stocked Ghs	Value sold Ghs	Ranking in terms of volume stocked	Cost/ m^3	Ranking in terms of Cost/ m^3
1	Ceiba/Onyina	4127	2658	1970880	1265445	1	**476**	48
2	Senya	2970	1325	3018810	1324953	2	**1000**	16
3	Wawa	2906	1884	2141280	1382072	3	**734**	38
4	Dahoma	2654	1935	2943332	2157376	4	**1115**	9
5	Ofram	2541	1619	2579910	1674735	5	**1034**	13
6	Esa	2033	1288	1729370	1107800	6	**860**	29
7	Mahogany	1873	1029	1959450	1038003	7	**1009**	14
8	Essia	1215	915	1180640	893260	8	**976**	22
9	Nyamedua	1170	759	558100	352310	9	**464**	49
10	Watapuo/wobre	1149	632	982420	580860	10	**919**	28
11	Papao	1082	980	1056800	961975	11	**982**	21
12	Emire	854	412	787180	385205	12	**934**	25
13	Cedrela	757	436	723360	414650	13	**951**	23
14	Otie	722	387	525860	276610	14	**715**	40
15	Odum	700	515	821340	608870	15	**1183**	6
16	Mansonia	657	444	779300	593880	16	**1338**	5
17	Akonkodie	568	343	274300	164800	17	**480**	47
18	Kotreamfo	554	352	353290	227830	18	**647**	42
19	Kyenkyen	521	313	249550	150980	19	**482**	46
20	Edinam (Tamatama)	491	338	359250	252025	20	**746**	36
21	Awiemfosamina	362	229	373450	237180	21	**1036**	12
22	Asanfina	353	253	383150	278850	22	**1104**	10
23	Wawabima	304	198	346630	226980	23	**1146**	8
24	Hyedua	295	210	459300	336100	24	**1601**	2
25	Koto	258	214	161800	134020	25	**626**	43
26	Konkroma	226	212	181750	166500	26	**784**	32
27	Yaya	196	96	156500	73290	27	**763**	33
28	Wonton	189	93	254600	124400	28	**1338**	5
29	Gmelina	169	64	168000	63700	29	**995**	17

No.	Timber species	Volume stocked m^3	Volume sold m^3	Value stocked Ghs	Value sold Ghs	Ranking in terms of volume stocked	Cost/ m^3	Ranking in terms of Cost/ m^3
30	Okoro	163	106	136100	87495	30	**823**	30
31	Kusia	154	107	156250	105650	31	**985**	20
32	Danta	154	117	141500	109450	31	**933**	26
33	Bonsamdua	110	68	115500	68250	32	**1004**	15
34	Tweneboa	107	65	90100	53800	33	**822**	31
35	Ngo ne Nkyene	94	41	102700	43435	34	**1059**	11
36	Abaku	91	68	90000	67500	35	**993**	18
37	Guarea	76	76	75000	75000	36	**993**	18
38	Nokwa	73	47	52820	33770	37	**723**	39
39	Aprokuma	63	37	41750	24450	38	**663**	41
40	Avodire	58	50	55010	46950	39	**942**	24
41	Katawani	51	25	38600	18200	40	**739**	37
42	Dawadawa-dua	49	37	22440	16870	41	**459**	50
43	Sapele	42	34	41375	33875	42	**988**	19
44	Opam	37	21	27300	15640	43	**747**	35
45	Onyina-Kobene	35	13	14400	5400	44	**409**	51
46	Akuakuoninsuo	29	19	11400	7600	45	**390**	52
47	Sintia	27	7	17750	11250	46	**1607**	1
48	Okuo	26	26	20000	20000	47	**757**	34
49	Apotwere	25	17	9600	6400	48	**387**	53
50	Walnut	23	15	33000	22000	49	**1457**	3
51	Akasa	19	15	17500	14000	50	**927**	27
52	Bediwonua	18	4	9450	2180	51	**552**	45
53	Wama	18	7	10250	3900	51	**587**	44
54	Kumanini	17	8	22100	11900	52	**1455**	4
55	Denya	7	7	7600	7600	53	**1150**	7
56	Utile	1	1	1125	1125	54	**993**	18

Table 10: Proportion of emerging timber species from three major timber products and their sources of supply

Major timber products	Total number of timber species identified	Emerging timber species recorded	Percentage of Emerging timber species
Lumber from bush cut	47	25	53.2
Boards from bush cut	27	12	44.4
Beams from bush cut	37	14	37.8
Lumber from sawmills	31	10	32.3
Boards from sawmills	20	6	30.0

Plate 40A and B: Timber merchant being interviewed by a survey enumerator

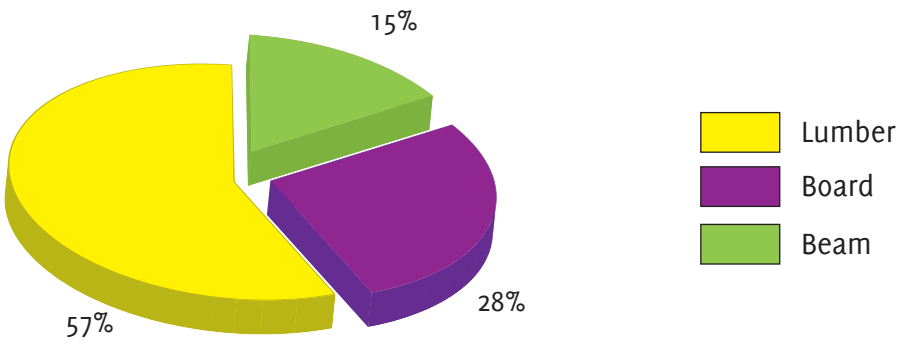

Figure 20: Monthly percentage volumes of the three wood products stocked to the total volume of the 56 timber species

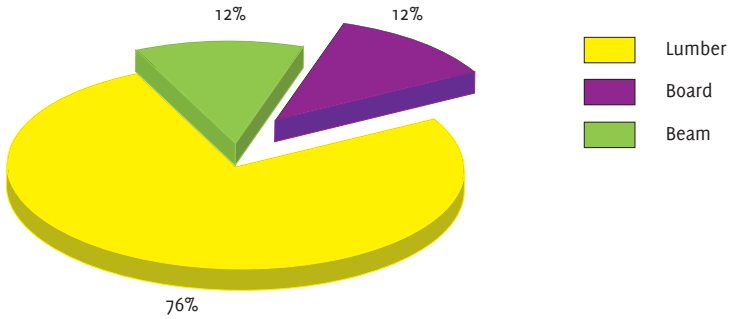

Figure 21: Percentage (%) monthly wood products distribution of volumes of stocked timber from the 28 wood species identified

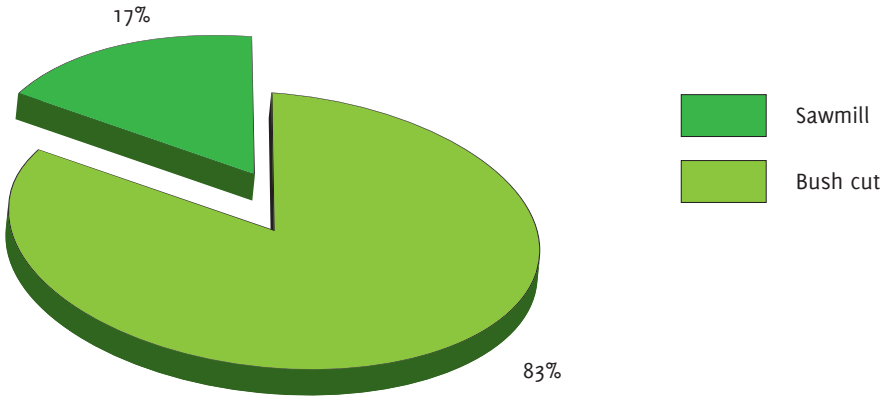

Figure 22: Percentage (%) volume of the sources of wood products supplied from the 56 species surveyed

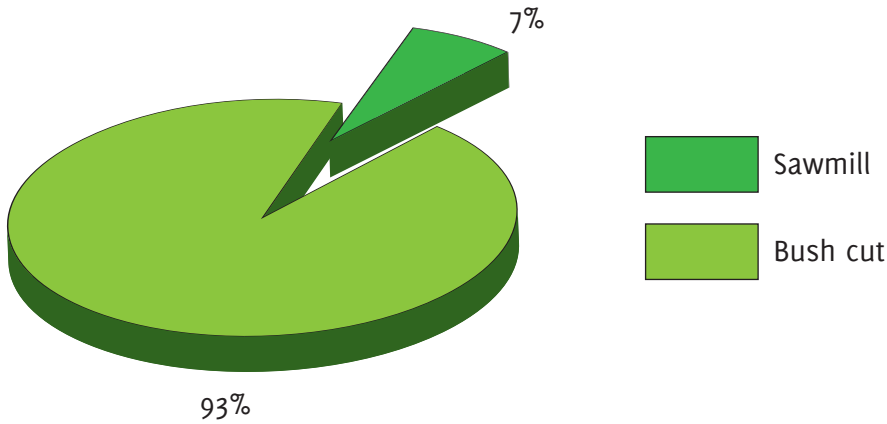

Figure 23: Percentage (%) volume of the sources of wood products supplied from the 28 emerging species surveyed

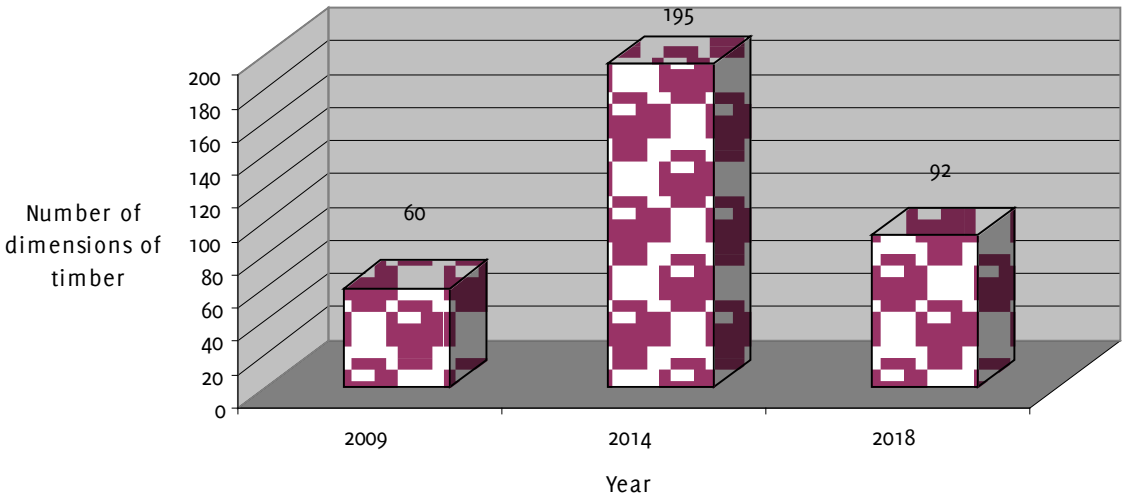

Figure 24: Dimensions of timber for three different periods of domestic market study in Ashanti region

OUTPUT 3.3 ACCREDITATION OF WOOD AND FURNITURE TESTING LABORATORY AT CSIR-FORIG

Research Team: *F.W. Owusu; H. Seidu; L. Damnyag; E. Ebanyenle; E. Appiah-Kubi; J. Govina; J. Korang; S. Ibrahim; F. Boakye; M. Mensah and B. Brentuo*

Donor: *SECO/UNIDO*

UNIDO through funding from the State Secretariat for Economic Cooperation (SECO), Switzerland is supporting CSIR-FORIG to set up and obtain accreditation for Wood and Furniture Testing Laboratory under ISO 17025. The laboratory will test and certify wood products for export in order to meet standards and become competitive in the international market. The objective is to enhance the export performance of Ghana by creating conditions for strengthening supply capacity in the wood industry. The specific objectives are: 1) To seek accreditation for WFTC at CSIR-FORIG according to the international standard ISO 17025. 2) To build the capacity of personnel and promote test laboratory to key stakeholders of the Ghanaian wood industry and boost the export and use of wood products through value addition by meeting standards.

Ten furniture companies in the Ashanti region were visited with the aim of educating them on the benefits of the Wood and Furniture Testing Centre that has been opened at CSIR-FORIG. Test standards for general safety requirements (EN 581-1) for seating (EN 581-2) and tables (EN 581-3) were used to test 13 chairs and 3 tables that were collected from some furniture companies in Kumasi. These were tested under the UNIDO sponsored activities. Standard procedures have been used to prepare reports for submission to clients. Samples of laminated bamboo and three wood species (*Mammea africana* - Bompagya, *Ceiba pentandra* - Onyina and *Triplochiton scleroxylon* - Wawa) were prepared and tested for their strength properties in accordance with the required standards. In addition, samples on acoustic test for *Terminalia superba* (Ofram) were prepared. Sheets of plywood collected from a plywood manufacturing company, were prepared into test specimens using a cross-cutting machine in accordance with EN 310 standard. The aim was to conduct a Round Robin test at WFTC in Ghana and BFH in Switzerland. These specimens were conditioned to enable them attain the same environmental conditions before test. Twenty-five plastic chairs of five (5) different sets of five replicates, were received from GSA for testing. These were prepared and taken through testing procedures. The use of composite materials for

the production of an executive swivel chair was undertaken (Plate 39). The aim was to establish a more efficient means of utilizing solid wood residues in Ghana. For efficient collaboration between CSIR-FORIG and Ghana Standards Authority (GSA), an MOU was proposed. Eleven (11) appropriate Ghanaian standards out of 18 that were requested from GSA, which had developed them, were received for use at WFTC. The centre is collaborating with Ghana Standards Authority (GSA) to use the WFTC facility to test and certify furniture, both domestic and imported ones, before they are allowed on the market. Therefore, an MOU between WFTC of CSIR-FORIG and GSA has been drafted and it is in its final stage. CSIR-FORIG in collaboration with Ghana Standards Authority (GSA) undertook promotional activity through TV3 by showcasing the activities at the Wood and Furniture Testing Centre from 20th August to 1st September 2019. Testing of five sets of five replicates each was completed and the reports have been compiled and submitted to GSA.

Ten furniture companies in Ashanti region were visited and sensitized on the use of standards as well as the testing facilities available at CSIR-FORIG. Reports for 16 tests on chairs and tables that had been undertaken were prepared using standard procedure and delivered to the customers. The Furniture companies were taken through the report to enable them make adjustments/ corrections to their designs where necessary.

Students from tertiary institutions had their wood samples tested for their mechanical strength properties (Plate 41). These wood samples were from laminated bamboo, *Mammea africana* (Bompagya), *Ceiba pentandra* (Onyina) and *Triplochiton scleroxylon* (Wawa) as well as the acoustic test on *Terminalia superba* (Ofram) were undertaken.

The quality management handbook, processes, manuals, templates for the laboratory that have been developed continues to be reviewed.

A seven (7) member Management committee for the Wood and Furniture Testing Centre (WFTC), chaired by the Director, CSIR-FORIG, had its maiden meeting in May 2019. Other members included Head, Finance Division, Head, Commercialisation Division, Head, Administration Division, Head, Wood Industry and Utilization Division, Quality Manager, WFTC and Technical Manager, WFTC. The Management Committee is responsible for the development of policies, procedures and resolution of resource issues. It also reviews the effectiveness and appropriateness of laboratory quality management system and conducts management reviews. Some decisions were taken at the meeting for the efficient operation of the Centre.

Two items, hand-held label printer (to print labels on both facilities/devices and products at the laboratory for easy identification) and hydrometer (for the measurement of humidity in the rooms at the centre where tests are conducted), as shown in Plate 43, had been acquired.

Two hundred and thirty-seven (237) visits from the following countries were made to the Wood and Furniture Testing Centre during the year under review: Ghana (230), United Kingdom (2), United States of America (2), Germany (1), Sweden (1) and Liberia (1).

Specimens for the round robin test were conditioned, as shown in Plate 44, before the test was conducted. This was completed and the results are being analyzed. Report on this test will be submitted to UNIDO Headquarters in Geneva through the UNIDO office in Ghana.

The production of an Executive Composite Swivel Chair was completed and tested for its durability, stability and strength. The swivel chair, which passed all the tests, has been named as *CSIR-*

FORIG Executive Composite Swivel Chair (Plate 45). The Centre is also being used to train students and conduct research (Plate 46).

UNIDO sponsored tests for some furniture products from some selected companies is completed and reports submitted. This has generated enough data for analysis as we wait for external assessors to assess the laboratory for international accreditation under ISO 17025. Corrective actions have been taken to address findings of the blank audit conducted by both the consultants from BFH, Switzerland and the technical expert from UNIDO. In addition, an internal blank audit has been planned by the Centre to check preparedness of staff towards accreditation. The quality manual continues to be revised as and when necessary. Wood and wood products from both the industry and students will continue to be tested in order to generate more data.

Plate 41: A chair failed at test

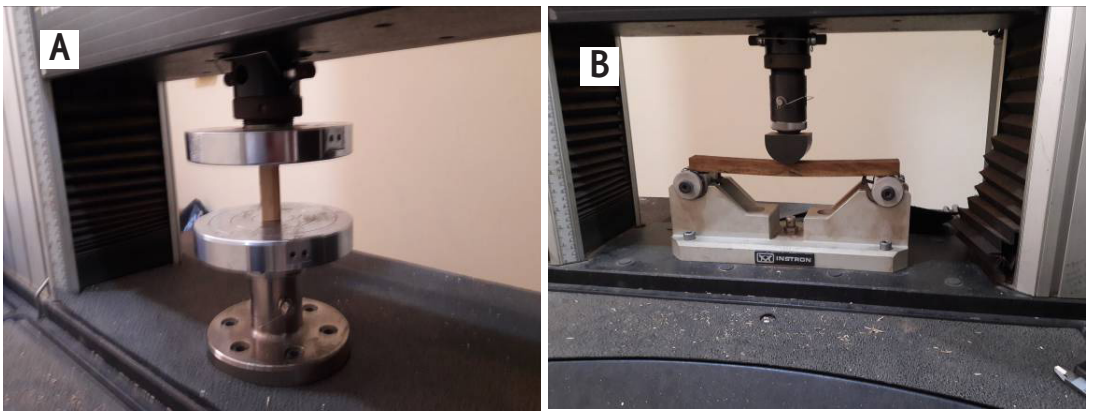

Plate 42: Mechanical strength tests on A= Compression perpendicular and B= Bending

Plate 43: Items acquired for use at WFTC
A=Hydrometers B= Hand-held label printer

Plate 44: Specimens for round robin test being conditioned in a climate chamber

Plate 45A - B: CSIR- FORIG Executive Composite Swivel Chair

Plate 46: Students receive training at the Furniture Testing Laboratory

OUTPUT 3.3 TRAINING OF HIGH-VOLUME TIMBER CONSUMERS (HVTC) ON SOURCING LEGAL TIMBER, LESSER KNOWN SPECIES, WOOD SPECIFICATIONS AND STANDARDS

Research Team: *F.W. Owusu; E. Appiah-Kubi and J.K. Govina.*
Donor: *UK-Department for International Development (DFID)*

Ghana has committed under the Voluntary Partnership Agreement (VPA)/Forest Legality, Governance and Trade (FLEGT) Programme with the European Union (EU) to ensure that legal timber is traded for the EU, other export markets and on the domestic market. The use of legal timber is designed to offset the over 60% of illegal timber that is presumed to be present on the domestic market in Ghana. Legal timber application will contribute to improving forest governance and the protection and preservation of the forest environment. A policy was crafted for the purpose since 2011. It is to "ensure supply of legal timber on sustainable basis, promote good governance and provide a framework that facilitates production and trade in legal timber on the domestic market." It is to realize the intention that a Public Procurement Policy (PPP) has been drafted for enactment so that State institutions together with their contractors and sub-contractors working on public projects procure only timber and timber products derived from legally and/or sustainably harvested forest or from legal sources. The PPP when approved will require that timber and timber product vendors register with the Forestry Commission (FC). This will enable FC to regulate and enforce the following measures on the domestic market: (i) procurement process, (ii) availability of legal timber, (iii) proof of legality, (iv) registration of vendors and dealers in timber and timber products, and (v) socio-economic safeguards and environmental protection in timber harvesting, processing and trade.

The supply of timber species to the domestic market has evolved. According to the Resource Management Service Center (RMSC) of FC, one hundred and three (103) timber species were harvested in 2015. Reports estimate that over 30 new species have been introduced to the

market in the last two decades. Therefore, the species availability in the forests and for the supply to the market is dynamic in nature.

Eighty-two (82) commercial timber species identified under the 2001 Multi Resource Inventory (MRI) of the FC were categorized into colors on the basis of their scarcity and exploitation. The production trend is showing increasing inclusion of green coded species (of no conservation concern) and pink species (utilisable but not as popular to the trade with cuts below 50% of their Annual Allowable Cut (AAC) to the timber species harvested. According to RMSC, (2016) green species contributed 41.3% of harvested volume in 2015. The others were 24.3% of Pink Star species; 10.9% of Red Star species (common but tend to be over-exploited at 100-200% of AAC) and 23.5% of Scarlet Star species (common but under high pressure from over exploitation-over 200% of their AAC).

Timber species transition is from Lesser Known Species (LKS) to Lesser Used Species (LUS), continuing to the Economic or High Demand Species, and then finally Protected Species. Timber traders have introduced several 'new' species onto the market. They are often deliberately and wrongly named to be same as or alternatives to known and popular timber species. That notwithstanding, their properties, preservation requirements and right uses are not known. There is therefore the need for research and information into the properties, preservation requirements and right uses of the 'new' species.

Ghana will soon issue FLEGT licenses covering legal wood products supplied to the EU, Export permits to non-EU and the Domestic Timber Certificate (DOTIC) to the domestic markets. In preparing to launch the issuance of these licenses and certificates, the DfID's Forest Governance, Market and Climate (FGMC) programme is providing support to the Nature and Development Foundation (NDF) working in collaboration with the Kumasi Wood Cluster (KWC) under the project titled: Building Capacities of Small and Medium Forest Enterprises (SMFEs) in Ghana and Liberia to Supply and Trade in Legal Timber. The project seeks to assist private sector institutions to acquire the various sets of knowledge and skills they will need to satisfy the legal and physical standards that define and regulate the supply of legal wood and wood products.

Assessments of the domestic market point to the fact that, private entities in the construction sector including Ghana Real Estates Developers' Association (GREDA), Chartered Institute of Building (CIOB), Association of Ghana Industries (AGI) and Association of Building and Civil Engineering Contractors of Ghana (ABCECG), who have been classified as High Volume Timber Consumers (HVTC) do so with little regard to quality and source of the timber. This is because they face a number of challenges, which include; 1) inadequate knowledge about technical properties of the abundant LUS timber predominant in the markets currently, 2) the difficulty of knowing who sells legal timber in the domestic market, and 3) getting evidence that what one buys is legal timber among others. The project will provide the support system to HVTCs to facilitate the ease of purchasing quality and legal timber in the domestic market.

The objective of CSIR-FORIG as consultant to the project is to assist private sector institutions to acquire the various sets of knowledge and skills, they will need to satisfy the legal and physical standards that define and regulate the supply of legal wood and wood products.

The dwindling timber resources in Ghana have reduced the volumes of timber species available to wood utilizers and most of the wood products available on the market are not from legal sources. According to Marfo *et al.*, (2017), main sources of timber supply to the domestic market

were chainsaw and sawmill of which 72% and 28% by volume of timber respectively were recorded. Further studies on the domestic markets in Ashanti region and Techiman registered percentage volumes of 83% for chainsaw and 17% for sawmill (Owusu *et al*., 2018). In Ghana, FC-RMSC (2019) records on the annual yield of timber from 2015-2018 indicate high volumes for wood species whose technical information are not available to the public thereby making it difficult for their efficient utilization. Ghana, which will soon issue FLEGT licenses to cover legal wood products that will be supplied to the EU, Export permits to non-EU and the Domestic Timber Certificate (DOTIC) to the domestic markets, is preparing to launch the issuance of these licenses and certificates. There is the need for the Small and Medium Forest Enterprises (SMFEs) in Ghana to Supply and Trade in Legal Timber. Creating and supporting a system that facilitates the ease of purchasing legal timber in the domestic market will not only motivate groups such as the HVTCs to buy legal timber but will also give a choice to individuals who are building houses or homes.

Forest management practices and policies have been tailored to solve most of the forestry related problems, but the problems still appear to exist owing to lack of adequate and or available technological information about the wood species.

A desk study on various timber species that are on the markets, their availability in terms of volumes and rating, and the availability of their technical information (properties), was conducted to identify gaps and recommend appropriate species for use by the HVTCs.

The desk study was undertaken to consider two major issues. Firstly, to identify the timber species that are available to wood users in Ghana and secondly, to find out the level of technical information (properties) that cover the available timber species. Studies done by CSIR-FORIG on species availability and emerging species on the domestic timber markets in Ghana from 2009 to 2017 were considered. Literature on the Ghanaian wood species with respect to their working properties was sought. Ninety-nine (99) timber species have been identified through the desk study, of which 33.3% have been researched for their working properties 37.4% have been partially researched i.e. those without full scientific information on their working properties and 29.3% have not been researched, that is, those without any scientific information on their working properties. The wood species are made up of prime species (i.e. commercially well-known species, whose properties have been established and available at both local and international markets), lesser used timber species (LUS: referring to timber species for which the wood quality and some other technological properties are known, promotional products developed and have been accepted in the local market, exported irregularly or occasionally over the last 40 to 50 years, the distribution and exploitable volumes are sufficient for market interest, but are hardly used), lesser known timber species (LKS: species which are yet to be traded in the international market and have limited use in the local market due to very limited information about their properties, but the distribution and exploitable volumes are sufficient for market interest) and technologically unknown (TU) (i.e. species with no information about their properties).

Visits were made to the following domestic timber markets in Ashanti, Bono and Ahafo regions to identify the timber species available for use by their various customers. The markets visited included the following: Sokoban, Akwatialine, Kwadaso, Ahwiaa, Abuakwa and Ejisu all in the Ashanti Region. Others are; Techiman, Sunyani-Social Welfare, Sunyani-Baakonuaba, Sunyani area 2, Estate junction and Wenchi in the Bono and Ahafo regions. Table 11 is the list of sixty-six (66) wood species that were available at the markets.

Table 11: Timber species surveyed at some domestic timber markets in Ashanti and Bono regions

S/no.	Scientific name	Local / trade name
1	*Albizia zygia*	Okoro
2	*Nauclea diderrichii*	Kusia
3	*Nesogordonia papaverifera*	Danta / Apro
4	*Milicia excelsa*	Odum
5	*Mansonia altissima*	Mansonia
6	*Entandrophragma cylindricum*	Penkwa / Sapele
7	*Rhodognaphalon buonopozense*	Akata
8	*Alstonia boonei*	Nyamedua
9	*Cola gigantea*	Watapuo/wobre
10	*Terminalia ivorensis*	Emire
11	*Pycnanthus angolensis*	Otie
12	*Blighia sapida*	Akyee
13	*Berlinia spp*	Kwatafompaboa
14	*Cedrela odorata*	Cedrella / Dua-gyeene
15	*Rhodognaphalon buonopozense*	Akonkodie
16	*Ficus sur*	Kotreamfo
17	*Antiaris toxicaria*	Kyenkyen
18	*Trichillia monadelpha*	Tandro,
19	*Sterculia tragacantha*	Foto
20	*Morinda lucida*	Konkroma
21	*Amphimas pterocarpoides*	Yaya
22	*Aidia genipaeflora*	Otweese
23	*Afzelia africana*	Papao
24	*Ceiba pentandra*	Onyina
25	*Morus mesozygia*	Wonton
26	*Gmelina arborea*	Gmelina
27	*Cordia millenii*	Twenaboa
28	*Tieghemella heckelii*	Abaku
29	*Holoptelea grandis*	Nokwa
30	*Pseudospondia macrocarpa*	Katawani
31	*Mammea africana*	Bompagya
32	*Rhodognaphalon buonopozense*	Onyina-kobene
33	Klainedoxa gabonesis	Kroma / Kruma

S/no.	Scientific name	Local / trade name
34	*Triplochiton scleroxylon*	Wawa
35	*Distemunanthus benthamianus*	Bosamdua
36	*Strombosia glaucescens*	Afina
37	*Zanthoxylum gilletii*	Okuo
38	*Lophira alata*	Kaku
39	*Ricinodendron heudelotii*	Wama
40	*Chrysophyllum subnudum*	Akasa
41	*Pterygota macrocarpa*	Koto
42	*Albizia ferruginea*	Awiemfosamina
43	*Manilkara spp*	Brekankum
44	*Anogeissus leiocarpus*	Kane
45	*Hallea stipulosa*	Subaha
46	*Honnoa klaineana*	Hotrohotro
47	*Cylicodiscus gabonensis*	Denya
48	*Guarea cedrata*	Kwabohoro
49	*Lovoa trichilioides*	Walnut / Dubenebiri
50	*Entand. utile*	Efoobrodedwo
51	Antiaris toxicaria	Ntedua
52	*Canarium schweinfurthii*	Bediwonua
53	*Heritiera utilis*	Nyankum
54	*Daniellia oliveri*	Senya
55	*Musanga cecropoides*	Odoma
56	*Anopyxis klaineana*	Kokote
57	*Celtis spp*	Esa
58	*Khaya spp.*	Mahogany / Dubene
59	*Petersianthus macrocarpus*	Essia
60	*Antrocaryon micraster*	Aprokuma
61	*Erythrophleum ivorense*	Potrodom
62	*Piptadeniastrum africanum*	Dahoma
63	*Terminalia superba*	Ofram
64	*Aningeria altissima*	Asanfina
65	*Sterculia rhinopetala*	Wawabima
66	*Margaritaria discoidea*	Pepea

Again, a survey was conducted on twenty (20) construction and furniture companies to find out their preferred timber species for construction and those available to them. Questionnaires were used to solicit information from the contractors and construction professionals on their preferred timber species for works as well as the trend of species usage in the past decades. Table 12 shows the list of twenty-six (26) species that the contractors and furniture manufacturers prefer and are able to find on the domestic markets. They complained that, the technical information available to them on some of the timber species at the domestic markets (++) are scanty and even in some cases are not available, hence, making them very difficult to use. So they always try to look for those species, mostly the prime, that are not easily available.

Table 12: List of preferred and available timber species to High Volume Timber Consumers (HVTCs) in Ghana

S/No.	Scientific name	Local/Trade name
1	*Milicia excelsa*	Odum/Iroko
2	*Triplochiton scleroxylon*	Wawa / Obeche
3	*Entandrophragma cylindricum*	Penkwa /Sapele
4	*Celtis spp*	Esa ++
5	*Daniella ogea*	Hyedua ++
6	*Piptadeniastrum africanum*	Dahoma
7	*Ceiba pentandra*	Onyina
8	*Petersianthus africanus*	Essia ++
9	*Terminalia ivorensis*	Emire
10	*Nauclea diderrichii*	Kusia
11	*Mansonia altissima*	Aprono Mansonia
12	*Daniellia oliveri*	Senya ++
13	*Lovoa klaineana*	Dubinibiri Walnut
14	*Terminalia superba*	Ofram ++
15	*Pycnanthus angolensis*	Otie ++
16	*Parinari excelsa*	Afam ++
17	*Aningeria spp.*	Asanfena
18	*Morus mesozygia*	Wonton ++
19	*Cylicodiscus gabunensis*	Denya
20	*Cola gigantea*	Watapuo/Wobre ++
21	*Antiaris toxicaria*	Kyenkyen ++
22	*Alstonia boonei*	Nyamedua/sinuro ++
23	*Tieghemella heckelii*	Abako / Makore
24	*Nesogordonia papaverifera*	Danta
25	*Albizia ferruginea*	Awiemfosamina
26	*Amphimas pterocarpoides*	Yaya ++

The Resource Management Service Center of the Forestry Commission was also visited for their annual timber yield allocation data from 2015 to 2018. A total of 107 timber species were given out for extraction with an estimated volume of 3,426,825.37 m^3. The 107 species have been star rated into Green (28), Pink (27), Red (14), Scarlet (13) and Others (25). The meaning of the colour ratings is shown in Table 13.

Tree species have been categorized on the basis of their availability at the resource base. Those that are available in high volumes at the resource base reflect on the domestic market. The different categories are referred to as star colours, i.e. Black, Gold, Blue, Scarlet, Red, Pink and Green. The pink and green star ratings, in terms of extraction levels, could be linked to the lesser-used and lesser-known timber species.

Table 13: Star Rating of Timber Species

STAR RATING	MEANING
Black	Rare internationally and uncommon in Ghana, highly protected
Gold	Fairly rare both internationally and/or in Ghana, high protection
Blue	Widespread internationally but rare in Ghana or vice versa. Protection required
Scarlet	Common, but under high pressure from over-exploitation. Strict controls on annual allowable cut if they are to remain commercially viable. Level of cut › 200% of AAC
Red	Common, but tend to be over-exploited, restriction needed, Level of cut 100-200% of AAC.
Pink	Utilisable but not as popular to the trade, present cut below AAC, hence the distribution and exploitable volumes are sufficient for market interest.
Green	No particular conservation concerns. The distribution and exploitable volumes are sufficient for market interest

Figure 25 indicate the star ratings of the first 40 species that have been selected (Table 14). The total volume of these species has been estimated as 3,331,112.77m^3, consisting of 97% of the total volume of the 107 timber species

Table 14: Selection of timber species from RMSC data based on total yield volume

	List of spp	Star rating		List of spp	Star rating
1	Onyina	Green	21	Krayie	Red
2	Wawa	Scarlet	22	Baku/Makore	Scarlet
3	Esa	Green	23	Hyedua	Pink
4	Dahoma	Pink	24	Asanfena	Pink
5	Papao	Red	25	Ohaa	Green
6	Kyen-Kyen	Pink	26	Onyinakoben	Red
7	Denya	Pink	27	Odum	Scarlet
8	Ofram	Pink	28	Dubinibiri/Walnut	Red
9	Dubini	Scarlet	29	Hotrohotro	Pink
10	Otie	Pink	30	Wawabima	Pink
11	Kyereye	Red	31	Kwabohoro	Pink
12	Sanya	Pink	32	Kusia	Scarlet
13	Akata	Green	33	Emire	Scarlet
14	Nyankom	Red	34	Watapuo	Green
15	Potrodom	Pink	35	Akasaa	Pink
16	Penkwa	Scarlet	36	Awiemfosamina	Scarlet
17	Danta	Pink	37	Asoma	Green
18	Esia	Green	38	Penkwa-Akoa	Scarlet
19	Edinam	Red	39	Kroma	Green
20	Yaya	Green	40	Krumben	Scarlet

In this case, pink star species comparatively recorded the highest volume of timber species that were extracted from the forest during the period. This is followed by the scarlet, green and red star species. These indicate the availability of the forty timber species on volume basis in the forests of Ghana and hence could be easily obtained by users. These species are also found in Tables 11-12, indicating that Table 14 will be the appropriate species to be recommended.

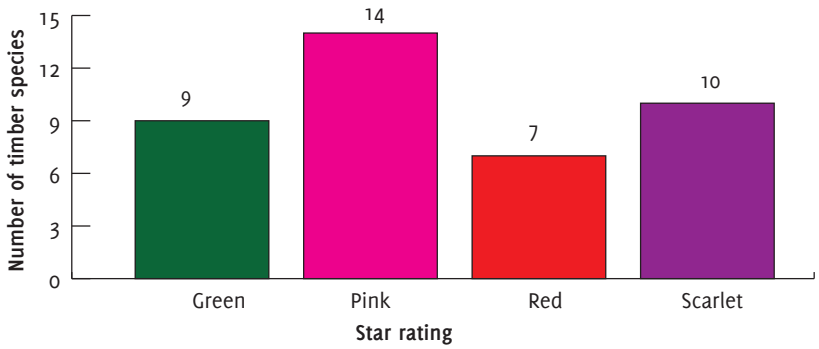

Figure 25: Selected 40 timber species with their star rating

There is therefore the need to determine their working properties, of which the red and scarlet star species with enough scientific information could be ignored.

Table 15: Selection of 40 species from RMSC 2015-2018 data based on yield volumes and star rating excluding red and scarlet star species

No.	Timber species	Star rating	Timber species	Star rating
1	Onyina	Green	Hotrohotro	Pink
2	Esa	Green	Asoma	Green
3	Dahoma	Pink	Kroma	Green
4	Kyen-Kyen	Pink	Sinuro	Green
5	Denya	Pink	Apapaye	Pink
6	Esia	Green	Afam	Pink
7	Ofram	Pink	Bediwonua	Pink
8	Otie	Pink	Atabene	Green
9	Sanya	Pink	Sopi	Pink
10	Akata	Green	Okoro	Green
11	Potrodom	Pink	Akyen	Green
12	Danta	Pink	Bonsamdua	Pink
13	Yaya	Green	Kumanini	Green
14	Hyedua	Pink	Bompagya	Pink
15	Asamfena	Pink	Tetekon	Green
16	Ohaa	Green	Wama	Green
17	Wawabima	Pink	Kwatafompaboa	Green
18	Kwabohoro	Pink	Ananta	Pink
18	Watapuo	Green	Kwadwuma	Pink
20	Akasaa	Pink	Otwese	Green

The desk study that was undertaken indicates that the scarlet star species, which are being over exploited, have enough scientific information for their utilization by the High-Volume Timber Consumers. Some of the red, pink and green star species do not have all the necessary information for their efficient utilization, hence the need to determine their properties. Without considering the scarlet species then appropriate data on thirty (30) of the timber species as shown in table 30 will be compiled for submission to Kumasi wood cluster for promotion. The properties that are not available and need to be researched into are shown in Table 17. This covers treatment, movement in service, working properties and mechanical strength properties.

Table 16: Selection of 30 species from RMSC 2015-2018 data based on yield volumes and star rating excluding scarlet star species

No.	List of spp	Star rating	No.	List of spp	Star rating
1	Onyina	Green	16	Edinam	Red
2	Esa	Green	17	Yaya	Green
3	Dahoma	Pink	18	Krayie	Red
4	Papao	Red	19	Hyedua	Pink
5	Kyen-Kyen	Pink	20	Asamfena	Pink
6	Denya	Pink	21	Ohaa	Green
7	Ofram	Pink	22	Onyinakoben	Red
8	Otie	Pink	23	Dubinibiri/Walnut	Red
9	Kyereye	Red	24	Hotrohotro	Pink
10	Sanya	Pink	25	Wawabima	Pink
11	Akata	Green	26	Kwabohoro	Pink
12	Nyankom	Red	27	Watapuo	Green
13	Potrodom	Pink	28	Akasaa	Pink
14	Danta	Pink	29	Asoma	Green
15	Essia	Green	30	Kroma	Green

Table 17: List of species with unavailable properties

No.	Scientific name	Local name	Star rating	Status (Prime /LK S/LUS)	Properties unavailable
1	*Ceiba pentandra*	Onyina	Green	Prime	-
2	*Celtis spp*	Esa	Green	LUS	Treatment
3	*Piptadeniastrum africanum*	Dahoma	Pink	LUS	-
4	*Afzelia africana*	Papao	Red	LUS	-
5	*Antiaris toxicaria*	Kyen-Kyen	Pink	LUS	Movement in service
6	*Cylicodiscus gabunensis*	Denya	Pink	LUS	-
7	*Terminalia superba*	Ofram	Pink	LUS	Treatment and movement in service
8	*Pycnanthus angolensis*	Otie	Pink	LUS	Treatment
9	*Pterygota macrocarpa*	Kyereye	Red	Prime	Treatment

No.	Scientific name	Local name	Star rating	Status (Prime /LK S/LUS)	Properties unavailable
10	*Daniellia oliveri*	Sanya	Pink	LUS	Sawing/ machining and movement in service
11	*Rhodognaphalon buonopozense*	Akata	Green	LUS	Treatment
12	*Heritiera utilis*	Nyankom	Red	Prime	-
13	*Erythrophleum ivorense*	Potrodom	Pink	LUS	-
14	*Nesogordonia papaverifera*	Danta	Pink	LUS	-
15	*Petersianthus macrocarpus*	Essia	Green	LUS	-
16	*Entandrophragma angolense*	Edinam	Red	Prime	-
17	*Amphimas pterocarpoides*	Yaya	Green	LUS	Treatment and movement in service
18	*Pterocarpus erinaceus*	Krayie	Red	LUS	Working properties and movement in service
19	*Daniella ogea*	Hyedua	Pink	LUS	-
20	*Aningeria altissima*	Asanfena	Pink	LUS	-
21	*Sterculia oblonga*	Ohaa	Green	LUS	-
22	*Rhodognaphalon brevicuspe*	Onyinakoben	Red	LUS	Movement in service
23	*Lovoa trichilioides*	Dubinibiri/ Walnut	Red	Prime	-
24	*Honnoa klaineana*	Hotrohotro	Pink	LUS	-
25	*Sterculia rhinopetala*	Wawabima	Pink	LUS	Treatment
26	*Guarea cedrata*	Kwabohoro	Pink	LUS	-
27	*Cola gigantean*	Watapuo	Green	LKS	Treatment
28	*Chrysophyllum subnudum*	Akasaa	Pink	LUS	-
29	*Parkia bicolor*	Asoma	Green	LUS	-
30	*Klainedoxa gabonesis*	Kroma / Kruma	Green	LUS	-

No.	Scientific name	Local name	Star rating	Status (Prime /LK S/LUS)	Properties unavailable
31	*Gilbertiodendron spp*	Tetekon	Green	LUS	Movement in service and treatment
32	*Mammea africana*	Bompagya	Pink	LUS	Working properties, movement in service and treatment
33	*Albizia zygia*	Okoro	Green	LUS	-

Desk study of species availability in Ghana for both researched and un-researched, field visits to some domestic timber markets, High Volume Timber Consumers (HVTCs) and Resource Management Service Center (RMSC) of the Forestry Commission and gap analysis of timber species information have been undertaken while compilation of properties on lesser-used and lesser-known timber species is in progress. Thirty-three (33) lesser-used and lesser-known timber species have been proposed for validation by HVTCs.

4.0 SCIENCE AND PEOPLE (SP)

4.1 Background and Highlights of Research Achievements under SP

Research activities under this theme was aimed at aligning science with the development priorities of local communities, government and development partners by focusing the socio-economic and sustainable resource management and utilization as well as highlighting the services that forests provide to society. In this regard, the research agenda is primarily focused on the following thematic areas:

- Policy and Governance
- Statistical, Social and Economic Research
- Culture, Indigenous Knowledge and Community Improvement
- Technology for Livelihoods and Wealth Creation

OUTPUT 4.2 CREATING AWARENESS AMONG BASIC SCHOOLS ON CLIMATE CHANGE SENSITIZATION & OUTREACH PROGRAMMES

Research Team: *G. D. Djagbletey; E. G. Foli; A. Duah-Gyamfi; S. D. Addo-Danso; G. K. D. Ametsitsi; R. T. Guuroh; J. O. Amponsah; D. A. Opoku; J. J. Twintoh; E. Okyere-Agyapong; C. Opoku-Kwarteng; A. Adu-Gyamfi; A. A. Brako; J. Odei Owusu–Asante and P.M. Gakpetor.*

Donor: *CSIR-FORIG*

Climate change and environmental sustainability are critical issues that need urgent collective action. The world is believed to be on the threshold of a disaster with mass extinction due to climate change. Many people (including children, movements and organizations) in different parts of the world, who have gained knowledge, understanding or experience of the current situation, are educating, mitigating, adapting or protesting against climate change and its adverse effects. To address these concerns, the Forest and Climate Change Division of the CSIR-Forestry Research Institute of Ghana (CSIR-FORIG) in collaboration with Scientists from other Divisions of CSIR-FORIG, formed a Schools' Outreach Team to carry-out awareness creation, education and information sharing on climate change and environmental issues, so as to reach out to as many people as practicable especially, children and the youth who are the next generation and likely to suffer grave consequences if actions are not taken to reduce the current impacts of climate change.

The main aim of the SOP is to embark on a countrywide school climate change and environmental sensitization campaign starting with schools within the Ejisu and Juabeng Municipal Assemblies. It is expected that this intervention would educate the pupils/students on the general importance/ benefits of the tropical forest, what climate change is, the causes and effects and what could be done to mitigate and/or adapt to the effects. Additionally, the programme aims at enhancing the visibility of CSIR-FORIG locally, nationally and beyond. The activities of the Team fall within the framework of the Education for Sustainable Development (ESD) programme, instituted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), among others,

to improve access to quality education on sustainable development (about climate change and biodiversity) at all levels. Furthermore, the CSIR-FORIG Schools' Outreach Programme addresses six (out of the 17) Sustainable Development Goals (SDGs) directly. These include climate action (SDG 13), life on land (SDG 15), clean water and sanitation (SDG 6), affordable and clean energy (SDG 7), good health and wellbeing (SDG 3), sustainable cities and communities (SDG 11).

CSIR-FORIG is committed to ensuring that environmental education is brought to the doorsteps of children in Ghana. Children are very receptive and quick in imbibing, keeping and sharing information for several years. Since the forest, and for that matter the environment as a whole, is to be conserved for posterity, children are expected to be the appropriate targets to be able to carry the message from generation to generation. The broad impact would ultimately be nationwide. The practical experience acquired will go a long way to create awareness in the children and foster their interest in environmental conservation. Contacts were made with school authorities to arrange for suitable dates and times for our team to visit and engage with the pupils. The programme entails: 1) engaging the students in a lecture to explain climate change issues, the effects, mitigation and adaptation measures through audio visual presentations, 2) engaging the pupils in field practical sessions like tree nursery activities, 3) tree planting exercises and 4) visit to a forest (where lectures on ecotourism, biodiversity, etc. are presented to them) and to let them have a physical feel of the tropical forest environment. For publicity and visibility, we involved media practitioners from various media houses in each outreach activity, to help disseminate the information to the wider society through radio, newspaper and television coverage.

Seven (7) schools have been visited since the inception of the programme in 2017. These schools include Hwereso R/C Primary and JHS, Kubease D/A JHS, Fumesua Anglican JHS, Fumesua MA JHS, CSIR Basic School, Ejisu Model School and Hill Top Platinum School. Pilot activities were carried out in the first four schools. The team developed manuals separately to target lower primary, upper primary and junior high schools in recognition of the fact that pupils have varying levels of knowledge. Thereafter, the team tested the manuals at the CSIR Basic School and this helped to fine-tune and further improve the manuals for subsequent outreach programmes in the two other schools (Ejisu Model School and Hill Top Platinum School) in 2019. Through the education on climate change and environmental sustainability, 567 have been educated in 2019 alone and over 2,000 since 2017. The children become educators by also sharing the information with friends, family and community at large. In addition, our outreach programme impacts the broader community through the trees that are planted with the children which serve as shade trees, wind breaks, controls for soil erosion, provision of oxygen, carbon dioxide sequestration and provision of other ecosystem services that are beneficial to all. Since the beginning of the outreach programme, approximately 1,150 trees have been planted on various school compounds as shown in Plate 47. Periodic visits to the schools are undertaken to assess the performance of all the planted trees and dead ones were replaced.

Plate 47A - D: Tree planting exercise by staff, resource persons and pupils from Ejisu Model School and Hilltop Platinum School

Monitoring was periodically carried out to ensure that the programme achieves the desired impact. The team follows up each outreach activity with evaluation by the pupils/students. Questionnaires were administered to solicit the views of each target group. The responses were analysed thereafter to enable the outreach team measure the impact and improve upon next visits. Evaluation through interviews were conducted in two schools with a total of one hundred and forty (140) questionnaires administered to pupils. Pupils were interviewed on the general organization of the SOP, knowledge on climate change and its effects, actions they were willing to take and had taken since the SOP. The data from their responses were entered in SPSS statistical software and have been analysed.

Out of the 140 pupils interviewed from Hill Top Platinum and Ejisu Model Schools, 56% were females and 44% were males. Approximately half of the pupils were in Primary class 4-6 (53%) and the other half in JHS 1-3 (47%). Majority of the pupils (60%) were teenagers between the ages of 12-16, with the remaining 40% between the ages of 8-11. Out of the pupils interviewed, 92% had never participated in an outreach programme before. Whiles 85% had never heard or had knowledge on the SOP on climate change implemented by CSIR- FORIG. Few (15%) had heard about the programme through television, a family member or a friend.

Pupils were asked about how they enjoyed the various sessions to help the team improve on the mode of delivery. Majority of the pupils (66%) enjoyed the tree planting exercise the most, followed by the presentation and discussion (14%), the video (11%), the excursion (6%), with about 3% enjoying the questions and answers session (Figure 26).

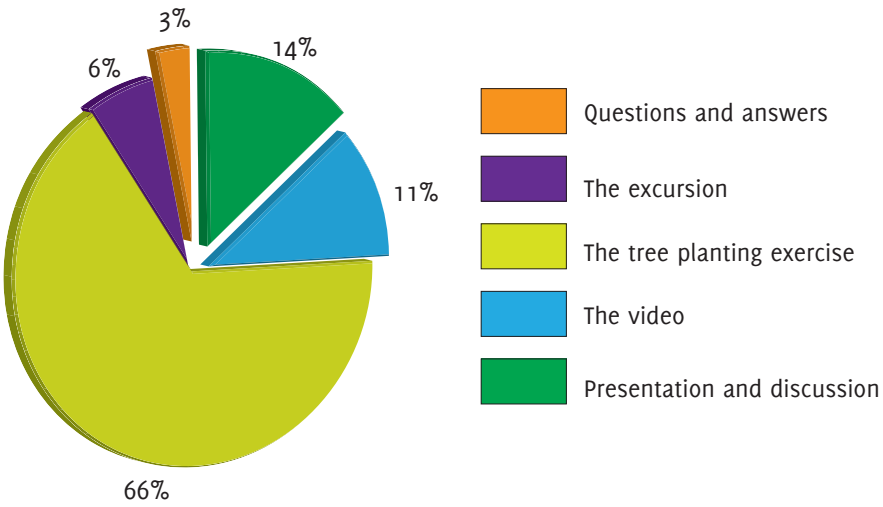

Figure 26: Pie chart showing the percentages of the different sessions of the SOP that were enjoyed by pupils

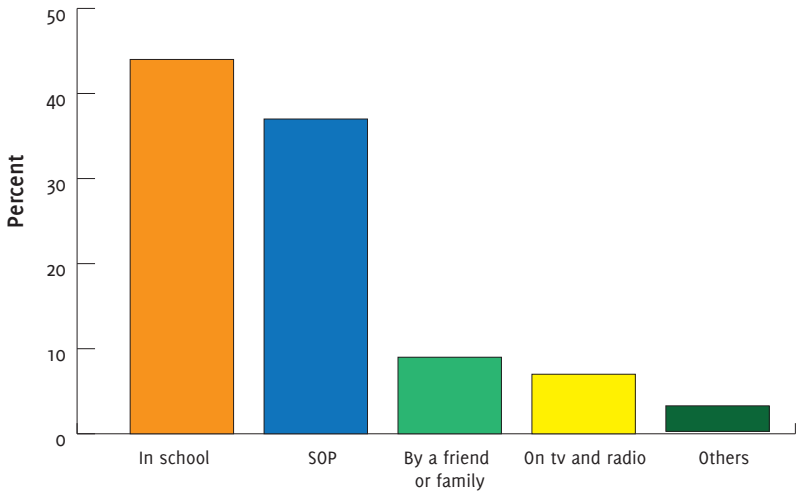

Figure 27: Bar chart showing percentages of the primary sources of information on climate change by pupils

To determine the foreknowledge of pupils and the primary sources of information on climate change, the pupils interviewed were asked if they had heard about climate change before and where they first heard it. Approximately one-third (37%) of the total number of pupils interviewed, had never heard about climate change and were hearing it for the first time through the SOP. About two-thirds (i. e. 63%) had heard about climate change before, out of which 44% had heard it in school, 9% had heard it through a family member or friend, 7% had heard it on TV or radio and 3% had heard it from other sources such as books or articles (Figure 27). Though majority of the pupils (about 63%) had heard about climate change before, 94 % of the interviewees confirmed they had learned more and new things on climate change through the SOP. All the students interviewed (100%) were willing to take action to reduce the negative effects of climate change. These actions included planting and caring for trees (96%), keeping the environment clean (88%), using water wisely (88%), sharing the climate change message with others (93%) etc.

The preliminary results indicate that education and awareness creation of school children in climate change and caring for the environment is crucial since, children are receptive and educating/sensitizing them has positive impacts now and even for the future. Climate change education and awareness creation among young children need to be promoted significantly to get all children informed of the current and future situation, as well as the actions they can take to adapt and contribute to climate change mitigation. Climate change education should be incorporated into the schools' curricula as early as possible since is it the main primary source of information for the children. To make climate change education more interesting and enjoyable, practical exercises like tree planting, environmental clean-ups and excursions should be made part of the school's calendar to make children feel involved in mitigating the effects of climate change.

In addition to the schools' curricula, outreach programmes or climate change and environmental sensitization campaign need to be promoted in schools and communities to get children and young people informed and involved. Government institutions, NGOs and other stakeholders, which are actively involved in climate change mitigation, adaptation and environmental conservation, need to spread the message on climate change to the children and the youth who form the future generation and get them involved in the practical solutions.

5.0 COMMERCIALISATION

OUTPUT 5.1 COMMERCIALISATION FOR SUSTAINABLE DEVELOPMENT AND INCREASED IGF – 2019 (COMMERCIALISATION DIVISION)

Research Team: *N. Appiah; A. A. Obeng and K. Asumadu*
Donor: *CSIR-FORIG*

CSIR-FORIG, a renowned forestry-based research institute has, through the efforts of seasoned scientists and competent supporting staff developed a number of marketable technologies and interventions. The Commercialisation Division was tasked to spearhead, coordinate and strategically focus on clear cut marketing strategies geared towards enhancing Internally Generated Funds (IGF) of the Institute. Commercial activities for the year under review focused on the production / processing and marketing of traditional products and services such as forest tree seeds and seedlings, high quality honey, prekese syrup, thinnings of wood, wood products, sale of bamboo plantlets, mushroom spawns, running of guesthouses, hiring of office facilities; and training in alternative livelihood technologies (beekeeping for honey production, snail farming and mushroom cultivation).

In 2019, the benchmark for assessing performance of the Division was based on the objective; "to build brand awareness and enhance customer relationships", amidst a competitive environment. This necessitated the implementation of aggressive and specific marketing strategies and tactics aimed at existing and potential clients in the industry. In this regard, social media marketing, with specific reference to professional, religious and social WhatsApp platforms were extensively used to create and build brand awareness of commercial products and services. Other marketing strategies and tactics which were adopted and geared towards achieving set objectives included clients' feedback to ascertain customers' opinions and recommendations for maximum satisfaction. The availability and accessibility of marketing staff resulted in improved relationship with clients and increased sale during the year. The design, printing and distribution of information sheets, official letters, flyers, posters, banners, expression of interest for contract bidding, partial partnership with FM stations and word of mouth advertisements were some strategies which enabled the Division to achieve set targets, notably the following.

With regards to visibility, more than eight (8) FM /TV stations (GTV, Joy, Dela, Sela, North Tongu, Bohye, New Mercury, Peace) either hosted or interviewed key staff of the division, particularly the training team; and featured over 20 news reports to promote among others, the benefits of the Institute's alternative livelihood programmes. Staff of the division designed and distributed over 35 separate hard and electronic training flyers and posters, coupled with a YouTube video on commercial snail farming at CSIR-FORIG. Prekese information sheet was extensively used (distribution of hard copies, institute's website and other social media platforms) in marketing the cash cow of CSIR-FORIG (prekese syrup). The resulting effect of these extensive promotional activities led to high patronage of training activities and an extremely high demand for other commercial products and services.

The reactivation of training sessions spearheaded by the Commercialization Division in the three livelihood technologies since mid-2017 has led to the training of over 800 persons in both

beekeeping and snail farming; 80% from various professional disciplines in Accra, Kumasi, Obuasi, Sunyani, Yeji, Takoradi, Ho and Battor opted for snail farming. Fifty-eight members of the public were also trained in the cultivation of both oyster and domo (oil palm or straw) mushrooms over the stipulated period. A total of 5 Nigerians, an Ivorian and 2 Togolese were beneficiaries of 2 livelihood activities: snail farming and beekeeping. However, in 2019, capacity building of 545 persons in the following areas were achieved; Snail Farming (336), Beekeeping (145) and Mushroom Cultivation (34). A net IGF of **GH¢ 26,871.00** was generated from beekeeping for honey production and snail farming training sessions; and **GH¢ 4,056** from mushroom cultivation respectively.

Plate 48: First group of trainees – July 2019

Plate 49: Beekeeping training session in Accra, 2019

Plate 50: Snail farming training session in Accra, 2019

The division took steps to establish linkages or collaborate with other public and private organizations for the purpose of Public Private Partnership (PPP) agreements. LOTS Services Limited (private company) has set up a subsidiary company named "The Bee Farms Ghana" and is working out the necessary modalities to partner CSIR-FORIG and "The Hive Kenya" to establish and develop a vibrant beekeeping industry in the country. The proposed partnership arrangement would be between LOTS Services Limited, CSIR-FORIG and The Hive Kenya; and consummated after a formal agreement is signed. As part of the initial preparation, LOTS Services Limited sponsored three CSIR staff and a staff from LOTS Services Limited to attend a one-week beekeeping business feasibility and top-up training tour to The Hive Kenya in October, 2019.

Plate 51 A- B: Three members of the training team visit an apiary at Masinga, Kenya

As regards R&D, there was a call for concept note on the Skills Development Fund (SDF) website to which the Division applied. A full project proposal titled: "**Training in Sustainable Beekeeping, Snail Farming and Mushroom (Domo) Cultivation**" was submitted and approved for funding. Funds are yet to be released to kick-start the project.

There were significant increases in the quantity and income of other commercial products and services during the year. The division produced and marketed over 11,850 bottles (250 mls – 80%; 125 mls – 20%) of prekese syrup, a difference of 3,850 bottles recorded for 2018. Similarly, over 23,000 bottles (500 mls) of honey were produced, processed and sold, a difference of

11,000 bottles over 2018. Clients of these products consisted of, but not limited to supermarkets, pharmacies, herbal clinics and shops, hospitals, schools and tertiary institutions and a host of identifiable wholesalers and retailers. Various species of forest tree seeds were collected, processed and sold; while over 450,000 seedlings were raised at the Institute's nursery and sold to cherished clients such as governmental and non-governmental organisations, donor funded agencies, private plantation developers and the general public.

The ensuing year will experience significant growth in certain key areas. The purchase of a new oven for prekese syrup production in 2020 is estimated to produce an average of 2,400 bottles per month to address the excess demand for the product in both the domestic and international markets. With funding from SDF, it is expected that CSIR-FORIG would develop a standardized short-term training programme in beekeeping, snail farming and mushroom (domo) cultivation for increased yield and productivity.

OUTPUT 5.2 PRODUCTION OF SEEDLINGS BY THE NATIONAL TREE SEED CENTRE (NTSC) FOR REFORESTATION

Research Team: *J. M. Asomaning; J. O. Amponsah; P.M. Gakpetor; S. Owusu and S. Asumadu*
Donor: *CSIR-FORIG*

The NTSC was established among other things to ensure the conservation and production of superior quality seeds. During the year under review, seeds were collected and processed for storage in a cold room as a gene bank. Seedlings were also produced from seeds collected for planting purposes. The following quantities of seeds and seedlings were produced.

Seed Production

Table 18: Quantity of tree seeds collected in 2019 and the number of hectares they can plant

SPECIES	TOTAL SEEDS COLLECTED (KG)	ESTIMATED NUMBER OF SEEDLINGS IN 1 KG	ESTIMATED NUMBER OF SEEDLINGS FROM SEEDS	NUMBER OF SEEDLINGS FOR HA (3×3)	NUMBER OF HECTARES SEEDLINGS CAN COVER
Terminalia superba (Ofram)	267	2,500	667,500	1111	593.33
Nauclea diderrichii (Kusia)	1.5	800/g	1,200,000	1111	1,066.67
Tieghemella heckilii (Baku)	20	11	210	562.5 (6×6)	0.37
Pericopsis elata (Kokrodua)	26	4,000	104,000	1111	92.44
Cedrela odorata (Cedrela)	12	15,000	180,000	1111	160.00
Entandrophragma angolensis (Edinam)	23	1,500	34,500	1111	30.67

SPECIES	TOTAL SEEDS COLLECTED (KG)	ESTIMATED NUMBER OF SEEDLINGS IN 1 KG	ESTIMATED NUMBER OF SEEDLINGS FROM SEEDS	NUMBER OF SEEDLINGS FOR HA (3×3)	NUMBER OF HECTARES SEEDLINGS CAN COVER
Mansonia altissima (Mansonia)	53	2,000	106,000	1111	94.22
Terminalia ivorensis (Emire)	110	1,000	110,000	1111	97.78
Khaya anthotheca (Mahogany)	55	1,500	82,500	1111	73.33
Tectona grandis (Teak)	378	1,000	378,000	1111	336.00
TOTAL	**945.5**		**2,862,710**		**2,544.81**

Seedlings produced by NTSC

The total number of seedlings raised and released for planting in the year under review was four hundred and fifty thousand **(450,000)** in support of reforestation programmes

Table 19: Quantity of tree seedlings produced for 2019 and the estimated hectare of land each species can cover (using 3 x 3 as planting distance)

SPECIES	QUANTITY IN STOCK	NUMBER OF HECTARES
Terminalia superba (Ofram)	63,300	56.27
Cedrela odorata (Cedrela)	26,956	23.96
Terminalia ivorensis (Emire)	3,100	2.76
Nauclea diderrichii (Kusia)	28,200	25.01
Entandrophragma angolensis (Edinam)	6,527	5.8
Mansonia altissima (Mansonia)	14,700	13.01
Pericopsis elata (Kokrodua)	8,000	7.11
Khaya anthotheca (Mahogany)	9,604	8.54
Ceiba pentandra (Onyina)	2590	2.3
TOTAL	**162,977**	**144.76**

The National Tree Seed Centre (NTSC) produced an average of **2,862,710** seeds within the year under review and the seeds were estimated to produce about four hundred and fifty thousand **(450,000)** seedlings. The seedlings produced can plant a total of **2, 544** ha per year

OUTPUT 5.3 MEDIA ENGAGEMENTS

Research Team: *E. Minkah; K. K. Mensah; E. Frans-Mensah; E. Sarpong and M.E. Nikoi*
Donor: *CSIR-FORIG*

CSIR-FORIG continued to engage with the media within the year under review in order to inform the general public as well as various stakeholders of numerous technologies the institute released in the year 2019. Many publications/articles were published in the national dailies such as the Daily Graphic, Ghanaian Times, GNA Website, and the Chronicle. Various television stations such as GTV, TV3, UTV, and FM/RADIO (Hello FM, Luv FM) held programmes with research scientists from CSIR-FORIG to educate the public on various technologies and scientific processes in afforestation and climate change in the country. Social media platforms such as WhatsApp, Facebook and YouTube were also employed to educate the general public especially the youth in planting trees. Many articles were also published on the institute's website. The CSIR-FORIG intent in engaging with the general public through the various forms of media was to increase its visibility.

News www.ghanaiantimes.com.gh 07
THURSDAY, APRIL 11, 2019 GHANAIAN Times

FAO to support Ghana combat climate change

E. HOPE, FUMESUA

The participants

News WEDNESDAY,

FORIG completes research into special tree species

FROM KINGSLEY E.HOPE, FUMESUA

SPECTATOR News Saturday, June 3, 2019 3

High consumption of bush meat affecting Ghana's biodiversity —Dr Kankam

From Kingsley E. Hope, Fumesua

Annual consumption of bush meat in Ghana is estimated at 385,000 metric tonnes.

SPECTATOR News Saturday, June 22,

New Frog species (Afia Birago), found in Ghana

From Kingsley Hope, Kumasi.

TWO Ghanaian Scientists have discovered a new frog species along a forest stream at Jukwa near the Central Region.

The new frog, Afia Birago

NOTICE

Table 20: Summary of CSIR-FORIG Media Engagements in 2019

DATE	MEDIA ORGANISATION	TITLE OF PUBLICATION
Jan. 16, 2019	Ghanaian Times	FORIG Completes research into special Tree Species
April 11, 2019	Ghanaian Times	FAO to Support Ghana combat Climate Change
June 1, 2019	The Spectator	High Consumption of bush meat affecting Ghana's biodiversity
June 22, 2019	Ghanaian Times	Don't Purchase Cocoa from Forestry Reserves – Government orders
June 22, 2019	The Spectator	New Frog Species (Afia Birago), found in Ghana
July 25, 2019	Ghanaian Times	Contribution of CSIR-FORIG in addressing the impact of Climate Change in Ghana
Oct. 19, 2019	Joy Online	Lands degraded by galamsey to be reclaimed with trees
Oct. 23, 2019	Ghanaian Times	50,000 Chinese are Engaged in Illegal Mining in Ghana
Nov. 4, 2019	Ghana News Agency (GNA)	Sustainable Utilization of Bio-energy production
Nov. 5, 2019	Ghana News Agency (GNA)	Local Communities affected by galamsey want free land reclamation
Nov. 19, 2019	Daily Graphic	Government must tighten laws against illegal mining
Nov. 27, 2019	Ghana News Agency (GNA)	Massive boost for wood industry as CSIR-FORIG sets up furniture and wood testing centre
Dec 24, 2019	Ghana News Agency (GNA)	CSIR-FORIG to conduct quality assurance tests on 29 newly identified timber species

6.0 EDUCATION AND CAPACITY BUILDING

OUTPUT 6.1 PROMOTING EDUCATIONAL LEADERSHIP IN CLIMATE SCIENCE AND INTEGRATED NATURAL RESOURCES MANAGEMENT AT MASTER OF PHILOSOPHY AND MASTER OF SCIENCE LEVELS

CSIR-FORIG through CCST has underscored its resolve to create opportunities for many Ghanaians and nationals from other West African countries to be trained to acquire professional skills and expertise needed to manage the threat of climate change in their respective countries. The programme has, in the past year (2019), targeted natural resource managers who wish to enhance skills as well as those who wish to continue their studies after obtaining a Bachelor's degree. The Programme also targets people who are already working in different sectors of forestry and wish to build a new career pathway into Climate Change and Natural Resources Management. The above-mentioned programme being promoted by CSIR-FORIG at Fumesua, near Kumasi, is aimed at providing an elevated level of professional and technical expertise to address the challenges of climate change and natural resources management in West Africa. The programme has so far delivered some empirically grounded and conceptually rich courses to 14 students who are expected to exit the programme with the knowledge, skills and competencies highly desired in the public, private and not-for-profit sectors.

Scholars of CSIR-FORIG who are renowned for their research and education in the fields of climate science and natural resources management are delivering the programme. Among the courses taught are Climate Science, Climate Change Impact, Adaptation and Mitigation, Climate Change Modelling, Geographical Information Systems (GIS), Project Planning and Management, Scientific Communication, Innovative Processing and Sustainable Utilization of Biomaterials and other useful courses. Learning has been accomplished through problem-based group work activities, presentations, interactive students-led seminars, laboratory work, literature-based research and/or assignments and discussions online and offline on the distance learning platform (Moodle). This was done alongside face-to-face teaching (conventional lectures). The Moodle platform for teaching enables students to learn at their own convenience from a distance, while face-to-face classroom interactions are organized at a time that is convenient to both students and lecturers.

Lectures for the second semester of 2018/2019 resumed on 7th January 2019. Pre- and post-examination moderation exercises were successfully organized by the Institutional Affiliation Office of the University of Cape Coast. The End of Second Semester examinations took place successfully from 21st January to 1st February 2019. Internship during vacation was arranged for eligible students to take place from 11th February to 22nd March, and supervision of those who were working on their thesis continued throughout the rest of the year. Four (4) MPhil students submitted their thesis for examination during the year, and subsequently defended their thesis at the *viva voce* held later during the year. The final corrected thesis were submitted to the College Registry for submission to the University of Cape Coast for approval and award of certificates.

During the May 2019 intake, two (2) students were admitted to the Programme, and nine (9) more students were admitted during the September intake, bringing the total number of students admitted in 2019 to eleven (11).

The first semester of the 2019/2020 academic year began on 16th September 2019 and all the courses were effectively delivered until the Christmas break from 23rd December 2019 until 6th January 2020.

By and large, the year 2019 was a successful year, with all planned activities duly executed.

7.0 ADMINISTRATION DIVISION

7.1 Objectives

The main objectives of the Division include the following:

i) To ensure implementation of policies, procedures, rules and regulations of Corporate CSIR at the Institute level to facilitate effective and efficient performance of work by all Divisions.

ii) To provide administrative machinery for the implementation of institutional initiatives and activities.

7.2 Staff Strength

The total staff strength of the Institute, as of December 2019 was 209. The breakdown is as follows:

Staff Category	No.
Senior Members	46
Technologists	16
Senior Staff	66
Junior Staff	81
Total	**209**

7.3 Appointment of A New Deputy Director

Dr. Luke C. N. Anglaaere, a Principal Research Scientist was appointed as the new Deputy Director of the Institute with effect from 1st August, 2019. He took over from Prof. Mark Appiah who ended his 2- year tenure.

7.4 Newly Recruited Staff

Eight (8) new staff comprising five (5) males and three (3) females were recruited for the period under review. Six out of the eight were recruited in the Senior Member category and the remaining two were Senior Staff. All of them reported to work. The details with respect to rank and date of appointment are provided in the table below:

No.	Name	Grade	Date of Appointment
1.	Dr. Haruna Abukari	Research Scientist	1st April, 2019
2.	Dr. Samuel Adu-Acheampong	Research Scientist	1st May, 2019
3.	Patience Mansa Gakpetor	Principal Technologist	1st April, 2019

No.	Name	Grade	Date of Appointment
4.	Judith Odei Owusu-Asante	Principal Technologist	1st April, 2019
5.	Prosper Mensah	Principal Technologist	1st April, 2019
6.	Emmanuel Minkah	Principal Technologist	1st April, 2019
7.	Tracy Amponsah Akoto-Bamfo	Technical Officer	1st April, 2019
8.	Emmanuel Duodu Nyarko	Technical Officer	8th April, 2019

However, Dr. Samuel Adu Acheampong, a Research Scientist resigned from the service of the Council at the end of June, 2019. He was replaced with **Dr. Courage Besah-Adanu,** a Research Scientist (Entomologist) on 1st July, 2019.

Two (2) other senior staff were transferred from CSIR Head Office to CSIR-FORIG in March 2019. The table below specifies their details.

No.	Name	Grade	Date of Appointment
1.	Habibu Alidu	Administrative Assistant	1st March, 2019
2.	Abigail Amponsah Ofosu-Brako	Technical Officer	22nd March, 2019

7.5 Institutional Transfers

The under-listed members of staff were transferred to CSIR-FORIG as follows:

No.	Name	Grade	Institute	Date of Transfer
1.	David A. Dafliso	Senior Asst. Transport Officer (Driver)	CSIR Head Office, Accra	2nd May, 2019
2.	Emmanuel M. K. Sosu	Research Scientist (ICT)	CSIR-OPRI, Kade	9th December, 2019

7.6 Staff Training

Currently the total staff in training stands at twenty-one (21). The detail with respect to level and type of training is summarized in the table below:

Level of Training	Type of Training		Total
	Local	*Foreign*	
Ph.D	2	6	8
MPhil. /MSc. /MA.	6	1	7
BSc. /BA	6	-	6
Others	-	-	-
Total	**14**	**7**	**21**

7.7 PROMOTIONS

a) **Senior Members**

Dr. Lawrence Damnyag, was promoted from Senior Research Scientist to Principal Research Scientists effective 1st July, 2018.

b) **Senior Staff**

The under-listed Senior Staff were promoted to the various grades effective 1st January, 2019 as indicated below:

No.	Name	Former Grade	Present Grade	Effective Date
1.	Georgina Boateng Yeboah	Prin. Acct. Asst.	Chief Acct. Asst.	1st January, 2019
2.	Jemima Owusu	Prin. Tech. Officer	Chief Tech. Officer	1st January, 2019
3.	Sandra Owusu	Prin. Tech. Officer	Chief Tech. Officer	1st January, 2019
4.	Benjamin S. Sarfo Mainoo	Senior Acct. Asst.	Prin. Acct. Asst.	1st January, 2019
5.	Kwabena Achina Owusu	Senior Acct. Asst.	Prin. Acct. Asst.	1st January, 2019
6.	Emmanuel Sarpong	Senior Library Asst.	Prin. Library Asst.	1st January, 2019
7.	King Alhassan	Security Officer	Snr. Security Officer	1st January, 2019

c) **Junior Staff**

The under-listed Junior Staff were promoted to the various grades effective 1st January, 2019 as indicated below:

No.	Name	Former Grade	Present Grade	Effective Date
1.	Helena Oboamah Asiedu	Snr. Catering Asst.	Technical Officer (Catering)	1st January, 2019
2.	Ruth Amuzu	Overseer	Asst. Farm Manager	1st January, 2019

d) **Monthly-Rated Junior Staff**

The under-listed Monthly-Rated Junior Staff were promoted to the various grades effective 1st January, 2019 as indicated below:

No	Name	Former Grade	Present Grade	Effective Date
1.	Michael Asaa Akayagre	Security Asst. Gd. 11	Security Asst. Gd. 1	1st January, 2019
2.	Anthony Appiah	Security Asst. Gd. 11	Security Asst. Gd.1	1st January, 2019
3.	Baba Mahama	Security Asst. Gd. 11	Security Asst. Gd. 1	1st January, 2019
4.	Job Akougba	Security Asst. Gd.11	Security Asst. Gd. 1	1st January, 2019
5.	Issa Abdulai	Security Asst. Gd. 11	Security Asst. Gd. 1	1st January, 2019
6	Paul Kyei	Security Asst. Gd. 11	Security Asst. Gd. 1	1st January, 2019
7	Kofi Nyarko	Security Asst. Gd. 11	Security Asst. Gd. 1	1st January, 2019
8.	Samuel Ayambire	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019

No	Name	Former Grade	Present Grade	Effective Date
9.	Oppong Duah Anthony	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
10.	Kwadwo Boadi	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
11.	Paul Assuming	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
12.	Kwame Tawiah	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
13.	Kofi Kanjarga	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
14.	Samuel Adu Boahen	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
15.	Akua Serwaah	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
16.	Gladys Opoku	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
17.	George Atinyele (Jnr.)	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
18.	Charles Sarpong	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
19.	Thomas Atendana	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
20.	Abdul Atinga	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
21.	Kwasi Amakye	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
22.	Collins Kwasi Ahenkorah	Supervisor Gd. 1	Asst. Overseer Gd.1	1st January, 2019
23.	Sampson Nketia	Supervisor Gd.1	Asst. Overseer Gd. 1	1st January, 2019
24.	Kwabena Oduro	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
25.	Seth Owusu	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
26.	Kofi Amakye	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
27.	WahabYakubu	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
28.	Edward Nsorwaah	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
29.	Ebenezer OwareTweneboah	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
30.	Amos Asemonu Biewko	Supervisor Gd. 1	Asst. Overseer Gd. 1	1st January, 2019
31.	Haruna Issaka	Supervisor Gd. 1	Asst. Overseer Gd.1	1st January, 2019
32.	Sulemana Abdulai	Driver Gd. 11	Driver Gd. 1	1st January, 2019
34.	Pius Yaw Addo	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
34.	Margaret Adablah Azumi	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
35.	Gifty A. Agyeiwaah	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
36.	Cletus Akudbilla Ayabilla	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
37.	Charles Adu	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
38.	Ali Inousa	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
39.	Gifty Tengan	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019

No	Name	Former Grade	Present Grade	Effective Date
40.	Leticia Laadi Atareyure	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
41.	Emmanuel Koduah	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
42.	Peter Ayambire Amoah	Supervisor Gd. 11	Supervisor Gd. 1	1st January, 2019
43.	Appiah Rawlings	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
44.	Salifu Iddi Serekye	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
45.	Amos Ania Akanzire	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
46.	Michael Fiawatsor	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
47.	Salifu Abdul	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
48.	Samuel Acheampong	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
49.	Jennifer Osei Owusu	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
50.	Nuhu Ali	Snr. Labourer	Supervisor Gd. 11	1ST January, 2019
51.	Agyenim Boateng	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
52.	Bernard Yeboah	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
53.	Kwabena Bosompem	Snr. Labourer	Supervisor Gd. 11	1st January, 2019
54.	Joyce Fosu	Snr. Labourer	Supervisor Gd. 11	1st January, 2019

7.8 Compulsory Retirements

A total of sixteen (16) members of staff went on compulsory retirement from the service of the Council during the year 2019. The breakdown is as follows:

a) Senior Member: 2

b) Senior Staff: 9

c) Junior Staff: 5

Total **16**

7.9 Resignation

One Senior Member resigned from the service of the Council as indicated below

No.	Name	Grade	Date of Resignation
1.	Dr. Ing. Emmanuel Appiah-Kubi	Research Scientist	1st June, 2019

7.10 Leave of Absence

CSIR granted one-year leave of absence approval for two (2) Senior Members, and two years leave of absence for one (1) Senior staff as follows:

1. Dr. Charles Essien - Wood Industry and Utilisation (WIUD) effective 1st December, 2019
2. Dr. Sandra Owusu Acheampong - Forest Improvement and Productivity Division (FIPD) effective 1st April, 2019

3. Abigail Ofosu-Brakoh - Forest and Climate Change Division (FCCD) effective 1st September, 2019

7.11 Resumption of Duty from Study Leave

The following members of staff resumed duty from study leave:

No.	Name	Programme	Institution	Date of Resumption
1.	Francis A. Abetia	MBA (Human Resource)	KNUST -Kumasi	1st August, 2019
2.	William Hagan Brown	MPhil GIS	KNUST- Kumasi	21st October, 2019
3.	Diana A. Tanoah	BBA	Christian Service University College - Kumasi	1st July, 2019

7.12 Obituary

During the year 2019, one (1) senior staff and three (3) junior staff passed on to glory.

No.	Name	Grade	Date of Death
1.	K. Prempeh Bandoh	Chief Technical Officer	20th February, 2019
2.	Kwadwo Boadi	Asst. Overseer Gd. 1	15th June, 2019
3.	Paul Kyei	Security Asst. Grade 1	29th August, 2019
4.	Solomon Adjei	Foreman	5th September, 2019

7.13 Major Events

The following major events took place during the year as follows:

No	Event	Date
1.	CSIR-FORIG Annual Thanksgiving Service	9th January, 2019
2.	Sensitization Workshop – (Modernizing Agriculture in Ghana) "MAG" Presenter: Dr. Luke Anglaaere	26th February, 2019
3.	76th Internal Management Committee (IMC) Meeting	21st March, 2019
4.	International Conference: (Conservation and use of Forest Genetic Resources in Sub-Saharan Africa (SAFORGEN).	9th-11th April, 2019
5.	45th CSIR-FORIG Management Board Meeting	25th April, 2019
6.	Training: (Advanced Data Analysis in 'R' Course) Presenter-: Dr. Stephen Adu-Bredu	27th April – 1st May, 2019
7.	Director-General Meeting with all Senior Members of the four (4) Kumasi – based Institute	9th May, 2019
8.	Durbar: First (1st) Staff Durbar for the year 2019.	6th June, 2019
9.	Orientation for 2019 Attachment Students.	10th June, 2019

No	Event	Date
10.	Meeting: Chairman of Council with CSIR-FORIG and some key Management Staff of CSIR.	12th June, 2019
11.	FORIG Staff Fund 15th Annual General Meeting	18th Jun, 2019
12.	Tree Planting Exercise	28th June, 2019
13.	End of service presentation for 2018/2019 National Service Personnel	31st July 2019
14.	Training Workshop: GIFMIS & GOG Hyperion Software Training for CSIR Northern Sector Accounting and Auditing staff members	16th - 21st September, 2019
15.	Health Screening for staff members	11th September, 2019
16.	National Service Orientation for 2019/2020 National Service Personnel	10th September, 2019
17.	46th Management Board Meeting	24th September, 2019
18.	47th Management Board Meeting	5th November, 2019
19.	78th Internal Mgt. Committee (IMC)Meeting	20th November, 2019
20.	Annual Review and Planning Meeting	11th – 13th Dec. 2019
21.	Staff End of Year Get-together and Awards Ceremony	20th December, 2019

7.14 COLLOQUIUM PRESENTATION

The following presentations were made at a colloquium during the year as follows:

No	Presenter(s)	Topic	Date
1.	Prof. Kate Parr from University of Liverpool, UK.	Do the little things run the world?	17th January, 2019
2.	Dr. Charles Essien	Fundamental Consideration & Application of Acoustic Techniques as a Forest Management Tool	24th January, 2019
3.	Hungarian Students	Presentations on scientific visits	5th February, 2019
4.	CSIR-College of Science and Technology (CCST)Students	Presentation of Thesis	14th February, 2019
5.	Hon. Dr. Emmanuel Marfo (MP for Oforikrom)	Interfacing Forest Science and Policy using Parliamentary Oversight Mechanism	28th February, 2019
6.	Dr. Ernest G. Foli	Tree Diversity and Natural Regeneration are Jointly Controlled by Aridity & Disturbances in Dry Lands of Ghana	14th March, 2019
7.	CCST Students	Research Presentations.	4th April, 2019

No	Presenter(s)	Topic	Date
8.	Mr. Lawrence K. Mensah	Presentation on Public Sector Employees Pension Scheme (PSWEPS) on Tier Two Pension for all SSNIT Contributors.	5th April, 2019
9.	Dr. Emmanuel Ebanyenle	XyloTron: A tool to combat illegal timber trade in Ghana	25th April, 2019
10.	Mr. Richard Ninnoni Esq, Dr. Bright Kankam, Dr. Lawrence Damnyag	Our Biodiversity, Our Food, and Our Health.	22nd May, 2019
11.	Mr. Kofi A. Quashie-Sam, Esq.	Introduction of Law of Contracts, Analysis and signing of Agreements, Leases, MOU's Application forms Part 1.	6th June,2019
12.	Dr. (Mrs.) Beatrice O. Darko, Dr. Reginald Guuroh, Dr. Akwasi Duah-Gyamfi, and Dr. Kwame A. Oduro	1. Establishing Land Restoration Research & Demonstration Area within Degraded Mining Sites. 2. Phytoremediation Potential of Indigenous and Exotic Tree Species in Ghana).	11th June, 2019
13.	Mr. Francis Wilson Owusu	Emerging Timber Species on the Domestic Markets in Ashanti Region and Techiman.	20th June, 2019
14.	Dr. (Mrs.) Beatrice Darko Obiri	Perception and Economics of Herbicide use in Forest Plantation Establishment in Ghana.	27th June, 2019
15.	Bangor University	Summer School	18th July, 2019
16.	CCST Students	Research Presentations.	15th August, 2019
17.	Mr. William Bandoh	Checking Individual Tree Logs with DNA Fingerprints	22nd August, 2019
18.	Lawyer Quashie-Sam	Introduction to Law of Contracts (Analysis and signing of agreements, Leases, MOU's, Application forms etc) Part 2	5th September, 2019
19.	Dr. Mireku Asomaning and Mr. James Amponsah	Seed Source Documentation	19th September, 2019
20.	Mr. Albert Armooh	Introduction to the Sustainability of Map: "An International Trade Centre (ITC) Tool"	26th September, 2019

No	Presenter(s)	Topic	Date
21.	Dr. Haruna Abukari	Comparing Park Management Strategies and Local Community Attitudes in Ghana and Tanzania	3rd October, 2019
22.	Dr. (Mrs.) Beatrice Darko-Obiri, Dr. Akwasi Duah Gyamfi, Dr. James Kofi Korang & Mr. Francis Wilson Owusu	Addressing Current Environmental Degradation in Ghana (Symposium)	17th October, 2019
23.	Dr. Cindy E. Prescott (Visiting Professor from UBC)	Publish… Don't Perish	21st October, 2019
24.	Mr. Prosper Mensah	Characterization of Particleboards Manufactured from Four (4) Agro-forest Residues using Cassava Starch and Urea Formaldehyde as Adhesives	31st October, 2019
25.	Mr. Haruna Seidu	Ransomware: Protection and Prevention of the Deadly Malware	14th November, 2019
26.	Prof. J.R. Cobbinah	Problem Analysis: A Critical Step in Research Project Design, Monitoring and Evaluation	21st November, 2019

7.15 Human Resources

One major asset of CSIR-FORIG is the number of highly qualified staff in all the Divisions. The names of Senior Members and Senior Staff in each of the nine (9) Divisions are provided in Appendix I and II.

8.0 FINANCE DIVISION

8.1 Objectives of Finance Division are as follows:

1) Provide suitable financial information to management for the daily management of the Units of the Institute
2) Assist in short and long-term planning
3) Help establish internal controls measures to safeguard assets of the Institute and ensure the completeness, accuracy and reliability of financial records.

8.2 Summary of Financial Results - 2019

Government of Ghana	Inflows (GHS)	Outflows (GHS)	Variance (GHS)
Personnel Emoluments (Note 1)	10,251,646	10,251,646	-
Administrative Expenditure (Note 2)	-	657,221	(657,221)
Service Expenditure (Note 3)	-	441,427	(441,427)
Internally Generated Funds (Note 4)	1,421,541	486,032	935,509
Guest Houses	238,350	36,767	201,583
Production Unit (Note 5)	66,961	51,182	15,779
Total	**11,978,498**	**11,924,276**	**54,223**
Donor (Note 6)	6,450,843	5,821,120	629,722

Note 1: The Personnel Emoluments figure represents staff emoluments paid directly by the Controller and Accountant General's department to staff. The Institute has no control over the expenditure.

Note 2: The Administrative (operational) expenditure was sponsored by IGF, because no grant was received from central government

Note 3: For some time now, service grant is not forth coming from Central Government. Expenditure under service are entirely financed from IGF and accumulated resources.

Note 4: Funds generated internally were used for both administrative expenditures, service expenditures and IGF expenditures.

Note 5: The total expenditure for the Production Unit excludes electricity expenses of GHS42,052 which was apportioned to the section for their 2019 consumption.

Note 6: Donor funds were received in Dollars, Euros, Pounds and Ghana cedis. They were converted to the local currency for consumption.

Note 7: The 2019 draft financial report is awaiting External Auditor's attention.

9.0 STAFF PUBLICATIONS

9.1 Journal Papers

1. Aguirre-Gutierrez, J.; Oliveras, I.; Rifai, S.; Fauset, S.; **Adu-Bredu, S.**; Affum-Baffoe, K.; Baker, T. R.; Feldpausch, T. R.; Gvozdevaite, A.; Hubau, W.; Kraft, N. J. B.; Lewis, S. L.; Moore, S.; Niinemets, U.; Peprah, T.; Phillips, O. L.; Zieminska, K.; Enquist, B. and Malhi, Y. (2019). Drier tropical forests are susceptible to functional changes in response to a long-term drought. *Ecology Letters*, 1-11 doi: 10.1111/ele.13243.

2. **Akpalu, S. E.;** Dawoe, E. L. and Abunyewa, A. A. (2019). Effects of boiled water pre-sowing treatment on the germination and early growth performance of *Faidherbia albida* in three ecological zones of Ghana. *Asian Journal of Agriculture and Forestry 4(3): 1-17.*

3. **Amissah, L.** and Ninnoni, R. K. (2019). Wildfire management in West Africa: a community effort. In: Global landscape fire challenges: a decade of progress. *Fire Management Today*, 77(1): 18-22.

4. **Antwi-Wiredu, A.;** Amiteye, S.; Asare, A.T.; Kusi-Adjei, R.; Diawuoh, R.G.; Aryee, C.O.; and Klu, G.Y.P. (2019). The use of microsatellite markers in genetic variation analysis of some introduced rubber tree (*Hevea brasiliensis*) clones cultivated in Ghana. *Journal of Agriculture Sciences-Sri Lanka*, 14(1):8-16, http://dx.doi.org/10.4038/jas.v14i1.8452

5. **Asomaning, J. M.** and Sacande, M. (2019). Desiccation, germination and water sorption isotherm of *Garcinia afzelii* Engl. (Clusiaceae) seeds. *Research Journal of Seed Science,* 12(1) :1-9.

6. **Asomaning, J. M.** (2019). Germination of *Garcinia kola* (Heckel) seeds in response to seed sectioning, chemical pretreatment and different temperatures. *Journal of Biodiversity and Environmental Sciences*, 14(4): 44-53

7. Borden. K. A.; **Anglaaere. L. C. N.; Adu-Bredu. S.** and Isaac, M. E. (2019). Root biomass variation of cocoa and implications for carbon stocks in agroforestry systems. *Agroforestry Systems* 93: 369 – 381. Doi 10.1007/s10457-017-0122-5

8. **Bosu, P. P.; Apetorgbor, M. M.; Amissah, L.** and Mutta, D. (2019). Status, trends and impacts of forest and tree pests in West and Central Africa. *African Journal of Rural Development* 4 (1): 93-107

9. Chabi, A.; Lautenbach, S.; Tondoh, J. E.; Orekan, V. O. A.; **Adu-Bredu, S.**; Kyei-Baffour, N.; Mama, V. J. and Fonweban, J. (2019). The relevance of using in situ carbon and nitrogen data and satellite images to assess aboveground carbon and nitrogen stocks for supporting national REDD + programmes in Africa. *Carbon Balance and Management,* 14(12): 1-13. https://doi.org/10.1186/s13021-019-0127-7

10. Cheng, Q.; **Essien, C.**; Via, B. and Banerjee, S. (2019). Cost savings from soy flour substitution in Methylene diphenyl diisocyanate for bonding flakes and particle. *Forest Products Journal,* 69(2): 154-158.

11. Danquah, J. A.; Ahiadzo, R. K.; **Appiah, M.;** Roberts, C.O. and Pappinen, A. (2019). Assessing smallholder farmers' understanding of environmental effects of modern agronomic practices in Ghana, *Journal of Experimental Agriculture International*, 29(6): 1-16, http://DOI:10.9734/JEAI/2019/45199

12. Defrenne, C. E.; McCormack, M. L.; Roach, W. J.; **Addo-Danso, S. D.** and Simard, S. W. (2019). Intraspecific fine-root trait-environment relationships across interior douglas-fir forests of Western Canada. Plants, 8(199): 1-16. http://doi:10.3390/plants8070199

13. **Dumenu, W. K.** (2019). Assessing the impact of felling/export ban and cities designation on exploitation of African rosewood (*Pterocarpus erinaceus*). *Biological Conservation Journal,* 236: 124–133.

14. **Essien, C.**; Devkota, P.; Via, B. K. and Eckhardt, L. G. (2019). Understanding relationship between the wood quality parameters and susceptibility of *Pinus taeda* to pine decline. *European Journal of Wood and Wood Products* https://doi.org/10.1007/s00107-019-01450-7.

15. Evans, B. J.; Gansauge, M.T.; Stanley, E. L.; Furman, B. L.; Cauret, C. M.; **Ofori-Boateng, C.,** Gvož dík, V.; Streicher. J. W. S.; Greenbaum, E.; Tinsley, R. C.; Meyer, M.; Blackburn D. C. et al (2019). Xenopus fraseri: Mr. Fraser, where did your frog come from? *PLoS ONE* 14(9): e0220892. https://doi.org/10.1371/journal.pone.0220892.

16. Gaitán, J.J.; Maestre, F.T.; Bran, D.E.; Buono, G.G.; Dougill, A.J.; Martínez, G.G.; Ferrante, D.; **Guuroh, R.T.;** Linstädter, A.; Massara, V.; Thomas, A.D. and Oliva, G.E. (2019). Biotic and abiotic drivers of topsoil organic carbon concentration in drylands have similar effects at regional and global scales. *Ecosystems,* 22:1445. https://doi.org/10.1007/s10021-019-00348-y

17. Gaither, C. J.; Yembilahb, R. and **Samar, S. B.** (2019). Tree registration to counter elite capture of forestry benefits in Ghana's Ashanti and Brong Ahafo regions. *Land Use Policy,* 85:340 – 349.

18. Issifu, H.; **Ametsitsi, G.K.D.**; de Vries, L. J.; **Djagbletey, G. D.**; **Adu-Bredu, S.**, Vergeer, P.; van Langevelde, F. and Veenendaal, E. (2019). Variation in vegetation cover and seedling performance of tree species in a forest-savanna ecotone. *Journal of Tropical Ecology* https://doi.org/10.1017/S0266467418000469.

19. Jongsma, G. F. M.; Zassi-Boulou, A.; Portik, D. M.; Bamba-Kaya, A.; Caviedes-Solis, I. W.; **Ofori-Boateng, C.;** Leaché, A. D. and Tobi, E. (2019). Defensive behavior of *Kassina maculosa* (Marbled Running Frog) and *K. Arboricola* (Ivory-Coast Running Frog). *Herpetological Review*, 50(2): 336-337

20. Krishnan, S.; **Ofori-Boateng, C.;** Fujita, M. K.; Leaché, A. D. (2019). Geographic variation in West African *Agama picticauda*: insights from genetics, morphology, and ecology. *African Journal of Herpetology.* doi.org/10.1080/21564574.2018.1509139

21. Kumeh, E. M.; Kyereh, B.; **Oduro, K. A.;** Brobbey, L. K.; Nketiah, S. K. (2019). Transparency in the governance of landscape restoration finance: a case study of Ghana's Forest Plantation Development Fund. *Scientific African*, 6: 1-12. https://doi.org/10.1016/j.sciaf.2019.e001852468-2276

22. Leaché, A. D.; Portik, D. M.; Rivera, D.; **Ofori-Boateng, C.** and Fujita, M. K. (2019). Exploring rainforest diversification using demographic model testing in the African foam-nest treefrog (*Chiromantis rufescens*). *Journal of Biogeography* https://doi.org/10.1111/jbi.13716

23. Messerli, P.; Kim, E.M.; Lutz, W.; Moatti, J-P.; Richardson, K.; Saidam, M.; Smith, D.; Eloundou-Enyegue, P.; **Foli, E.G.**; Glassman, A.; Licona, G.H.; Murniningtyas, E.; Staniskis, J.K. and Ypersele, J. P. (2019). Expansion of sustainability science needed for the SDGs. *Nature Sustainability*, 2: 892 – 894.

24. Mitchual1, S. J.; **Owusu, F. W.** and Minkah, M. A. (2019). Sanding and shaping characteristics of *Gmelina arborea* grown in two ecological zones in Ghana. *Journal of Engineering Research and Reports,* 4(3): 1-12.

25. Morel, A. C.; Sasu, M. A.; **Adu- Bredu, S.;** Quaye, M.; Moore, C.; Asare, R. A.; Mason, J.; Hirons, M.; McDermott, C. L.; Robinson, E. J. Z.; Boyd, E.,;Norris, K. and Malhi, Y. (2019). Carbon dynamics, net primary productivity and humanž appropriated net primary productivity across a forest–cocoa farm landscape in West Africa. *Global Change Biology,* 1–17.

26. Morel, A.C.; Hirons, M.; Adu Sasu, M.; Quaye, M.; Ashley, Asare R.; Mason, J.; **Adu- Bredu, S.;** Boyd, E., McDermott, C. L., Robinson, E. J. Z., Straser, R., Malhi, Y. & Norris, K. (2019). The ecological limits of poverty alleviation in an African Forest-Agriculture Landscape. *Frontiers in Sustainable Food Systems, 3:57*. http://doi.org/10.3389/fsufs.2019.00057

27. Moore, C.; Morel, A. C.; Asare, R. A.; Sasu, M. A.; **Adu-Bredu, S.** and Malhi, Y. (2019). Human appropriated net primary productivity of complex mosaic landscapes. *Frontiers in Forests and Global Change*, 2(38): 1-14.

28. **Obeng, E. A.; Oduro, K. A.; Obiri, B. D.; Abukari, H.; Guuroh, R. T.; Djagbletey, G. D.;** Appiah-Korang, J. and **Appiah, M.** (2019). Impact of illegal mining activities on forest ecosystem services: local communities' attitudes and willingness to participate in restoration activities in Ghana. *Heliyon,* 5(10):1-11 https://doi.org/10.1016/j.heliyon.2019.e02617

29. **Obeng, E. A.; Oduro, K. A. and Obiri, B. D.** (2019). Application of the theory of planned behavior in predicting US residents' willingness to pay to restore degraded tropical rainforest watersheds. *Journal of Sustainable Development*, 12 (6): 62-81.

30. Portik, D. M.; Bell, R. C.; Blackburn, D. C.; **Ofori-Boateng, C.** and McGuire, J. A. (2019). Sexual dichromatism drives diversification within a major radiation of African amphibians. *Systematic Biology,* 68(6):859–875.

9.2 Books and Handbooks/Book Chapters

1. Lindsell, J.; Agyei, R.; Bosu, D.; Decher, ; Hawthorne, W.; Marshall, C.; **C. Ofori-Boateng** & Mark-Oliver Rödel (2019). *The Biodiversity of Atewa Forest*: research report. Accra, Ghana: Arocha Ghana.

2. **Amissah, L.** and Aflakpui, G. K. S. (2019). Achieving food and nutrition security: the role of agroecology, In Leal Filho, W., Azul, A.M., Brandli, L., Özuyar, P.G., Wall, T. (eds.) Zero Hunger. Encyclopaedia of the UN Sustainable Development Goals. Springer Nature Switzerland AG, https://doi.org/10.1007/978-3-319-69626-3_58-1

3. **Akpalu S. E.; Adeyiga G. K.**; Amooh M. K.; Kyere D. and Akpalu M. M. (2019). Population density and diversity of trees on farmlands in the Upper East Region of Ghana: implications for Food Security and Ecosystem Sustainability. In: New Perspectives in Agriculture and Crop Science. 1:13, (2019).

4. Dompreh, D.; Nsor, C. A. and **Amissah, L.** (2019). Has *Talbotiella gentii* lost its insect pollinators? A threat to its fragmentation and extinction. In: 0. P. Jenkins (ed.). Advances in Animal Science and Zoology, 13. New York: Nova Science Publishers. https://novapublishers.com/shop/advances-in-animal-science-and-zoology-volume-13/

5. Jamnadass, R.; **Ofori, D. A.;** Dawson, I. K.; Tchoundjeu, Z.; McMullin, S.; Hendre, P. S. and Graudal, L. (2019). Enhancing agroforestry systems through tree domestication. In: van Noordwijk M, (ed.) Sustainable development through trees on farms: agroforestry in its fifth decade. Bogor, Indonesia: World Agroforestry (ICRAF) Southeast Asia Regional Programme. pp 45Ž 59.

9.3 Conference Papers

1. **Addo-Danso, S.D.; Amissah, L.; Appiah, M.; Foli, E.; Ofori, D.; Ametsitsi, G.; Duah-Gyamfi, A.; Guuroh, R.T.; Djagbletey, G.D. and Adu-Bredu, S.** (2019). Climate and fire influence fine root traits of tropical forests across Ghana. International Union of Forest Research Organizations (IUFRO) XXV World Congress, Curitiba, Brazil, 29th September-5th October, 2019.

2. **Addo-Danso, S.D.; Duah-Gyamfi, A.; Adu-Bredu, S.**; Forzia, I.; Moore, S.; Amponsah, E.M. and Malhi, Y. (2019). Net primary productivity and its allocation in tropical old growth and logged-over forests in Ghana. Association for Tropical Biology and Conservation (ATBC) Meeting, Antananarivo, Madagascar, 30 July – August 4, 2019

3. **Adu-Bredu, S.**; Moore, S.; **Duah-Gyamfi, A.; Addo-Danso S.; Ibrahim; F.; Djagbletey, G.**; Oliveras I.; Gvozdevaite A. and Malhi Y. (2019). Forest biomass, productivity, and carbon cycling along a rainfall gradient in West Africa. *53rd Annual Meeting for the Association*

of Tropical Biology and Conservation; 30th July to 3rd August, 2019, Antananarivo, Madagascar PTS/209-PTS3 (*Abstract p* 305).

4. **Amissah, L.;** Mohren, G. M. J; Bongers, F.; Kyereh, B. and Poorter, L. (2019). Traits shape the drought survival and tree species distribution along a rainfall gradient in Ghana. Abstract Book. 56th Annual Meeting Association of Tropical Biology and conservation meeting, 30 July – August 4, 2019 Antananarivo, Madagascar

5. **Appiah-Kubi, E.,** Kankam, C.K. and Ansa-Asare, K. (2019). Mechanical properties of four Lesser - Known Ghanaian timber species. International Conference on Innovative Practices in Management, Engineering & Social Sciences, Singapore, 20-23 June 2019. 10pp.

6. **Damnyag, L. and Owusu, F.W.** (2019). Determining financial values of tree-level lumber in Community Forests Plantation, Ghana. IUFRO 3.08.00 Small-scale Forestry 2019 Conference, Concurrent Session 12 held on July 8-10, 2019 Duluth, MN USA. Book of abstract, P. 65.

7. **Djagbletey, G. D.; Ebanyenle, E.;** Bosu, P. P.; **Adeyigah, G. K.; Akpalu, S. E.**; Okyere-Agyapong, E.; **Govina, J. K.; Foli, E. G.**; Peprah, T.; **Guuroh, R.T.; Anglaare, L. C.,** and **Ofori, D. A.** (2019). Utilization of bamboo for degraded land restoration in Ghana: Contribution of CSIR-FORIG. Regional Workshop on Bamboo for bioenergy security organized by Bamboo and Rattan (INBAR) and CGIAR Research Programme on Forests, Trees and Agroforestry (FTA) on 26-27 November 2019, at Royal Beulah Hotel, East Legon-Accra (Oral Presentation)

8. **Duah-Gyamfi, A.; Foli, E. G.;** Dwomoh, F. and Kwaku, M. (2019). Stand characteristics and aboveground biomass of *Bambusa vulgaris* stands in the Western region of Ghana. INBAR Regional Workshop on bamboo for bioenergy security, 26-27 November, 2019, Accra, Ghana.

9. **Foli, E.G.** (2019). Content and Processes in the development of Ghana's REDD+ Strategy. MLNR Training workshop on specialized courses in resource management. FCTC, Akyawkrom. 24 - 25 January 2019.

10. **Foli, E. G.** (2019). The Future is now: Science for achieving sustainable development. Presented at the UN Information Centre, Accra. 31 October 2019.

11. **Foli, E. G.** (2019). Forest landscape restoration activities: Ghana case study. IUFRO – Presented at the IUFRO-SPDC Pre-congress Training Workshop. XXV IUFRO World Congress, Alta Reggia Plaza Hotel, Curitiba, Brazil, 26th - 28th September 2019.

12. **Foli, E. G.** (2019). Implications of silvicultural interventions for sustainable forest management: Case study of Bobiri forest in Ghana. XXV IUFRO World Congress. ExpoUnimed, Positivo University, Curitiba, Brazil. 29th September – 05th October 2019.

13. **Foli, E. G.** (2019). African forest landscape restoration initiative: challenges in implementation. XXV IUFRO World Congress. ExpoUnimed, Positivo University, Curitiba, Brazil. 29th September – 05 October 2019.

14. **Guuroh, R.T.; Foli, E. G. and Ofori, D.A.** (2019). Improving rural livelihoods and contributing to climate change mitigation and adaptation through landscape restoration: examples from Ghana. XXV IUFRO, 29 September - 5 October 2019, Curitiba, Brazil.

15. **Guuroh, R.T.; Adeyiga, K.G.**; Markesteijn, L. and Linstädter, A. (2019). Land-use change overrides climate change effects on the diversity and regeneration of Africa's dryland woody vegetation. 62nd Annual Symposium of the International Association of Vegetation Science: Vegetation Science and Biodiversity Research, 14th – 19th July 2019, Bremen, Germany.

16. **Guuroh, R. T.; Addo-Danso, S. D.; Foli, E. G.; Amissah, L.; Appiah, M.; Anglaaere, L. and, Ofori, D.A.** (2019). Overview of landscape restoration across Ghana. Asasefest, *Global Landscape Forum,* 29-30 October, 2019.

17. **Ofori, D.A.;** Kouame, C.; Mowo, J.; Jamnadass, R.; **Akpalu, S.** and Graudal, L. (2019). Sustainable land management for improved livelihoods and environmental sustainability: the role of agroforestry. In: Matos et al (eds.), Book of Abstracts, XXV IUFRO World Congress, 29 Sept – 5th October 2019, Curitiba, Brazil. *Brazilian Journal of Forestry Research,* Special Issue 2019, ISSN 1809-3647. p.31.

18. Opoku, P. and **Akoto, D.A.** (2019). Maximizing landscape restoration to the benefit of smallholder farmers in forest agro-ecological zones in Ghana. Tropentag Conference, Kessel Germany, September 18-20, 2019.

19. Sraku-Lartey, M. and **Foli, E.G.** (2019). Contribution of indigenous knowledge by local communities to forest management and climate change mitigation and adaptation: A case study of Offinso Municipality in Ghana. XXV IUFRO World Congress. ExpoUnimed, Positivo University, Curitiba, Brazil. 29 September – 05 October 2019.

9.4 Posters

1. **Ametsitsi, G.K.D.;** Van Langevelde, F.; Janssen, T.; Medina-Vega, J.; Issifu, I., Ollivier, I.; **Adu-Bredu, S.;** Logah, V.; Vergeer, V.; Lloyd, L. and Veenendaal, E. M. (2019). Sharp transitions with soft edges: three years of field observations reveal multiple fire mediated feedbacks in a forest-savanna ecotone in West Africa. Poster session presented at the 44th New Phytologist Symposium, Accra, Ghana. August, 2019.

2. **Amissah, L.** (2019). Regional Sub-Saharan Africa Wildland Fire Network. Under the Auspices of The Global Wildland Fire Network United Nations International Strategy / Office for Disaster Risk Reduction. A Voluntary Commitment to the Implementation of the Sendai Framework for Disaster Risk Reduction 2015-2030 Presented at the 7th International Wildland Fire Conference. 28 October - 1 November 2019, Campo Grande – MS, Brazil

3. **Amponsah, J. O.** (2019). Phenology and seed germination improvement of two economic forest species in a moist semi-deciduous forest of Ghana. Poster number (18), *Species on the Move Conference,* 22-26 July 2019, Kruger National Park, South Africa

4. Baidoo, E.; **Ametsitsi, G. K. D.;** Logah, V.; Veenendaal, E.M. and Lloyd, J. (2019). Edaphic characteristics of thicket vegetation and adjacent ecosystems at Kpong in the coastal savannah of Ghana. Poster session presented at the 44th New Phytologist Symposium, Accra, Ghana. August, 2019.

5. **Foli, E. G.; Addo-Danso, D.S. and Guuroh, R.T.** (2019). Progress on landscape: Ghana report. International Union of Forest Research Organizations (IUFRO) Special Report, XXV IUFRO World Congress, 29th September – 5th October 2019, Curitiba, Brazil.

6. **Gakpetor, P. M.;** Mohammed, H.; Moreti, D. and Nassar, N. M. A. (2019). Periclinal Chimera Technique: new plant breeding approach. Poster presented at the African Plant Breeders' Association and maiden International Conference under the theme: advances in classical breeding and application of modern breeding tools for food and nutrition security in Africa. Economics Department Conference Hall of the University of Ghana, Accra. 23rd - 25th October, 2019.

7. Issifu, H.; Vergeer, P.; **Ametsitsi, G. K. D.**; Klijn, J.; Bayor, H.; Logah, V.; Van Langevelde., F. and Veenendaal, E. M. (2019). Grass competition preceding fire affects post fire recovery of forest and savanna tree seedlings differentially in the savannah. Poster session presented at the 44th New Phytologist Symposium, Accra, Ghana. August, 2019.

8. **Owusu, F. W.;** Appiah-Kubi, E.; **Govina, J.; Brentuo, B.; Seidu, H.; Ebanyenle, E.; Korang, J.; Apetorgbor, M.;** Owusu, J.; Mensah, M. and Alorbu, C. (2019). Assessment of 4-year-old Eucalyptus hybrid species for use as electrical power transmission poles in Ghana. Poster presented at Annual Review and Planning Programme 2019. CSIR-Forestry Research Institute of Ghana, 11th - 13th December, 2019, Kumasi, Ghana

9.5 Technical Reports

1. **Akoto, D.A.; Govina, J. K.; and Wumbeidow, H. M.** (2019). Report on Annual Review and Planning Programme 2018. CSIR-Forestry Research Institute of Ghana, 3rd - 5th December, 2018, Kumasi, Ghana

2. International Union of Forest Research Organizations (2018). Global fire challenges in a warming world. Robinne F.-N., Burns, J., Kant, P., de Groot, B., Flannigan M. D., Kleine M., Wotton D. M. (eds.). Occasional Paper No. 32. IUFRO, Vienna, 2018. (**Amissah, L.** et al. Contributing authors and reviewers)

3. **Amponsah, J.; Minkah, E. and Ofori D. A.** (2019). SARFOGEN workshop report on the conservation and use of Forest Genetic Resources in Sub-Saharan Africa: strengthening tree seed systems. 9-11 April, 2019. Kumasi, Ghana

4. **Amponsah, J.** (2019). Botanic Gardens Conservation International (BGCI) workshop report on conserving the threatened trees of Ghana and Ivory Coast. 31st October- 2nd November, 2019. Kumasi, Ghana

5. **Antwi-Wiredu, A. and Gakpetor, P. M.** (2019). Assessment of vegetative propagation technologies for mass production of *Paulownia* (*P. fortunei* and *P. elongata*) tree

species in Ghana. *Paulownia* Species Trials Report Submitted to CSIR-Forestry Research Institute of Ghana.

6. **Appiah, M.; Wumbeidow, H.M.; Minkah, E; Akoto, D.A. and Ofori D.A.** (2019). CSIR- FORIG 2018 Annual Report, CSIR-Forestry Research Institute of Ghana, Kumasi, Ghana.

7. Appiah-Kubi, E.; **Owusu, F. W.; Ebanyenle, E.; Korang, J.; Apetorgbor, M.; Seidu, H.; Govina, J.; Brentuo, B.; Mensah, M.**; Alorbu, C. and **Boakye, F.** (2019). Assessment of suitability of a four-year plantation-grown Eucalyptus hybrid species as utility pole material in Ghana. Technical report submitted to the Management of Asuboa Wood Treatment and MIRO (Ghana) FC. CSIR FORIG/TR/EAK, FWO, EE, JK, MA, HS, JG, BB, MM, CA, FB/2019/175. 51pp.

8. **Asomaning, J. M.;** Ansah, P. B.; Fosu, N. A.; Owusu, S. and **Asumadu, S.** (2019). Moist storage of desiccation sensitive *Garcinia afzelii* Engl. (Clusiaceae) seeds. Technical Report. CSIR FORIG/TR/JMA,PBA,NAF,SO,SA/2019/174. 12 p.

9. **Bosu, P.; Kankam O. B.; Amissah, L.; Djagbletey, G.;** Adjei, E. O.; Quansah, G. and Gaisie, E. R. (2019). Vegetation & soil erodibility monitoring of reclaimed sites, Ahafo South Mine (MA-03090-2017). Consultancy report prepared for Newmont Ghana Gold Limited. CSIR-FORIG/TR/PB, BOK, LA,GDD, EOA,GQ,ERG/2019/179

10. **Ebanyenle, E. (**2019). Research on identification of commercial timbers of Ghana at the center for wood anatomy research (CWAR), US-Forest Products Laboratory (FPL), Madison, Wisconsin, USA, 25th August - 23th November, 2018. Back to office report submitted to CSIR. 3pp

11. **Ebanyenle, E. (**2019). Bamboo for the protection of the Volta Lake. Project progress report submitted to Bamboo and Rattan Unit, Forestry Commission, Accra. 8pp

12. **Ebanyenle, E. (**2019). Forensic wood science research, training, and subsequent purchase of equipment, Project progress report submitted to US Forest Service International Programmes, Africa and Middle East Programme, Washington DC2005, USA. 10pp

13. **Gakpetor, P. M.** (2019). Report on the launch of the African plant breeders' association and maiden International Conference under the theme: Advances in classical breeding and application of modern breeding tools for food and nutrition security in Africa. Economics Department Conference Hall of the University of Ghana, Accra. 23rd -25th October, 2019.

14. **Obeng, E. A.; Oduro, K. A.;** Seidu, M. and Asomaning, G. (2019). Bottlenecks to supplying legal wood to the domestic market. *Final Report*, Submitted to Nature & Development Foundation. CSIR-FORIG/TR/EAO,KAO,MS,GA/2019/176, January 2019.

15. **Obeng, E. A.; Obiri, B. D.; Oduro, K.A.; Guuroh, R.T.; Djagbletey, G.; Appiah, M.** (2019). Establishing a land restoration research and demonstration area within degraded mining sites in the Bibiani Areas, Ghana: impact of illegal mining activities on forest ecosystem services and rural livelihoods: value orientations and willingness to pay for improved

ecosystem services. Part 1: Socio-economic Study. *Technical Report,* CSIR-FORIG/TR/EA0,BD0,KA0,RTG,GDD,MA/2019/178

16. **Obeng, E. A.; Oduro, K. A.; Obiri, D. B.; Gyamfi, A. D. and Pentsil, S.** (2019). Assessment of Socio-economic baseline for proposed Yawmatwa Ntwewora and Manzan CREMAs. Shaded Cocoa Agroforestry Systems (SCAFS) Project. *Consultancy Report,* Submitted to SNV Netherlands Development Organization. CSIR-FORIG/TR/EA0,KA0,BD0,ADG,SP/2018/177

17. **Obiri, D.B.; Obeng, E.A.; Oduro, K.; Pentsil, S. and** Appiah-Kubi, E. (2019). Ghana bamboo value chain mapping study. *Final Research Report*. INBAR-China

18. **Obiri, D.B.**; Osei, I.; Kemausour, F.; Addo, A.; Decker, E. and Abayeta, G. K. (2019). Financial analysis of biomass (Sawmill & Oil Mill Solid Waste) combustion for electricity and heat generation. Feasibility studies on renewable energy for pilot project implementation in Ghana. BMF Germany/Wascal/CSIR-Ghana

19. Messerli, P.; Murniningtyas, E.; Moatti, J. P.; Furman, E.; Richardson, K.; Lutz, W.; van Ypersele, J. P.; **Foli, E. G.**; Smith, D.; Saidam, M.; Staniskis, J.K.; Licona, G. H.; Kim, E. M. and Glassman, A. (2019). The Future is Now: Science for Achieving Sustainable Development, *Global Sustainable Development Report, 2019* (New York, 2019).

9.6 Part-Time Teaching

1. Mr. Francis Wilson Owusu: Department Forest Resources Technology, KNUST, Kumasi
2. Mr. Prosper Mensah: Department of Construction and Wood Technology Education, University of Education, Winneba, Kumasi Campus.
3. Prof. Joseph R. Cobbinah: Department of Natural Resources Management, CCST, Kumasi
4. Prof. Daniel A. Ofori: Department of Natural Resources Management, CCST, Kumasi.
5. Prof. Andrew Oteng-Amoako: Department of Natural Resources Management, CCST, Kumasi
6. Prof. Mark Appiah: Department of Natural Resources Management, CCST, Kumasi.
7. Dr. Ernest G. Foli: Department of Natural Resources Management, CCST, Kumasi.
8. Dr. Stephen Adu-Bredu: Department of Natural Resources Management, CCST, Kumasi.
9. Dr. Lawrence Damnyag: Department of Natural Resources Management, CCST, Kumasi.
10. Dr. Luke C.N. Anglaaere: Department of Natural Resources Management, CCST, Kumasi.
11. Dr. (Mrs.) Beatrice Darko Obiri: Department of Natural Resources Management, CCST, Kumasi.
12. Dr. Kwame Antwi Oduro: Department of Natural Resources Management, CCST, Kumasi.
13. Dr. (Mrs.) Lucy Amissah: Department of Natural Resources Management, CCST, Kumasi.

14. Dr. James Korang: Department of Natural Resources Management, CCST, Kumasi.
15. Dr. Emmanuel Ebanyenle: Department of Natural Resources Management, CCST, Kumasi.
16. Dr. Reginald Guuroh: Department of Natural Resources Management, CCST, Kumasi.

9.7 Supervision of Students

1. Mr. Francis Wilson Owusu: Seven (7) undergraduate students, Department of Forest Resources Technology, KNUST- Kumasi.
2. Mr. Prosper Mensah: Five (5) undergraduate students, Department of Construction and Wood Technology Education, University of Education, Winneba, Kumasi Campus.
3. Prof. Mark Appiah: Two (2) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
4. Dr. Stephen Adu-Bredu: Five (5) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
5. Dr. Lawrence Damnyag: Three (3) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
6. Dr. Luke C.N. Anglaaere: One (1) postgraduate student, Department of Natural Resources Management, CCST, Kumasi.
7. Dr. (Mrs.) Beatrice Darko Obiri: Four (4) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
8. Dr. Kwame Antwi Oduro: Four (4) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
9. Dr. (Mrs.) Lucy Amissah: Five (5) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
10. Dr. Emmanuel Ebanyenle: One (1) postgraduate student, Department of Natural Resources Management, CCST, Kumasi.
11. Dr. Reginald Guuroh: Four (4) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
12. Dr. (Mrs) Elizabeth Asantewaa Obeng: Two (2) postgraduate students, Department of Natural Resources Management, CCST, Kumasi.
13. Dr. Akwasi Duah-Gyamfi: Two (2) postgraduate students, Department of Natural Resources Management, CCST, Kumasi and one (1) PhD. student, Department of Silviculture and Forest Management, KNUST, Kumasi.
14. Mr. William K. Dumenu: One (1) postgraduate student, Department of Natural Resources Management, CCST, Kumasi.

10.1 APPENDIX I: List of Senior Members

ADMINISTRATION DIVISION	
Daniel A. Ofori	BSc. Agric., MPhil. Tree Improvement, PhD. Forest Genetics (Molecular Biology,) *Chief Research Scientist*, **Director**
Lawrence K. Mensah	B.A. Social Sciences, MPA Public Administration, *Senior Adm. Officer*, **Head of Administration**
Comfort D. Kontoh (Ms.)	B.A. (Hons) Economics, Dip. Education, MBA Strat. & Consultancy Mgt., *Senior Administrative Officer*
Georgia M. Coffie (Mrs.)	B. Ed. Secretarial & Mgt., MSc E-Comm. & Marketing, *Senior Administrative Officer*
FOREST POLICY, GOVERNANCE AND LIVELIHOODS DIVISION	
Kwame Antwi Oduro	BSc. Nat. Res. Mgt., MSc. Forestry and Land Use, PhD. Forest Management and Forest Governance, *Senior Research Scientist,* **Head of Division**
Elizabeth A. Obeng (Mrs.)	BSc. Agric., MSc. Sustainable Res. Mgt., PhD Forest Resource Economics, *Senior Research Scientist*
William K. Dumenu◐◐	BSc. Nat. Res. Mgt., MSc. Forest Ecol. & Mgt., *Research Scientist*
Emmanuel Marfo °	BSc. Nat. Res. Mgt., MSc. Tropical Forestry, PhD. Environmental Science, *Principal Research Scientist,*
Haruna Abukari	*BSc. Agricultural Technology, MPhil. Environment Science, PhD Natural Resource Assessment & Mgt, Research Scientist*
BIODIVERSITY CONSERVATION & ECOSYSTEM SERVICES DIVISION	
Luke Cyprian N. Anglaaere	BSc. Nat. Res. Mgt., MSc. Silv. & Forest Biology, PhD. Agroforestry, *Principal Research Scientist,***Deputy Director**
Bright O. Kankam	BSc. Nat. Res. Mgt., MPhil. Wildlife and Range Mgt. PhD. Primatology, *Senior Research Scientist,* **Head of Division**
Stephen Adu-Bredu	BSc. Nat. Res. Mgt., MSc. Silv. Mgt., PhD. Silv. Mgt./ Ecophysiology, *Principal Research Scientist*
Lucy Amissah (Mrs.)	BSc. Nat. Res. Mgt., MPhil. Silv. & For. Mgt., PhD. Forest Ecology & Forest Mgt. (Functional Ecology), *Senior Research Scientist*

Akwasi Duah Gyamfi	BSc. Nat. Res. Mgt., MPhil. Ecology & Mgt., PhD. Forest Science. *Senior Research Scientist*
Caleb Ofori Boateng	B.Sc. Nat. Res. Mgt., PhD. Wildlife & Range Management, *Research Scientist*
Hamdia M. Wumbeidow (Mrs.)	BSc. Agricultural Technology, MPhil Zoology, *Research Scientist*
WOOD INDUSTRY & UTILISATION DIVISION	
Emmanuel Ebanyenle	BSc. Nat. Res. Mgt., MPhil. Wood Science, PhD. Forest Science, *Senior Research Scientist*, **Head of Division**
Francis W. Owusu°°	BSc. Agric. Engineering, MPhil. Wood Technology, *Principal Research Scientist*
James K. Korang	BSc. MSc. PhD. Chemistry, *Research Scientist*
Charles Essien°	BSc. Nat. Res. Mgt., MPhil. Wood Technology, PhD. Forestry, *Research Scientist*
Bridgette Brentuo	BSc. Physical Sci., MPhil. Wood Technology, *Research Scientist*
James Kudjo Govina	BSc. Nat. Res. Mgt., MSc. Forestry Science *Principal Technologist*
Haruna Seidu	HND. Agric. Engineering, MSc. Information Technology *Principal Technologist*
Prosper Mensah	B.Ed. Education Technology, MPhil Wood Science & Technology, *Principal Technologist*
Judith Odei Owusu-Asante	BSc. Chemistry, MPhil. Analytical Chemistry, *Principal Technologist*
FOREST PRODUCTS & MARKETING DIVISION	
Lawrence Damnyag	BA., MPhil. Economics, PhD. Forest Economics, *Principal Research Scientist/* **Head of Division**
Beatrice Darko-Obiri (Mrs.)	BSc. Agric., MSc., PhD Agroforestry, *Principal Research Scientist,*
Andrew Oteng Amoako**	BSc. Wood Technology, MSc. Wood Science, PhD Wood Products & Eng., *Chief Research Scientist*
Sarah Pentsil (Mrs.)	BSc. (Hons) Nat. Res. Mgt., MSc. Dev. Policy & Planning, *Research Scientist*
Samar B. Sparkler°°	BA.(Econs. & Geog.), MA. Geog. & Rural Dev.,*Research Scientist*
Jacqueline Joyce Twintoh (Ms.)	BA. Business Adminstration, MSc.Bio-Economy and Nat. Res. Mgt., *Principal Technologist*

Safia Ibrahim (Ms.)	BSc. Economics & Statistics, MPhil. Economics, *Principal Technologist*
FORESTS & CLIMATE CHANGE DIVISION	
Gloria D. Djagbletey (Mrs.)	BSc. Nat. Res. Mgt., Mphil., PhD. Silv. & Forest Mgt., *Senior Research Scientist,* **Head of Division**
Ernest G. Foli**	BSc. Nat. Res. Mgt., Mphil Forest Men./Inventory PhD. Silv. & Mgt., *Principal Research Scientist*
Joseph Cobbinah**	BSc. Biological Sci., PhD. Forest Entomology., *Chief Research Scientist*
Stephen E. Akpalu°°	BSc. Agric., Mphil. Env. Sci. *Research Scientist*
George K. Ametsitsi°°	BSc. Nat. Res. Mgt., MSc. Env. Res. Mgt., *Research Scientist*
Daniel Shalom Addo-Danso	BSc. Nat. Res. Mgt., MSc. Forest Ecol. And Mgt., PhD. Forestry, *Research Scientist*
Gloria Kukurije Adeyiga °°	BSc. Nat. Res. Mgt., MSc. Sust. Env. Mgt., M.Sc. Agric Dev't., *Research Scientist*
Reginald T. Guuroh	BSc. Nat Res. Mgt, MSc. Env. Forestry, PhD. Plant Ecology, *Research Scientist.*
Dorothy Asare Akoto (Ms.)	BSc. Nat. Res. Mgt., MSc. Tropical Forestry, *Principal Technologist*
Daniel Kwame Debrah	Dip. Nat. Res. Mgt., BSc For. Res. Tech., MSc. Forestry Science, *Principal Technologist*
Christian Opoku Kwarteng	BSc. Nat. Res. Mgt., MSc. Environmental Science, *Principal Technologist*
FOREST IMPROVEMENT & PRODUCTIVITY DIVISION	
Joseph Mireku Asomaning	BSc. Agric., MSc. Seed Technology, PhD. Seed Science and Technology, *Senior Research Scientist*/ **Head of Division**
Mark Appiah	BSc. MSc. PhD. Agroforestry, *Principal Research Scientist*
Mary M. Apetorgbor (Mrs.) **	BSc. Botany, PhD. Plant Pathology/Mycology, *Chief Research Scientist*
John K. Mensah°°	BSc. Botany, MSc. Plant Pathology, *Research Scientist*
Sandra Acheampong Owusu	BSc. Nat. Res. Mgt., MSc., PhD. Plant Genetics, *Research Scientist*
William K. Nuako Bandoh	BSc. Biochemistry, Mphil. Environmental Science, *Research Scientist*
Emmanuel Opuni-Frimpong°	BSc. Nat. Res. Mgt., Mphil. Silv. Mgt. PhD. Forest Entomology, *Principal Research Scientist,*

Anthony Antwi-Wiredu	BSc. Agriculture, Mphil. Nuclear Agriculture, *Principal Technologist*
James Oppong Amponsah	BSc. Environmental Science, MSc. Seed Science and Technology, *Principal Technologist*
Courage Besah-Adanu	BSc. Entomology & Wildlife, MPhil., PhD. Entomology, *Research Scientist*
Patience Mansa Gakpetor	BSc. Agriculture, MSc. Plant Science, *Principal Technologist*
COMMERCIALISATION DIVISION	
Naomi Owusu Appiah (Mrs)	B.A. Publishing, MBA Marketing, Senior *Marketing Officer,* **Head of Division**
Alexander Ansong Obeng	BSc. Nat. Res. Mgt., MSc Marketing, *Marketing Officer*
Osei-Tutu Boateng	B.A. Sociology and Social Work, M.A Public Administration, *Administrative Officer*
FINANCE DIVISION	
Yaw Osei Adjei	BSc MBA, ACCA, *Accountant,* **Head of Division**
Kwasi Agyeman Prempeh	ICA, Accounting, *Accountant*
Evelyn Owusu Agyemang	BSc. Accounting, MBA Accounting, *Accountant*
Isaac Boahen	BEd. MBA Accounting, CA, CIPFA (AFIL), *Accountant*
Samuel Atusong	B.A. Business Administration, CEMBA, *Accountant*
Gifty Wiafe Mensah-Tenkorang (Mrs)	BBA. Accounting, CEMBA, *Accountant*
INFORMATION AND COMMUNICATION SECTION	
Martina Elizabeth Nikoi (Ms.)	B.A. Information Studies, M.A. Information Studies, *Principal Technologist,* **Head of Section**
Stella Britwum Acquah (Mrs.)°°	BSc. Computer Science, MBA. Mgt. Info. Systems, MSc. Biometrics, *Senior Research Scientist*
Emmanuel Minkah	BSc. Agriculture, MSc Food & Postharvest Engineering, *Principal Technologist, Scientific Secretary*
Emmanuel M. K. Sosu	BSc. Computer Science, MSc Advance ICT Studies, *Research Scientist*

°° Study leave

° Leave without pay

** Post retirement contract

10.2 APPENDIX II: List of Senior Staff

No	Name	Grade
1	Michael Mensah	Chief Technical Officer
2	John Agbozo	Chief Technical Officer
3	Mavis Serwaah Kwarteng	Chief Accounting Assistant
4	Paul Kankam	Chief Technical Officer
5	John Sackey	Chief Works Supt.
6	Magdalene Prempeh Agyeman	Chief Technical Officer
7	Samuel Kyei Yamoah	Chief Technical Officer
8	Elizabeth Appiah	Chief Auditing Assistant
9	Peter Loving Arthur	Chief Technical Officer
10	Eric K. Frimpong	Chief Technical Officer
11	Emmanuel Asiedu-Opoku	Chief Technical Officer
12	Markfred Mensah	Chief Technical Officer
13	Francis Asare Abetia	Chief Admin. Assistant
14	Ernest Osei Boakye	Chief Technical Officer
15	Frank Baffour Assuming	Chief Technical Officer
16	Sarfo Kwame Bonsu	Chief Technical Officer
17	Awurama Andoh	Chief Administrative Assistant
18	Kwasi Baah Acheamfour	Chief Technical Officer
19	Richard Kwadwo Adjei	Chief Technical Officer
20	Anastasia Duah-Gyamfi	Chief Administrative Asst.
21	Felix Boakye	Principal Technical Officer
22	Kwaku Asumadu	Chief Marketing Assistant
23	Jemima Owusu	Chief Technical Officer
24	Margaret Adubigire	Principal Administrative Assistant
25	Jonathan Dabo	Principal Technical Officer
26	Daniel Peprah	Principal Technical Officer
27	Sandra Owusu	Chief Technical Officer
28	Samuel Larbi	Principal Administrative Assistant
29	Georgina Boateng Yeboah	Chief Accounting Assistant
30	Elvis Nkrumah	Principal Technical Officer
31	Emmanuel Amponsah Manu	Principal Technical Officer
32	Wendy O. Amankwah	Principal Accounting Assistant
33	Hamdia Bijay Hudu	Principal Administrative Assistant

No	Name	Grade
34	Daniel Damte	Principal Draughtsman
35	Michael Ampah	Principal Administrative Assistant
36	Ebenezer Frans Mensah	Principal Technical Officer
37	Constant Ezuame	Principal Technical Officer
38	Eunice Okyere-Agyapong	Principal Technical Officer
39	John Bismark Amokwandoh	Senior Technical Officer
40	Samuel Apraku Yeboah	Principal Technical Assistant
41	Mark Debrah Marfo	Senior Technical Officer
42	Ebenezer Ofori	Principal Technical Officer
43	Jackson Nti	Senior Assistant Transport Officer
44	Sampson Adonteng	Senior Assistant Transport Officer
45	Peter Gamadey	Senior Assistant Transport Officer
46	Osei Boateng	Senior Security Officer
47	Gabriel Lumor	Senior Works Superintendent
48	Michael Atitsougbui	Senior Security Officer
49	William Hagan Brown	Senior Technical Officer
50	Mavis Agyekumwaah Bamfo	Senior Technical Officer
51	Adu-Gyamfi Asamoah	Senior Technical Officer
52	Isaac Donkor	Senior Administrative Assistant
53	Kwabena Achina Owusu	Principal Accounting Assistant
54	Emmanuel Sarpong	Principal Library Assistant
55	Sylvester Kuudaar	Technical Officer
56	Kester K. Mensah	Administrative Assistant
57	Joseph Sebuka	Administrative Assistant
58	Hilda Dokey	Administrative Assistant
59	Victoria Apaseku	Technical Officer/Catering
60	Patrick Baidoo-Ansah	Technical Officer/Catering
61	Maxwell Asante Boachie	Senior Security Officer
62	Michael Kwarteng	Senior Security Officer
63	George Kwabla Kpodo	Senior Security Officer
64	Benjamin S. Sarfo Maino	Principal Accounts Assistant
65	King Alhassan	Senior Security Officer
66	Eunice Basanio Boadi	Technical Officer
67	Habibu Alidu	Administrative Assistant

No	Name	Grade
68	Abigail Amponsah Ofosu-Brako	Technical Officer
69	Tracy Amposah Akoto-Bamfo	Technical Officer
70	Emmanuel Duodu Nyarko	Technical Officer
71	David A. Dafliso	Senior Assistant Transport Officer
72	Stephen E. K. Acheampong	Security Officer
73	Joseph K. Ansah	Security Officer

10.3 APPENDIX III: List of Junior staff

No.	Name	Grade
1	Jacob Mensah	Traffic Supervisor
2	Samuel Asamoah	Driver Gd. 1
3	William Berchie	Traffic Supervisor
4	Mary Nyarkoah	Overseer
5	Grace Akunzebe	Overseer
6	Juliana Afari Aikins	Overseer
7	Stella Asare	Overseer
8	Edward Okyere	Foreman
9	Kwame Asiedu	Junior Foreman
10	Diana Afua Tanoah	Senior Clerk
11	Richard Boamah	Junior Foreman
12	Solomon Kwaku Adjei	Junior Foreman(Operator)
13	Joyce Oforiwaa	Clerk Gd. 1
14	Akabayie Sampson	Senior Security Assistant
15	King Kwabla Hiatorpe	Snr. Security Assistant
16	Stephen Kwame Appiah	Senior Security Assistant
17	Zac Achab	Senior Caretaker
18	Michael Asaa Akayagre	Security Assistant Gd. 1
19	Anthony Appiah	Security Assistant Gd. 1
20	Baba Mahama	Security Assistant Gd. 1
21	Job Akoubga	Security Assistant Gd. 1
22	Issa Abdulai	Security Assistant Gd. 1
23	Paul Kyei	Security Assistant Gd. 1
24	Kofi Nyarko	Security Assistant Gd. 1
25	Kofi Abraham	Security Assistant Gd. 11

No.	Name	Grade
26	Samuel Ayambire	Asst. Overseer Gd.1
27	Oppong Duah Anthony	Asst. Overseer Gd.1
28	Paul Assuming	Asst. Overseer Gd.1
29	Kwame Tawiah	Asst. Overseer Gd.1
30	Kofi Kanjarga	Asst. Overseer Gd.1
31	Samuel Adu Boahen	Security Assistant Gd.1
32	Christopher Kudze	Junior Foreman
33	Akua Serwaah	Asst. Overseer Gd.1
34	Gladys Opoku	Asst. Overseer Gd.1
35	George Atinyele (Jnr.)	Asst. Overseer Gd.1
36	Charles Sarpong	Asst. Overseer Gd.1
37	Thomas Atendana	Asst. Overseer Gd.1
38	Abdul Atinga	Asst. Overseer Gd.1
39	Sulemana Abdulai	Driver Gd. I
40	Kwasi Amakye	Asst. Overseer Gd.1
41	Collins Kwasi Ahenkorah	Asst. Overseer Gd.1
42	Sampson Nketiah	Asst. Overseer Gd.1
43	Kwabena Oduro	Asst. Overseer Gd.1
44	Seth Owusu	Asst. Overseer Gd.1
45	Kofi Amakye	Asst. Overseer Gd.1
46	Wahab Yakubu	Asst. Overseer Gd.1
47	Edward Nsorwaah	Asst. Overseer Gd.1
48	Peter Lumor	Supervisor Gd. 1
49	Ebenezer Oware Tweneboah	Asst. Overseer Gd.1
50	Amos Asemonu Biewko	Asst. Overseer Gd.1
51	Haruna Issaka	Asst. Overseer Gd.1
52	Kwasi Nyamekye	Supervisor Gd. II
53	Daniel Awatey	Supervisor Gd. 1
54	Samuel Boateng	Supervisor Gd I
55	Pius Yaw Addo	Supervisor Gd. 1
56	Margaret Adablah Azumi	Supervisor Grade 1
57	Simon Kumah	Supervisor Gd. 1
58	Gifty Adwoa Agyeiwaah	Supervisor Gd. 1
59	Joseph Ofori	Supervisor Gd. II

No.	Name	Grade
60	Cletus Akudbilla Ayabilla	Supervisor Gd. 1
61	Charles Adu	Supervisor Gd. 1
62	Ali Inousa	Supervisor Gd. 1
63	Gifty Tenga	Supervisor Gd. 1
64	Leticia Laadi Atareyure	Supervisor Gd. 1
65	Emmanuel Koduah	Supervisor Gd. 1
66	Peter Ayambire Amoah	Supervisor |Gd. 1
67	Anthony Osei Kwaku	Supervisor Gd. II
68	Comfort Adoma	Supervisor Gd. II
69	Stephen Abaidoo	Supervisor Gd. II
70	Appiah Kubi	Supervisor Gd. II
71	Wiafe Kwaku	Supervisor Gd. II
72	John Mensah	Supervisor Gd. 11
73	Francis Yeboah	SeniorLabourer
74	Appiah Rawlings	Supervisor Gd. 11
75	Salifu Iddi Serekye	Supervisor Gd. 11
76	Amos Ania Akanzire	Supervisor Gd. 11
77	Michael Fiawatsor	Supervisor Gd. 11
78	Salifu Abdul	Supervisor Gd.11
79	Samuel Acheampong	Supervisor Gd. 11
80	Jennifer Osei Owusu	Supervisor Gd. 11
81	Nuhu Ali	Supervisor Gd. 11
82	Agyenim Boateng	Supervisor Gd. 11
83	Bernard Yeboah	Supervisor Gd. 11
84	Kwabena Bosompem	Supervisor Gd.11
85	Joyce Fosu	Supervisor Gd. 11

For more information, please contact

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