Population Status And Conservation Hotspots Of *Prunus Africana* (Hook. F.) Kalkman In South Nandi Forest, Western Kenya

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ABSTRACT

Prunus africana is assessed as vulnerable globally by the International Union for Conservation of Nature. The conservation status is however general and under-illustrated. It lacks details on the actual threats that cause precarious spatial distribution of the population in certain localities such as South Nandi Forest, Western Kenya. This study assessed the population structure of *P. africana* by correlation of biometric variable including Diameter at Breast Height and height class distribution and regeneration with the diversity and frequency of threats in spatial context of the plant species. Stratified Random Sampling was used to establish three belt transects of 400 m by 2 km within the forest and 1 km buffer zone in farmlands. The measure of mean, spread, normal distribution and correlation of biometric variables of *P. africana* was analysed using PAST (Version 4.3). Population structure was summarised using histograms and bar charts. Frequency distribution table was used to analyse the number of incidence of the threats to *P. africana* at plot level. T-test was used to test for differences in *P. africana* parameters among transects. The spatial distribution model of *P. africana* in the forest and buffer zone was mapped using the maximum entropy suitability mapping method as implemented in MAXENT software (Version 3.3.3k) and QGIS Brighton (version 2.6). *Prunus africana* population was highly concentrated in North eastern part of the forest and surrounding farmlands with admirable number of mature individuals. The Diameter at Breast Height distribution of *P. africana* in the forest showed unstable and intermittent population structure unlike a stable population in the surrounding farmlands. Although the seeds germinated profusely, there was poor establishment and survival. Key conservation threats were overgrazing, firewood collection, logging and charcoal burning. The study recommends both *in-situ* and *ex-situ* conservation measures.

Keywords: multipurpose, overgrazing, regeneration, vulnerable

1. INTRODUCTION

Prunus africana, commonly known as the Red Stinkwood, African Cherry, or Bitter Almond, is a medicinal tree (Betti, 2008; Orwa *et al.*, 2009; Bii *et al*., 2010). It is indigenous to the montane regions of West, Central, East and Southern Africa, including Madagascar (Jimu, 2011; Kadu *et al*,. 2011; Kadu *et al.*, 2013; Mbatudde *et al*., 2013; Vinceti *et al*., 2013; Cheboiwo et al., 2014). In Kenya, the species occurs in moist evergreen forests, riverine, often in remnants or on forest margins between 1350 and 2750 m above sea level (Beentje, 1994). It is common in Mt. Kenya, Aberdares, Kakamega, and Cherangani forests. It also occurs in Timboroa, Nandi and western part of Mau forest (BIOTA, 2004). In south eastern Kenya, *P. africana* occurs naturally in Taita Hills cloud moist and highly fragmented forests.

The role of agricultural expansion and harvesting on the decline of natural forest resources has been clearly evident and documented (Sunderland & Tako, 1999; Ingram, 2014; Drescher *et al.*, 2016). The range of *P.*

africana has been affected by past climate change and anthropogenic pressures. It is predicted that many regions of Africa suffer from temperature increases and droughts caused by range shifts along altitudinal and moisture gradients (Jimu, 2011). Furthermore, the wild-collection is no longer sustainable where harvest adversely affects morbidity and mortality rates of harvested populations (Stewart, 2003; Mugaka *et al*., 2013). The modelled distribution indicates that the species is likely to be negatively affected in future, with an expected decrease in distribution by 2050 (Vinceti *et al*., 2013). The high demand and rapidly diminishing populations therefore poses immediate need of conservation strategies of the remaining *P. africana* populations (Franzel *et al.,* 2009; Mbatudde *et al*., 2013; Ingram *et al.,* 2015).

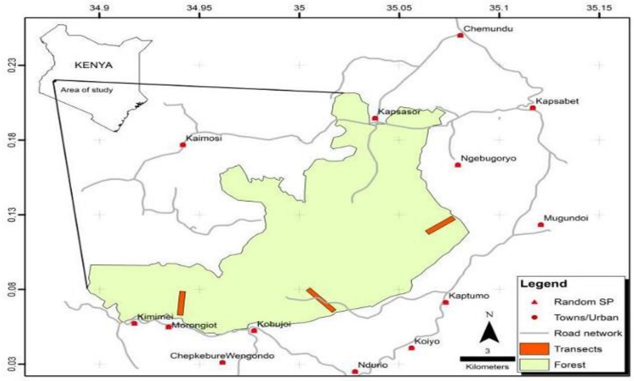
The International Union for Conservation of Nature (IUCN) (2012) has documented the conservation status of *P. africana* as vulnerable. It is also recognized globally that *P. africana* is declining from its natural range, and even getting extinct from some of the localities due to habitat loss and overexploitation. However, this information is at large scale and does not provide local information on the population status and conservation threats affecting the species. Without the conservation of viable populations of *P. africana*, the species could be harvested to extinction. The study aimed at understanding the population status and spatial distribution of *P. africana* in South Nandi Forest (SNF). This information can be used in designing suitable monitoring programmes and to curb unsustainable exploitation of *P. africana.* The study also supports government's plans in the management of protected areas and sustainable utilization of natural resources by influencing policy decision making process.

2. MATERIALS AND METHODS

South Nandi Forest is located (between latitudes 0˚05'N and 0˚21'N and longitudes 34˚90'E and 35˚08'E) in Nandi County, Western Kenya (Figure 1). The forest is within an altitudinal range of 1700 – 2100 m above sea level. The forest land measures approximately 18000 ha, with the area under forest measuring about 13000 ha. Rainfall is high (1600 to 1900 mm annually) depending on altitude. The forest is drained by the Kimondi and Sirua rivers, which merge to form the Yala River flowing into Lake Victoria.

Stratified Random sampling was used based on disturbance gradient, assuming higher disturbance near forest edges (Fashing, 2004). Three belt transects each measuring 2 kilometres long and 400 m wide was established from the forest edge towards the interior of the forest. *Prunus africana* was targeted for establishing reference points which would potentially form centre of 5 Permanent Sampling Plots (PSP) measuring 100 m by 100 m with an interval of 400 m along transects. Additionally, ten random PSP outside the transects within the forest as well as random sampling of *P. africana* population in farmlands within a 1 km buffer zone outside the forest edge were included in the study.

Figure 1 A map showing the study area and sampling plots



Source: Author

Hand-held Geographic Positioning System (Garmin etrex) devise was used for mapping the plots and acquiring spatial references of all the *P. africana* encountered (Araya *et al.*, 2009; Earle-mundil, 2010). *Prunus africana* trees were also fitted with aluminium plates with a unique code held to the trunks using aluminium nails.

Diameter at Breast Height (DBH) of *P. africana* individuals measuring > 5 cm DBH was recorded at 1.3 m above the ground using a DBH meter. Tree height was determined using a clinometer (Suunto). The longest and the shortest diameter of the tree crown were measured using a tape measure and averaged to obtain the crown length. Seedlings and saplings of less than 1.5 m in height and with DBH < 5 cm were counted in smaller plots of 5 m radius from the center of *P. africana* tree (Nzilani, 1999). Those with height of less than 30 cm were considered as seedlings while those with height > 30 cm and DBH ≤ 5 cm were considered as saplings (Kent and Coker, 1992). The reproductive stages of every individual tree of *P. africana* encountered in transect were recorded as flowering, fruiting or none using binoculars for inspection.

Physical observation was used to assess the major conservation threats to *P. africana* and within the sub-sampling plot (20 m by 20 m) in the study sites (table 1).

Table 1 Indicators of conservation threats

Threat	Indicators/Measurable
Logging	Stumps (old and new), remaining logs, saw dust
Grazing	Presence of livestock, dung, hoof marks, browsed vegetation
Charcoal burning	Active kiln, Charcoal remains, Burnt soil
Forest fire	Burnt bushes/tree barks, chars on ground,
Resource extraction	Debarking, Pruning, uprooting, fire wood
Infestation	Presence of pests and parasites, deformed leaves, colouration, wounds
Invasive species	Alien plants species,

Source: Author

The dependent variables of *P. africana* in the forest was analysed using PAST (Version 4.3) (Hammer, 2012). Frequency distribution table was used to analyse the number of incidence of the threats to *P. africana* at plot level. T-test was used to test for differences in *P. africana* parameters among transects. All statistical significance was reported at 0.05 and at 95% confidence levels. Suitability distribution models of *P. africana* was created using the maximum entropy suitability mapping method (Phillips *et al*,. 2006; Phillips & Dudık, 2008), as implemented in MAXENT software (Phillips *et al.*, 2006) and QGIS Brighton (version 2.6) while the conservation hotspots were mapped using QGIS Brighton (version 2.6).

3. RESULTS

The highest and the lowest abundance of *P. africana* was recorded in Transect 1 (T1) and Transect 2 (T2) with 96 and 12 individuals respectively (table two). A total of 29 individuals were recorded in all the 15 PSP in the three transects representing a mean density of 2 trees/ha (table three). However, there was a high density per PSP in T1 (n=19) followed by T3 (n=10) and T2 (n=7) respectively. A maximum density of 15 individuals of *P. africana* per PSP was recorded.

Table 2 A table showing the abundance of P. africana per transect in South Nandi forests

Transect	Abundance	DBH Mean ± SD	Height Mean ± SD	Crown length Mean ± SD
T1	96	118.6±39.3	22.7±4.4	12.9±4.1
T2	12	66.6±22.2	19.6±3.4	13.6±5.1
T3	17	118.3±39.3	24.3±4.6	14.5±5.3

Table 3 A table showing the density of P. africana per PSP in South Nandi forests

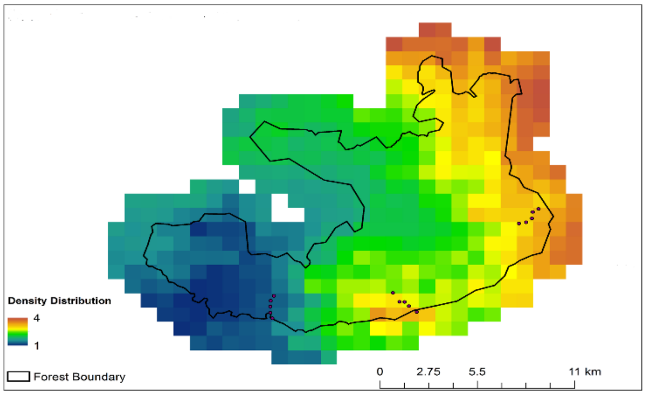
Transect	PSP	(Density/Ha)	DBH Mean ± SD	Height Mean ± SD	Crown length Mean ± SD
	1	15	108.3±40	28.4±5	13.1±4
	2	1	165	30	17.5
T1	3	2	178±21	25	16.25±2
	4	1	134	25	9
	5	-	-	-	-
	1	1	100	26	22
	2	1	65.4	19	11
T2	3	-	-	-	-
	4	4	75.5±25	21.4±2	13.1±6
	5	1	141	27	14
	1	2	55.8±69	12.5±5	5±4
	2	1	100	12	2.5
T3	3	3	88.3±37	23.7±2	12.7±6
	4	1	126	28	17.5
	5	3	103.1±51	27.7±3	16.3±2

Note. (-) denotes P. africana absent

Source: Author

Using the spatial data of *P. africana,* the modelled distribution showed a higher density to be found towards the North Eastern parts of the forest especially along the edges and the surrounding farmlands within the buffer zone with a maximum of 4 individuals/ha. Conversely, a lower density is found towards the South Western parts of the forest with a chance of getting at least 1 individual/ha (Figure two).

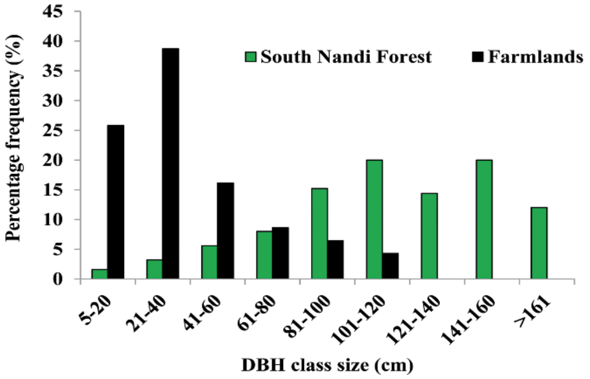
Figure 2 Density distribution of P. africana in South Nandi forest



Source: Author

Although the population structure of *P. africana* in the forest was represented in almost all DBH size classes, there was a progressive decline of the proportion in the smaller individuals as compared to the bigger ones. This resulted to a 'j' shaped distribution pattern whereby the majority of the individuals were of higher DBH class size of above 81-100 cm (82%) (Figure three). There was statistically significant difference in mean DBH (One Sample t-test, $t = 31.12$, $p < 0.05$). Conversely, the population structure of *P. africana* in the farmlands ($n = 93$) exhibited a typical inverse J-shaped curve (Figure three). The DBH class of 5–20 cm, 21-40 cm and 41–60 cm accounted for 26%, 39% and 16% of the total individuals. The subsequent classes of 61-80 cm, 81-100 cm, and 101-120 cm accounted for 9%, 6% and 4% respectively. There was statistically significant difference in the mean DBH between *P. africana* individuals in the forests and farmlands (Two sample t-test, $F < 0.05$, $t < 0.05$)

Figure 3 DBH class distribution of P. africana in South Nandi Forest and Farmlands



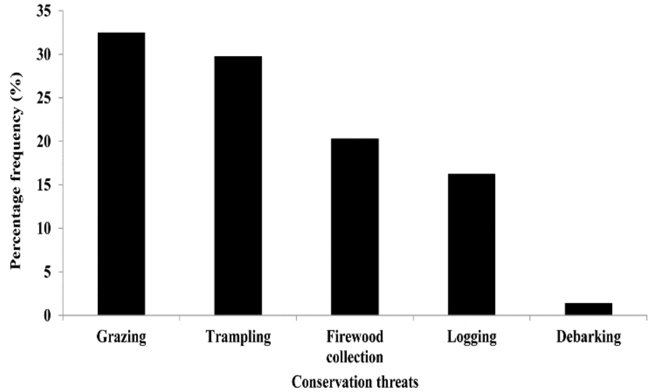
Source: Author

Majority of individuals in T1 ($n = 96$, Mean = 119±39) and T3 ($n = 17$, Mean = 118±39) had individuals of more than the average DBH. However, majority of individuals in T2 ($n = 12$, Mean = 67±22) were of smaller to average DBH range. There was statistically significant difference in the mean DBH among transects (Kruskal Wallis test, *H* = 92.58 $p < 0.05$). Spearman rank correlation analysis of the DBH and height class distribution using the total sample populations of *P. africana* in SNF (n=125) showed a strong positive linear correlation (R^2=0.65).

A total of 1987 (99.9%) seedlings counted were of ≤ 0.5 m in height while only 2 and 1 individual were between 0.5-0.9 m and 1.0-1.49 m respectively. There was statistically significant difference in mean seedling density among the three class size categories (One Way ANOVA F = 11.98, $p < 0.05$). Out of the total individuals of *P. africana* observed, 99.3% of the trees were not in any reproductive stage while only 0.3% was observed as flowering at the time of sampling.

Grazing ranked as a major conservation threat to *P. africana* based on frequency of occurrence while trampling, firewood collection and logging followed respectively (Figure four). Majority of the farmers in SNF grazed livestock in the forest throughout the year and constant trampling prevents seedlings establishment. Other minor threats included debarking, charcoal burning and invasive species. Uncontrolled firewood collection was recorded in most of the sampling sites especially in T2 while charcoal burning was recorded most frequently in T3. The frequency of *P. africana* was high among *P. africana* and *Croton megalocarpus* communities. *Prunus africana*, *Croton megalocarpus*, *C. macrostachyus* and *Albizia gumiffera* communities showed a higher number of *P. africana* seedlings. There was high frequency of threats in *P. africana*, *C. megalocarpus* and *C. macrostachyus* communities respectively. There was a high frequency of mature individuals of *P. africana* in plots where grazing, logging, trampling and firewood collection were recorded respectively. The average DBH, height and crown diameter of *P. africana* was high in plots where trampling was recorded as the most frequent threat and fairly distributed across the other threats. The *P. africana* population, vegetation communities and threats incidences were used as dependent variables for deciding and mapping the priority conservation areas.

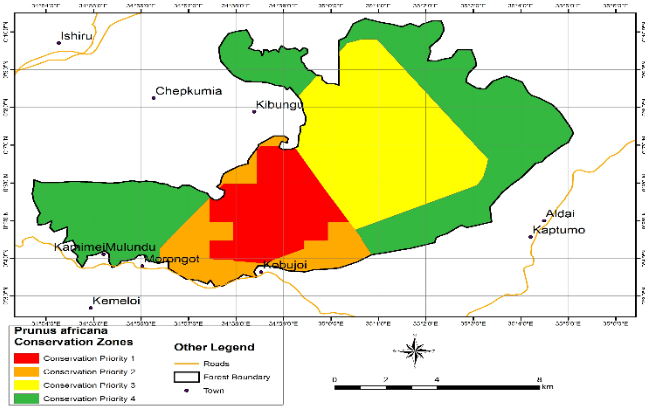
Figure 4 Conservation threats of P. africana in South Nandi forests



Source: Author

The convex hull matrices interception of the sites based on *P. africana* density, its frequency among vegetation communities and threat incidences was used to draw conclusions on conservation priorities levels within the forest (figure five). For instance, conservation Priority 1 had a high density of *P. africana*, a high frequency among vegetation communities and high frequency of threats incidence. This formed the area of the forest between Kobujoi and Chepkongony area towards the north eastern side of the forest. Conservation priority 2 had a lower density of *P. africana*, a relatively lower frequency of *P. africana* among vegetation communities as well as a lower frequency of threats incidence than conservation priority 1. Moreover, Conservation priority 3 had a lower density of *P. africana,* a lower frequency of *P. africana* among vegetation communities and a higher incidence of conservation threats. Finally, Conservation priority 4 formed the rest of the forest block where there was no interception of any of the three matrices.

Figure 5 Conservation priority areas for P. africana in South Nandi Forest



Source: Author

4. DISCUSSION

The high abundance of *P. africana* in T1 was attributed to the low anthropogenic disturbance especially logging and charcoal burning. On the other hand, low abundance in T2 and T3 was attributed to the high incidence of logging, charcoal burning and firewood collection. Forest logging and charcoal burning are known as the key threats to *P. africana* due to high quality charcoal and firewood characteristics (Sunderland & Tako, 1999; Fashing, 2004). Also, variation in habitat and effects of human disturbance are major contributing factors to difference in abundance and distribution of species (Sunderland & Tako, 1999; Vinceti *et al*., 2013; Ingram, 2014). Generally, *P. africana* was abundant along the forest edges in SNF with an open canopy compared to closed canopy cover toward the interior. Invasive species such as *Alchemilla kiwuensis* dominated some parts and probably suppressed the regeneration of other woody tree species including *P. africana*. *Prunus africana* a light demander and prefers disturbed areas with low percentage canopy cover and good penetration of light for seedlings and saplings recruitment for good regeneration (Hall, 2000; BIOTA, 2004; Fashing, 2004; Farwig, 2006; Abebe, 2008; Farwig *et al*,. 2008b; Weru, 2012; Owiny & Malinga, 2014). The north eastern and central part of South Nandi Forests and surrounding farmlands around Kobujoi experienced lower degradation which resulted to a high population *P. africana*. This can be attributed to its high regeneration and establishment under various conditions (Cheboiwo *et al.*, 2014). Conversely, the Southern part of the forest and the surrounding farmlands had low population of *P. africana* which can be attributed to difference in ecological conditions and anthropogenic pressures which might not favour the establishment of *P. africana* (Davis, 1994; Salem, 2003; Brummitt *et al,*. 2008 and Breugel *et al,*. 2011).

The overall diameter class distribution with a high percentage of large trees indicates unstable and intermittent population structure of *P. africana* in the forest hence threatening their survival in the future (Cunningham, 2008; Abebe, 2008; Kleinschroth, 2010; Girma, 2011; Girma, 2015). This pattern has been described by Mligo *et al.*, (2009) as interrupted, and Khan *et al.*, (2015) as unsatisfactory due to lack of replacement of the older tree implying static structural succession.

Although the seeds germinated profusely, there was poor establishment and survival to the subsequent levels. This observation has been reported as one of the main causes of the species population decline (ICRAF, 1997; Orwa *et al.*, 2009). Usually, *P africana* has a good reproductive performance manifested by high density of seedlings but survival is poor (Fashing, 2004; Abebe, 2008). This can be attributed to predation and extensive herbivory of seedling and saplings by livestock that results into low establishment and mortality at a given seedling stage (Tsingalia, 1989; Abebe, 2008; Khan *et al.*, 2015). Other factors affecting survival of *P. africana* are overgrazing (Abebe, 2008; Girma 2011), legal and illegal harvesting (Sunderland & Tako, 1999; Stewart, 2003; Navarro *et al.*, 2008; Betti *et al*., 2014; Ingram, 2014), invasive species (Jimu and Ngoroyemoto, 2011), climate change (Vinceti *et al*., 2013) and Fire (Betti, 2008).

The local communities targeted *P. africana* for firewood, timber and charcoal burning. Although majority of the population of *P. africana* had no signs of destruction, the study noted that those debarked were of medium DBH (81-100 cm). Other studies have also reported that younger individuals were targeted for debarking (Fashing, 2004; Jimu, 2011). Furthermore, herbalists have been reported to prefer medium sized individuals because they have a higher level of the medicinal compounds used for treatment (Gachie *et al.*, 2012).

The suitability distribution modelling of *P. africana* in South Nandi forest helped to predict where its population is expected to be high. Geographic Information System is an important tool for monitoring biodiversity (Davis, 1994). It has been adapted in determining the distribution patterns of various biodiversity components for better management and conservation (Gontier *et al.*, 2006; Breugel *et al.*, 2011). A database on biodiversity information has to be geographically based to increase certainty in predicting new population distribution and hotspots of endangered species with a limited known range (Salem, 2003; Gontier, 2007; Lung, 2010). The conservation priority map of *P. africana* in South Nandi forests has shown a high population to be found around Kobujoi area. Systematic collections and GIS data have been used to determine coverage of the target species which are interpreted primarily through the use of maps to help in identifying areas of high priority for conservation (Funk *et al.*, 1999). The limited resources available for conservation of biodiversity and ecosystem services call for prioritization scheme (Cunningham *et al.*, 2002; Brooks, 2010; Freudenberger *et al.*, 2013) indicating potential hotspots (Salem, 2003).

5. CONCLUSION AND RECOMMENDATIONS

The current study shows *P. africana* species are highly concentrated along North eastern area of SNF, with admirable number of mature individuals. The overall diameter class distribution with a high percentage of large trees indicates unstable and intermittent population structure of *P. africana* in the forest unlike a stable population in the surrounding farmlands. Grazing is a major conservation threat of the species in SNF. The *P. africana* conservation priority map is a useful tool for determining prioritization areas in South Nandi forest for the *in-situ* conservation efforts of the species. The study recommends that the *P. africana* hotspots forms part of the *in-situ* conservation measures to maintain a viable populations and used as a seed source for *ex-situ* conservation. Depending on the available resources, conservation efforts can be extended from conservation priority 1 to the other conservation. However, in order to ensure sustainable utilization of *P. africana*, there is need to conserve the whole forest in general.

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