



**FORESTRY RESEARCH INSTITUTE OF GHANA**

# **Book of Abstracts 2016 Refereed Journal Articles**



**Book of Abstracts  
2016**

**Book of Abstracts - 2016**

**CSIR-FORESTRY RESEARCH INSTITUTE  
OF GHANA**

**BOOK OF ABSTRACTS**

**2016 REFEREED JOURNAL ARTICLES**

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## **Preface**

The centerpiece of CSIR-FORIG's mission is to undertake demand-driven research, promote application of technologies and disseminate scientific knowledge for the benefit of society. In 2016, CSIR-FORIG contributed towards addressing challenges in the forestry sector by undertaking projects and consultancies through multi-disciplinary teams within the Institute and with its Local and International partners. The findings have been published in refereed journals.

A compilation of abstracts of all refereed journal articles published by Scientists of CSIR-FORIG in 2016 are presented in this booklet for easy reference. These articles cover the areas of biodiversity conservation and ecosystem services, forest improvement and productivity, wood industry and utilization, forest products and marketing, forest policy, governance and livelihoods and Forests and climate change. Citation of the articles should be based on the original source detailed in the booklet. Full papers of the articles can also be obtained at the CSIR-Forestry Research Institute of Ghana.

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



Dr. Daniel A. Ofori  
(Director, CSIR-FORIG)

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## **Introduction**

This publication is a compilation of articles written by CSIR-FORIG scientists in 2016. The aim is to bring these articles together in one publication so that colleague scientists can be made aware of them. The publication is for non-commercial purposes and all sources have been duly acknowledged. Some articles accepted in 2016 but published in early 2017 however have been included. Others were submitted in 2016 but were back dated by the publishers due to publication challenges.

A total of 44 journal articles were published by scientists of CSIR-FORIG in peer reviewed journals worldwide. Some articles were joint publications with partners and colleagues others were sole publications by scientists. The names of each CSIR-FORIG scientists have been highlighted in the citations. All sources have been duly acknowledged and follow the publishers' guidelines on the re-use of their journal articles.

The abstracts have been arranged in alphabetical order and numbered chronologically.

## Book of Abstracts - 2016

1. Aabeyir, R.; **Adu-Bredu, S.**; Agyare, W.A. and Weir, M. J. C. (2016). Empirical evidence of the impact of commercial charcoal production on woodland in the Forest-Savannah transition zone, Ghana, *Energy for Sustainable Development* 33:84–95.

The impacts of charcoal production on woodland were assessed in the Forest-Savannah Transition Zone of Ghana to facilitate policy formulation for a win-win situation for both sustainable woodland management and charcoal production. Twenty-three harvested sites in two charcoal producing communities were assessed in terms of the extent of harvested sites, changes in biomass carbon stock and tree basal area. The boundary of each site earmarked for charcoal production was mapped with a hand-held Global Positioning System, and the diameters at breast height (dbh) and the heights of trees of  $\text{dbh} \geq 5 \text{ cm}$  were measured, prior to harvest. The extent of harvested sites was compared with the Intergovernmental Panel on Climate Change criterion of “devegetation” using Wilcoxon test, while the biomass carbon and basal area of the harvested trees were compared with those of the remnant trees using Mann Whitney t-test. The median of the extent of harvested sites ( $M = 0.23 \text{ ha}$ ,  $P = 1.00$ ) was significantly higher than  $0.05 \text{ ha}$ , the Intergovernmental Panel on Climate Change minimum criterion for “devegetation”, while the difference between median basal area of harvested and remnant trees was significantly greater than zero ( $G_h - G_r = 2.6 \text{ m}^2 \text{ ha}^{-1}$ ;  $P = 0.001$ ) at 95% significant level. The Mann Whitney test also provided sufficient evidence ( $n = 23$ ;  $M_{hc} - M_{rc} = 12.07 \text{ t ha}^{-1}$ ;  $P < 0.001$ ) against the null hypothesis that the difference between the medians of the aboveground biomass carbon in the harvested and remnant is zero at 95% significant level. On the basis of the IPCC definition of “devegetation” and the changes in basal area, it suggests that intensive charcoal production has the potential of degrading woodlands. Nonetheless, it is worth highlighting that, none of the harvested sites had zero basal area or biomass carbon after harvest, which is a significant revelation for sustainable woodland management for charcoal production. The study further revealed that the extent of harvested site is not an appropriate measure of the impact of charcoal production on woodland since it does not account for the number and sizes of the trees harvested. Therefore, the impact of charcoal production on woodland may not be as alarming as it is generally perceived when the extent of harvested site is used as a measure. The impact of charcoal production is often over-generalized and that, “devegetation” of harvested sites is an issue of post-harvest woodland management and not the impact of charcoal production per se. Therefore, the evidence of the impact of charcoal production on

woodlands shown in this study should be basis for sustainable woodlands management and not basis for halting charcoal production in the study area.

2. Abengmeneng, C.S., **Ofori, D.A.**, Kumapley, P., Akromah, R., Jamnadass, R. and Quain, M. (2016). Genetic relationships among 36 genotypes of *Ceiba pentandra* (L.) as revealed by RAPD and ISSR markers. *American Journal of Agriculture and Forestry* 4(4):86-96.

*Ceiba pentandra* (L.) Gaertn (trade name Ceiba) of the family Bombacaceae is an important multi-purpose tree species in Ghana and demand for it is rising daily. As a result, it has been included as one of the species for the National Forest Plantation Development Programme of Ghana as part of the efforts towards its restoration. Seedlings for the programme are being raised from seed collected from the wild without regard for their genetic quality and its future adverse effects. The absence of adequate information on the genetic diversity within the species therefore serves as a potential threat to its long term sustainable management and efficient genetic conservation. The phylogenetic relationships of 36 genotypes of *C. pentandra* from natural range of the species in five ecological zones (populations) of Ghana were therefore analyzed using 10 polymerase chain reaction (PCR) markers (5 random amplified polymorphic DNAs (RAPDs) and 5 inter simple sequence repeats (ISSRs)). The principal component analysis (PcoA) defined by axis 1 and 2 accounted for 67.15% of the variation observed. Cluster analysis using GeneStat Discovery showed that, 14 (38.89%), 21 (58.33%) and 4 (11.11%) of the accessions had a coefficient of similarity of 1 from the RAPD, ISSR and the combined RAPD and ISSR polymorphism respectively. The most distantly related accessions from the RAPD polymorphism analysis were BAW 1 and KON 8 with a similarity coefficient of 0.06 whereas those from the ISSR polymorphism were BAW 10 and ASE 1 with 21% similarity between them. Similarly, BUF 1 and KUE 1 were the most dissimilar accessions from the combined RAPD and ISSR fragments analysis with a similarity coefficient of 0.23. Nine (25%) accessions with high degree of dissimilarity between them were identified in the study. These accessions could serve as good candidates for conservation as seed trees and in breeding programs of *C. pentandra* in Ghana. Implications of the findings for effective management of the genetic resources of the species were also discussed.

- 3. Addo-Danso, S. D., Prescott, C.E., and Smith, A.R. (2016).** Methods for estimating root biomass and production in forest and woodland ecosystem carbon studies: A review. *Forest Ecology and Management*, 359:332-351.

Fine and coarse roots are key contributors to belowground net primary productivity, and play critical roles in the biogeochemical cycling of forest and woodland ecosystems. Despite their critical roles, roots have been understudied mainly due to methodological challenges. There is currently no consensus on which methods are most suitable to accurately study root biomass and production. Critical evaluation of the assumptions, strengths and inherent limitations of methods to study root biomass and production are necessary to help investigators decide which method is best for their purposes. This synthesis compares existing methods for root biomass and production estimation based on relevant criteria that include cost, labor requirements, time efficiency and accuracy and, also compares fine- and coarse-root biomass and production estimates from different methods measured at the same sites. Root excavation and soil-pit methods are commonly used to estimate coarse-root biomass, despite the high cost and labor required. Ground-Penetrating Radar is a very promising indirect approach to estimate coarse-root biomass, but may not be suitable for ecosystems with dense understory and soils with high organic matter and ion contents. Soil-core remains the most preferred method to estimate fine-root biomass. Empirical models are accepted as fast and cost-effective indirect approach to predict fine- and coarse-root biomass and production. Fine-root production is usually estimated with the (mini) rhizotrons, sequential-coring and ingrowth-core methods. Coarse-root biomass estimates were not significantly different between soil-pit and soil-core methods. There was a significant positive correlation ( $r^2 = 0.91$ ,  $p < 0.0001$ ) between fine-root biomass estimates obtained from soil-pit and soil-core methods. Fine-root production estimates were lower in the ingrowth-core ( $2.06 \pm 0.23 \text{Mgha}^{-1} \text{ year}^{-1}$ ) compared to the (mini) rhizotrons ( $3.81 \pm 0.46 \text{Mgha}^{-1} \text{ year}^{-1}$ ) and sequential-coring ( $3.84 \pm 0.93 \text{Mgha}^{-1} \text{ year}^{-1}$ ) methods. Based on the reviewed literature and comparative analysis we propose that (mini) rhizotrons should be preferred over the others in estimating fine-root production. In situations where cost and site conditions preclude their use, the sequential-coring and ingrowth-core methods are suitable. The ingrowth-core should be used with caution in sites where root growth is slow and root biomass may be influenced by strong seasonal fluctuations. Multiple methods are still recommended for yielding realistic estimates of fine- and coarse-root production, and more comparative studies of different methods should be conducted on the same sites.

4. Aggrey-Smith, S., Preko, K. and **Owusu, F.W.** (2016). Study of thermal properties of some selected tropical hard wood species. *International Journal of Materials Science and Applications*. 5(3):143-150.

The uses of wood and wood-based materials in everyday life ranging from domestic to industrial purposes have called for renewed updating of the information and knowledge on various thermal properties of the materials at various stages and classifications. This paper investigates the thermal properties (specific heat capacity and thermal conductivity) of some selected tropical hard wood species using the method of mixtures and the Lee's Disk method respectively. The results show that the thermal conductivity of the selected wood species fall within the general range of 0.1-0.8 W/mK for tropical wood materials, with *Celtis mildraedii* having the least thermal conductivity of 0.08W/mk and *Strombosia glaucescens* the highest value of 0.392 W/mK. The specific heat capacity was highest for *Holorrhena floribunda* (1.97 J/g.K) and the lowest for *Pterygota macrocarpa* (1.01 J/g.K). These results can be used for testing the validity and efficiency of hard woods used for domestic and industrial applications

5. Aggrey-Smith, S., Preko, K., **Owusu, F.W.** and J. K. Amoako (2016). Study of radiation shielding properties of selected tropical wood species for X-rays in the 50-150 keV Range. *The Open Access Journal of Science and Technology*. 4:1-8, doi:10.11131/2016/101150

This paper compares the attenuation coefficients of 20 tropical hard wood species based on their linear and mass attenuation and half value layer (HVL) properties for X-rays of energy 50–150 keV using a narrow collimated beam from a Cs-137 source. The narrow collimated beam method made corrections from multiple and small-angle scatterings of photons unnecessary. The attenuation depended on the chemical composition and densities of the wood species. The linear attenuation coefficients of wood species at 50–150 keV were highest for *Pterygota macrocarpa* ( $4.53 \text{ m}^{-1}$ ) and lowest for *Antiaris africana* ( $1.24 \text{ m}^{-1}$ ); the mass attenuation coefficient was highest for *Triplochiton scleroxylon* ( $17.62 \text{ m}^2/\text{kg}$ ) and lowest for *Nesogordonia papaverifera* ( $2.27 \text{ m}^2/\text{kg}$ ). The HVL was highest for *Antiaris africana* (0.27 m) and lowest for *Pterygota macrocarpa* (0.149 m). *Pterygota macrocarpa* of about 0.36 m thickness could serve as a more affordable radiation shielding material against secondary scatter and leakage radiations in place of lead, copper or concrete for low X-ray radiations up to 150 keV.

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6. Agyeman, V.K., **Addo-Danso, S. D.**, Boateng, K., Abebrese, I.K. (2016). Vegetation assessment of native tree species *Broussonetia papyrifera*-dominated degraded forest landscape in southern Ghana. *Applied Vegetation Science*, 19: 498-507.

We established sampling areas and assessed seedlings and saplings <5 cm DBH in nine habitats. The habitats were logging road, skid trail, large canopy gaps dominated by *B. papyrifera*, large canopy gaps dominated by invasive *Chromolaena odorata*, *Nauclea diderrichii* plantation, *Mansonia altissima* plantation, *Terminalia ivorensis* plantation, abandoned farmland and unlogged forest. We found that the abundance of pioneers declined with increasing abundance of *B. papyrifera*. This trend was more pronounced in the farmland and in the *N. diderrichii* plantation. By contrast, increased abundance of *B. papyrifera* did not lead to a decrease in the abundance of the shade-tolerant species. *B. papyrifera* seedlings and saplings were absent in the forest understorey. We also found a lower abundance and richness of some vulnerable tree species and valuable timber species in the *N. diderrichii* plantation and in gaps dominated by *B. papyrifera*. However, we recorded both shade-tolerant and shade-intolerant species in the gaps dominated by *B. papyrifera*. We found both shade-tolerant and shade-intolerant species in the *B. papyrifera*-dominated gaps. This can provide a basis for future studies to explore the potential of such tree species in restoration programmes targeted at *B. papyrifera*-invaded sites. Our results also suggest that the integrity of the undisturbed forest patches in the landscape must be protected to help prevent *B. papyrifera* from spreading further. We suggest further studies should be conducted at replicated sites with a similar habitat that represent varying levels of invasion by *B. papyrifera* to draw conclusions regarding the species' potential to facilitate regeneration of native tree species.

7. Anjarwalla, P., **Ofori, D.**, Owino, A., Matuku, D., Adika, W., Njogu, K., & Kehlenbeck, K. (2016). Testing different grafting methods for vegetative propagation of baobab (*Adansonia digitata* L.) in Kenya to assist its domestication and promote cultivation. *Forests, Trees and Livelihoods*, 26(2):85-95

Baobab (*Adansonia digitata* L.) is an indigenous fruit tree species of drylands in sub-Saharan Africa. Its leaves, fruits and seeds are important for income generation and food and nutrition security of local communities. Its fruit pulp is rich in vitamin C and calcium,

among other nutrients. Domestication of baobab, using mother trees with desired traits for vegetative mass propagation and planting, could meet the increasing demand for baobab pulp and the decreasing abundance of the trees in natural habitats. Two grafting methods were tested in the ICRAF nursery site (Nairobi, Kenya) to identify a suitable propagation technique. Two mother trees were selected (Trees 1 and 2) for harvesting scions. 'Top cleft' and 'side veneer' grafting were performed on a total of 38 rootstocks for each mother tree (20 of 1-year and 18 of 2-year age), resulting in a total of 76 grafted trees. The grafted trees were then followed during eight months. The experiment was conducted to evaluate grafting success and shoot growth. Statistical analyses included Binomial Logistic Regression for survival rates and three-factorial ANOVA for shoot length. The overall grafting survival rate was 63%. Top cleft grafting showed slightly more survival success than side veneer (71% vs. 55%,  $p = 0.114$ ). Using 2-year old rootstock was significantly more successful than 1-year old ones (75% vs. 53%;  $p = 0.029$ ). Using scions from mother Tree 1 was significantly more successful than from Tree 2 (82% vs. 45%;  $p = 0.001$ ). Length of new shoots growing from the scions of the successful grafts did not significantly differ among the treatments. Our results showed that both grafting methods and rootstock ages were successful and can contribute to the development of baobab domestication programmes for improving food security and livelihoods in African drylands.

8. **Apetorgbor, M. M., Pephrah, T., Ofori, D. A.** and Jamnadass, R. (2016). Mycorrhizal association and its benefits to *Allanblackia parviflora* tree seedlings in the nursery, *West African Journal of Applied Ecology*, 24(1):19–29.

*Allanblackia* species are high value multipurpose indigenous fruit trees whose seeds contain edible oil that has become a foreign exchange earner for rural-based enterprises. Wild harvesting could not sustain the supply to industry and therefore domestication was focused on developing propagation techniques, selecting and collecting elite planting materials. Little emphasis was placed on the soil nutrient requirements where preliminary results showed seedlings grown in rhizosphere soil of wild trees had good growth performance. A study was undertaken to examine microbial-*Allanblackia parviflora* plant interactions and determine their benefits to nursery seedlings. Roots of wildlings and rhizosphere soil from *A. parviflora* trees were collected from three forest reserves and the roots assessed for mycorrhizal colonization. *Allanblackia parviflora* seedlings were raised

in different potting media with different ratios and their height and diameter determined. Soil treatments were also analyzed for nutrient and chemical contents. Vesicles, arbuscular structures, hyphal coils and intercellular hyphae were found on root tips of wildlings collected from rhizosphere soil of *Allanblackia* (AB) trees and seedlings grown in soil treatments containing AB soil. Root colonization of *A. parviflora* was largely in the form of extensive cell-to-cell growth of hyphal coils characteristic of Paris-type morphology. Addition of Agricultural field soil (Ferric Acrisol, Afs) or Humus (H)+Afs to AB improved height of seedlings. Seedlings grown in AB soil alone increased best in height with age followed by those grown in combination of 75% AB soil and 25% Afs. Available P was highest in Afs (220.84 mgP/kg) and low in AB soil (6.54 mgP/kg) while combination of H + Afs to AB increased K level to 341.34 mgK/kg. The improvement in growth must be due to both vesicular-arbuscular mycorrhizal fungi and soil chemical content of AB soil.

9. **Appiah-Kubi, E., Kankam, C.K., Frimpong-Mensah, K. and Opuni-Frimpong, E.** (2016). Bending and modulus of elasticity properties of plantation grown *Khaya ivorensis* from Ghana. *Journal of Indian Academy of Wood Science* 13(1): 48-54. DOI: 10.1007/s13196-016-0165-7.

In the wake of dwindling timber resources in Ghana, the establishment of plantations has become necessary and the government and industry are actively pursuing this course. Plantations of *Khaya ivorensis*, which is one of the most valuable wood species, have been established in Ghana. However, concerns have been expressed by industry and stakeholders about the properties of fast-grown plantation trees compared to natural tree stands. It is believed that plantation grown species have relatively inferior wood quality to the trees from the natural stands. Wood properties such as bending strength and stiffness need to be determined to effectively recommend specific end use for the species. The aim of the study was to determine the modulus of rupture (MOR) and modulus of elasticity (MOE) of plantation-grown *K. ivorensis* and compare with the trees from natural stands. Plantation trees had higher strength values with a characteristic MOR of 67.35 N/mm<sup>2</sup> compared to natural trees with a characteristic MOR of 55.27 N/mm<sup>2</sup>. Results indicated that the properties of plantation trees were not inferior to the trees from the natural forest, and even had relatively higher strength properties. Mahogany plantations are therefore recommended to ensure the sustainable supply of the species to the wood industry.

10. Cardoso, A. W., Medina-Vega, J. A., Malhi, Y., **Adu-Bredu, S., Ametsitsi, G. K.D., Djagbletey, G.**, van Langevelde, F., Veenendaal, E., and Oliveras, I. (2016) Winners and losers: tropical forest tree seedling survival across a West African forest–savanna transition. *Ecology and Evolution*, 6(10):3417–3429.

Forest encroachment into savanna is occurring at an unprecedented rate across tropical Africa, leading to a loss of valuable savanna habitat. One of the first stages of forest encroachment is the establishment of tree seedlings at the forest–savanna transition. This study examines the demographic bottleneck in the seedlings of five species of tropical forest pioneer trees in a forest–savanna transition zone in West Africa. Five species of tropical pioneer forest tree seedlings were planted in savanna, mixed/transition, and forest vegetation types and grown for 12 months, during which time fire occurred in the area. We examined seedling survival rates, height, and stem diameter before and after fire; and seedling biomass and starch allocation patterns after fire. Seedling survival rates were significantly affected by fire, drought, and vegetation type. Seedlings that preferentially allocated more resources to increasing root and leaf starch (starch storage helps recovery from fire) survived better in savanna environments (frequently burnt), while seedlings that allocated more resources to growth and resource-capture traits (height, the number of leaves, stem diameter, specific leaf area, specific root length, root-to-shoot ratio) survived better in mixed/transition and forest environments. Larger (taller with a greater stem diameter) seedlings survived burning better than smaller seedlings. However, larger seedlings survived better than smaller ones even in the absence of fire. *Bombax buonopozense* was the forest species that survived best in the savanna environment, likely as a result of increased access to light allowing greater investment in belowground starch storage capacity and therefore a greater ability to cope with fire. *Synthesis*: Forest pioneer tree species survived best through fire and drought in the savanna compared to the other two vegetation types. This was likely a result of the open-canopied savanna providing greater access to light, thereby releasing seedlings from light limitation and enabling them to make and store more starch. Fire can be used as a management tool for controlling forest encroachment into savanna as it significantly affects seedling survival. However, if rainfall increases as a result of global change factors, encroachment may be more difficult to control as seedling survival ostensibly increases when the pressure of drought is lifted. We propose *B. buonopozense* as an indicator species for forest encroachment into savanna in West African forest–savanna transitions.

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11. Dawoe, E., Asante, W., Acheampong, E. and **Bosu, P.P.** (2016). Shade tree diversity and carbon stocks in cocoa agroforestry systems: Implications for REDD+ implementation in a West African cocoa landscape. *Carbon Balance Management, 11(17):1-13*

The promotion of cacao agroforestry is one of the ways of diversifying farmer income and creating incentives through their inclusion in REDD+ interventions. We estimated the aboveground carbon stocks in cacao and shade trees, determined the floristic diversity of shade trees and explored the possibility of implementing REDD+ interventions in cacao landscapes. Using replicated multi-site transect approach, data were collected from nine 1-ha plots established on 5 km long transects in ten cacao growing districts in Ghana West Africa. Biomass of cacao and shade trees was determined using allometric equations.

12. Djagbletey, E. D., **Djagbletey, G. D.**, Tuffour, H. O., and Abubakari, A. (2016). Assessment of forest cover depletion due to logging in the Offin River portion and Offin shelterbelt forest reserves in Ghana. *Journal of Global Ecology and Environment. 4(3):161-165*

The study was conducted to investigate the extent of forest cover depletion resulting from logging in two forest reserves in Ghana. Seven communities were covered in this study and forest inventory results were analysed. Illegal logging, surface mining, NTFP harvesting and processing, unsustainable agriculture practices were observed to be prevalent in the seven (7) forest dependent communities. Over an eleven (11) year period, a total sum of 21.3% forest loss has been detected in the Offin Shelterbelt and Tano Offin forest reserves. It is anticipated that should current over-exploitation and forest degradation continue in the Offin Shelterbelt forest reserve, the stand density in terms of basal area ( $\text{m}^2 \text{ha}^{-1}$ ) shall be reduced to less than  $5 \text{m}^2 \text{ha}^{-1}$  threshold in seventeen (17) years. The afore mentioned malpractices has adverse practical implications inclined towards to the decimation of prime species which are valuable genetic resources across various disciplines, with an eventual extinction of these floral lives. The declination of forest cover and bad land use practices in the catchment have impacted negatively on the regularity of the flow and water quality of River Offin on which surrounding communities are heavily dependent on in the cultural proceedings.

13. Djagbletey, E. D., **Djagbletey, G. D.**, Tuffour, H. O., and Abubakari, A. (2016), Socio- economic impacts of logging on riverine communities along the Offin river basin in the Ashanti Region of Ghana. *Journal of Global Agriculture and Ecology*. 5(3):134-147

Loss of forest cover due to anthropogenic factors presents enormous challenges to the vulnerable forest dependent communities in terms of water supply, health, food security, employment and shelter. The study was conducted to investigate the impact of logging on the social life of the people in the riverine communities in the Tano-Offin and Tano Shelterbelts. Seven communities were covered in the study. Structured questionnaires and Satellite imagery data were collected and analysed. A total sum of 21.3% forest loss was detected in the Offin Shelterbelt and Tano Offin forest reserves over an eleven (11) year period. This may have contributed significantly to the intermittent flow of the Offin River in portions previously noted to be perennial, the prevalence of water borne diseases and guinea worm infestations, and the consequent migration of the youth to urban centres. Such a situation could have far reaching implications on these vulnerable forest dependent communities whose major source of livelihood (employment, water supply, food supply, shelter etc.) are intrinsically linked to these forests

14. Djagbletey, E. D. **Adu-Bredu, S., Djagbletey, G. D.**, and Tuffour, H. O. (2016). Assessment of temperature and rainfall variability on grass productivity under three forest reserves in a savannah ecosystem in Ghana. *International Journal of Advanced Research*, 4(6):1622-1632.

The study was conducted to determine the grass biomass productivity in three selected forest reserves in the Guinea Savanna agro-ecological zone of Ghana. Prediction of grass productivity using both additive and multiplicative models showed that accuracy in terms of the predictability of the models based on the coefficient of determination ( $R^2$ ) was in the order Klupene (0.816) > Sinsablegbinni (0.664) > Kenikeni (0.660) for the additive model and Klupene (0.769) > Kenikeni (0.639) > Sinsablegbinni (0.567) for the multiplicative model. It was realized that accuracy in the predictability of the models directly depend on the extent of canopy cover, soil fertility, soil type, wildfires and livestock grazing.

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15. **Dumenu, W.K.** and **Obeng, E.A.** (2016). Climate change and rural communities in Ghana: Social vulnerability, impacts, adaptations and policy implications. *Environment Science and Policy* 55:208-217

This study assessed social vulnerability level, impacts and adaptation strategies to climate change in rural communities in four ecological zones in Ghana. Primary data were collected through questionnaires and interviews from 196 households in 14 rural communities. Using six demographic, social and economic indicators in assessing social vulnerability to climate change, the Sudan and Guinea Savanna zones were ranked the most vulnerable to climate change with SVI of 0.552 and 0.550, respectively. Social vulnerability factors such as high illiteracy level, heavy dependence on climate sensitive occupation, less diversified sources of income and limited access to climate change information contributed to the high vulnerability level of the zones. Frequently experienced climate change impacts in the four ecological zones were erratic rainfall, reduction in crop yield, prolonged drought and shift in cropping season. Most engaged adaptation strategies included crop diversification, engagement in non- farm secondary jobs, rural–urban migration and increasing farm size. The results highlight the importance of local-level climate change vulnerability assessment and demonstrate the need for local area-specific actions/policies to reducing vulnerability and enhancing adaptation in rural communities. The study approach and findings are useful for policymakers in developing countries in identifying avenues to building local communities’ resilience to climate change.

16. **\*Dumenu, W.K.** and **Bandoh, W.N.** (2016). Situation analysis of African Rosewood (*Pterocarpus erinaceus*) in Ghana: Evidence of unsustainable exploitation? *Ghana Journal of Forestry* (Accepted for publication)

The rapid increase in demand for rosewood in Asia (particularly, China) has led to increased exploitation of *Pterocarpus erinaceus* (African rosewood) in Ghana. In 2014, Ghana was ranked second to Nigeria in Africa and fourth in the world among top suppliers of rosewood logs to China by volume. The precipitous exploitation of rosewood has raised concerns about the sustainability of the species particularly when there is very little scientific and technical information about the species in Ghana. Consequently, this paper assesses rate, level and patterns of exploitation of *P. erinaceus* and factors influencing its exploitation in Ghana. Drawing on field inventory, export and other secondary data, the

results showed that, rosewood is predominantly exploited for timber and woodfuel. Between 2004-2013, an estimated 111,110 m<sup>3</sup> (RWE) have been exploited at an average of 11,111 m<sup>3</sup> per annum in a 10-year period. The current level of exploitation is highly unsustainable as the size class distribution showed a departure from the inverse J-shape indicative of a balanced and stable forest stand under sustainable management. The lowest diameter class constitutes only 9% of the population while the immediate size class is 49% suggesting the inability of the existing stock base to sustain continuous exploitation. Through key informant interviews, value shift, lag in review of species schedule and stumpage fee, weak forest law enforcement, and land tenure system were identified as factors influencing the precipitous exploitation of the species. For sustainability of rosewood in Ghana, the paper argues that, biology, genetics, ecology, silvicultural research on the species be commissioned, while a long term total export ban is maintained.

17. **Ebanyenle, E.**, Burton, A.J., Storer, A.J., Richter, D.L. and Glaeser, J.A. (2016). Elevated tropospheric CO<sub>2</sub> and O<sub>3</sub> may not alter initial wood decomposition rate or wood-decaying fungal community composition of northern hardwoods. *International Biodeterioration and Biodegradation*, 111:74-77.

We examined the effects of elevated CO<sub>2</sub> and/or O<sub>3</sub> on the wood-decaying basidiomycete fungal community and wood decomposition rates at the Aspen Free-Air CO<sub>2</sub> and O<sub>3</sub> Enrichment (Aspen FACE) project. Mass loss rates were determined after one year of log decomposition on the soil surface, and wood-decaying basidiomycetes were isolated from decaying wood and identified via DNA sequencing. Aspen (*Populus tremuloides* Michx.) and birch (*Betula papyrifera* Marshall) wood differed significantly in wood-decaying basidiomycete fungal communities and decomposition rate. Twelve years of site exposure to elevated CO<sub>2</sub> and/or O<sub>3</sub> did not have significant effects on wood-decaying fungal communities. Growth under elevated CO<sub>2</sub> and/or O<sub>3</sub> did not produce wood that differed in decay rate from that grown under ambient atmospheric conditions. Similarly, wood decay rate was not altered significantly when decomposition occurred in elevated CO<sub>2</sub> and/or O<sub>3</sub> environments. Our results suggest that wood-decaying fungal community composition and decomposition rates of northern hardwoods may not be directly affected by elevated tropospheric CO<sub>2</sub> and O<sub>3</sub>.

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18. Gailing, O., Staton, M.E, Lane T., Schlarbaum, S. E., Nipper, R., **Owusu S. A.**, Carlson J.E. (2016). Construction of a genetic linkage map in *Gleditsia triacanthos* L. *Plant Molecular Biology Reporter*. 1-11

Genomic resources are sparse in most ecologically and economically important North American hardwood species. As part of the Hardwood Genomics project (<http://www.hardwoodgenomics.org/>), we evaluated the utility of restriction site associated DNA sequencing (RAD-Seq) for framework genetic linkage map construction in honeylocust (*Gleditsia triacanthos* L.), a leguminous tree common in eastern North America. Starting with a large open-pollinated family of progeny from a single tree, a mapping pedigree of 92 putative full-sibs was identified by kin group assignment and paternity analyses with microsatellite markers. RAD-Seq using Illumina next-generation DNA sequencing (NGS) generated over 117 M reads among the 92 plants. De novo reference genome clustering and alignment of samples to the reference genome revealed 5849 candidate single nucleotide polymorphisms (SNPs), of which 1570 were retained after quality filtering. Of the 1570 SNPs, 236 were in pseudo-testcross mapping configuration in the maternal parent and segregated approximately in the expected 1:1 ratio. The final map generated has a total length of 815.57 cM and consists of 178 markers on 14 linkage groups, corresponding to the haploid chromosome number in honey locust. Synteny and collinearity between honey locust and model legumes *Glycine max*, *Medicago truncatula*, and *Phaseolus vulgaris* were found for six of the honey locust linkage groups. RAD-Seq proved to be useful for framework linkage map construction in honey locust, a species for which no genomic resources had previously been available. However, greater sequence coverage and larger full-sib mapping pedigrees are necessary for the development of high-density linkage maps with future applications in quantitative trait locus (QTL) mapping.

19. \* Hudson, L. N., Newbold, T., Contu, S., Hill, S. L. L., Lysenko, I., **Ofori-Boateng, C.**, ... Purvis, A. (2017). The database of the PREDICTS (Projecting Responses of Ecological Diversity In Changing Terrestrial Systems) project. *Ecology and Evolution*, 7(1):145–188. <http://doi.org/10.1002/ece3.2579>

The PREDICTS project—Projecting Responses of Ecological Diversity In Changing Terrestrial Systems ([www.predicts.org.uk](http://www.predicts.org.uk))—has collated from published studies a large, reasonably representative database of comparable samples of biodiversity from multiple

sites that differ in the nature or intensity of human impacts relating to land use. We have used this evidence base to develop global and regional statistical models of how local biodiversity responds to these measures. We describe and make freely available this 2016 release of the database, containing more than 3.2 million records sampled at over 26,000 locations and representing over 47,000 species. We outline how the database can help in answering a range of questions in ecology and conservation biology. To our knowledge, this is the largest and most geographically and taxonomically representative database of spatial comparisons of biodiversity that has been collated to date; it will be useful to researchers and international efforts wishing to model and understand the global status of biodiversity.

20. Koech, G., Ofori, D., Muigai, A.W.T., Muriuki, J., Anjarwalla, P, de leeuw, J., Mowo, J.,G (2016). Variation in the response of eastern and southern Africa provenances of *Faidherbia albida* (Delile A. Chev) seedlings to water supply: A greenhouse experiment. *Global Ecology and Conservation* 8:31-40.

Rural communities value *Faidherbia albida* in farming systems and pastoralism. *Faidherbia albida* provides products such as medicine, fodder, fuel, wood, food and services such as shade, soil fertility and nutrient cycling. Excessive browsing by animals, branch lopping and pod harvesting, have critically reduced the natural regeneration in some areas which exposes it to challenges due to dependence upon natural regeneration. The objective of this research was to evaluate response of *Faidherbia albida* provenances from eastern (Taveta Wangingombe) and southern Africa (Lupaso, Kuiseb Manapools) to different watering regimes to aid in selection of provenances for domestication. The observed difference in growth was analyzed to determine whether they are genetic or environmentally induced. Genotype  $\times$  interaction were significant at ( $p \leq 0.001$ ,  $p \leq 0.05$ ) in seedling height, diameter and leaf numbers. Seedling height ( $r=0.94$   $p=0.001$ ) recorded the highest correlation coefficient among all the growth variables analyzed. The growth variation was greater for seedling height than that of diameter and leaf numbers ( $h^2 = 0.97$ ). Hierarchical cluster analysis grouped the provenances into three clusters with cluster iii consisting of Taveta, Kuiseb and Lupaso while cluster ii and i composed of Wangingombe and Manapools respectively. Manapools recorded the highest genetic distance from Taveta, Kuiseb and Lupaso at 84.55 units. Wangingombe and Manapools are closely related genetically at a distance of 7.32. The maximum inter-cluster distance

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between cluster i and iii indicated wider genetic diversity between the provenances in these clusters and selection should be from these clusters for hybridization program to achieve novel breeds.

21. Leaché, A. D., Grummer, J. A., Miller, M., Krishnan, S., Fujita, M. K., Böhme, W., Schmitz, A., LeBreton, M., Ineich, I., Chirio, L., **Ofori-Boateng, C.**, Eniang, E. A., Greenbaum, E., Rödel, M.-O., and P. Wagner. (2016). Bayesian inference of species diffusion in the West African *Agama agama* species group (Reptilia, Agamidae). *Systematics and Biodiversity*, 15(3):192-203 Available at: <http://dx.doi.org/10.1080/14772000.2016.1238018>.

The savannah and tropical forest biomes of Africa have a long history of expansion and contraction, and the recent and rapid spread of dry savannah habitats has influenced the spatial and temporal diversification of vertebrate taxa across this region. We used a combination of species tree and phylogeographic methods to describe the spatio-temporal changes through time and across space (= species diffusion) in a clade of seven West African lizard species in the *Agama agama* species group. A Bayesian species tree diffusion approach was used to compare the relative rates at which species ranges changed across the landscape. We found that some species have high diffusion rates characterized by significant movement in their range location and minor changes to their overall range size, whereas other species show little movement in their range centre with an exponential increase in range size. This discrepancy between the rates that range locations shift versus change in their relative area could be linked to populations tracking their preferred habitats through time. A continuous Bayesian phylogeography approach using a relaxed random walk model was used to estimate the timing and rate of population size change and geographic diffusion in *A. picticauda*, the single species in the group with an extensive African distribution from Mauritania to Ethiopia. The mean dispersal rate of *A. picticauda* increased dramatically throughout the Pleistocene, and a Bayesian skyride analysis supports exponential population growth over this same time period. A comparison of genetic diversity across different loci and species suggests that *A. lebretoni* experienced a mitochondrial selective sweep that has caused a deficit of variation at this locus in relation to nuclear loci.

22. \*Owusu, S., Anglaaere, L. C. N. and Abugri, S. (2016). Aboveground biomass and carbon content of a cocoa-Gliricidia agroforestry system in Ghana. *Ghana Journal of Agricultural Science* (Accepted for publication)

To help overcome the challenge faced in re-establishing cocoa in degraded lands, some agroforestry trials were established with exotic leguminous tree species to determine their suitability for cocoa cultivation. However, our understanding of biomass accumulation and carbon sequestration in such specific agroforestry practices is still limited. In this study the above-ground biomass and carbon storage and partitioning in a gliricidia-cocoa agroforestry system was investigated. Above-ground biomass accumulation and carbon stock varied significantly between the components of the system, with the gliricidia shade trees having the highest values and the cocoa trees having the lowest. The inclusion of the gliricidia shade trees in the system increased above-ground biomass and carbon capture of the system by some 60%, a greater proportion of which was contained in the branches of the shade trees. This pattern of dry matter distribution makes the species appropriate for use as a biomass producing species in agroforestry systems and demonstrates the potential of cocoa agroforestry systems for capturing and storing more atmospheric carbon than sole cocoa systems.

23. Owusu, S. A., Schlarbaum S. E., Carlson J. E., Gailing O. (2016). Pollen gene flow and molecular identification of full-sib families in small and isolated population fragments of *Gleditsia triacanthos* L. *Botany*, 94(7):523-532, 10.1139/cjb-2015-0244.

To analyze the utility of isolated remnant populations for full-sibling (full-sib) identification among open-pollinated single-tree progeny in the outcrossing and insect-pollinated tree *Gleditsia triacanthos* L. (honey locust), we performed paternity analyses in forest fragments from two geographic regions using nuclear microsatellites. The first plot (Butternut Valley population) comprised only 7 trees, and 552 seedlings from a single seed parent were characterized at nuclear microsatellites. A large number of putative pollen donors (59) were identified in kinship analyses, but their individual contributions to the progeny were highly variable. Kinship and paternity analyses identified 149 putative full-sibs for genetic mapping sired by an external (unsampled) pollen parent. To better assess the frequency of long-distance pollen dispersal, a total of 180 seeds were collected from 6 seed parents in another fragmented population. In both plots, contemporary

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pollen dispersal occurred generally from outside the plots (99.38% and 87.50%–100% at the Butternut Valley and Ames Plantation sites, respectively) and thus over very long distances (>12 000 m in the Ames Plantation) suggesting that in highly fragmented landscapes, insect pollinators of honey locust are likely very effective long-distance dispersers.

24. \*Pentsil, S., Dzacka, R. and Korang, J. (2016). A decade and half of Ghana's trade in mahogany: A review. *Journal of Energy and Renewable Natural Resource* (Accepted for publication).

This paper sought to review Ghana's performance with regard to trade in African mahogany from 2001 to 2015. The study assessed the volume, types of product exported, extent of product innovation and export destinations of the species and wood products in general. From the results, the highest export volume was recorded in 2007 (32,149m<sup>3</sup>) and the least of 14,082m<sup>3</sup> in 2001. The timber industry was mainly involved in secondary processing of mahogany as veneer, block board, air and kiln dried lumber and plywood. Tertiary processing was comparatively lower and products like floorings and furniture parts were rarely exported. The major markets were in Europe, Africa, America, Asia and the Middle East. Considering the depletion of this important timber species in the national forest estate and its attendant loss of revenue, Ghana should vigorously restock degraded areas and incentivize mills engaged in tertiary processing of timber species.

25. \*<sup>i</sup>Pentsil, M. and Pentsil, S. (2016). Environmental benefits of a restored forest using contingent valuation method: Asubima Forest Reserve, Ghana, *Ghana Journal of Forestry* (Accepted for publication)

This study aimed at valuing the expected improvement in environmental quality through the rehabilitation of degraded forest reserves in Ghana. The rehabilitation of the selected degraded forest reserves was through the implementation of the Government of Ghana (GoG)/African Development Bank (AfDB) funded Community Forestry Management Project (CFMP). The motivation for the study arose from the inability of the CFMP Appraisal Document to provide a valuation of the environmental benefits to be derived from the project. The contingent valuation (CV) method was used to elicit the value of indirect use forest benefits to the forest fringe participants of the CFMP in the Asubima forest reserve,

Ghana. This valuation was to provide an indication of the value of the improved environmental quality expected through the implementation of the project with respect to the functional benefits of the forest resource such as improvement in micro-climatic conditions, watershed values, soil conservation, habitat for wildlife etc. A CV survey was undertaken with 150 household respondents in the Asubima forest reserve. The result of the survey was aggregated over all the 3,000 households in the six reserves participating in the CFMP. A mean Willingness To Pay (WTP) bid value of GH¢652 was elicited for the conservation of flora and fauna and improvement in water conservation and environmental quality, with an aggregate NPV value of approximately GH¢1.95 million (£1.15 million). Regression analysis could however explain only 6% of the variability in bids due to the limited range of bid values and unfamiliarity of the respondents with CV elicitation methods. Future studies should accordingly allocate more time in familiarising respondents with CV elicitation methods and provide a platform for the generation of a greater range of bid values.

26. Stephens, S.S., **Bosu, P.P.** and Wagner, M.R. (2016). Effect of overstory tree species diversity and composition on ground foraging ants (Hymenoptera: Formicidae) in Timber Plantations in Ghana. *International Journal of Biodiversity Science, Ecosystem Services and Management* 12(1):1-12.

Plantation forests are becoming an increasingly important component of the world's forested ecosystem. However, relatively little is known about how forest plantation management, overstory tree species composition and diversity impact biodiversity of nontree components of the forest. We assessed changes in ant functional group composition as related to changes in overstory tree diversity (monocultures vs. polycultures), species composition (native African species vs. exotic teak), and time (one and two years after planting). A pitfall trapping scheme was implemented during the summer months of 2006 and 2007. A total of 7473 specimens were collected representing six subfamilies, 22 genera, and 65 species. We found no significant differences in traditional diversity measures or functional group composition between treatments one year after planting. Two years after planting, we found that species richness of ground foraging ants had significantly increased ( $F = 4.60$ , d.f. = 4, 15,  $p = 0.01$ ). Several observed trends may have indicated that these ant communities were in transition and will likely become more distinct over time as the different plantation types recover from disturbance and diverge from each other in overstory structure.

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27. \*Sraku-Lartey, M., Acquah S. B., Samar S.B.; and Djagbletey G. D (2017). Digitization of indigenous knowledge on forest foods and medicines, *International Federation of Library Associations and Institutions*, p.340035216681326. Available at: <http://dx.doi.org/10.1177/0340035216681326>.

This paper discusses the digitization of indigenous knowledge on forest foods and medicine for the effective management of Ghana's forest resources. The paper is based on a survey conducted in nine communities in Ghana where primary data were obtained from 606 respondents using in-depth face-to-face interviews. The aim of the study was to assess what knowledge local communities had about products of the forest especially indigenous forest foods and medicine. The findings reveal that local communities have an in-depth knowledge of indigenous forest foods and medicines. They are conversant with what foods and medicines are available in the forests, how they are consumed and when they mature. The study reveals that consumption of indigenous forest foods is on the decline, while the use of traditional medicine is on the ascendancy. The study recommends the promulgation of laws and legal instruments to protect communities from bio-piracy.

28. Sullivan, A. R., Owusu S. A., Weber J.A., Hipp A, Gailing O (2016). Hybridization and divergence in multispecies oak (*Quercus*) communities. *Botanical Journal of the Linnean Society* 181(1):99–114, DOI: 10.1111/boj.12393

Oaks (*Quercus*: Fagaceae) commonly interbreed yet retain their morphological, genetic, and ecological distinctiveness. Post-zygotic isolation mechanisms, such as ecologically-dependent selection on adaptive loci, may therefore limit introgression. To test this hypothesis, we quantified hybridization and genetic divergence across the contact zone of four red oaks (*Quercus* section *Lobatae*) in the Great Lakes region of North America using a suite of 259 AFLPs and 27 genic and genomic microsatellite markers. First, we identified hybrids using genetic structure analysis and confirmed the reliability of our assignments via simulations. Then, we identified candidate loci for species maintenance with three complementary tests for directional selection and obtained partial gene sequences linked to an outlier locus and three other highly-differentiated loci. We detected evidence of recent hybridization among all species and considerable gene-flow between *Q. ellipsoidalis* and *Q. velutina*. Overall, about 20% of *Q. velutina* had recent ancestry from *Q. ellipsoidalis* while nearly 30% of *Q. ellipsoidalis* had a *Q. velutina* ancestor. Most loci were

negligibly to weakly differentiated among species, but two gene-linked microsatellites significantly deviated from neutral expectations in multiple, complementary outlier tests. Both outlier loci were located within the same 15 cM bin on the existing *Q. robur* linkage map, a region targeted by divergent selection in other oak species. Adaptive loci in this highly-differentiated genomic region may contribute to ecological divergence among species and limit introgression.

29. **Tekpetey, S.L., Essien, C., Appiah-Kubi, E., Opuni-Frimpong, E. and Korang, J.** (2016). Evaluation of the chemical composition and natural durability of natural and plantation grown African Mahogany *Khaya ivorensis* A. Chev. in Ghana. *Journal of the Indian Academy of Wood Science* 13(2):152–155. DOI: 10.1007/s13196-016-0179-1

Little information exists on the properties of tropical tree species that are now being used in plantations in different tropical countries including Ghana. In this study, the variation in chemical composition and natural durability of both plantation grown and natural African Mahogany harvested in Ghana were evaluated using TAPPI standards, ASTM D 1758-06 (2008) and AWWA E-7-07 (2008). The total extraneous materials in plantation grown African Mahogany was relatively higher than the natural stands. Results showed that the alcohol extractives in plantation and natural samples were 2.7 and 1.8% respectively. However, the natural samples recorded higher cellulose, holocellulose and lignin contents of 39.2, 32.2%; 66.4, 61.4% and 17.3, 15.2%. After 26 weeks of assessment of the natural durability under the graveyard test, the bottom portions of both types of mahoganies were rated as moderately attacked, the middle portion rated as moderate to severe attack while the top portion rated as severely attacked. Moreover, both the plantation grown and naturally grown mahoganies were rated as moderately to severely attacked after 26 weeks exposure in the field. It is recommended that as plantation of indigenous species are encouraged, their properties should be evaluated to enhance their acceptance and utilization.

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30. Telahun, M., Damnyag, L., and Anglaaere, L. C.N. (2016). The Ankasa Forest Conservation Area of Ghana: ecosystem service values and on-site REDD+ opportunity cost. *Forest Policy and Economics* 73:168-176.

The Ankasa Forest Conservation Area is one of the most important protected areas (PA) in West Africa. This study aimed at estimating the economic values of selected ecosystem services of the PA and the direct on-site REDD+ opportunity costs to communities. We found that the PA stocks 32.8 million m<sup>3</sup> (627m<sup>3</sup>/ha) of standing trees with a stumpage value of about \$ 19.1 million (364 \$/ha), 64.3 million tCO<sub>2</sub>e (1230 tCO<sub>2</sub>e/ha) of carbon worth of \$379.5 million (\$7257/ha), and 6380 tons of nutrients worth of 0.64 million USD. The direct on-site REDD+ opportunity cost for conserving the PA until 2042 was about 6.7–24.1 \$/tCO<sub>2</sub>e (0.22–0.80 \$/tCO<sub>2</sub>e per year) in net present value. From our field observation of the PA, we did not see a buffer zone that separates the PA from the surrounding land uses. Establishing a buffer zone is very important for the sustainability of the PA. Such an effort, however, should take in to account the opportunity costs to the rural communities associated with possible displacement. Thus, the results of the study could be used as important input for designing policies that will reinforce the sustainability of the Ankasa PA and other conservation sites in Ghana.

31. Tsobeng, A., Asaah, E., Tchoundjeu, Z., Van Damme, P., Ofori, D., & Jamnadass, R. (2016). Growth, flowering and fruiting of stecklings, grafts and seedlings of *Allanblackia floribunda* Oliver (Clusiaceae). *Agroforestry Systems*, 1-12.

A study was carried out to assess the growth, flowering and fruiting of stecklings (rooted cuttings), grafts and seedlings of *Allanblackia floribunda* in Cameroun. Thirty-one individuals of each plantlet type were planted in May 2006. Height, collar and crown diameters were recorded in September and October, while flowering and fruiting were recorded each month from January to December. In 2014, the trees with the greatest height were those from seeds ( $6.98 \pm 0.25$  m), followed by those from grafts ( $1.65 \pm 0.23$  m) and cuttings ( $1.09 \pm 0.21$  m). Grafts started flowering and fruiting 3 years after planting, while seedlings started flowering and fruiting after four and 6 years, respectively. Stecklings still had not flowered 8 years after planting. Fruit weight and length from seed-origin trees are about seven times higher than grafts. Correlations between height and crown diameter were significant and positive irrespective of the

nature of the planting material. In conclusion, grafts fruited earlier, while seedlings grew faster and had greater yields than grafts and stecklings of *A. floribunda*.

32. Yeboah, E.; Ofori, D. A.; Peprah, T.; Harmanjeet, R.; Jamnadass, Alain Tsobeng (2016). The effect of indigenous growth media on *Allanblackia parviflora* A. Chev. Ghana. *Open Journal of Soil Science*, 6:89-97

*Allanblackia parviflora* A. Chev. also called vegetable tallow tree provides a variety of non-timber forest products of great importance to rural households including shade, timber, medicine and seed oil but attempts have not been made to improve the tree species and increase its production. Consequently, the species is being threatened due to unsustainable exploitation and poor regeneration and cultivation appears as the only viable option. In order to cultivate the species at meaningful scale, it is necessary to establish the optimum range of environmental factors that influence its propagation and growth. This study was therefore designed to investigate *Allanblackia* growth parameters and bio-accumulation under different growth media in a greenhouse study. The media were: 1) TS = top soil alone, 2) AB soil = *Allanblackia* soil alone, 3) TS + H = Top soil alone + humus, 4) AB + TS = *Allanblackia* soil alone + Top soil alone and 5) SAB = Sterilized *Allanblackia* soil alone. Each treatment was replicated three times in a complete randomized design. The experiment lasted for 18 months. Results showed that Fe was the micronutrient that accumulated greatest in the plant tissue. Among the treatments, *Allanblackia* soil showed the highest accumulation of Zn in the plant tissue with the top soil showing the least ( $7.67 \text{ mg}\cdot\text{kg}^{-1}$ ). Humus contributed largely to the bio-accumulation of Cu in the plant tissue. Bio-accumulation of manganese in the plant tissue ranged from  $13.30 \text{ mg}\cdot\text{kg}^{-1}$  to  $207 \text{ mg}\cdot\text{kg}^{-1}$  suggesting difference in manganese absorption by *Allanblackia* as influenced by the treatments. The growth parameters of *Allanblackia parviflora* were impacted differently by the growth media. The result was however controversial since no differences were found between growth of seedlings in sterilized *Allanblackia* soil and *Allanblackia* soil.

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33. Zhou, L., **Addo-Danso, S.D.**, Wu, P., Li, S., Zou, X., Zhang, Y., and Ma, X. (2016), Leaf resorption efficiency in relation to foliar and soil nutrient concentrations and stoichiometry of *Cunninghamia lanceolata* with stand development in southern China. *Journal of Soils and Sediments*, 16:1448-1459.

The relationships among resorption, and leaf nutrient status and soil nutrient availability remains unresolved. Moreover, the dynamics of resorption and leaf and soil nutrients and stoichiometry as Chinese fir stands develop have rarely been studied. This study quantified the resorption efficiencies of nitrogen (N), phosphorus (P) and potassium (K), and their potential correlations with stoichiometric ratios with leaf and soil as Chinese fir stands develop, and also evaluated the nutritional control on resorption in the stands based on the 'relative resorption hypothesis'. Leaf and soil samples were collected from Chinese fir stands at different developmental stages (young, mature and over-mature) at the Xinkou National Forest in southern China. Samples of green leaves were collected from different portions of the crown from representative trees in different seasons. Samples of senesced leaves were collected from litter traps placed under the representative trees every month. Soils were sampled at three depths (0-20, 20-40, and 40-60 cm). Samples of green and senesced leaves were analyzed to determine nutrient (N, P, and K) concentrations, stoichiometric ratios and resorption efficiencies. Soil samples were also analyzed for nutrient concentrations (organic matter, N, P, and K) and stoichiometric ratios. P (75%) and K (74%) resorption efficiencies were higher than the N resorption efficiency (51%), but did not vary among the stands. However, K resorption efficiency decreased from the young to the overmature stage. N and P resorption efficiencies were influenced by season, and leaf nutrient stoichiometric ratios varied with stand stage. Green-leaf N and P concentrations, and senesced-leaf K concentration increased with stand developmental stage. The concentrations of N, P and K decreased with soil depth, and there was no interaction effect of stand stage and soil depth on stoichiometric ratios of the soil nutrients. The correlation results showed that nutrient resorption efficiencies were mostly affected by leaf nutrient status, but seldom by soil nutrient concentration and stoichiometry. The results suggest Chinese fir might preferentially resorb P and K from senescing leaves before abscission. Based on the 'relative resorption hypothesis' the Chinese fir plantations are more limited by P, and that resorption may be an important mechanism to conserve nutrients in these stands in order to reduce dependence on soil nutrient pools. There is an indication that stand development affects these processes; however the resorption process and internal mechanism need further investigation for the long term.

34. Zhou, L., **Addo-Danso, S. D.**, Wu, P., He, Z., Liu, C., and Ma, X. (2016), Biomass production, nutrient cycling and distribution in age-sequence Chinese fir (*Cunninghamia lanceolata*) plantations in subtropical China. *Journal of Forestry Research*, 27:357-368.

Biomass production and nutrient (N, P, K, Ca and Mg) accumulation, distribution and cycling were quantified in young, mature and over-mature (10-, 22-, and 34-year old) Chinese fir [*Cunninghamia lanceolata* (Lamb.) Hook] plantations in southern China. Total stand biomass of young, mature and over-mature stands was 38, 104 and 138 t ha<sup>-1</sup> respectively. Biomass production increased significantly with age. Stem wood represented the highest percentage of stand biomass, accounting for 41, 55 and 63 % in the young, mature and over-mature plantations respectively. Nutrients concentration was highest in live needles and branches, and lowest in stem wood. The plantations accumulated more N, followed by K, Ca, Mg, and P. Nutrient return amount, nutrient utilization efficiency, nutrient turnover time, the ratio of nutrient return and uptake increased with stand age, which implies that young Chinese fir deplete soil nutrients to maintain growth, and efficiently utilize nutrients to decrease dependence on soil nutrients as they age. Harvesting young Chinese fir plantations would therefore lead to high nutrient loss, but prolonging the rotation length could improve soil recovery, and help sustain productivity in the long-term. Improved nutrient return through litterfall as stands get older may also be beneficial to nutrient pool recovery

35. <sup>ii</sup>Prescott, C., Godbold, D.L., Helmisaari, H-S., and **Addo-Danso, S.D** (2016). Introduction to forests, roots and soil carbon. *Forest Ecology and Management*, 359: 321.

**PAPERS PUBLISHED IN 2016 BUT BACKDATED TO 2015 AND 2014 BY PUBLISHERS**

- 36. Appiah-Kubi, E., Owusu, F.W., Tekpetey, S.L. and Essien, C. (2014).** Bamboo for housing in Ghana: challenges and prospects for the future. *Journal of Bamboo and Rattan*, 13(3&4):45-54.

Bamboo can be used for housing and is widely regarded as an excellent substitute for wood in the form of laminated bamboo boards. The extent of bamboo housing in Ghana is relatively low and is mainly traditional and rudimentary. It is perceived as a "poor man's house". A stakeholder meeting was organized to identify the key challenges to the efficient use of bamboo in housing and propose recommendations for extensive utilization. The paper reports on the challenges identified, the opportunities and prospects available and major recommendations made to enhance bamboo utilization for housing. Lack of adequate expertise in bamboo processing and construction as well as appropriate technology for processing local bamboo species was identified as major challenge to bamboo usage. Furthermore, lack of commitment on bamboo usage by various stakeholders (industry, government, professionals, Non Governmental Organizations, private enterprises, individuals) was also identified as inhibiting bamboo development in the country. Opportunities available for enhanced bamboo utilization include the availability of the raw material and relevant institutions with capacity to support the industry. It was agreed by stakeholders that stronger institutional collaboration, capacity building and exhibitions are needed to promote bamboo for housing. To ensure a sustainable resource base, it is important to consider bamboo species as part of the priority species selected for the national plantation programme and should be managed appropriately.

- 37. Appiah-Kubi, E., Owusu, F.W., Tekpetey, S.L. and Essien, C. and Seidu, H. (2014).** Investigating the mechanical properties of some bamboo species for efficient utilization in Ghana. *Journal of Bamboo and Rattan*, 13(3&4):81-89.

The use of bamboo is advocated to reduce pressure on dwindling commercial timber species, around the world. To extensively utilize bamboo in various forms such as housing, their properties need to be known. But little information exist on these properties especially their mechanical properties. In this study, the mechanical properties viz. static bending strength (MOR), Modulus of Elasticity (MOE) and compressive strength, of laminated bamboo boards produced from three plantation managed bamboo species namely *Bambusa vulgaris*, *Dendrocalamus brandisii* and *Guadua chacoensis* were

determined. The bamboo species were obtained from Kade which is located at the moist semi-deciduous ecological zone in Ghana. The bamboo culms were prepared and glued into boards after they were air dried to about 13% moisture content. The lamination was done with three different glue types available on the Ghanaian market. The test specimens were prepared as required by the British Standard BS 373:1957. Tests revealed that *Bambusa vulgaris* laminated with a 5-minute hardening polyurethane adhesive had a mean 2 2 MOR of 62.58N/mm and MOE of 9915 N/mm. *Dendrocalamus brandisii* laminated boards had mean 2 2 MOR of 99.73N/mm and MOE of 11594 N/mm. *Guadua chacoensis* with the same adhesive had a mean 2 2 MOR of 80.25N/mm and MOE 7861N/mm. The laminated boards from these three species exhibited properties that make it suitable to be used as boards for housing.

38. **Bosu, P. P., Apetorgbor, M. M. and Nkrumah, E. E.**(2015). Methodology for efficient survey of pests in small holder tree plantations: The case of Community Forestry Management Project in Ghana. *Ghana Journal of Forestry*, 31:21-33.

The challenges of forest pest surveys in smallholder tropical plantations can be different from those encountered in large scale industrial plantations making it necessary to develop more appropriate survey methods. In this article, we report on non-conventional approaches used to assess pest and disease status in smallholder plantations established under the Community Forestry Management Project in Ghana. A combination of interviews, focus group discussions, and follow-up field assessments were employed to determine pests and disease incidences in the plantations. The interviews were conducted with the aid of pictures and samples of potential key pests, as well as pictures of symptomatic trees to elicit forest health conditions as perceived by farmers. Twenty-three communities and over 2,000 hectares of taungya-type plantations that were planted with two exotic species *Tectona grandis* (teak) and *Cedrela odorata* (cedrela), and two indigenous species *Terminalia superba* (ofram) and *Ceiba pentandra* (ceiba) were surveyed. A wide range of tree health problems that included biotic, abiotic and human-induced stresses were recorded. Coleopterous stem borers of pole-size trees, grasshopper (*Zonocerus variegatus*) defoliation of actively growing saplings and retardation of growth due perhaps to nutrient deficiency, were the key problems observed on teak. Stem canker and dieback were observed on *C. odorata* and *C. pentandra*, respectively. We noted that involvement of the communities in the survey process greatly increased our ability to

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detect pest in the plantations. We concluded that pest surveys in smallholder plantations should not only focus on the technical aspects, but also the cultural and socioeconomic orientations of the local community, as well as engender their active participation in the process.

39. **Duah-Gyamfi, A.**, Kyereh, B., Agyeman, V. K., Adam, K. A., **Afriyie, K. O.** and Swaine. M. D. (2015). Seedling abundance, composition and growth forecast under two logging intensities in a moist tropical forest in Ghana. *Ghana Journal of Forestry*, 31:1-20.

Timber species differ in their response to logging disturbance. Knowledge about the impacts of different logging intensities is necessary to determine levels of timber extraction compatible with species responses in order to refine management interventions. We examined the effects of two logging intensities on the abundance and composition of tree seedlings in gaps in Pra Anum Forest Reserve within a Moist Semideciduous forest in Ghana. In addition, we assessed seedling growth by forecasting the probability of locating a seedling ( $\geq 55$  cm) in the two logging intensities compared to controls. Logging was carried out experimentally at two intensities, 26 m<sup>3</sup>/ha (1 AAC) and 52 m<sup>3</sup>/ha (2 AAC) of extracted timber, in a 128 ha compartment. Twenty plots each of 60 m<sup>2</sup> were randomly established in gaps in each of the logging treatments and in the unlogged forest. These plots were monitored for number of seedlings and height growth of timber tree species for 33 months in four different enumerations. We used mixed effect models to assess the abundance of seedlings over time. A non-metric multidimensional scaling (NMDS) was used to determine the shifts in species composition. Seedling abundance was significantly different in gaps for both high and low logging intensities, however, a significant interaction effect between abundance and time was found only in the low intensity treatment. There was a significant difference in the rate of change in species composition between the high intensity and unlogged forest ( $P = 0.03$ ) but the rate of change between the low intensity and unlogged forest was not significant ( $P = 0.27$ ). After 3 years, we predicted that it was approximately three and two times more likely to locate a seedling ( $\geq 55$  cm) in the low and high intensity treatments, respectively compared to controls. An explanation for this is that the high intensity treatment enhanced competition from herbaceous weeds, which affected the survival and growth of tree seedlings. Based on this result, we recommend enforcement of silvicultural

prescriptions to the management of logged forests in order to achieve the level of forest manipulation needed to ensure productivity.

40. **Korang, J.K., Obiri, D. B.,** Awuku, S. and Appiah, H. (2015). Calorific values and gravimetric yield of six wood fuel tree species in the forest transition of Ghana. *Ghana Journal of Forestry*, 31:51-61

The biomass and energy-calorific values of six of the most common tree species used for wood fuel production in the Transition Forest Zone of Ghana were assessed. Moisture content (mc), volatile matter (vm), ash content (ash), fixed carbon (fc) and calorific value (cv) were determined for the species; *Azadirachta indica*, *Senna siamea*, *Anogeissus leiocarpus*, *Azalia africana*, *Pterocarpus erinaceus* and *Khaya senegalensis*. Results showed that *A. africana*, *K. senegalensis*, *P. erinaceus* and *A. indica* have the highest mc, vm, ash content and fixed carbon content, respectively. *P. erinaceus* gave the highest gravimetric yield (gy) of 33.30% during carbonization, which correlated very well with green density of the species. *A. africana* and *A. indica* possess the highest (5.17 kcal/g) and lowest (3.39 kcal/g) calorific values for fuel wood, respectively. Similarly, *A. indica* and *A. africana* have the highest (6.79 kcal/g) and lowest (6.07 kcal/g) calorific values for charcoal respectively. Contrary to the assertion that fast growing species produce poor quality wood fuel, this work has shown that exotic fast growing species such as *S. siamea* produces good quality charcoal.

41. **Nutakor, E.** (2015) The significance of medicinal plants in a valley rice growing eco-system (Sawah): The case of Ahafo-Ano South District, Ghana. *Ghana Journal of Forestry*, 31:34-44

The technology for wet valley rice production or Sawah, has gained increased popularity in Ghana as it holds promise for improved food production and poverty reduction. However, there is concern that this system could have negative implications for wetland ecosystems especially in the provision of medicinal plants (MPs) for human health. The study identified medicinal plants and their utilization by local people in 3 Sawah pilot communities in Ahafo-Ano South District, Ghana. It assessed their perceptions of the Sawah system in relation to distribution, diversity and availability of medicinal plants in the ecosystem. Data was collected using participatory research approach. In terms of distribution and diversity of MPs, the results revealed that, out of 84 different plant

species mentioned, 48% were found in the Sawah system, while 61%, 38% and 30% were in upland farms, forests and homesteads/gardens, respectively. The Sawah system was ranked (perceived as) second in the availability of medicinal plants by 32% of respondents compared to other land use types such as farms (39%); forest (17%) and homestead/gardens (12%). Availability of MPs varied across land use types with farms and homesteads/gardens having the highest mean availability indices of 2.64 and 2.36 respectively with the Sawah system ranking slightly above forest lands with least availability index. The MPs are generally on the decline in the ecosystem, thus there would be the need for interventions to conserve them in the ecosystem.

42. **Owusu., F.W., Appiah-Kubi, E., Tekpetey, S.L. Essien, C., Arthur, P.L and Zorve, G.K.** (2014). Products development of laminated panel doors from plantation grown bamboo species in Ghana. *Journal of Bamboo and Rattan*, 13(3&4):91 – 105.

The level of awareness and acceptance of products from native bamboo species from many countries is low. Efficient promotion through establishment of its working properties is essential. In this study, bamboo culms from plantations in Ghana were extracted, processed, dried, planed and glued. Test samples were prepared using ASTM D 143-94 and 1666-87. These were planed with two cutting angles and three feed speeds at a spindle speed of 5,200rpm. The surface qualities of the planed samples were evaluated and graded according to ASTM D 1666-87. The samples were further used for sanding tests using five grit sizes of sand papers and belt sander. A second sanding operation with grit size 250 was performed manually to finally prepare the surfaces of the prototype products for the application of wood finishes. Results revealed that surface planing quality increased with decreasing cutting angle and feed speed. Sandpaper P60 eliminated all torn/chipped grain defects while the highest percentage surface quality for each species was recorded with P150 followed by P120 and P100. The ease of planing and sanding was classified as moderately easy to slightly difficult. Laminated wood members for panel door production were prepared and sanded and fixed together using dowels and 'Woodchem' adhesive. A good quality laminated bamboo panel door was produced. Bamboo utilization for door manufacturing is recommended for enhanced marketing.

43. **Owusu, F.W., Tekpetey, S.L., Appiah-Kubi, E., Essien, C., Appiah, J.K. and Boakye, F.** (2014). Ripping and planing characteristics of some exotic bamboo species grown in Ghana. *Journal of Bamboo and Rattan*, 13(3&4):67-79.

In this study, the machining characteristics of eight exotic bamboo species extracted from Daboase, Kusi near Kade and Amantia in southern Ghana were assessed. The bamboo species include *Dendrocalamus latiflorus*, *Bambusa bambos*, *Guadua angustifolia*, *Guadua chacoensis*, *Dendrocalamus brandisii*, *Bambusa vulgaris* var. *vittata*, *Bambusa vulgaris* (from plantation) *Bambusa vulgaris* (from natural forest). These were cross-cut into the butt and top portions. All the samples for the six were evaluated and graded in accordance with ASTM D 1666-87. The results indicate that the case of ripping was better with the top samples than the butt and ripped surfaces were generally smooth. Ripping quality was better with the butt samples from the three localities than the top portion. *Bambusa vulgaris* were no statistically significant differences between 20° and 30° cutting angles ( $P \geq 0.05$ ). Data on ripping and planing of the selected bamboo species that have been generated can form the basis for more comprehensive research on the machining properties of bamboo species in Ghana.

44. **Sraku-Lartey, M.** (2014). Information literacy: A vital link in the research chain. *Ghana Library Journal*, 26(1):1-6

Information literacy consists of the competencies researchers must have in order to locate, retrieve, evaluate, select, and use information. Information literacy competencies are vital assets researchers must have in order to meet their information needs. These competencies however are developed over time and are essential for lifelong learning. For researchers, the questions that arise relate to how these competencies can be imparted to them and be woven into the fabric of the research agenda. This cannot be done overnight but rather over a period of time so that one can develop an information literate researcher. This paper is based on a study of the seven pillars of information literacy developed by the Society of College, National and University Libraries (SCONUL) and is used to assess the competencies needed by researchers in accessing their information needs. Several issues that are discussed include how to measure researchers' competencies and what could be done for those who lack information literacy skills. The model can be used as an instrument to help achieve best practices in information literacy; and provides support mechanisms and training for researchers to enable them play their role in developing their own competencies and their information literacy levels. Results of

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the study indicate that to make effective use of information resources researchers must be acquainted with the seven pillars of information literacy and develop self-learning regimes that would equip them with the relevant skills for using information

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\* Article was accepted in 2016

ii Introductory paper. Has no abstract