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Influence of Paper Mulberry Presence on Native Tree Species in Mabira Central Forest Reserve in Uganda

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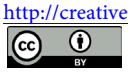

Abstract

Mabira Central Forest Reserve in Uganda (MCFR) is facing biodiversity loss, especially other tree species in the paper mulberry dominated area due to Charcoal burning activities and the presence of paper mulberry (*Broussonetia papyrifera*). Paper mulberry (*Broussonetia papyrifera*) in the family *Moraceae* or *Morus papyrifera* is found mostly in the production zone identified as hotspot of biodiversity in Mabira central Forest reserve. Several studies in western and East Africa have indicated that paper mulberry consumes a lot of ground water which may reduce water availability for other species and lead to reduced growth level of native species around. This study has tried to investigate the influence of paper mulberry (*Broussonetia papyrifera*) presence on the loss of native tree species in buffer and production zone in MCFR. The study used 1 km transects and thirty plots of 20 m × 10 m each. The index of Shannon and Simpson were used for species diversity and Jaccard similarity index was used for species similarity. The overall non-paper mulberry plant species or native tree species richness decreased significantly (76.92%) ($P = 0.04$) from the paper mulberry dominated area within the production zone of Mabira central forest reserve. The Shannon Wiener diversity index was 2.7 for production, 2.4 buffer and 0.8 for paper mulberry dominated area, which simply means that the paper mulberry dominated area was less diverse than the two other study sites. Seven hundred sixteen (716) trees were found in total with 56 different tree species where only one species which is paper mulberry was found 233 times and only 483 times of the 55 native species. Mabira central forest reserve is at risk of losing its natural forest in the years to come. This Impact is likely to increase with the increasing of paper mulberry planting. To avoid this the management should think on not planting paper mulberry trees within the natural forest and stop charcoal burning activities.

Subject Areas

Environmental Sciences

Keywords

Biodiversity, Mabira Forest, Native Trees Species, Paper Mulberry

1. Introduction

Broussonetia papyrifera, (Paper mulberry) either Kikambakamba or Nkulaido in local name is a flowering plant in the family *Moraceae* also known as *Morus papyrifera*, originated from Japan and Taiwan, found now worldwide. In Africa it is most found in West Africa (Ghana) and East Africa (Uganda) [1]. Across the continent in Uganda, throughout the Mabira Central Forest Reserve (**Figure 1**), paper mulberry has become a dominant plant along many of the forest's paths, roads, and edges, and has even begun to show up well into the forest [2]. Paper mulberry is one of the tree species growing fast and possible to attain the height starting from 10 to 21 m and the diameter at breast height of 70 cm with a round, spreading crown when growing under best conditions [3]. *Broussonetia papyrifera* can tolerate a wide range of climates, including humid tropical (monsoon), humid and sub-humid subtropical, and warm temperate areas. It can survive for about 3 - 4 month of dry season [4], but tends to be most abundant on soils that are generally moist. For nowadays, tree such as acacia and paper mulberry is the major concern for the world forest conservation. Paper mulberry is one of the best plant used for making paper worldwide, and helps some countries to generate more income from the sales of the paper mulberry trees to companies producing papers. Even though other factors such as, anthropogenic activities including charcoal burning, and tree harvesting are the major contributors of deforestation. Also, timber exploitation is the major contributor of losing natural forest as people are now planting tree producing good timber for increasing their income. This contributes to reducing the forest by the replacement of natural trees with artificial trees for timber and other related products from trees as well as Paper mulberry influence to the higher loss of natural forest.

The Paper Mulberry reduces animal pasture by 80 percent and affects food production. In parts of Busoga region where the tree has grown animals have no pasture and communities cannot plant any crops. According to Wanda *et al.*, 2016 [5] a senior research Officer Aquatic weeds management at NaFIRRI, the shade created by the Paper mulberry tree cannot allow light to penetrate through it, which kills off other plants. This kind of plant "Paper mulberry" which is native to Eastern Asia has become an invader on several continents and in over a dozen countries including Uganda and Ghana in the African continent [6]. Some images for identification of paper mulberry fruits and leaves are shown in **Figure 2** and **Figure 3** respectively.

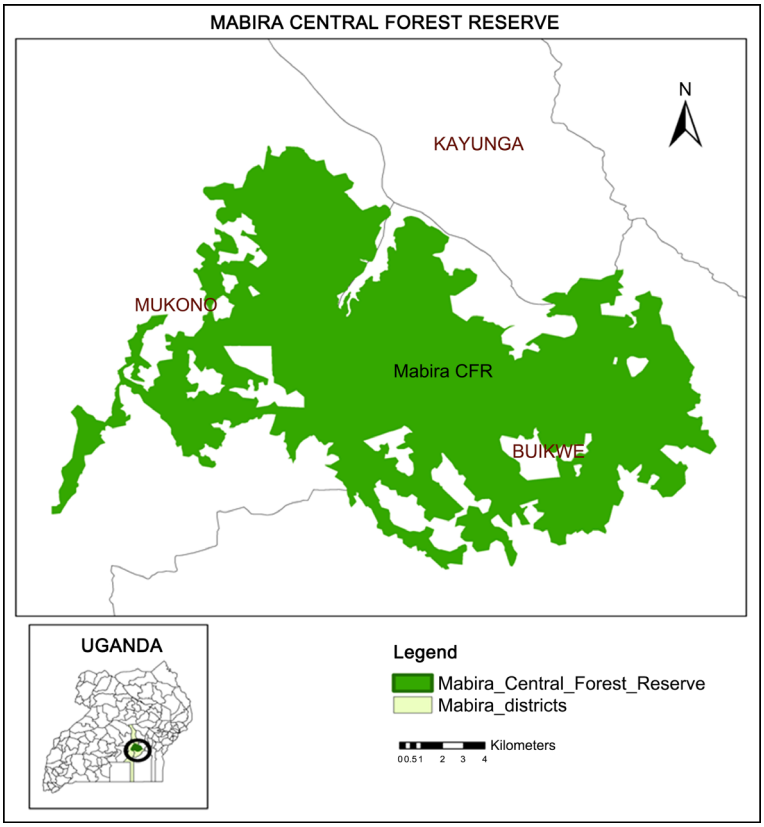

Figure 1. Map of the study area.

Figure 2. Paper mulbery fruits.

Figure 3. Paper mulbery leaves.

2. Material and Methods

2.1. Field Site Description

This study was conducted in Mabira Central Forest Reserve is one of the Uganda's largest surviving Natural Forests covering an area of 306 square km. Mabira has Natural Habitat of 312 species of trees, home of 315 species of Birds, 218 Butterfly Species, 97 Moth Species, 23 Small Mammal Species. Many activities are doneincluding Forest Walks with over 68 km of well-developed trail length, Mountain Biking, Bird Watching, Environmental Education and Research, Camping and Picnics, Primate Watching, Butterfly Identification and General Forest Exploration.

Mabira boosts of 3 Bandas which can accommodate a maximum of 10 Guests at the Eco-Tourism Site near Najjembe Trading Centre. The Bandas are self-catering although some light meals can be prepared for you by the House keeper. There is also a Camping Ground near the Site for do-it-yourself caravans at a modest fee. Mabira Forest Lodge, a modern eco-friendly facility by the Alam Group of Companies is nearing completion. Mabira Central Forest Reserve is located on the main Kampala-Jinja Highway in Mukono District. It is 54 km from the City Centre of Kampala and 26 km from Jinja Town. The Eco-tourism Site is about half a kilometer from the road head along a short dirt road off the Najjembe trading center. The Forest is therefore accessible by all vehicles throughout the year [7].

The mature mixed forest type occupies the largest area and constitute 52% of the area of Mabira. It is indeed a mixed forest with 229 tree species [8] which have been noted to grow to timber size.

2.2. Research Design and Sampling Strategy

In this study, systematic sampling was employed in data collection, in selection of the study zones. Production zone and buffer zone are two zones were involved in this study. The production was divided into two areas, one named production zone and paper mulberry dominated area. One transects line was laid in each of the three areas. The transect direction was determined by use of campus as well as hand held Global Positioning System GPS for coordinates. The transect length was 1000 m in buffer zone and 1000 m in production zone and zone dominated by Paper mulberry. All trees with DBH ≥ 5 cm were identified and DBH measured using caliper/diameter tap. A total of 30 rectangular plots, 7 in production zone with non-paper mulberry, 8 in buffer zone, 15 in production zone dominated by paper mulberry, with area of 200 m (20 m × 10 m) were demarcated on the transect lines at plot interval of 20 m in systematic alternate pattern by use of a measuring tape.

2.3. Data Collection Methods

This study was conducted in June, 2019 the transect methods was used to deter-

mine the composition of the two different areas (production zone and buffer zone). One compartment was selected from Buffer zone and two compartments from Production zone. Three transects with the lengths of 1000 m or 1 km were selected within each compartment and fifteen plots of 20 m × 10 m each with distance of 20 m. The Geographical Positioning System (GPS) was used to help us to locate transect and the coordinates of each plot. Plot was systematically demarcated on the transect after every 50 meters. All trees with diameter at breast height (DBH) equal and greater than 5 cm and height greater than 1.5 m above the ground was identified and recorded and their DBH measured. The NFA agents under the instruction of Mabira Central Forest Reserve helped us with the tree identification for the encountered tree species in local names and as researcher I managed to get the scientific names.

2.4. Data Analysis

To evaluate the species diversity, two diversity indices were used, the indices used were: Shannon-Wiener index (H0 ¼ Ps i¼1 *pi*ln*pi*) and Simpson's index (D ¼ 1=Ps t¼1 *pi*ln*pi*), where ***s*** is the total number of species and **p** is the relative abundance of the ***i*** species. In contrast to direct measures of species richness, these indices take into account the relative abundances of species [9]. Species compositional similarity between the two areas, encroached forest and native forest was estimated using the Jaccard similarity index. The Jaccard similarity index uses species presence/absence data for two sample sets [10] (in this case zone types) and was calculated using this formula:

$$Sj = a/a + b + c$$

where ***a*** is the number of species common to both quadrats/samples, ***b*** is the number of species in quadrat/sample 1 only, and ***c*** is the number of species in quadrat/sample 2 only. Often the coefficient is multiplied by 100 to give a percentage similarity figure [11] for the species accumulation curves, and estimation of species diversity and compositional similarity [12]. ANOVA was used to test the statistical significance differences in mean DBH, density and basal area in the three areas. To determine if the DBH-size class distribution of individuals of plants between different areas was significantly different after testing for normality the Hutcheson t-test was used. The statistically significance levels are reported at $P \geq 0.05$ [13].

2.5. Result

2.5.1. Species Abundance, Richness, Diversity and Community Similarity

Species abundance and richness

A total of 716 plants were found in all zones including 233 of paper mulberry and 483 trees of other non-paper mulberry species or native tree species. In all three different zones 56 different species were identified, in production zone was the most diverse with 204 individuals of 40 different species, followed by Buffer zone with 245 individuals were found of 32 different species and Paper mulberry

dominated area with 267 individuals of 13 species, the last being the first in species dominance. Moreover, the production zone was the first in terms of species richness having 40 different species or 69.6 percent (69.6%) of the study area followed by buffer zone and paper mulberry dominated area being the last. In terms of abundance Paper mulberry dominated area was most abundant site with a total of 268 individuals or 37.43 % followed by buffer zone with 245 plants or 34.21 % of total individuals identified and the production zone was last abundant site with 207 individuals or 28.91% (**Table 1**).

2.5.2. Species Diversity

Species diversity was higher in production zone followed by buffer and least in paper mulberry. Shannon-Weiner diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when between 1.0 and 2.0 and very low when it is smaller than 1.0 [14]. For this study, the Shannon Weiner diversity index was 2.7 for production zone, 2.4 buffer zone and 0.8 for paper mulberry zone which simply means that the production zone was more diverse than the two others. Jaccard similarity index of (s/s1 + s2 + s) was used to evaluate the similarity the results were 0.17 for Production and Paper mulberry, 0.25 for Buffer and Paper mulberry zone. The species diversity is most seen in the production zone where in the 57 species identified it accounts 40 different species followed by buffer zone with 31 different species and the last one in term of species diversity is the paper mulberry dominated area within the production zone with only 12 different species. This means in the paper mulberry dominated area there is a drastic loss of natural tree species as shown in **Figure 4**.

2.5.3. Species Similarity

Shannon-Weiner diversity index is high when it is above 3.0, medium when it is between 2.0 and 3.0, low when between 1.0 and 2.0 and very low when it is smaller than 1.0 [15]. The Shannon wiener diversity index was 2.7 for production, 2.4 buffer and 0.8 for paper mulberry. Jaccard similarity index of (s/s1 + s2 + s) was used to evaluate the similarity and the results were as follows: 0.17 for Production and Paper mulberry, 0.25 for Buffer and Paper mulberry zone.

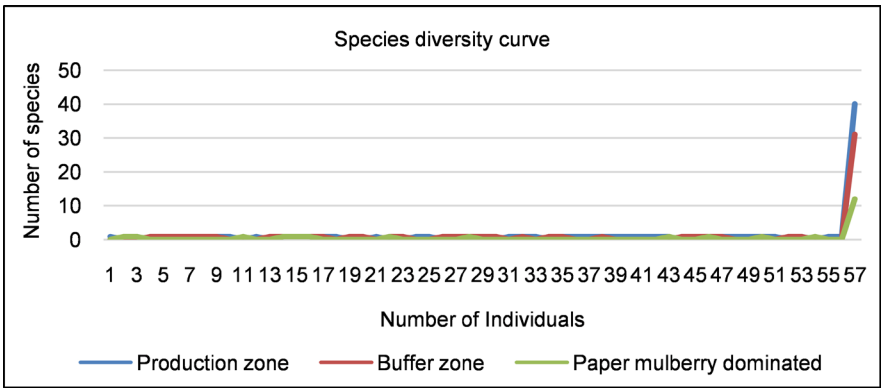

Figure 4. Species diversity.

Table 1. Abundance of tree species in three different study sites of Mabira central Forest Reserve in Uganda.

Species	Buffer Zone	Production Zone	Paper Mulberry Dominated Area	Total
Afzelia africana	0	1		1
Agave sisalana	0	1		1
Olea welwitschii	1			1
Albizia ferruginea	4	1		5
Alibizia spp.			2	2
Alstonia boonei	1		1	2
Antaris toxicaria	13	7	1	21
Artocarpus heterophyllus	0		1	1
Balanites wilsoniana	2			2
Blighia unijugata	3	3	1	7
Bosqueia phoberos	0	2		2
Bridelia micrantha	0	1		1
Broussonetia papyrifera	11	1	221	233
C. africana	0	1		1
Canarium schweinfurthii	0	1		1
Celtis africana	3	2		5
Celtis durandai	1			1
Celtis mildbraedii	23	55	11	89
Celtis zenkeri			1	1
Chrysophyllum albidum	1	6		7
Coffea canephora	0	1		1
Dichrostachys cinerea	4	4	2	10
Diospoyros absynica	2	1		3
Euphorbia hirta L	26	5		31
Ficus carparsis	0	1	5	6
Ficus exasperata	1			1
Ficus mucuso			2	2
Funtumia africana	69	26	2	97
Harungana madagascariensis Lam. Ex Poir.	0	1		1
Holoptelea grandis	7	3		10
Justicia heterocarpa	0	1	17	18
Khaya anthotheca	0	1		1

Continued

Khaya spp.	1	2		3
Erythrophleum suaveolens	2	4		6
Macaranga kilimandscharica	0	3		3
Maesopsis eminii	1			1
Mondia whytei	0	1		1
Makhemia lutemia	1			1
Margaritaria descodius	2	9		11
Markhamia lutea (*Benth.*) *K. schum*	1			1
Milicia excelsa	1			1
Monodora melistica	0	1		1
Morus mesozygia	0	1		1
Musanga cecropioides	0	1		1
Oxyanthus speciosus	13	3		16
Pachystela brevipes	4	10		14
Podocarpus latifolius	1			1
Prunus africana	1			1
Sapium ellipticum	1	6		7
Tabernaemontana pachysiphon	0	1		1
Teclare nobilis	36	28		64
Trema orientalis	6	1		7
Trichilia dregeana	0	1		1
Trichilia rubescens	0	5		5
Trimeria grandifolia	2			2
Warburgia ugandensis	0	1		1
Total per area	**245**	**204**	**267**	**716**

Source: Survey June, 2019.

2.5.4. Structural Characteristics

The DBH-size class distribution of the number of individuals of non-paper mulberry plants in the three different zones is shown in **Figure 5**. Significant differences in the distribution of non-paper mulberry plants in the DBH-size classes were found between the production zone and the paper mulberry dominated area (Hutcheson t-test, P-value < 0.05), and between buffer zone and the paper mulberry dominated area. 55% of the species belong to the first class of 5 - 10, 18% belong to 10 - 15, 8.4% for 15 - 20, 6% belong to 20 - 25, 3.4% belong to 25 - 30, 2.2% belong to 30 - 35, 1% belong to 35 - 40, 2% belong to 40 - 45, 1% belong to 45 - 50, 0.7% belong to 50 - 55, 1.7% belong to >55. This indicated a high frequency distribution in a low diameter class of 5 - 10, and decreased

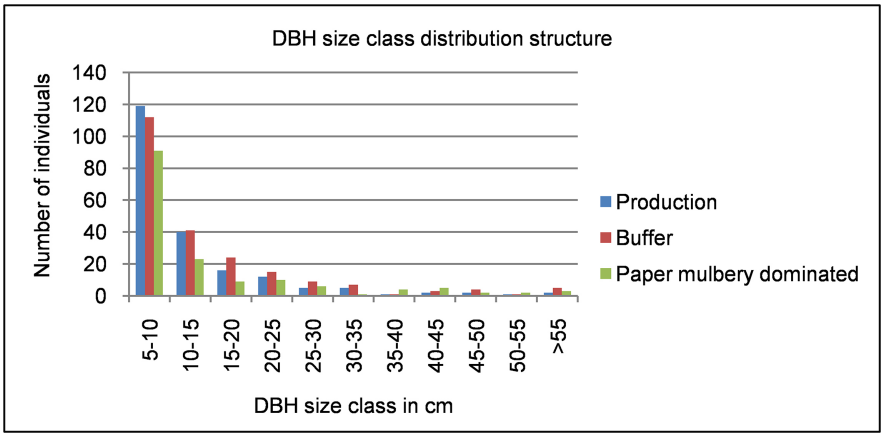

Figure 5. Size class distribution structure.

towards the higher classes. However, from the middle classes of 35 - 40, 40 - 45, species in buffer and production zone tend to disappear than paper mulberry. The significance in abundance was at P value 0.04, 0.05 critical level at 95% confidence level between buffer and paper mulberry dominated zone as provided in **Figure 5**.

2.6. Discussion

The results in this study show that Paper mulberry known locally as "Kikamba-kamba or nkulaido" is not found in the natural forest where natural plants are more abundant and it is more dominant in its zone where natural plants species are rare and likely to disappear. Species richness and composition is continually decreasing in the paper mulberry dominant area compare to native forest. The results from Shannon Weiner diversity index show, medium species diversity in production zone and Buffer and very low diversity in paper mulberry zone. Broussonetia papyrifera showed dynamic growth, extending over large areas in the moist semi-deciduous forest zone to the exclusion of many other plant species. Thus, invaded areas have considerably low herbaceous and woody species richness and diversity. Therefore, plant species diversity decreases with dominance of Broussonetia papyrifera [15]. The diameter class structure showed nearly J-shape with a decline in density from 7 middle class. An indicator of over harvesting of the forest especially of trees with DBH ranging from 35 cm to 55 cm, in production zone and buffer than in paper mulberry zone which is favoring paper mulberry to multiply aggressively party due to the favorable climatic condition and fertile soils.

3. Conclusion

Broussonetia papyrifera (L.) Vent. (Paper mulberry) is the major contributor of nature forest loss, as it consumes a lot of water and preventing other natural plants to get the necessary water and nutrient for regeneration growth and foods for plant that causes other species to die and leave the space to the dominant

plant. Paper mulberry, because of its high rate of water consumption compare to other tree species, if not planted in its own zone or mixed with other natural plants will lead to the loss of natural forest which can increase the tree harvesting from the restricted area because of the scarcity in the production zone. Paper mulberry has an influence on other tree species regeneration, so it should not be mixed with other tree species in case that we want to conserve our natural forest.

4. Recommendation

As shown in the result above of this study, the paper mulberry has dominance on other tree species with the same area, I would recommend that this dominance and invasion should be regularly monitored and checked to help in the protection of the other species. Likewise, for not losing the natural trees, the paper mulberry should not be mixed with other trees species; it should be planted in its own area to avoid the drastic loss of natural forest that would occur when grown together with other tree species. Most research should be done on paper mulberry dominance to help the forest management officials to get accurate relevant information for sustainable use of natural forest and maintain its ecological status.

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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Appendix (Abstract and Keywords in French)

Resume

La réserve forestière centrale de Mabira en Ouganda (MCFR) fait face à une perte de biodiversité, en particulier d'autres espèces d'arbres dans la zone dominée par le mûrier à papier en raison des activités de brûlage du charbon de bois et de la présence de mûrier à papier (Broussonetia papyrifera). Le mûrier à papier (Broussonetia papyrifera) dans la famille *Moraceae* ou *Morus Papyrifera* se trouve le plus dans la zone de production identifiée comme point chaud de la biodiversité dans la réserve forestière centrale de Mabira. Plusieurs études en Afrique de l'Ouest et de l'Est ont indiqué que le mûrier à papier consomme beaucoup d'eau souterraine, ce qui peut réduire la disponibilité en eau pour d'autres espèces et conduire à un niveau de croissance réduit des espèces indigènes environnantes. Cette étude a tenté d'étudier l'influence de la présence de mûrier à papier (*Broussonetia papyrifera*) sur la perte d'espèces d'arbres indigènes dans la zone tampon et de production du MCFR. L'étude a utilisé des transects de 1 km et trente parcelles de 20 m × 10 m chacune. L'indice de Shannon et Simpson a été utilisé pour la diversité des espèces et l'indice de similarité de Jaccard a été utilisé pour la similitude des espèces. La richesse globale en espèces de mûriers autres que le papier ou la richesse en espèces d'arbres indigènes a diminué de manière significative (76.92%) ($P = 0.04$) dans la zone dominée par le mûrier à papier dans la zone de production de la réserve forestière centrale de Mabira. L'indice de diversité de Shannon Wiener était de 2.7 pour la production, 2.4 tampons et 0.8 pour la zone dominée par le mûrier à papier, ce qui signifie simplement que la zone dominée par le mûrier à papier était moins diversifiée que les deux autres sites d'études. Sept cent seize (716) arbres ont été trouvés au total avec 56 espèces d'arbres différentes où une seule espèce qui est le mûrier à papier a été trouvée 233 fois et seulement 483 fois sur les 55 espèces indigènes. La réserve forestière centrale de Mabira risque de perdre sa forêt naturelle dans les années à venir. Cet impact est susceptible d'augmenter avec l'augmentation des plantations de mûriers à papier. Pour éviter cela, la direction devrait penser à ne pas planter de mûriers à papier dans la forêt naturelle et arrêter les activités de brûlage du charbon de bois.

Mots Clés

Biodiversité, Espèces D'arbres Indigènes, Forêt de Mabira, Mûrier à Papier