



**CSIR-FORESTRY RESEARCH INSTITUTE OF GHANA
(SCIR-FORIG)**

BOOK OF ABSTRACTS 2018



**2018 REFEREED
JOURNAL ARTICLES**

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INSTITUTE OF GHANA**

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Foreword

We present to you the 2018 edition of CSIR-FORIG's Book of Abstracts. The articles published in this book cover biodiversity conservation and ecosystem services, climate change, forest improvement and productivity, forest policy, governance and livelihoods, forest products and marketing, and wood industry and utilization among others.

The articles have already been published in various journals so all citations should be based on the original source detailed in the booklet. Full papers of the articles may be obtained from the original journals or from the author.

With adequate support, the Institute will continue to disseminate information on innovative technologies and methodologies that could contribute to sustainable management of forest resources for the benefit of society.

A handwritten signature in blue ink, appearing to read 'Daniel A. Ofori', is positioned above the printed name.

Prof. Daniel A. Ofori
Director, CSIR-FORIG

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Introduction

The 2018 Book of Abstracts is a compilation of scientific articles written by CSIR-FORIG scientists in 2018. The publication is to create awareness by selectively disseminating the outputs of research which have been published in international and local journals during the year under review.

The publication is for non-commercial purposes and cannot be reproduced for any monetary gain. A total of 35 journal articles were published by scientists of CSIR-FORIG in peer reviewed journals worldwide. Some articles were joint publications with local and international partners and colleagues, while others were sole publications by scientists.

Each abstract has been arranged in alphabetical order and numbered chronologically. The name of each CSIR-FORIG scientist has also been highlighted in each abstract. All sources have been duly acknowledged and follow the publishers' guidelines on the re-use of their journal articles.

1. Acquah, S. B., Sraku-Lartey, M., Samar, S. B. and Djagbletey, G. D. (2018). Traditional knowledge and consumption of forest plant foods in Ghana. *Ghana Journal of Forestry*, 34 (1): 49-70.

Promoting the consumption of forest plant foods is a sustainable way of ensuring good nutrition and food security. This study assessed traditional knowledge on and use of forest plant foods in three administrative districts of Ghana and evaluated their potentials for domestication and processing. A total of 606 households were randomly selected and interviewed using enumerator-administered questionnaires. Validation workshops with 30 participants were held in each district to help identify the species mentioned. In all, 83 species belonging to 45 families were documented. Knowledge of forest plant foods was found to be higher among older respondents than younger ones, indicating an urgent need to document traditional knowledge on forest plant foods before it disappears along with the older generation. *Artocarpus altilis* (Parkinson) Fosberg and *Tetrapleura tetraptera* (Schumach. & Thonn.) Taub. were identified as potential species for domestication and processing. Domestication and processing of forest plant foods on larger scale presents opportunity for economic development, sustainability benefits and food security.

Keywords: *Artocarpus altilis*, domestication, food security, indigenous knowledge, *Tetrapleura tetraptera*

2. Acquah, G. E., Essien, C., Via, B. K., Billor, N. and Eckhardt, L. G. (2018). Estimating the basic density and mechanical properties of elite loblolly pine families with near infrared spectroscopy. *Forest Science*, 64(2):149–158.

Near infrared spectroscopy coupled with partial least squares regression was utilized as a high throughput tool in assessing the density, modulus of rupture, and modulus of elasticity of elite loblolly pine families (*Pinus taeda* L.). These properties dictate wood quality for structural applications. PLS models were calibrated and validated with 260 samples processed from loblolly pine families and commercially acquired southern pine lumber. Developed models having R²s greater than 0.7 and RPDs meeting the 1.5 screening criteria were used to predict the wood traits of 351 live trees representing 14 elite families planted on two sites. Two-way ANOVA testing the effect of family, site, and family x site interaction was significant for family for all traits. Within a family, site also affected the density, but to a lower extent. With the significant family x site interaction term on density and MOR, landowners and tree breeders would have

to keep in mind that desired traits of the families might be unstable on different sites. Notwithstanding, four out of the 14 screened families had consistently high density, MOR, and MOE values irrespective of site. This knowledge can be incorporated in tree breeding programs to further improve wood quality 3

Keywords: *Pinus taeda*, near infrared spectroscopy, wood density, modulus, high throughput techniques.

3. Addo-Danso, S.D., Prescott, C.E., Adu-Bredu, A., Moore, S., Guy D.R., Forrester, D.I., Owusu-Afriyie, K., Marshall, P.L., Malhi, Y. (2018). Fine-root exploitation strategies differ in tropical old growth and logged-over forests in Ghana. *Biotropica*, 50: 606-615.

Understanding the changes in root exploitation strategies during post-logging recovery is important for predicting forest productivity and carbon dynamics in tropical forests. We sampled fine (diameter < 2 mm) roots using the soil core method to quantify fine-root biomass and architectural and morphological traits to determine root exploitation strategies in an old growth forest and in a 54-yr-old logged-over forest influenced by similar parent material and climate. Seven root traits were considered: four associated with resource exploitation potential or an 'extensive' strategy (fine-root biomass, length, surface area, and volume), and three traits which reflect exploitation efficiency or an 'intensive' strategy (specific root area, specific root length, and root tissue density). We found that total fine-root biomass, length, surface area, volume, and fine-root tissue density were higher in the logged-over forest, whereas the old growth forest had higher total specific root length and specific root surface area than the logged-over forest. The results suggest different root exploitation strategies between the forests. Plants in the old growth forest invest root biomass more efficiently to maximize soil volume explored, whereas plants in the logged-over forest increase the spatial distribution of roots resulting in the expansion of the rhizosphere.

Keywords: Exploitation efficiency, exploitation potential, post-logging recovery, root architectural traits, root morphological traits, root tissue density, specific root length, tropical moist forest

4. Adu-Bredu S., Ofori D.A., Ræbild A., Hansen J.K., Koffi A., Vigneron P. & Erik D Kjar E.D. (2018). Trait variations in 28-year-old teak (*Tectona grandis*) provenance field trials in Ghana, West Africa. *Southern Forests: A Journal of Forest Science*, DOI: 10.2989/20702620.2018.1490993.

Stem straightness, axis persistence, presence/absence of protuberant buds and epicormics, diameter and height have profound influence on timber quality and volume of teak (*Tectona grandis*). Provenance trials of teak were established in the 1970s in Ghana, as part of the Food and Agriculture Organization (FAO) International Series of Provenance Trials, with the view of selecting teak germplasm for sites with specific environmental conditions. Two field trials were located in dry semi-deciduous (dry) and moist semi-deciduous (moist) ecological zones of Ghana. They consisted of 13 provenances, including four landraces each from Ghana and Indonesia, and two and three provenances from India and Laos, respectively. Trees were assessed at 9, 17 and 28 years to (1) quantify the potential variation in quality and timber volume production, (2) examine possibilities for determining early selection of parameters of superior provenances and (3) select provenances for sites with particular environmental conditions. Production traits were higher on the moist site than the dry site. Mean height was 23.2 and 20.2 m tree⁻¹, stem cross-sectional area at breast height was 0.0896 and 0.0474 m² tree⁻¹, and stem volume was 0.75 and 0.34 m³ tree⁻¹ for the moist and dry sites, respectively. Nilambur provenance from moist India had the highest mean stem straightness score of 19% above average, whereas Savannakhet from Laos had the best protuberant bud score with 18% of the trees above average. Indonesian landraces performed better in the dry zone, whereas provenances from India and Laos, respectively. Trees were assessed at 9, 17 and 28 years to (1) quantify the potential variation in quality and timber volume production, (2) examine possibilities for determining early selection of parameters of superior provenances and (3) select provenances for sites with particular environmental conditions. Production traits were higher on the moist site than the dry site. Mean height was 23.2 and 20.2 m tree⁻¹, stem cross-sectional area at breast height was 0.0896 and 0.0474 m² tree⁻¹, and stem volume was 0.75 and 0.34 m³ tree⁻¹ for the moist and dry sites, respectively. Nilambur provenance from moist India had the highest mean stem straightness score of 19% above average, whereas Savannakhet from Laos had the best protuberant bud score with 18% of the trees above average. Indonesian landraces performed better in the dry zone, whereas provenances from India and Laos performed better in the moist zone. Phenotypic correlations between age 9 and 28 years were moderate (r 0.54–0.90) to high (r > 0.90) for production and qualitative characteristics, indicating feasibility of early assessment for identification of superior provenances. Nilambur and Savannakhet II provenances proved to be favourable choices for the moist zone, whereas the Temandsang provenance from Indonesia was found to be the best choice for the dry site.

Keywords: Axis persistence, epicormics, forestry, landraces, natural range, stem straightness

5. Aguilar, FX, Obeng, E. A. and Cai, Z. (2018). Water quality improvements elicit consistent willingness-to-pay for the enhancement of forested watershed ecosystem services. *Ecosystem Services* 30, 158-171.

The aim of this study is to improve understanding of willingness-to-pay (WTP) for the enhancement of selected ecosystem services from forested watersheds. Results from a nationwide survey of over 1000 U.S. households showed limited knowledge of payment for ecosystem service (PES) programs and antagonistic opinions regarding initial WTP for watershed conservation and corresponding PES financial charges. Water quality dominated importance among selected PES attributes used in a discrete-choice experiment followed by provisioning of habitat for threatened plant and animal species, flood control, and landscape aesthetics. Econometric analyses elucidated that environmental attitudes significantly influenced WTP results even more than annual household income. Results show WTP levels for improvements in water quality were homogeneous across the nation but heterogeneous for the enhancement of habitat, landscape and flood control. Findings support the establishment of PES initiatives that enhance forested watersheds conditions across the U.S. primarily driven by improvements in water quality. PES programs should be tailored locally to emphasize the provisioning of other ecosystem services such as habitat for threatened species and flood control.

Keywords: Forest, watershed, willingness-to-pay, discrete-choice, mixed-logit, U.S.

6. Amisah, L., Mohren, G. M. J., Kyereh, B., Agyeman, V. K. and Poorter, L. (2018). Rainfall seasonality and drought performance shape the distribution of tropical tree species in Ghana. *Ecology and Evolution*, 8: 8582-8597. doi: 10.1002/ece3.4384

Tree species distribution in lowland tropical forests is strongly associated with rainfall amount and distribution. Not only plant water availability, but also irradiance, soil fertility, and pest pressure covary along rainfall gradients. To assess the role of water availability in shaping species distribution, we carried out a reciprocal transplanting experiment in gaps in a dry and a wet forest site in Ghana, using 2,670 seedlings of 23 tree species belonging to three contrasting rainfall distributions groups (dry species, ubiquitous species, and wet species). We evaluated seasonal patterns in climatic conditions, seedling physiology and

performance (survival and growth) over a 2-year period and related seedling performance to species distribution along Ghana's rainfall gradient. The dry forest site had, compared to the wet forest, higher irradiance, and soil nutrient availability and experienced stronger atmospheric drought (2.0 vs. 0.6 kPa vapor pressure deficit) and reduced soil water potential (- 5.0 vs. - 0.6 MPa soil water potential) during the dry season. In both forests, dry species showed significantly higher stomatal conductance and lower leaf water potential, than wet species, and in the dry forest, dry species also realized higher drought survival and growth rate than wet species. Dry species are therefore more drought tolerant, and unlike the wet forest species, they achieve a home advantage. Species drought performance in the dry forest relative to the wet forest significantly predicted species position on the rainfall gradient in Ghana, indicating that the ability to grow and survive better in dry forests and during dry seasons may allow species to occur in low rainfall areas. Drought is therefore an important environmental filter that influences forest composition and dynamics. Currently, many tropical forests experience increase in frequency and intensity of droughts, and our results suggest that this may lead to reduction in tree productivity and shifts in species distribution.

Keywords: Drought, dry forest, physiology, species distribution, tropical forest, wet forest

7. Amponsah, J. O., Maaleku, B. K., Djagbletey, G. D., Asomaning, J. M., Kumah, F. and P. K. Tandoh. (2018). Phenology and seed germination improvement of *Terminalia superba* and *Terminalia ivorensis* in a moist semi-deciduous forest in Ghana. *Ghana Journal of Forestry*, 34 (1): 1-14.

Understanding the phenology and seed germination improvement techniques of forest tree species is crucial for their conservation and use in reforestation activities. This study examined the reproductive and vegetative phenology of two economic indigenous forest tree species; *Terminalia superba* and *Terminalia ivorensis*, relative to local climatic variables within the Bobiri Forest Reserve (BFR). We also assessed the effect of four physical and chemical seed germination improvement techniques on the seeds under ambient temperatures for 36 days. Phenology was observed and documented over a two-year period within six compartments in the reserve. Period and intensity of leaf flushing, flowering, fruiting and seed dispersal phenophases of 105 selected individuals of the two species were monitored and scored using the widely adopted Biologische Bundesanstalt, and Chemical Industry (BBCH) system of coding

plant phenology. Leaf flushing in both species coincided with the onset of the wet season (April-July), which was closely followed by flowering during August and September. Fruiting and seed dispersal phenophases occurred between October and February. A strong positive correlation ($r = 0.7325$, $p < 0.05$) was established between the highest leaf flushing phenophase in *T. superba* and mean monthly rainfall. The highest fruiting phenological phase correlated negatively with mean monthly maximum temperatures (T_{Emx}). Chemical scarification (soaking in 2M H_2SO_4 for 20 minutes prior to sowing) improved seed germination in *T. superba* above 30%. Results indicate that *T. superba* and *T. ivorensis* undergo a consistent and synchronized annual reproductive cycle dependent on temperature and rainfall regimes within BFR. We further indicate that large scale climatic fluctuations may affect the reproductive and vegetative phenology of these species.

Keywords: Conservation, degraded forest, phenophase, restoration, scarification

8. Antwi-Wiredu, A., Amiteye, S., Diawuoh, R. G. and Klu, G. Y. P. (2018). Ex vitro propagation of rubber tree (*Hevea brasiliensis*) using stem cuttings. *International Journal of Environment, Agriculture and Biotechnology*, 3(3): 846-854. <http://dx.doi.org/10.22161/ijeab/3.3.20>

Stem cutting propagation preserves the genetic traits and leads to transfer of superior and genetically similar traits of parent plants to progenies. This method is also used to propagate recalcitrant, nonviable and difficult to germinate seeds. Stem cutting in tree species is used to address phenological and intraclonal problems. The use of rubber cuttings as planting material is a feasible option, worthy of investigation. There has been little or no research studies into the usage of *Hevea brasiliensis* stem cuttings as an alternative vegetative propagation method for an in vivo propagation of rubber tree in Ghana. Propagation of *H. brasiliensis* by stem cutting techniques was used to study alternative procedures for mass production of rubber planting materials. Brown and green rubber stem cuttings of Clone I and Clone II were soaked for 6 hours in 0.0-22.5g/L Naphthalene Acetic Acid (NAA) followed by propagation in a nursery bag filled with nutrient-rich soil. Only the brown stem cuttings of *H. brasiliensis* survived. The percent survival, length of shoots, number of roots as well as length of roots of Clone II was significantly ($P < 0.05$) higher than Clone I. Rubber stem cuttings treated with 15.0g/L NAA significantly ($P < 0.05$) developed higher shoots (83.33%), number of roots (6.167), length of shoots (15.38cm) and length of roots (6.00cm) than the remaining treatments. There was significant ($P < 0.05$) effects of NAA and Clone II in sprouting and rooting growth of the brown stem cuttings. Successful in vivo propagation of rubber tree

(*H. brasiliensis*) was achieved.

Keywords: Brown and green, *Hevea brasiliensis* clones, naphthalene acetic acid, sprouting and rooting growth, stem cuttings.

9. Antwi-Wiredu, A., Amiteye, S., Diawuoh, R. G. and Klu, G.Y. P. (2018). In vitro propagation of rubber tree (*Hevea brasiliensis*) using shoot-tip and nodal cutting explants. *International Journal of Advances in Scientific Research and Engineering*, 4(6): 17-29. doi: <http://dx.doi.org/10.7324/IJASRE.2018.32743>

Hevea brasiliensis which belongs to the Euphorbiaceae family is the primary source of natural rubber. Propagation of rubber tree by grafting on to unselected seedlings sustains intraclonal heterogeneity for vigour and productivity which could be improved via in vitro techniques. Micropropagation from rubber nodal and shoot tip explants is possible. In vitro technique is needful to mass propagate disease-free and genetically similar rubber plantlets. In vitro results in increased growth and vigour of rubber tree, However, in vitro techniques of rubber tree have not been given much critical research attention in Ghana. Propagation of *H. brasiliensis* by in vitro techniques was used to study alternative procedures for mass production of rubber planting materials. Murashige and Skoog (MS) basal medium amended with 30.0g/L sucrose, 100.0mg/L myo-inositol, 2.0g/L activated charcoal, 1.0mg/L silver nitrate AgNO₃, 2.0mg/L GA₃ and control, 2.5, 5.0, 7.5 or 10.0mg/L kinetin was used to culture both *H. brasiliensis* shoottip and nodal explants. The MS medium with 5.0mg/L kinetin significantly ($P<0.05$) enhanced higher shoot development (84.00%), number of shoots (3.60) and leaves (23.40) of the shoot-tip explants compared to other treatments. In nodal explants, the control medium developed higher shoots (94.00%), the height of shoot (4.80cm), number of leaves (19.20), number of shoots (6.00) and number of roots (7.00) than those with kinetin treatments. Conversely, 7.5mg/L kinetin of the nodal culture also performed significantly after the controls. Successful in vitro regeneration of plantlets was achieved using *Hevea brasiliensis* shoot-tip and nodal cutting explants cultured on an MS medium supplemented with kinetin.

Keywords: *Hevea brasiliensis*, In vitro propagation, shoot-tip and nodal culture, MS medium, kinetin. 8

10. Armani, M., van Langevelde F., Tomlinson, K.W., Adu-Bredu, S., Djagbletey, G.D. & Veenendaal, E.M. (2018). Compositional patterns of overstorey and understorey woody communities in a forest-savanna boundary in Ghana. *Plant Ecology & Diversity*. doi:10.1080/17550874.2018.1539133

Forest and savanna vegetation in the zone of transition (ZOT) contain distinct woody species due to fire, drought and herbivory barriers that constrain forest species from invading adjacent savannas and vice-versa. Little is known if these barriers cause divergence in species composition between the overstorey and understorey strata in these vegetation types. We investigated woody species composition across overstorey and understorey strata in the ZOT and explored the relationship between soil fertility and species composition patterns. We sampled overstorey and understorey woody species and determined soil nutrient concentrations in twenty-five 20 m × 20 m plots in a ZOT in Ghana. Forest and savanna species dominated the overstorey and understorey of their respective environments. However, species composition was decoupled between the overstorey and understorey strata in both forest and savanna vegetations. Few savanna and forest species had individuals co-occurring in both overstorey and understorey such that ~65% of the dominant species was limited to only one stratum. Soil fertility had little effect on these patterns. These patterns indicate that, forest and savanna species face significant recruitment barriers in their respective environments, suggesting that requirements for juvenile establishment may differ from recruitments to the canopy layer.

Keywords: Forest–savanna boundary, overstorey, recruitment barrier, species composition, strata, zone of transition

11. Banibéa Sanbena Bassan, B.S., Nuto, Y., Bosu, P. P., Komina Amevoin, K. Kokou, K. (2018). Insectes associés à *Nauclea diderrichii* (Rubiaceae): diversité, caractéristiques et importance des dégâts Au Togo, Afrique De l'Ouest. *Afrique Science* 14(6):103 - 115

This work focuses on the entomological fauna of *Nauclea diderrichii* (De Wild) Merrill (Rubiaceae). The objective of the study was to identify the possible pests of the plant species whose damage could impede its cultivation in Togo. *Nauclea diderrichii* is a high-value forest species that naturally grows in the tropical and subtropical humid zones of Africa. In Togo, it is found only in the plain of Litime. The study was carried out to determine the diversity of insects associated with *N. diderrichii*, to characterize and estimate their damage. Direct observation of nurseries, pure and mixed plantations of *N. diderrichii* in forest and savannah areas made it possible to identify 57 species of insects belonging to 31 families and 9 orders associated with it. The harmful species were sucking-stingers, especially hemipterans and defoliators which were mainly Curculionidae beetles, Orthoptera and caterpillars of Lepidoptera. Some useful insects had been identified. Most of the captured insects were found in nurseries and plantations in forest as well as in savannah zones. The damages were characterized by leaf parts grazed by defoliators and hemipteran bites on leaves

that became curled up. The observed damage could not compromise plant growth in nurseries and experimental fields in the study areas in Togo.

Keywords: *Nauclea diderrichii*, forest and savannah areas, insects, damage

12. Bosu, P. P., Frimpong-Anin, K., Adjaloo, M.K., Braimah, H., Oduro, W., Annoh, C. E. Aidoo, K. and Kwapong, P.K. (2018). Monitoring insect populations in cocoa agro-ecosystems within the catchment of the Bobiri Forest Reserve in Ghana. *Ghana Journal of Horticulture (JHORT)* 13(1): 121-136.

Population diversity of insects in an ecosystem at any given time is a good indication of their role in ecosystem function, and it helps to facilitate their management. A two-year monitoring survey was conducted in cocoa farms within the catchment of the Bobiri Forest Reserve in Ghana. Pan traps consisting of fluorescent white, blue and yellow plastic bowls were set in 10 cocoa farms spread out in the study area. On each farm, 30 traps consisting of 10 white, 10 yellow and 10 blue were each mounted on a 1m high 5 cm wide PVC pipe stand. Sampling was carried out during the major and minor cocoa flowering seasons in 2011 and 2012, with each sampling session lasting approximately 48 hours. A total of 496 insects were collected at the end of the survey period with yellow and white traps being more attractive to pollinators in the study area. The dominant taxa recorded were Dipterans 177 (35.69%), of which midges constituted 79 (15.9%). There were 175 (35.3%) Hymenopterans, which included 100 (20.2%) ants, 57 (11.5%) stingless bees, 15 (3.0%) wasps, and 3(0.6%) honey bees. There were 77 (15.5%) coleopterans (beetles) and lepidopteran groups recorded and 52 (10.5%) lepidopterans. The primary cocoa pollinator *Forcipomyia* midge was recorded both in the minor (October-January) and major (April-July) cocoa flowering seasons. Midges' population in the cocoa ecosystem proved to be generally high in the wet season. The results suggest differences in the adaptation of resident insects in the cocoa agroecosystem.

Keywords: *Insect diversity, cocoa ecosystem, pollinators, Forcipomyia spp, honeybees, insect populations*

13. Darko Obiri, B., Obeng, E. A., Nunoo, I, Peprah, T. and Opuni Frimpong, E. (2018). Financial analysis of fuelwood production from woodlots in the savanna transition zone of Ghana. *Ghana Journal of Forestry*, 34 (1): 35-48

Fuelwood production undoubtedly contributes to deforestation in Ghana although this industry is the source of over 50 percent of energy for cooking in

households as well as the service and processing industries in the country. Over dependence on fuelwood from natural forest estate and trees on farmlands threatens its sustainability and livelihoods in the long term. Fuelwood production from managed woodlots/plantations ensures sustainable supply of raw material. However, there is limited knowledge on its economics. This paper entails an ex-ante analysis of the profitability of fuelwood production from on-farm smallholder woodlots of mixed native and exotic species (Acacia-Neem-Cassia-Anogeissus-Mahogany) integrated with food crops (yam, maize, and cassava). Using Senna [Cassia] siamea as a test species, input-output data involving costs and revenues were collected and subjected to financial cost-benefit analysis. Results indicate that fuelwood production from woodlots was profitable returning an NPV of GH¢ 1,787.00, B/C ratio of 1.17 and IRR of 40.42 percent at a market discount rate of 22 percent over 25 years. Profitability is quite sensitive to increases in production costs and quite stable to decline in wood yield up to 75 percent, although this returns marginal profit. A multipurpose 5-year rational woodlot system is proposed to ensure sustainable supply of fuelwood in smallholder systems. This also allows for intermittent crop production for household food and cash needs. The B/C ratio and NPV values indicates that profitability could increase three times at a lower discount rate of 10 percent. Energy intervention programmes to support sustainable fuelwood production would need to support beneficiaries with loans at lower interest rates, at least 10 percent to encourage widespread adoption.

Keywords: Fuelwood, cost-benefit analysis, woodlots, smallholder forests, farm forestry

14. Djangbletey, G.D., Adu-Bredu, S., Duah-Gyamfi, A., Abeney, E.A., Asante, W.A., Akyeampong, E., Addo-Danso, S.D., Ametsitsi, G.K., Amponsah-Manu, E., Dabo, J., Amponsah, J.O. (2018). Floristic composition and carbon stocks of tree species of different conservation status following selective logging in a moist semi-deciduous forest in Ghana. *Ghana Journal of Forestry*, 34(1): 15-34.

Understanding the impact of commercial logging on composition and carbon storage of functionally different species is critical for sustainability of forest resources. This study assessed the floristic composition and carbon stocks of tree species of different conservation status along a post-logging chronosequence regime within the Bobiri Forest Reserve (BFR). Experimental plots were established in different post-logged sites within BFR, namely: 1-, 10-, 21-, 30-, 43- and 50 years post-logged sites (tagged as Y1, Y10, Y21, Y30, Y43, and Y50). In addition, plots were established in an unlogged /undisturbed area which shows the characteristics of a strict nature reserve (tagged SNR) as

control. Data was collected in 10 randomly selected temporary sampling plots (TSPs) in each site. The main sample plot (MSP) i.e. 50 m x 50 m (2500 m²) was divided into four sub-plots (SP) of size 25 m x 25 m (625 m²) and the sub-plots were further subdivided into sub-sub plots (SSP) of size 12.5 m x 12.5 m (156.25 m²), to form a nested sample plot design. Tree species in the stands were identified and classified according to their conservation status/ star rating. The results of the study indicated that proportional abundance of species with different star ratings was significantly different with green and pink stars generally dominant across the stands. Carbon stock estimates increased from 193.5 ± 36.4 in the SNR to 293.3±45.1 in Y50, but was not significantly different. However, carbon storage among star categories was significant ($p < 0.05$) despite the low abundance of species in some of the categories. This phenomenon was due to the high proportions of carbon stocks in large and medium trees of species belonging to the green, pink, red and scarlet stars. The high carbon stocks of scarlet and red star species despite their low densities calls for management interventions to enhance their stocking levels within the reserve.

Keywords: Abundance, carbon, post-logging chronosequence, star rating, sustainability

15. Durán, J., DelgadoBaquerizo, M., Dougill, J. A., Guuroh, R.T., Linstädter, A., Thomas, A. D. and Maestre, F.T. (2018). Temperature and aridity regulate spatial variability of soil multifunctionality in drylands across the globe. *Journal of Ecology*, 99 (5): 1184– 1193.

The relationship between the spatial variability of soil multifunctionality (i.e., the capacity of soils to conduct multiple functions; SVM) and major climatic drivers, such as temperature and aridity, has never been assessed globally in terrestrial ecosystems. We surveyed 236 dryland ecosystems from six continents to evaluate the relative importance of aridity and mean annual temperature, and of other abiotic (e.g., texture) and biotic (e.g., plant cover) variables as drivers of SVM, calculated as the averaged coefficient of variation for multiple soil variables linked to nutrient stocks and cycling. We found that increases in temperature and aridity were globally correlated to increases in SVM. Some of these climatic effects on SVM were direct, but others were indirectly driven through reductions in the number of vegetation patches and increases in soil sand content. The predictive capacity of our structural equation modelling was clearly higher for the spatial variability of N- than for C- and P-related soil variables. In the case of N cycling, the effects of temperature and aridity were both direct and indirect via changes in soil properties. For C and P,

the effect of climate was mainly indirect via changes in plant attributes. These results suggest that future changes in climate may decouple the spatial availability of these elements for plants and microbes in dryland soils. Our findings significantly advance our understanding of the patterns and mechanisms driving SVM in drylands across the globe, which is critical for predicting changes in ecosystem functioning in response to climate change. 12

Keywords: Multifunctionality, carbon cycling, nitrogen cycling, phosphorous cycling, spatial heterogeneity, climate change

16. Essien, C., Via, B. K., Cheng, Q., Gallagher, T., McDonald, T., Eckhardt, L. (2018). Determining the predictive accuracy of whole tree modulus of elasticity (MOE) of 14-year-old loblolly pine using density and dynamic MOEs estimated by three different acoustic tools. *European Journal of Wood and Wood Products*, 1-12. <https://doi.org/10.1007/s00107-018-1317-9>

Resonance based acoustic tools for evaluating wood properties have been reported to be more accurate in estimating the expected log MOE than time-of-flight (ToF) ones. However, there is no published study on the variations within different brands on these two major classes of acoustic tools. In this study, models were developed to predict the whole tree static MOE (WMOET) and rupture (WMORT) using log dynamic MOEs estimated by two resonance tools [Director HM200 (EHM200) and FAKOPP resonance log grader (ERLG)], ToF [FAKOPP Microsecond Timer (EFMT)], and density (green density, air-dry density) for a 14-year-old loblolly pine stand from two sites in the southern USA. The log velocity estimated by ToF was 33 and 30% more as compared to the resonance-based tools (Director HM200 and FAKOPP RLG respectively); translating into whole log static MOE (WMOEL) been 11 and 20% lower than those estimated by the resonance (HM200 and RLG respectively), and 90% lower than that estimated by the ToF tools (EFMT). Although the dynamic MOE estimated by ToF tool (EFMT) was higher, its WMOET predictive performance ($R^2 = 51\%$) lies between the 39 and 74% for the resonance based tools (HM200 and RGL respectively). This result supports the theory that ToF tools generate dilatational wave, and hence their velocity will be generally higher than resonance tools. The presence of predictive variation within the resonance suggests the need for within tools calibration. The linear relationship between the WMOET vs Etree was stronger than that of WMOET vs EHM200 suggesting that the ToF acoustic tool measurements are not restricted to the outer wood zone for small diameter logs.

Keywords: Acoustic velocity, dynamic modulus of elasticity, resonance acoustic tool, loblolly pine

17. Essien, C., Via, B. K., Gallagher, T., McDonald, T., Eckhardt, L. (2018). Distance error for determining the acoustic velocity of standing tree using tree morphological, physical and anatomical properties. *Journal of Indian Academy of Wood Science*, 15(1): 52-60.

Time-of-flight (ToF) acoustic tools is one of the most practical nondestructive methods for predicting tree stiffness. In the literature, 120 cm between probes has been adopted as the standard for the assessment of tree acoustic velocity. However, there is no empirical study supporting this assertion, hence this study is aimed at determining the effect of distance on error for a common ToF acoustic tool. Twenty-five trees each were randomly selected from four loblolly pine plantations. Seven distances from 120 to 10 cm between probes were used to measure velocity. The morphological characteristics, physical and anatomical properties of the selected trees were also determined. The results indicated, at distances below 60 cm, the waveform is dominated by the fundamental frequency of the transmitter probe hence the velocities determined within 10–60 cm are not statistically different. Consequently, distances from 80 to 120 cm constitute the optimum range for velocity determination for this ToF acoustic tool. Furthermore, velocity determined at 40 cm is significantly higher than that determined at 120 cm suggesting velocity is dependent on the between probes distance. Using 120 cm as a standard distance, the dynamic stiffness is overestimated by 13, 50, 102, and 197 MPa respectively for 100, 80, 60, and 40 cm. Finally, microfibril angle and the fiber wall thickness are the main anatomical properties driving the signal at the micro-level.

Keywords: Distance error, crown ratio, crown light, foliage transparency, crown density, time-of-flight

18. Ferner, J., Schmidlein, S., Guuroh, R. T., Lopatin, J., and Linstaedter, A., (2018). Disentangling effects of climate and land-use change on West African drylands' forage supply. *Journal of Global Environmental Change*, 53: 24–38.

Livestock rearing is the most important agricultural activity in global drylands, making forage supply an essential ecosystem service (ES). Most drylands are expected to experience increasing levels of climatic aridity and land-use pressure in the future. As few studies account for combined effects of these global change drivers, we still have a limited understanding of how these drivers jointly shape forage supply. Here, the concept of social-ecological systems

(SESs) is useful, as it helps to formalize the complex interrelationships of drivers. Taking advantage of steep gradients of climatic aridity and land-use pressure in West Africa, a crossed space-for-time substitution was applied to capture combined effects of climate and land-use change on forage supply. We have operationalized the SES concept via structural equation modelling, and analysed how drivers directly or indirectly affected forage quantity, quality and their integrated proxy (metabolisable energy yield). Results demonstrate that contemporary dryland SESs are mainly controlled by land-use, which has often been used as a proxy for other variables, such as climatic aridity. Aridity was also directly linked to a higher risk of vegetation degradation, indicating that future drylands will be less resilient to grazing pressures. The importance of land-use drivers for ES provision implies that sustainable grazing management could potentially mitigate detrimental climate change effects. However, model effects mediated by intermediate variables, such as aridity, short-term vegetation dynamics, and weather fluctuations, make it extremely difficult to predict climate change effects on ESs. Integrating structural equation modelling into the well-defined SES concept is thus highly useful to disentangle complex interdependencies of global change drivers in dryland rangelands, and to analyze drivers' direct and indirect effects on ESs. Our novel approach can thus foster a deeper understanding of patterns and mechanisms driving ecosystem service supply in drylands, which is essential for establishing sustainable management under conditions of global change.

Keywords: Ecosystem service, forage, land-use, climate, drylands, social-ecological systems

19. Guuroh, R. T., Linstädter, A., Ferner, J., Canak, K., Ruppert, J. C., Schmidtlein, S., (2018). Drivers of forage provision and erosion control in West African savannas – A macroecological perspective. *Journal of Agriculture, Ecosystems & Environment*, 251: 257 – 267.

Rangelands' ability to provide ecosystem services (ESs) depends on ecosystem properties and functions, which are interactively driven by biophysical and land-use drivers. In West Africa's savanna rangelands, the relative importance of these drivers for ES supply is still poorly understood, hampering the identification of appropriate management strategies. In this context, trade-offs between the ES of forage provision and the regulating ES of erosion control are of particular importance. Taking a macroecological perspective, we aimed at detecting consistent patterns in ES drivers and identifying good predictors. The study area comprises a steep gradient of climatic aridity across West Africa's Sudanian savannas from northern Ghana to central Burkina Faso, in combination with local gradients of land-use intensity and topo-edaphic

conditions. We used aboveground biomass, metabolisable energy and metabolisable energy yield as proxies for forage provision, and the cover of perennials in the grass layer as a proxy for erosion control. Linear mixed-effect models and model selection were used to test relationships between multiple environmental variables and ES proxies. We found differential responses of ES proxies to environmental drivers. Vegetation properties were important for all ESs. Antecedent rainfall was the most important predictor of aboveground biomass, while plants' phenology and land-use were most important for metabolisable energy. Environmental variables (such as aridity, soil properties and grazing intensity) mediated via vegetation properties were the most important predictors of erosion control followed by the direct effect of climatic aridity. Our finding that antecedent rainfall was more important for forage provision than climatic aridity implies that the effects of long-term climatic aridity may in a given year be overridden by current season's precipitation particularly in case of a good rain year. The observed importance of land-use and vegetation properties implies that well-conceived adaptation strategies could mitigate potential negative effects of climate change.

Keywords: Ecosystem service, rangeland, forage provision, vegetation properties, West African savanna, environmental drivers

20. Gvozdevaite, A., Oliveras, I., Domingues, T.F., Peprah, T., Boakye, M., Afriyie, L., da Silva, K.P., de Farias, J., de Oliveira, E.A., Farias, C.C.A., Prestes, N.C.C.S., Neyret, M., Moore, S., Marimon, B.S., Marimon Junior, B.H., Adu-Bredu, S. & Malhi, Y. (2018). Leaf-level photosynthetic capacity dynamics in relation to soil and foliar nutrients along forest–savanna boundaries in Ghana and Brazil. *Tree Physiology*, 38(12): 1912–1925. doi:10.1093/treephys/tpy117

Forest–savanna boundaries extend across large parts of the tropics but the variability of photosynthetic capacity in relation to soil and foliar nutrients across these transition zones is poorly understood. For this reason, we compared photosynthetic capacity (maximum rate of carboxylation of Rubisco at 25 C° (V_{cmax25}), leaf mass, nitrogen (N), phosphorus (P) and potassium (K) per unit leaf area (LMA, Narea, Parea and Karea, respectively), in relation to respective soil nutrients from 89 species at seven sites along forest–savanna ecotones in Ghana and Brazil. Contrary to our expectations, edaphic conditions were not reflected in foliar nutrient concentrations but LMA was slightly higher in lower fertility soils. Overall, each vegetation type within the ecotones demonstrated idiosyncratic and generally weak relationships between V_{cmax25} and Narea, Parea and Karea. Species varied significantly in their V_{cmax25} Narea

relationship due to reduced investment of total Narea in photosynthetic machinery with increasing LMA. We suggest that studied species in the forest–savanna ecotones do not maximize $V_{\text{max}25}$ per given total Narea due to adaptation to intermittent water availability. Our findings have implications for global modeling of $V_{\text{max}25}$ and forest–savanna ecotone productivity.

Keywords: Carboxylation capacity, leaf traits, nitrogen, photosynthesis, tropical vegetation transitions.

21. Janssen, T.A.J., Ametsitsi, G. K. D., Collins, M., Adu-Bredu, S., Oliveras, I., Mitchard, E.T.A. & M. Veenendaal, E.M. (2018). Extending the baseline of tropical dry forest loss in Ghana (1984–2015) reveals drivers of major deforestation inside a protected area. *Biological Conservation* 218: 163-172

Tropical dry forests experience the highest deforestation rates on Earth, with major implications for the biodiversity of these ecosystems, as well as for its human occupants. Global remote sensing based forest cover data (2000 - 2012) point to the rapid loss of tropical dry forest in South America and Africa, also, if not foremost, inside formally protected areas. Here, we significantly extend the baseline of tropical dry forest loss inside a protected area in Ghana using a generalizable change detection technique. The forest cover change detection is based on the normalized difference vegetation index (NDVI) derived from historical Landsat data (1984–2015). Field measurements were carried out in dry semi-deciduous forest and in the adjacent savanna and woodland. Estimates of the canopy area index and above ground woody biomass were related to NDVI derived from Landsat 8 data. The change detection indicated significant NDVI decrease in a large area initially covered by tropical dry forest, associated with deforestation. The peak in deforestation was found to have occurred between 1990 and 2002, hereafter, the conservation status of the area was improved. A combination of remote sensing data corroborated by secondary data sources provides evidence for the almost complete clearance of a tropical dry forest inside a strictly protected area, attributable to logging and land clearing for arable farming. The NDVI change detection also revealed NDVI increase in the adjacent woodlands from 2002 to 2015, demonstrating woody encroachment. Historical fire data from the MODIS burned area product indicate that the deforested area experienced a high frequency of anthropogenic burning since 2004, which may have caused further degradation and largely prevents forest regeneration. The results show the ongoing destruction of tropical ecosystems even within ostensibly protected areas and ask for the revision of protection and management strategies of such areas.

Keywords: Forest-savanna ecotone, vegetation structure, canopy cover, wildfire, woody encroachment, forest regeneration, deforestation, tropical forest loss,

22. Julier, A.C.M., Jardine, P.E., Adu-Bredu, S., Coe, A.L., Fraser, W.T., Lomax, B.H., Malhi, Y., Moore, S. & Gosling, W.D. (2018). Variability in modern pollen rain from moist and wet tropical forest plots in Ghana, West Africa. *Grana*, 58(1): 45-62, <https://doi.org/10.1080/00173134.2018.1510027>

How pollen moves within and between ecosystems affects factors such as the genetic structure of populations, how resilient they are to environmental change, and the amount and nature of pollen preserved in the sedimentary record. We set artificial pollen traps in two 100 m by 100 m vegetation plots, one in a wet evergreen forest, and one in a moist semi-deciduous forest in Ghana, West Africa. Five traps from each plot were counted annually from 2011 to 2014, to examine spatial and temporal variation in the pollen rain of the most abundant taxa shared between pollen and vegetation assemblages. Samples from the wet evergreen plot exhibited high variability within years, with the dominant pollen types changing between samples, and many pollen taxa being over-represented relative to their parent plant abundance in some traps whilst being entirely absent from others. The most abundant plant taxa of the wet evergreen plot (*Drypetes* and *Cynometra*) do, however, constitute major components of the pollen rain. There is less variation between samples from the moist semi-deciduous plot spatially, as it is dominated by *Celtis*, which typically comprises >70% of the pollen assemblages. We conclude that pollen rain in these tropical ecosystems is highly heterogeneous, and suggest that pollen assemblages obtained by trapping are susceptible to small-scale variations in forest structure. Conversely, this may mean that current recommendations of more than three years of trapping in tropical systems may be too high, and that space could substitute for time in modern tropical pollen trapping.

Keywords : Palynology, pollen, dispersal, Tropics, Ghana

23. Julier, A.C.M., Jardine, P.E., Adu-Bredu, S., Coe A.L., Duah-Gyamfi A., Fraser, W.T., Lomax, B.H., Malhi Y., Moore, S., Owusu-Afriyie, K. & Gosling, W.D. (2018). The modern pollen–vegetation relationships of a tropical forest–savannah mosaic landscape, Ghana, West Africa. *Palynology* 42(3): 324-338

Transitions between forest and savannah vegetation types in fossil pollen

records are often poorly understood due to over-production by taxa such as Poaceae and a lack of modern pollen-vegetation studies. Here, modern pollen assemblages from within a forest-savannah transition in West Africa are presented and compared, their characteristic taxa discussed, and implications for the fossil record considered. Fifteen artificial pollen traps were deployed for 1 year, to collect pollen rain from three vegetation plots within the forest-savannah transition in Ghana. High percentages of Poaceae and Melastomataceae/Combretaceae were recorded in all three plots. *Erythrophleum suaveolens* characterised the forest plot, *Manilkara obovata* the transition plot and *Terminalia* the savannah plot. The results indicate that Poaceae pollen influx rates provide the best representation of the forest-savannah gradient, and that a Poaceae abundance of >40% should be considered as indicative of savannah-type vegetation in the fossil record.

Keywords: Pollen, transitions, Poaceae, savannah, Ghana, palaeoecology, Bosumtwi

24. Kemigisha, E., Owusu, E.O., Elusiyan, C. A., Omujal, F., Tweheyo, M. and Bosu, P. P. (2018). *Tetrapleura tetraptera* in Ghana, Nigeria and Uganda: households uses and local market. *Forests, Trees and Livelihoods*. DOI: 10.1080/14728028.2018.1498027

Tetrapleura tetraptera is an indigenous fruit tree in Tropical Africa. Scientific findings indicate its medicinal and nutritional properties, vital for rural livelihood sustainability. Despite this reported scientific potential, its uses in local communities have not received much attention. This study assessed *T. tetraptera* local uses in selected communities in Ghana, Nigeria and Uganda. Data were collected through semi-structured interviews with a total of 420 user households and 30 traders. Reported uses of *T. tetraptera* were medicine, food, timber, firewood, shade and cultural applications. When ranked by importance, medicinal uses emerged highest in Ghana, Nigeria and Uganda. Except for food uses that differed significantly ($p < 0.05$) between Uganda and Ghana, other *T. tetraptera* uses were not significantly different across the three countries. Household sales exclusively concerned the fruits, and were low, comprising only 16%, 15% and 6% of respondent households in Ghana, Nigeria and Uganda respectively. Our results reveal the importance of *T. tetraptera* for medicinal and food uses in local communities and its potential for improving local livelihoods through its domestication.

Keywords: *Tetrapleura tetraptera*, fruit tree, local market, Uganda, Ghana, Nigeria, household use

25. Mitchual S. J., Minkah M. A., Owusu, F. W. and Okai, R. (2018). Planning and turning characteristics of *Gmelina arborea* grown in two ecological zones in Ghana. *Advances in Research*, 14(2): 1-11. DOI: 10.9734/AIR/2018/39024

Gmelina arborea grown in Ghana has not been promoted for its efficient use by the wood industry due to the limited technical information available and is therefore classified as a lesser-used timber species. This paper presents research findings on the planning and turning properties of *Gmelina arborea* cultivated in two ecological zones in Ghana. Samples of logs from six trees of the species were obtained from Daboase and Abofour in the Wet Evergreen and Dry Semi-Deciduous Forest zones of Ghana. These were crosscut into top, middle and butt sections using a chainsaw. An LT 15 Wood-Mizer bandsaw was used to saw each log into 2.6 cm -thick boards; these were then stacked for air drying. Planning and turning tests were conducted following the American Society for Testing and Materials International D1666-87-2004 method to determine the machining characteristics of the wood. The results of the study indicate that *Gmelina arborea* is a medium-density species and that irrespective of where it is grown, the best planning performance is obtained at a feed speed of 6 m/min using a cutting angle of 30°. The results also indicate that the turning characteristics of *Gmelina arborea* obtained from the two ecological zones were best at spindle speeds of 1850 rpm and 2500 rpm. At the 5% level of significance, the spindle speed and the interaction between location and spindle speed, tree section and spindle speed and location, tree section and spindle speed had a significant effect on the surface quality of the turned specimen. It is therefore found that *Gmelina arborea* cultivated in Ghana has good planning and turning characteristics.

Keywords: Feed speed, *Gmelina arborea*, species density, spindle speed, surface quality. 19

26. Moore, S., Adu-Bredu, S., Duah-Gyamfi, A., Addo-Danso, S.D., Ibrahim, F., Mbou, A.T., de Grandcourt, A., Valentini, R., Nicolini, G., Djagbletey, G., Owusu-Afriyie, K., Gvozdevaite, A., Oliveras, I., Ruiz-Jaen, M.C., Malhi, Y. (2018). Forest biomass, productivity and carbon cycling along a rainfall gradient in West Africa. *Global Change Biology*, 24(2): 496-510. <https://doi.org/10.1111/gcb.13907>

Net Primary Productivity (NPP) is one of the most important parameters in describing the functioning of any ecosystem and yet it arguably remains a poorly

quantified and understood component of carbon cycling in tropical forests, especially outside of the Americas. We provide the first comprehensive analysis of NPP and its carbon allocation to woody, canopy and root growth components at contrasting lowland West African forests spanning a rainfall gradient. Using a standardized methodology to study evergreen (EF), semi-deciduous (SDF), dry forests (DF) and woody savanna (WS), we find that (i) climate is more closely related with above and belowground C stocks than with NPP (ii) total NPP is highest in the SDF site, then the EF followed by the DF and WS and that (iii) different forest types have distinct carbon allocation patterns whereby SDF allocate in excess of 50% to canopy production and the DF and WS sites allocate 40%–50% to woody production. Furthermore, we find that (iv) compared with canopy and root growth rates the woody growth rate of these forests is a poor proxy for their overall productivity and that (v) residence time is the primary driver in the productivity-allocation-turnover chain for the observed spatial differences in woody, leaf and root biomass across the rainfall gradient. Through a systematic assessment of forest productivity, we demonstrate the importance of directly measuring the main components of above and belowground NPP and encourage the establishment of more permanent carbon intensive monitoring plots across the tropics.

Keywords: Africa, allocation, biomass, carbon cycle, net primary productivity, rainfall gradient, residence time, tropical forests

27. Obeng, E. A., Aguilar, F. X. and McCann, L. M. (2018). Payments for forest ecosystem services: a look at neglected existence values, the free-rider problem and beneficiaries' willingness to pay. *International Forestry Review*, 20(2): 206-219

Payment for ecosystem services (PES) programs have emerged as a financial mechanism to ameliorate market failures associated with the multitude of non-market ecosystem services (ES) provided by forest ecosystems. However, the defining principles of PES in theory is far from what pertains in practice. Focusing on the concept of total economic value (TEV) of ES, we identify that PES often include compensation as a proxy for the supply of ES and largely neglect to encompass the different attributes of an ES' TEV, particularly existence values. Most PES schemes are limited by scope of funding and incentives often account for as little as 0.1% to 8.5% of the full annual ES economic values per ha. The mechanism of PES therefore needs to be broadened to integrate potential levels of payments that direct and indirect beneficiaries might be willing to pay to preserve forest ecosystems and their services. Some beneficiaries might be willing to pay for some ES and altruistically expect others to free-ride on their payment. Research efforts should aim at providing

better understanding of beneficiaries' willingness to pay in order to expand the demand-side of PES and reduce uncertainties.

Keywords: Ecosystem services, forests, PES, ecosystem values, willingness-to-pay

28. Obeng, E. A. and Aguilar FX. (2018). Value orientation and payment for ecosystem services: perceived detrimental consequences lead to willingness-to-pay for ecosystem services. *Journal of Environmental Management* 206,458-471. <https://doi.org/10.1016/j.jenvman.2017.10.059>

This research analyzed whether the three distinct value orientations posited under the Value-Belief-Norm (VBN) model determine willingness-to-pay (WTP) for a payment for ecosystem services (PES) program. A survey instrument gathered U.S. residents' knowledge and attitudes toward ecosystem services and PES, and elicited WTP for the restoration of a hypothetical degraded forest watershed for improved ecosystem services. Data from over 1000 respondents nationwide were analyzed using exploratory factor analysis (EFA) and ordered logistic regression. Urban respondents were more familiar with the concepts of ecosystem service and PES than rural respondents but familiarity did not yield statistically different WTP estimates. Based on results from the EFA, we posit that latent value orientations might be distinguished as 'detrimental', 'biospheric' and 'beneficial (egoistic)' e as compared to 'altruistic', 'biospheric' and 'egoistic' as suggested in the VBN's general awareness of consequences scale. Awareness of biospheric and detrimental consequences along with ascriptions to personal norms had positive and significant effects on stated WTP. Beneficial (egoistic) value orientation was negatively associated with WTP and carried a negative average WTP per household per year (US\$ - 30.48) for the proposed PES restoration program as compared with biospheric (US\$ 15.53) and detrimental (US\$ 3.96) orientations. Besides personal norms, awareness of detrimental consequences to human wellbeing from environmental degradation seems the stronger driver of WTP for the restoration and protection of forest watershed ecosystem services under a PES program.

Keywords: Value orientation, payment for ecosystem services, environmental attitudes, willingness-to-pay, non-market ecosystem services 21

29. Oduro, K.A., Arts, B., Kyereh, B., & Mohren, G. (2018). Farmers' motivations to plant and manage on-farm trees in Ghana. *Small-scale Forestry* 17(3): 393-410.

Deforestation and forest degradation, especially in the agricultural landscapes,

are serious threats to biodiversity conservation and sustainability of the timber industry. Planting trees on farms has been identified as having great potential to increase forest resources from agricultural landscapes. This paper examined farmers' motivations and behaviour to engage in on-farm tree planting and management in Ghana by combining internal and external factors in a socio-psychological model. Data were collected from 156 smallholder farmers from five communities in two forest districts using a semi-structured questionnaire. Additional farm inventory data were collected from 33 farmers under two on-farm tree planting schemes. On-farm tree planting was perceived as providing income, access to personal timber for furniture, and access to loan facilities. Incentives such as provision of grants, farming inputs, capacity training, and access to markets for agricultural produce are factors that motivate on-farm tree planting in Ghana. The average standing volume of on-farm trees in the study area is 51.9 m³/ha which is almost twice the national average for the off-reserve areas in the semi-deciduous forests to which much of the study sites belong. Many farmers considered high financial costs and limited knowledge of appropriate techniques in managing planted on-farm trees as barriers to the development of tree stock on farms.

Keywords: Farmer motivation, decision-making, socio-psychological, model agroforestry

30. Owusu, F. W., Damnyag, L., Marfo, E., Opong, J. A. (2018). The demand and supply patterns of timber at the domestic market in Ghana. *Journal of Energy and Natural Resource Management (JENRM)*, 1(1): 63-79. DOI: <https://doi.org/10.26796/jenrm.v1i1.93>

Chainsaw milling continues to thrive with regular timber delivery for domestic timber market to meet the needs of consumers. It is largely recognized as a major challenge for sustainable forest management, hence very exigent to obtain and maintain reliable data for planning and for informed policymaking in the forestry sector. This paper aimed at determining the size of the domestic timber market in Ghana. The country was zoned into five and five survey teams were raised, collected the data within the same period for 14 days simultaneously. Data collection was through structured questionnaires and personal interviews. The study revealed that the total annual national projected stock volume of timber was estimated as 2,513,428.9m³ of which 1,532,199m³ was consumed. A total of 108 domestic timber markets were identified nationwide and categorized into small, medium and large based on the estimated number of sheds per market. The number of timber merchants, 1157 and timber trade associations, 55 were surveyed in the ten regions. The main sources of timber supply were bush cut and sawmill of which the percentages of the monthly

timber supply with respect to the national monthly volume were 72% and 28% respectively. Major timber products identified were beams, boards and lumber. The number of dimensions recorded from the three timber products was 194 and 99 timber species were identified with six of the species available in all the 10 regions of Ghana. The stock volume of the first 10 dominant species on the domestic market constituted 72% of the total national volume stocked.

Keywords: Chainsaw lumber, domestic timber market, supply pattern, sources of supply, timber products.

31. Rifai, S.W., Girardin, C.A.J., Berenguer, R., del Aguila-Pasquel, J., Dahlsjö, C.A.L., Doughty C.E., Jeffery, K.J., Moore, S., Oliveras, I., Riutta, T., Rowland, L.M., Murakami, A.A., Addo-Danso, S.D., Brando, P., Burton, C., Ondo, F.E., Duah-Gyamfi, A., Amézquita, R.F. Freitag, R., Pacha, F.H., Huasco, W.H., Ibrahim F., Mbou, A.T., Mihindou, V.M., Peixoto, K.S., Rocha, W., Rossi, L.C., Seixas, M., Silva-Espejo, J.E., Abernethy, K.A., Adu-Bredu, S., Barlow J., da Costa, A.C.L., Marimon, B.S., Marimon-Junior, B.H., Meri, P., Metcalfe, D.B., Phillips, O.L., White, L.J.T., Malhi, Y. (2018). ENSO drives interannual variation of forest woody growth across the tropics. *Philosophical Transactions of the Royal Society B: Biological Science*, 373: 20170410. <https://doi.org/10.1098/rstb.2017.0410>

Meteorological extreme events such as El Niño events are expected to affect tropical forest net primary production (NPP) and woody growth, but there has been no large-scale empirical validation of this expectation. We collected a large high-temporal resolution dataset (for 1–13 years depending upon location) of more than 172 000 stem growth measurements using dendrometer bands from across 14 regions spanning Amazonia, Africa and Borneo in order to test how much month-to-month variation in stand-level woody growth of adult tree stems (NPPstem) can be explained by seasonal variation and interannual meteorological anomalies. A key finding is that woody growth responds differently to meteorological variation between tropical forests with a dry season (where monthly rainfall is less than 100 mm), and aseasonal wet forests lacking a consistent dry season. In seasonal tropical forests, a high degree of variation in woody growth can be predicted from seasonal variation in temperature, vapour pressure deficit, in addition to anomalies of soil water deficit and shortwave radiation. The variation of aseasonal wet forest woody growth is best predicted by the anomalies of vapour pressure deficit, water deficit and shortwave radiation. In total, we predict the total live woody production of the global tropical forest biome to be 2.16 Pg C yr⁻¹, with an

interannual range 1.96–2.26 Pg C yr⁻¹ between 1996–2016, and with the sharpest declines during the strong El Niño events of 1997/8 and 2015/6. There is high geographical variation in hotspots of El Niño–associated impacts, with weak impacts in Africa, and strongly negative impacts in parts of Southeast Asia and extensive regions across central and eastern Amazonia. Overall, there is high correlation ($r = -0.75$) between the annual anomaly of tropical forest woody growth and the annual mean of the El Niño 3.4 index, driven mainly by strong correlations with anomalies of soil water deficit, vapour pressure deficit and shortwave radiation.

Keywords: El Niño, tropical forests, woody net primary production, drought, meteorological anomalies

32. Sraku-Lartey, M., Buor, D., Adjei, P. O. W., Foli, E. G. (2018). Perceptions and knowledge on climate change in local communities in the Offinso Municipality, Ghana. *Information Development*, 1-20. DOI: [10.1177/0266666918811391](https://doi.org/10.1177/0266666918811391)

Climate change is considered to be a significant threat that faces mankind in this century. In Ghana, it is expected to have a significant effect on agriculture and other climate dependent livelihoods in all ten regions of the country. The development and implementation of policies on climate change in Ghana require the incorporation of local people's perception and knowledge of the risks they are exposed to. A study to assess the perceptions and knowledge of climate change was undertaken in the Offinso Municipality in Ghana. The study used a cross-sectional design where the information gathered represented what was going on at one point in time. Respondents (307) were selected from Kwapanin, Koforidua, Kyebi, Sampronso and Anyinasuso communities using the systematic sampling method. The study used questionnaires, focus group discussions and targeted interviews to collect primary information on local people's perception on climate change. The analysis used descriptive statistics (frequency and percentages) and chi-square to detect any association between demographic characteristics of local people and their perception of climate change. In addition, the knowledge levels of respondents on climate change was analysed. The results indicate that perception of climate change is not influenced by origin, gender or level of education; however, it is significantly influenced by age. A knowledge portfolio showed that local people did not have in-depth knowledge on climate change in general. There is therefore the need to create awareness and sensitize local people on causes, indicators and effects of climate change.

Keywords: Climate change, Ghana, indigenous knowledge, knowledge, perception 24

33. Thomson, E.R., Malhi, Y., Bartholomeus, H., Oliveras, I., Gvozdevaite, A., Pehrah, T., Suomalainen, J., Quansah, J., Seidu, J., Adonteng, C., Abraham, A.J., Herold, M., Adu-Bredu, S. & Doughty, C.D. (2018). Mapping the leaf economic spectrum across West African tropical forests using UAV-Acquired Hyperspectral Imagery. *Remote Sensing* 10: 1532; doi: 10.3390/rs10101532 www.mdpi.com/journal/remote_sensing.

The leaf economic spectrum (LES) describes a set of universal trade-offs between leaf mass per area (LMA), leaf nitrogen (N), leaf phosphorus (P) and leaf photosynthesis that influence patterns of primary productivity and nutrient cycling. Many questions regarding vegetation-climate feedbacks can be addressed with a better understanding of LES traits and their controls. Remote sensing offers enormous potential for generating large-scale LES trait data. Yet so far, canopy studies have been limited to imaging spectrometers onboard aircraft, which are rare, expensive to deploy and lack fine-scale resolution. In this study, we measured VNIR (visible-near infrared (400–1050 nm)) reflectance of individual sun and shade leaves in 7 one-ha tropical forest plots located along a 1200–2000 mm precipitation gradient in West Africa. We collected hyperspectral imaging data from 3 of the 7 plots, using an octocopter-based unmanned aerial vehicle (UAV), mounted with a hyperspectral mapping system (450–950 nm, 9 nm FWHM). Using partial least squares regression (PLSR), we found that the spectra of individual sun leaves demonstrated significant ($p < 0.01$) correlations with LMA and leaf chemical traits: $r^2 = 0.42$ (LMA), $r^2 = 0.43$ (N), $r^2 = 0.21$ (P), $r^2 = 0.20$ (leaf potassium (K)), $r^2 = 0.23$ (leaf calcium (Ca)) and $r^2 = 0.14$ (leaf magnesium (Mg)). Shade leaf spectra displayed stronger relationships with all leaf traits. At the airborne level, four of the six leaf traits demonstrated weak ($p < 0.10$) correlations with the UAV-collected spectra of 58 tree crowns: $r^2 = 0.25$ (LMA), $r^2 = 0.22$ (N), $r^2 = 0.22$ (P), and $r^2 = 0.25$ (Ca). From the airborne imaging data, we used LMA, N and P values to map the LES across the three plots, revealing precipitation and substrate as co-dominant drivers of trait distributions and relationships. Positive N-P correlations and LMA-P anticorrelations followed typical LES theory, but we found no classic trade-offs between LMA and N. Overall, this study demonstrates the application of UAVs to generating LES information and advancing the study and monitoring tropical forest functional diversity.

Keywords: Leaf traits, leaf economic spectrum, UAV, hyperspectral,

34. Tsobeng, A., Asaah, E., Leakey, R., Tchoundjeu, Z., Van Damme, P., Ofori, D., Jamnadass, R. (2018). Effects of pre-severance irradiance on the growth of *Allanblackia floribunda* Oliv. Stockplants and on the subsequent rooting capacity of leafy stem cuttings. *New Forests*. <https://doi.org/10.1007/s11056-018-9673-1>

The rooting of *Allanblackia* stem cuttings is typically slow and with the formation of very few roots. Irradiance has positive effects on the relative growth of plants and rooting ability, but there is no information relating to *Allanblackia* species. Stumps of *Allanblackia floribunda* Oliv. were grown under three levels of irradiance (2008 $\mu\text{mol m}^{-2}\text{s}^{-1}$, 542 $\mu\text{mol m}^{-2}\text{s}^{-1}$ and 160 $\mu\text{mol m}^{-2}\text{s}^{-1}$) and were assessed for growth (plant height and the number of cuttings) and the influence of irradiance on the rooting ability of leafy stem cuttings. Shade light regime 542 $\mu\text{mol m}^{-2}\text{s}^{-1}$ resulted in significantly greater stockplant height than in 160 and 2008 $\mu\text{mol m}^{-2}\text{s}^{-1}$. Significantly more useable cuttings were harvested from the tall plants under an irradiance of 542 $\mu\text{mol m}^{-2}\text{s}^{-1}$, fewer from 160 $\mu\text{mol m}^{-2}\text{s}^{-1}$, and the least from 2008 $\mu\text{mol m}^{-2}\text{s}^{-1}$. The rooting ability of cuttings was greatest from stockplants receiving 542 $\mu\text{mol m}^{-2}\text{s}^{-1}$ (> 60%) and least from those receiving 160 $\mu\text{mol m}^{-2}\text{s}^{-1}$ (20%). 45% of cutting rooted from stockplants under full sun (2008 $\mu\text{mol m}^{-2}\text{s}^{-1}$). The speed of rooting of cuttings followed the same ranking with the fastest rooting from plants receiving 542 $\mu\text{mol m}^{-2}\text{s}^{-1}$ (7.1 ± 1.04 weeks to reach 25% of rooting) and the slowest from those under 160 $\mu\text{mol m}^{-2}\text{s}^{-1}$ (12.3 ± 1.85 weeks to reach 25% of rooting). The results of this study demonstrate that the light management of *A. floribunda* stockplants is important for the maximization of the yielding of cutting and the speed of rooting of leafy stem cuttings. Tree plantation being a key option to alleviate environmental challenges that the world is facing today, these results confirm previous findings which postulates that appropriate light management in stockplants can increase the production speed of required seedlings.

Keywords: Number of cuttings, rooting percentage, shoot length, shade level, speed of rooting

35. Zhou, L., Lin S., Huang P., Lin, S., Addo-Danso, S.D., Ma Z., Ding G. (2018). Effects of leaf age and exogenous hormones on callus initiation, rooting formation, bud germination, and plantlet formation in Chinese fir leaf cuttings. *Forests*, 9: 478. doi: 10.3390/f9080478.

To guide the cultivation of superior Chinese fir plantlets, we designed an L16(4)4

orthogonal experiment to determine how leaf age and exogenous hormones influence key growth processes in leaf cuttings. Hormone concentration and treatment duration significantly affected leaf cuttings in all three age categories; 6-benzylaminopurine (6-BA), 1-naphthaleneacetic acid (NAA), and treatment time exerted the strongest effects on callus initiation rates. Additionally, NAA had the largest effect on the rooting rate across all cuttings, and all three hormones significantly influenced the bud germination rate. Based on our experimental results, expected optimal treatments for callus initiation were 10 mg·L⁻¹ indole-3-butyric acid (IBA) for 10 min, 30 mg·L⁻¹ NAA for 15 min, and 10 mg·L⁻¹ NAA plus 30 mg·L⁻¹ IBA for 10 min. For the rooting rate, the expected optimal treatment was 50 mg·L⁻¹ NAA and 40 mg·L⁻¹ IBA for 5–20 min. Finally, for bud germination, optimal treatments were 20 min of immersion in water, 30 mg·L⁻¹ 6-BA plus 50 mg·L⁻¹ NAA for 15 min, and 30 mg·L⁻¹ 6-BA for 5 min. Plantlet formation only occurred in the <one-year-old leaves, and at very low rates (maximum 5.8%); this outcome is likely attributable to the mother plant's relatively old age (five years). Plantlet formation from cuttings is dependent on ensuring the rooting rate after callus initiation. Therefore, to promote rooting rates and bud germination, we recommend leaving more xylem at the base of leaf cuttings.

Keywords: Chinese fir, leaf cuttings, callus initiation, rooting formation, bud germination, plantlet formation, exogenous hormones, leaf ages

