LONG-TERM CHANGES IN LAND COVER, FLORISTICS AND STRUCTURE OF MPANGA FOREST RESERVE. FACTS FROM SATELLITE IMAGES AND OBSERVATIONAL PLOTS AND THEIR RELEVANCE FOR FOREST ECOLOGY AND MANAGEMENT

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Explore opportunities... for managing natural resources and a better life for all

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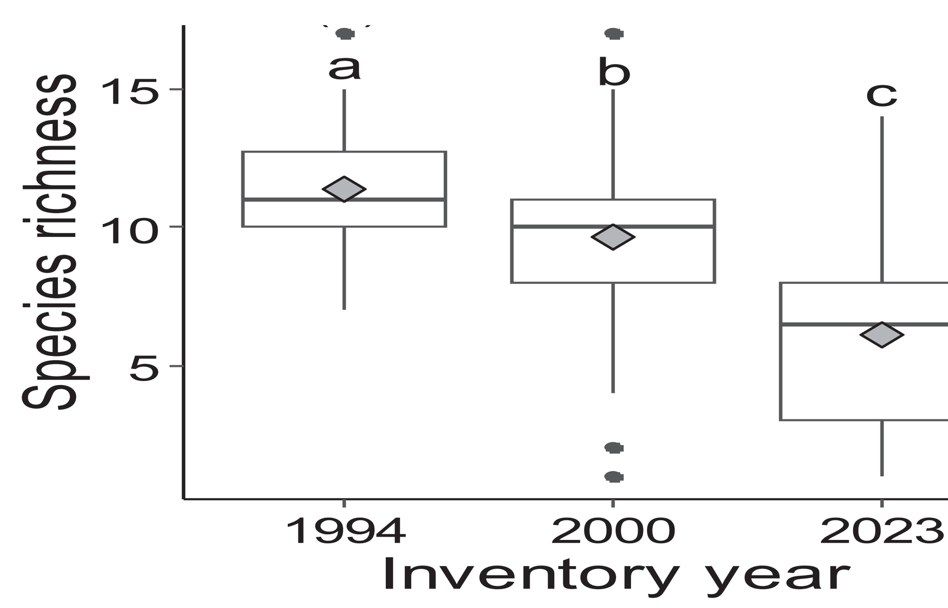
Highlights

- Between 1990 and 2023, the extent of natural forest, shrubland and grassland declined while settlements and cropland increased.
- Between 1994 and 2023, the tree species composition of Mpanga forest reserve shifted substantially mainly driven by changes in relative abundance of dominant species.
- A significant decline was recorded in tree species richness, stem density, basal area, aboveground biomass and canopy over while human activities, particularly cutting of saplings and mature trees increased.
- Tree species supporting economic activities of local communities through drum making showed disrupted regeneration and their long term survival is not guaranteed.
- We monitored land cover, floristics and structure in Mpanga Forest Reserve, central Uganda in 1990 -2023 and found drastic decline in forest integrity and an increase in extractive human activities.

Graphical abstract



INTRODUCTION

Tropical forests are crucial for the functioning of the earth system by storing vast amounts of carbon (Bonan 2008; Pan et al. 2011). They furnish habitat for much of the planet's biodiversity (Pillay et al. 2022), and support humans' livelihoods by providing a range of ecosystem services (IPBES 2019; Smith et al. 2023). However, tropical forests are under increasing pressure from anthropogenic disturbances (e.g. agriculture, logging, fires, mining, livestock grazing) which result in degradation and deforestation (FAO and UNEP 2020). Recently (2010–2020), Africa suffered the largest annual rate of net forest loss at 3.9 million ha (FAO 2020). Forest loss decreases the provision of ecosystem services (Thompson et al. 2013; Smith et al. 2023) and reduces ecosystem resilience to future perturbations (Ghazoul et al. 2015).

Monitoring the dynamics of the remaining forests, particularly in the long term, can help to detect the occurrence of adverse anthropogenic disturbances (Taylor et al. 2008) and assess the magnitude to which forests have been altered (Knapp et al. 2013). Besides, monitoring data could contribute to an understanding of ecological processes that include patterns of change in forest conditions (Sheil et al. 2000), maintenance of plant species diversity (Sheil 2001; Baker et al. 2004) and functionality of plant communities (Rees 2001). Moreover, this information is needed for planning, implementing and evaluating strategies for sustainable forest management (Knapp et al. 2013; Amaral et al. 2019). Include the study parameters with recent studies.

While the general trend of tropical forest loss is undeniable, our knowledge of long-term effects on stand characteristics and relevance for forest ecology and management is still limited, particularly in Africa. This deficit is in part because of the fewer long-term observational plots (see Taylor et al. 2008 and references therein). Where observational plots exist, they are costly to maintain (Taylor et al. 2008) and resample regularly.

This study aimed at reducing this gap by analyzing data from remote sensing (1990-2023), and repeat surveys of 30 observational plots (1994-2023) with respect to land cover, floristics (diversity and composition) and structure (basal area, aboveground biomass and tree height, regeneration status as well as human activities in Mpanga forest reserve in central Uganda

MATERIALS AND METHODS

Mpanga Forest Reserve (0°127'N, 32°175'E) (Fig.1) is an area of moist semi-deciduous forest that extends over some 450 ha of gently undulating land between 1140 m and 1200 m altitude in Mawokota County, southern Mengo, Uganda, 3 km to the southwest of the town of Mpigi and about 40 km to the west of Kampala (the main Kampala - Masaka road bisects the forest) (Taylor et al. 2008). The forest is surrounded by farmlands, wetlands and rapid rise in peri-urban human settlements. This has accelerated commercial trade as urban sprawl hits on.

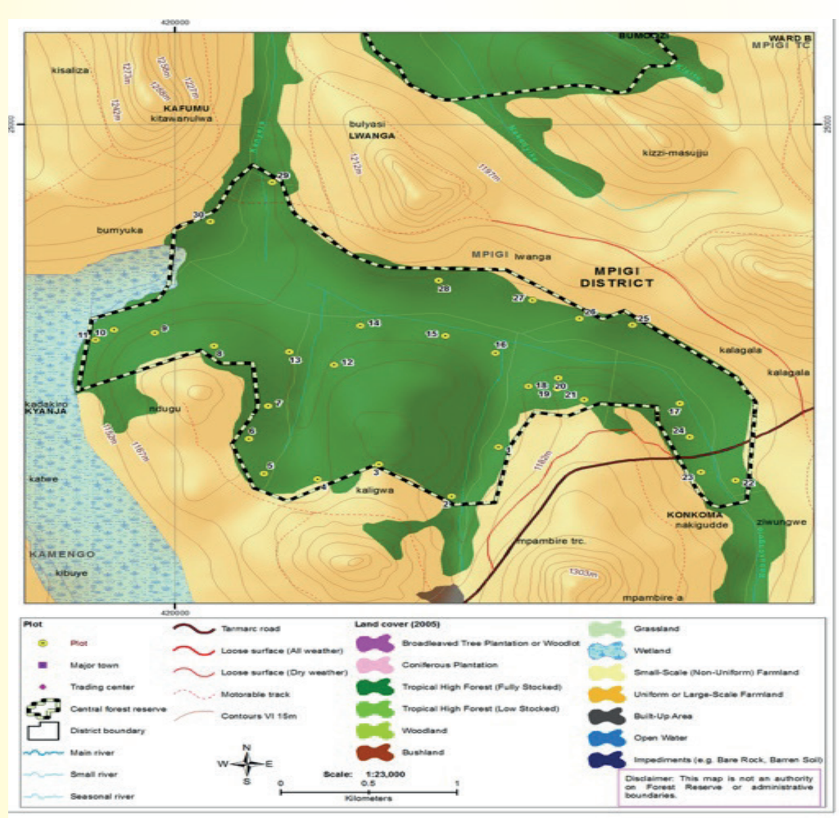


Figure 1: Mpanga Central Forest Reserve

Two rainy seasons as typical for the Lake Victoria zone are experienced, being between March and June as well as September to October. The average annual precipitation amounts to 1,170 mm p.a. and average lowest and highest temperature is 17.2 °C, respective 26.1 °C. The soil is "generally red and yellow latsols on hilltops and ridges, grey sands on lower-hill slopes and blue-grey clays and silts on the lowermost hill-slopes and in valley bottoms" (Baron et al. 2017).

The forest vegetation varies and is reported to have an abundance of the species Celtis mildbraedii and Trilepisium madagaskariense as well as Euphorbia teke in the understory of the forest, "Celtis-Aningeria associations" as characteristic for the slopes while Pseudospondias microcarpa, Erythrina excelsa and Canarium schweinfurthii reported to be common for the main forest (Akite et al. 2015).

METHODS

Flora assessment at forest plot level

Forest data were collected using random sampling technique of 30 circular concentric sample plots (IFRI Manual 1994). The location of the plots in the forest were based on coordinated random numbers. Once the center of a plot was located using GPS hand held receiver, three concentric circles were marked. In the inner circle (1 m radius), the amount of ground cover by herbs and seedlings was estimated. In the middle circle (3 m radius), shrubs, and tree saplings were identified, their heights estimated and stem diameter at breast height (dbh) measured (Fig 2). Saplings were defined as young trees with a maximum stem diameter greater than 2.5 cm, but less than 10 cm. In the outer circle (10 m radius) trees were identified, their dbh measured and total heights (Ht) estimated (Fig. 3). Further, on-site assessments of plot conditions in relation to human and natural disturbances were recorded (Namaalwa 2008). Canopy cover, soil texture, evidence of epiphytes were also recorded.

Figure 2: Tree measurement in Mpanga Central Forest Reserve

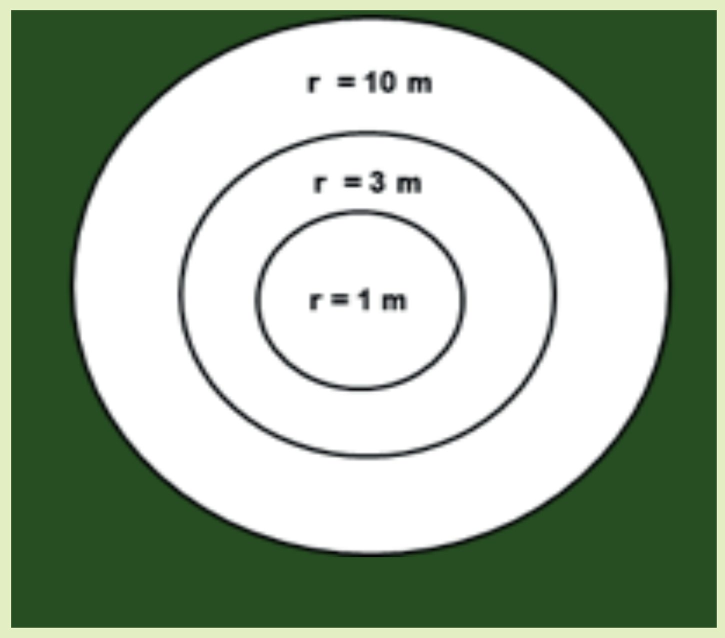


Figure 3: Tree measurement in Mpanga Central Forest Reserve

Figure 3. Concentric sample plots used for vegetation inventory in 1994, 2000 and 2023 in Mpanga Forest Reserve, Central Uganda. Shrubs and saplings (diameter at breast height, dbh = 2.5 - 9.9 m were recorded in the 3 m subplot and adult trees (dbh ≥ 10 cm) in the entire 10 m plot.

RESULTS

Spatial-temporal extents of land cover

Within the period of 30 years, there was either a decrease or an increase in each of the LULC classes in area of coverage and percentage (Table 1). Settlements and crop land (Agriculture) showed the highest positive change of 94.39% from the 1990 to 2022, and a change of 70.78% between the same periods.

Within the period of 30 years, there was a decrease in the natural forest cover by -29.01% as well as the scrubland by -82.41%. Between 2000 and 2010, there was an appreciation of the forest cover by 7.3%, but this was again curtailed between 2010 and 2022 which show a decline of natural forest cover by -36.8%. LULC classes in area of coverage and percentage (Table 8).
Table1: Land use land cover area (Ha) statistics for the period 1990 to 2022

Evidence of the land cover and land use Area (Ha) significantly reducing from 2010 to 2022 (Fig. 3) respectively.

Table 1: The LULC classes in area of coverage and percentages

Land use cover types	1990	2000	1990-2000	2010	2000-2010	2022	2010-2022	1990 - 2022
	Area(ha)	Area(ha)	%Change	Area(ha)	%Change	Area(ha)	%Change	%Change
Settlement	3.15	13.32	76.4	31.05	57.1	56.16	44.7	94.39
Scrubland	348.03	360.27	3.4	276.48	-30.3	190.8	-44.9	-82.41
Grassland	186.39	54.27	-243.4	138.15	60.7	224.01	38.3	16.79
Cropland	78.3	193.95	59.6	143.73	-34.9	267.93	46.4	70.78
Natural Forest	575.55	566.01	-1.7	610.47	7.3	446.13	-36.8	-29.01
Wetland	46.44	50.04	7.2	37.98	-31.8	52.83	28.1	12.10

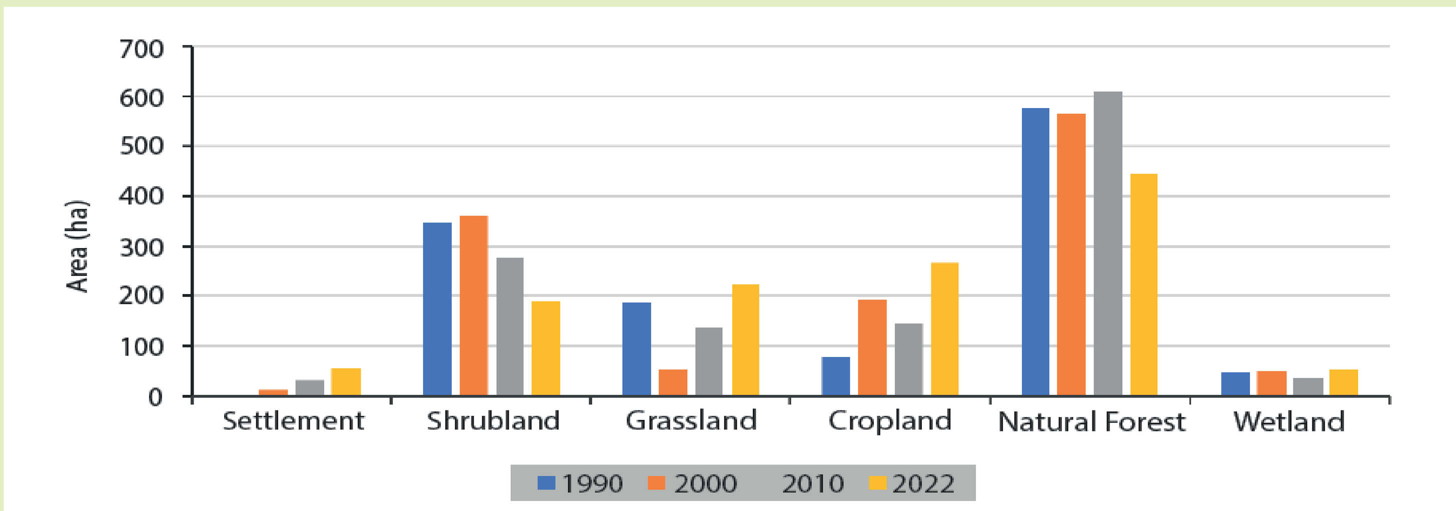


Figure 4: Evidence of the land cover and land use in and around Mpanga Forest

The spatio-temporal extents of land cover are shown in Fig. 5. In the 1990s the largest part of Mpanga site was predominantly forested with a total area of 575.55 hectares and a significant extent of scrubland with a total area of 348.03 hectares. In the year 2000, the scrubland show an increase of 3.4% while the natural forests show a decline of -1.7%. Between 2010 and 2022 the settlements (44.7%), the grassland (38.3% cropland (46.4%) and wetlands (28.1) are observed. Only scrubland (-44.9% and natural forest (-36.8%) are observed.

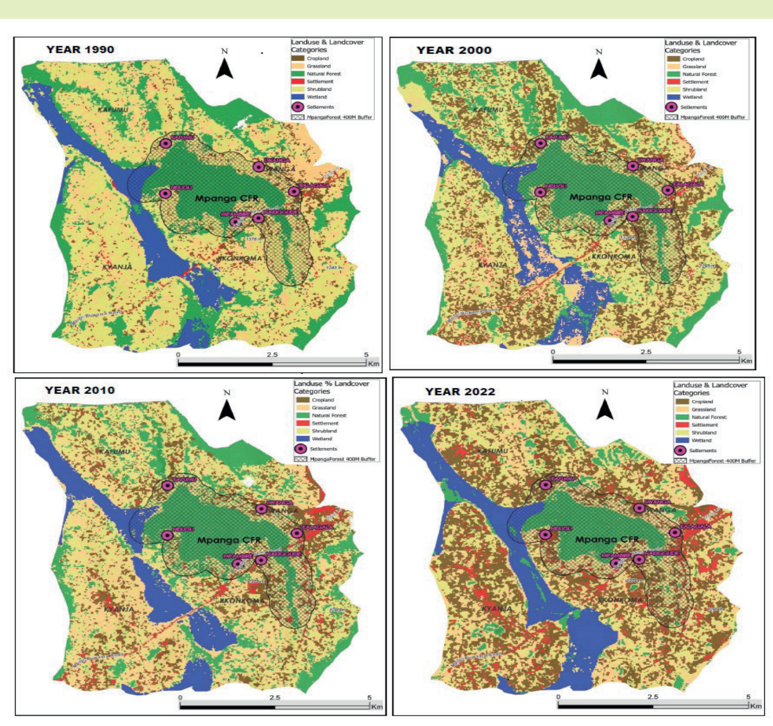


Figure 5: Results from satellite analysis

COMMUNITY UTILIZATION OF THE FOREST

The communities around the forest use it for different purposes ranging from fuelwood, timver drum making, medicinal collection and brick making. In the long run, these lead to loss of biodiversity and forest cover.

Conclusion and recommendations

Inventory data showed that tree species composition shifted due to a decline in relative abundance of dominant species. Species richness and structure (stem density, maximum height, basal area, and aboveground biomass) declined. Human activities like cutting of saplings and mature trees increased. Undergrowth density increased while canopy cover and dead wood declined. Tree species used for drum making showed disrupted population structures so their long-term survival is not guaranteed. These changes in land cover, floristics and structure affect ecosystem services and wildlife through reducing forest productivity and habitat availability. In order to recover the historical conditions, the forest could be restored through assisted natural regeneration and active restoration involving native species. The density of preferred tree species can be increased through enrichment planting within the forest. To reduce the pressure on the forest, domestication of preferred tree species through on-farm planting and farmer-managed natural regeneration need to be promoted in forest adjacent communities.

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