

# Carbon stock of Agoro Agu Central Forest Reserve, in Lamwo District, Northern Uganda

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# Abstract

Uganda has since not undertaken carbon stock inventories for these conservation areas, especially with dry Afromontane forests like Agoro-agu central forest reserve (CFR). This study was carried out to estimate carbon stock of Agoro-agu CFR, for its potential in climate change mitigation. A stratified sampling design was used, where 65 sample plots were established. Nested, fixed area circular sample plots with sub-plots of varying radii for tree height, diameter measurements and soil sampling. The mean total carbon stock of Agoro-agu CFR was estimated at 606.7 mg ha<sup>-1</sup>, for which 409, 72, 124 and 0.24 mg ha<sup>-1</sup> was stored as above ground carbon, below ground carbon, soil organic carbon and carbon in litter herbs and grass respectively. The study illustrates the carbon sequestration potential of the forest for any results-based payment projects for climate change mitigation, which calls for multi-stakeholders' collaboration from direct resource users to national level to enhance forest conservation and reduce forest degradation.

## Introduction

Forest ecosystems cover about a third of the total land mass on the earth's surface (FAO, 2020). These terrestrial biomes sequester and store carbon (C) through the process of photosynthesis thus contributing to the stabilisation of atmospheric Carbon dioxide (CO<sub>2</sub>) concentrations (Gibbs, Brown, Niles, & Foley, 2007; Kalaba *et al.*, 2013). Forests store C in five major pools which include; above-ground and below-ground biomass, deadwood, litter and soil carbon (IPCC, 2006). Intergovernmental Panel on Climate Change (IPCC) estimates a net uptake by terrestrial ecosystems from less than 1.0 to as much as 2.6 Pg C year<sup>-1</sup> for the 1990s (IPCC, 2006). Globally, forests store about 289 Gt of carbon (1 Gt = 10<sup>12</sup> g) in biomass alone, representing about 1,060 Gt CO<sub>2</sub>-equivalents (CO<sub>2</sub>-eq) (FAO, 2020), thereby playing a crucial role in global climate regulation (Betts *et al.*, 2008).

International negotiations, for example the Kyoto Protocol and Paris agreement (UNFCCC, 1997, 2015), to limit greenhouse gases also require an understanding of the current and potential future role of forest carbon emissions and sequestration in both managed and unmanaged forests. The 2007 Bali Action Plan acknowledges the importance of carbon accounting through reducing emissions from deforestation and degradation (REDD+), and the nationally determined contributions (NDCs) providing avenues of results-based payments for carbon offset projects. Certainly, developing countries have taken commitment to meet these ambitions which require an explicit understanding of the carbon sequestration potential of forest landscapes. It is clear that inventorying carbon of a forest is key for estimating carbon offsetting and its potential as a sink for carbon dioxide.

In Uganda, forest cover was estimated at 24% of total land area in 1990, which has declined to 2.5 million hectares (12%) in 2015 (MWE, 2015, 2018). Forest area loss to other land uses such as agriculture and settlements, contribute to loss of forest carbon stocks. This poses a great threat to the future of forests potential of providing ecosystem services and sector contribution to the country's gross domestic product (GDP). To this effect, Uganda reported her forest reference emissions level (FREL) in 2017 to the UNFCC

(MWE, 2018) which predicted that Tropical high forests stored up to a range of 61-240tha<sup>-1</sup> woodlands encompassing tropical shrubland and dry forests sequestered up to a range 9-94tha<sup>-1</sup> and plantations up to a range of 9-71tha<sup>-1</sup> (MWE, 2018).

Carbon stock assessments in tropical forest landscapes is through either direct or indirect approaches. Direct approaches involve the use of destructive sampling techniques to develop plot level or species-specific models to quantify biomass that is later converted into Carbon or tons of carbon dioxide equivalents (tCO<sub>2</sub>-eq), while indirect approaches employ developed allometric models or equations, tested form factors, area expansion factors and wood basic density (Leley et al., 2022). Each method has its pros and cons for example direct approach yields results with a high precision and reliability, it is costly in terms of time, with restrictions where a forest or a species is threatened with degradation and extinction respectively. Allometric equations are less time consuming and do not harm the subject under study (Chave et al., 2014). Depending on the concentration of study, models can be developed from species level, to habitat or biome level, to regional level to regional level (Pearson et al., 2007). This study uses allometric equations for dry pan tropic forests by Chave et al., (2014).

Dry forests represent about half of tropical and subtropical vegetation stretching from expanses of Africa, South America and the Asian Pacific (Okullo et al., 2021). Dry forests occupy areas receiving a tropical climate with precipitation ranging from 500–1500 mm per annum. Africa's dry forest landscapes account 70–80% of forested areas, and are mostly in highland areas between 1000–2700 m above sea level (Solomon et al., 2018). In East Africa, dry Afromontane vegetation extend from the southern part of Arabian Peninsula to the eastern arm of the rift valley in the Drakensberg Mountains. These ecosystems have been reported to be rich in biological diversity and as centres of endemism with various range-restricted species (Okullo et al., 2021). Agoro-Agu CFR is one of the dry Afromontane Forest in Uganda at the border of Uganda and South Sudan, in Agoro hills. Recent scholars have reported that Afromontane landscapes are biodiversity hotspots of both flora and fauna (Environmental Alert, 2017; IUCN, 2015). The vegetation of Agoro-Agu CFR is largely classified as dry Combretum savanna, wooded-savanna mosaics and dry highland forest dominated by *Combretum molle* R. Br ex G. Don, *Vachellia hockii* De Willd, *Hagenia abyssinica* Steud.ex. A. Rich and *Terminalia glaucescens* Benth species (IUCN, 2015; Okullo et al., 2021).

Dry land forests also act as sink and sources of carbon given their expansive nature and are reported to store about one third of global carbon budget (Leley et al., 2022). There is a wealthy body of literature on carbon stocks and storage potential of dry forests at both international and regional level but not to a commune level of Agoro-Agu CFR, considering the heterogenous vegetation communities of the area. Further, previous studies in Uganda have quantified forest carbon stocks but in moist montane forests and tropical rainforests. In the recent past, forest disturbances have been reported in the Agoro-Agu CFR landscape which is anticipated to affect carbon storage and greenhouse gas emissions of the forest. Therefore, this study was carried out to understand the carbon stock potential of Agoro-Agu CFR in Northern Uganda, whose result could provide baseline information to resource users and managers for any carbon-based projects in the Landscape.

# Materials And Methods

## Study area

Agoro-Agu CFR is found between 3°40'-3° 53' N and 32°42'-33°04'E, in Lamwo district, Northern Uganda which is about 460km from Kampala, the capital city of Uganda (Environmental Alert, 2017), and at an altitude of 2600 meters above sea level (Fig. 2). Gazetted in 1937, it occupies 26,508 hectares (Ha) of land with enclaves of Barley plantations (IUCN, 2015).

The forest reserve is drained by Okura stream in the East and Aringo stream in the West of the reserve. The CFR receives a bimodal rainfall pattern from late March or early April and late November, with highest in April and August, ranging from 800 mm – 1000 mm (Fig. 1). December to mid-March are the hottest months with temperature ranging between 20°C and 28°C (Environmental Alert, 2017; IUCN, 2015).

Gray-brown sands superimposing red clay or brown sandy loam soils describe the area. The vegetation of the landscape is largely Afromontane undifferentiated forest majorly of *Combretum* wooded landscapes, assemblages of low land bamboo, and *Acacia* thickets at the foothills of Agoro Agu hills (IUCN, 2015). The CFR is also said to have endemic species of the Eastern Afro Montane hot spot, and among the 15 forest reserves in Northern Uganda that were reported to have endemic species than any other forest reserve in Uganda (Okullo et al., 2021).

## Sampling Design And Procedure

Agora-Agu landscape was purposively selected because of its participation in Reducing Emissions from Deforestation and Forest Degradation (REDD+) pilot project, a high conservation value area and long history of deforestation and forest encroachment by the local communities (Blomley et al., 2017). A reconnaissance field tour of Agoro-Agu CFR was conducted in August 2021 with the help of the forest rangers and support staff under the instruction of the NFA administration. From this reconnaissance survey, land cover variations were identified based on the IPCC (IPCC, 2006) guidelines and the Uganda Biomass land cover map (Avitabile et al., 2011; Majaliwa et al., 2018). It is from this that site vegetation measuring and soil sampling were taken. A total of 65 sample plots were established randomly in the selected LCTs.

Stratified random sampling design based on land cover was employed to achieve precise biomass and carbon stock estimates. Stratification ensures that measurements are more alike within each stratum than in the whole sample frame (Pearson et al., 2007). For this study, temporary sample plots (TSPs) were laid. Fifteen parallel transects with 1 Km distance were laid throughout the forest at every 500 m distance apart. Nested, fixed area circular sample plots with sub-plots of varying radii, were laid out in the identified LCTs. Nested circular plots are efficient in inventorying individual trees that grow at different rates accounting uneven size distribution [13]. For each of these nested plots, three concentric plots of radii 20 meters, 14 meters and 4 meters were laid out at each of the sampling plot. So at every 400 m

along the transect, sample plots of 1,257 m<sup>2</sup>, (20m radius) and 50m<sup>2</sup> (4m radius) ( within the main plot) size were established for trees and shrub assessment, and grass, herb and litter sampling, respectively (T. Pearson et al., 2005). Five quadrant areas of (1m x 1m) were established along and the middle of the 4m radius circular plot for grass, herb and litter sampling from which a composite was prepared. Overall, a total of 64 sample plots were set up for C stock estimation and vegetation records. Number of plots were calculated using the following formula adopted from Pearson (T. R. H. Pearson et al., 2007):

$$n = \frac{(\sum_{i=0}^n Ni * Si)^2}{\frac{N^2 * E^2}{t^2} + (\sum_{i=0}^n Ni * Si^2)}$$

.....Equation (1)

where: E = allowable error or the desired half-width of the confidence interval. Calculated by multiplying the mean carbon stock by the desired precision (that is, mean carbon stock ×0.1, for 10% precision, or 0.2 for 20% precision), t = the sample statistic from the t-distribution for the 95% confidence level. *t* is usually set at 2 as the sample size is unknown at this stage, N<sub>*i*</sub> = number of sampling units for stratum *i* (area of stratum in hectares or area of the plot in hectares), n = number of sampling units in the population and S<sub>*i*</sub> = standard deviation of stratum *i*.

Plot data were extrapolated to full-hectare area to generate carbon-stock estimates (Mgha-1).

Extrapolation uses expansion factors by calculating the proportion of a hectare (ha) (1 ha = 10,000 m<sup>2</sup>), that is occupied by a given plot and so, this study adopted expansion factors outlined by (T. R. H. Pearson et al., 2007). That is, for a series of nested circular plots measuring 4, 14, and 20 m in radius being used, their areas equal 50, 616 and 1,257 m<sup>2</sup> respectively and so, their expansion factors for converting the plot data to a hectare basis are 198.9, 16.2, and 8.0 respectively.

## Biomass Inventory And Carbon Estimation

### Biomass Inventory

Tree species were identified and measured for diameter at breast height (DBH) (1.3 m aboveground level) and height (H) (Malimbwi et al., 1994). Whereas for the aboveground biomass (AGB) estimation, field transects of 200 m distance of circular sampling method were employed (T. R. H. Pearson et al., 2007). In the plot, local names of trees were recorded and identified with their English and scientific names based on (Kalema & Hamilton, 2020) book. Species not identified in field were collected (specimens), pressed and taken to Makerere University herbarium for further identification.

The biomass of herbs and litter were collected during the end of the rainy season, since it is the expected peak growth period. All the herbaceous vegetation emerging within the quadrant areas (1m x 1m) were cut at the ground level, weighed with a 100g precision balance to get a composite sample that was

placed in a marked bag for oven-dry mass determination in the laboratory (T. R. H. Pearson et al., 2007). For all samples collected, location data (x and y) coordinates were captured using Garmin GPS.

## Soil Sampling

Samples were collected for bulk density and soil organic carbon (SOC) analysis. Soil samples were taken from quadrants (1m<sup>2</sup>) found in the five directions (north, south, centre, east and west) of the inner circular sample plot. Samples for the determination of SOC were collected from 30 cm soil depth within 1 x 1 m quadrant where five (5) samples were picked by using auger, and the five soil samples were mixed to form a composite mixture (Pearson et al., 2007). Samples were air-dried then titrimetric method based on (Walkley & Black, 1934) method for SOC determination used.

## Carbon Stock Estimation

### Above ground Biomass and Carbon

A combination of forest inventories with allometric tree biomass regression models were used to determine the aboveground biomass (AGB) of the study area (Houghton, 2005; IPCC, 2006). These included; 1) The selection and application of an allometric biomass function for the estimation of individual tree biomass, 2) The summation of individual tree AGB to estimate plot AGB, and 3) The calculation of an across-plot average to hectare based.

In this study, the most recent pan-tropical tree AGB equation (Chave et al., 2014) based on  $D$ ,  $H$  and wood density ( $\rho$ , g cm<sup>-3</sup>) was adopted. Therefore, the following allometric equation was used to calculate the AGB:

$$AGB \text{ (kg)} = 0.0673(\rho D^2 H)^{0.976} \dots\dots\dots \text{Equation (2)}$$

where, where AGB is aboveground biomass of trees (kg),  $\rho$  is the specific wood density (g cm<sup>-3</sup>),  $D$  is the diameter at breast height (cm), and  $H$  is the average height of trees (m). Above ground carbon was estimated at 50% of AGB of the study area (IPCC, 2006).

Wood densities ( $\rho$ ) were sourced from the online databases (Ketterings et al., 2001; Zanne et al., 2009). However, where species-wise value was not found, genus-wise mean was used, and if genus-wise mean could not be calculated, the mean values for species in different regions were used (Gebeyehu et al., 2019).

The Chave et al., (2014) dataset is limited to only old-growth or secondary woody vegetation and deficient of other species and forestry systems. Therefore, a separate equation was used for *Acacia sp*, which are common in dry Afromontane forests in Uganda. The equation for *Acacia sp* AGB estimation was;

$$AGB \text{ (kg)} = \exp (-1.59 + 2.19 \times \ln (D) \times 1.05) \dots\dots\dots \text{Eq. (3)}$$

## Below-ground Biomass and Carbon

A regression model for tropical forests was adopted from Cairns (Cairns et al., 1997) to estimate below-ground biomass (living and dead, fine and coarse roots) as a function of above-ground biomass.

$$\text{Below Ground Biomass (BGB)} = \exp(-1.0587 + 0.8836 \times \ln \text{AGB}) \dots \dots \dots \text{Eq. (4)}$$

where BGB is below-ground biomass density in Megagrams per hectare (Mg/ha) and AGB is above-ground biomass density (Mg/ha).

## Herb and Litter Biomass Estimation

All litter and herbs within the frame and samples from the subplots were pooled and weighed of 100grams (g). A well-mixed subsample was used to determine the oven-dry-to-wet mass ratios to convert the total wet mass to oven-dry mass. The collected samples from herbs and litter were taken to laboratory, oven-dried at 70°C till constant weight was reached. For the forest floor (understory wood vegetation, herbs, grass, and litter), the amount of biomass per unit area was given by Pearson et al., (2007):

$$\text{Oven - dry mass} = \frac{\text{Sub sample Dry mass (kg)}}{\text{Sub sample Fresh mass (kg)}} * \text{Field Mass (kg)} \dots \dots \dots \text{Equation (5)}$$

The carbon content in herbaceous biomass was calculated by multiplying herbaceous biomass by 0.5.

## Soil Organic Carbon

Soil carbon analysis was from samples collected from the field TSPs. Soil samples of 100g were air-dried for 48 hours, well mixed and sieved through a 2 mm mesh size sieve. Then SOC was analysed following Walkley & Black, (1934), method with laboratory work conducted at Makerere University Soil Testing Laboratory. Bulk density was determined after drying the core samples of soil at 105°C where the weight of the soil was divided by the volume of the core sampler. The weight of the gravel above 2 mm diameter was subtracted to determine the bulk density of the soil samples.

$$\rho = \frac{ODW}{CV - \left( \frac{RF}{PD} \right)} \dots \dots \dots \text{Eq. (6)}$$

Where,  $\rho$  = Bulk density of the < 2mm fraction, ( $\text{gm}^{-3}$ ), ODW = Oven-dry mass of fine fraction (< 2 mm) in g, CV = Core volume ( $\text{cm}^3$ ), RF = Mass of coarse fragments (> 2 mm) in g, PD = Density of rock fragments ( $\text{g}/\text{cm}^3$ ) (Estimated at  $2.65\text{gm}^{-3}$ )

The SOC was estimated using [13]:

$$\text{Soil Organic Carbon stock} = [\rho * d * \%C]100 \dots\dots\dots$$

Equation (7)

Where,  $\rho$  = Bulk density ( $\text{gm}^{-3}$ ),  $d$  = depth of soil sample (cm) and %C = Percent carbon concentration

## Total Carbon Stock Estimation

The total carbon stock was calculated as a summation of all carbon pool stock using the following formula according to Pearson et al., (2007):

$$T C_{\text{Stock}} = C_{\text{AGB}} + C_{\text{LGH}} + C_{\text{BGB}} + \text{SOC} \dots\dots\dots \text{Eq. (8)}$$

where,  $T C_{\text{stock}}$  = carbon Stock [ $\text{Mg C ha}^{-1}$ ],  $C_{\text{AGB}}$  = carbon in above-ground biomass [ $\text{Mg C ha}^{-1}$ ],  $C_{\text{BGB}}$  = carbon in below-ground biomass [ $\text{Mg C ha}^{-1}$ ],  $C_{\text{LGH}}$  = carbon in litter, herb & grass [ $\text{Mg C ha}^{-1}$ ], and  $\text{SOC}$  = Soil organic carbon [ $\text{Mg C ha}^{-1}$ ].

The total carbon stock was converted to tons of  $\text{CO}_2$  equivalent by multiplying it by 44/12, or 3.67 Pearson et al., (2007).

Further, a Pearson correlation analysis was performed to determine the relationship between SOC and vegetation parameters. All analyses were performed in MINITAB version 14 at 95% confidence level. Tukey's honestly significant difference test was executed to separate means.

## Results

### Biomass and Carbon stock of different Carbon Pools

The total number of trees enumerated in the forest reserve were 677. Eighty-five species (85) were identified from 54 genera belonging to 28 families. The mean, maximum and minimum DBH of sampled trees was 21.04 cm, 42.84 cm and 2.87 cm respectively. *Ficus ingens* and *Oxytenanthera abyssinica* exhibited the maximum and minimum DBH respectively. The mean, maximum and minimum H of trees were 9.2m, 24.8m and 1.7m respectively. *Prosopis africana* and *Pterygita mildbraedii* recorded the minimum and maximum tree heights respectively.

The mean AGC stock of Agoro-agu CFR was  $409 \pm 32.5 \text{ Mgha}^{-1}$ . The first top five species which stored the highest above ground carbon stock of the reserve were *Vangueria apiculate*, *Ficus glumosa*, *Vitellaria paradoxa*, *Ficus saussureana*, and *Hymenocadia acida* with values of 784.87, 704.54, 525.47, 498.20 and 497.99  $\text{mgha}^{-1}$  respectively. While the lowest above ground carbon stock was reported in *Stereospermum kunthianum*, *Steganotaenia araliacea*, *Bridelia scleroneura*, *Vernonia amygdalina*, and *Bridelia scleroneuroides* at 8.10, 8.07, 6.35, 4.43 and 3.54  $\text{mgha}^{-1}$  respectively.

The mean BGC, SOC and carbon stock of litter, herbs and grass was  $72.32 \pm 6.13$ ,  $124 \pm 3.51$  (Fig. 3), and  $0.24 \pm 0.011$  mgha<sup>-1</sup> respectively.

The mean soil bulk density was  $0.60 \pm 0.012$  g cm<sup>-3</sup> with a range of 0.32 to 0.88 gcm<sup>-3</sup>. Plots located in the higher elevation, where human disturbances and encroachment are hardly reported recorded high soil bulk density values depicting the high mineral soils in the hills of Agoro-agu CFR. There was no much variation in soil organic matter, where 17.4% and 13.72% were the highest and lowest soil organic values of the study area.

The mean total carbon stock of all carbon pools in Agoro-agu CFR was  $606.7 \pm 37.9$  mg ha<sup>-1</sup>, with the total carbon values ranging from 168.6 to 1284.4 mg ha<sup>-1</sup>. The mean carbon stock across the carbon pool was statistically significant ( $P= 0.000$ ), with a 58% variation. There was a significant difference between soil organic carbon and DBH ( $P= 0.03$ ), while other pools remained insignificant.

## **Relationship Between Carbon Pools And Dendrometric Parameters**

### **Contribution and Pearson Correlation between Carbon pools and vegetation parameters**

The analysis of individual carbon pool contribution to the total carbon stock sequestered by the forest reserve showed significant variations. Much of the carbon in the forest is stored in above ground biomass (67.55%) followed by soil organic matter (20.49%), below ground carbon pool (11.92%), and litter, herbs and grass (0.04%) respectively. From this study result, litter, herbs and grass contribution to the carbon stock of the forest was insignificant.

A Correlation between carbon pools and tree parameters was tested using Pearson's correlation coefficient, which showed a significant positive correlation between height and DBH, AGC and DBH, and BGC and AGC.

Table 1  
Pearson's Correlation Coefficients and P-Values between Carbon Pools and Dendrometric Parameters

	DBH	H	AGC	BGC	SOC	LHG
H	0.906* 0.000	1				
AGC	0.239* 0.057	0.108 0.394	1			
BCG	0.134 0.291	0.024 0.851	0.748* 0.000	1		
SOC	0.367 0.33	0.235 0.62	0.132 0.297	0.051 0.689	1	
LHG	0.092 0.467	0.039 0.762	0.010 0.938	0.171 0.176	0.137 0.281	1

Notes: Pearson's correlation coefficients (Upper cell values), P-values (lower cell values); \*P < 0.05, H- height, BDH-Diameter at breast height, AGC-Above ground carbon, BCG-Below ground Carbon, SOC- Soil Organic Carbon, and LHG-Carbon in Litter, herbs and Grass.

## Discussion

### Carbon stock of Agoro-agu central forest reserve

Species that reported high carbon stock had high mean DBH. The result showed that DBH has a significant influence in carbon capture and storage of a forest over time. Most of these tree species were encountered in the higher elevation areas of the forest that are in undisturbed forest zone (Okullo et al., 2021). One of the impeding factors for forest growth and trees attaining a bigger diameter is rampant forest degradation and subsistence farming triggering deforestation, especially in the lower elevation of the forest reserve (Dibaba et al., 2019). The AGC and BGC in Agoro-agu CFR were higher than those estimated by IPCC (IPCC, 2006, 2014) for Afromontane dry forests in the tropics. The higher average carbon stock in above ground biomass in the study area is also largely attributed to DBH (Solomon et al., 2018) and maybe elevation that discourages human activities in the reserve.

The mean C stock in LHG in Agoro-agu CFR was generally low. This could be attributed to high rates of decomposition in the tropical areas but also because of the steep slopes, vegetation is under growth is limited upon litter being washed off to valleys (Binkley & Fisher, 2013). Further, a large section of the forest reserve is under a closed canopy with less light under growth. This later affects the soil properties to support grass and herb growth. The mean SOC of Agoro-agu CFR was higher than mean SOC of Tropical & Subtropical Moist Broadleaf forests (57 t ha<sup>-1</sup>) (Henry et al., 2009a). The differences in SOC between different biomes could be due to the diversity in tree, shrub species, variation in the physical and

chemical properties of soil and differing soil profiles, climate, elevation, anthropogenic disturbances, and process use to determine organic soil carbon content (Henry et al., 2009b). Whereas the current study reported more carbon in above ground biomass, it has been reported that the soil carbon pool stores vast amounts of carbon but under situations of deep rooting systems by the overlaying vegetation that recharges the soil bank through decomposition and transportation, minimum to no disturbances of the soils especially by human activities. Dedicated efforts to maintain the forest reserve with minimal disturbances will increase amount of carbon sequestered over time (Amundson, 2001; Ciais et al., 2021).

The mean carbon stock of Agoro-agu CFR was higher than that reported of any Afromontane dry forest. Previous estimates by IPCC (IPCC, 2006), show that sub-Saharan Africa tropical forests, tropical seasonal forests and tropical dry forest stored 200, 152 and 72 t ha<sup>-1</sup> respectively. The differences in carbon stock across different biomes could be explained by inaccurate determination of tree Dendrometric parameters of height and DBH, absence of site-specific or species specific allometric models, the presence relics with huge diameters accounting for high basal area, a higher population of woody species especially in secondary forests following natural (floods, natural fires, hailstorms, landslides) and anthropogenic modifications (Dibaba et al., 2019; Dixon et al., 1994).

Statistically significant positive correlation between DBH and H as well as AGC stock and BGC explains the fact that vegetation parameters, and diversity of plant communities affect carbon dynamics of a forest ecosystem (Doughty et al., 2015; Solomon et al., 2018; Sullivan et al., 2017).

## **Conclusion**

The current study quantified carbon stock across carbon pools in Agoro-agu central forest reserve and the result show on average, a high carbon stock storage compared to the average value previously reported of tropical forests. Across the carbon pools, AGC was the highest followed by SOC in the forest reserve. Nevertheless, the influence of litter, herbs and grass carbon pool was statistically insignificant. All carbon pools were positively correlated with Dendrometric parameters (DBH and H). AGC pool was statistically significantly correlated with BGC, and so does DBH and H. The result of a high carbon stock in Agoro-agu forest landscape illustrates the carbon sequestration potential of the forest for any results-based payment projects like REDD + for climate change mitigation. Dedicated efforts to enhance forest conservation and reduce forest degradation will require multi-stakeholders' collaboration from direct resource users to national level.

## **Declarations**

### **Statement on Conflict of Interest**

We declare no conflict of interest

### **Funding declaration.**

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### Author Contribution

**V.B:** Conceptualised the study, designed study methodology, collected data, analysed and drafted the manuscript;

**S.W.D:** Reviewed the study methodology, analysed and reviewed the Manuscript.

**M.S.M:** Supervised and guided field data collection, validated methodology, discussed the results.

**M.D-J:** Discussed the concept, analysed data and reviewed the manuscript.

All authors reviewed, validated and revised the manuscript.

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## Figures

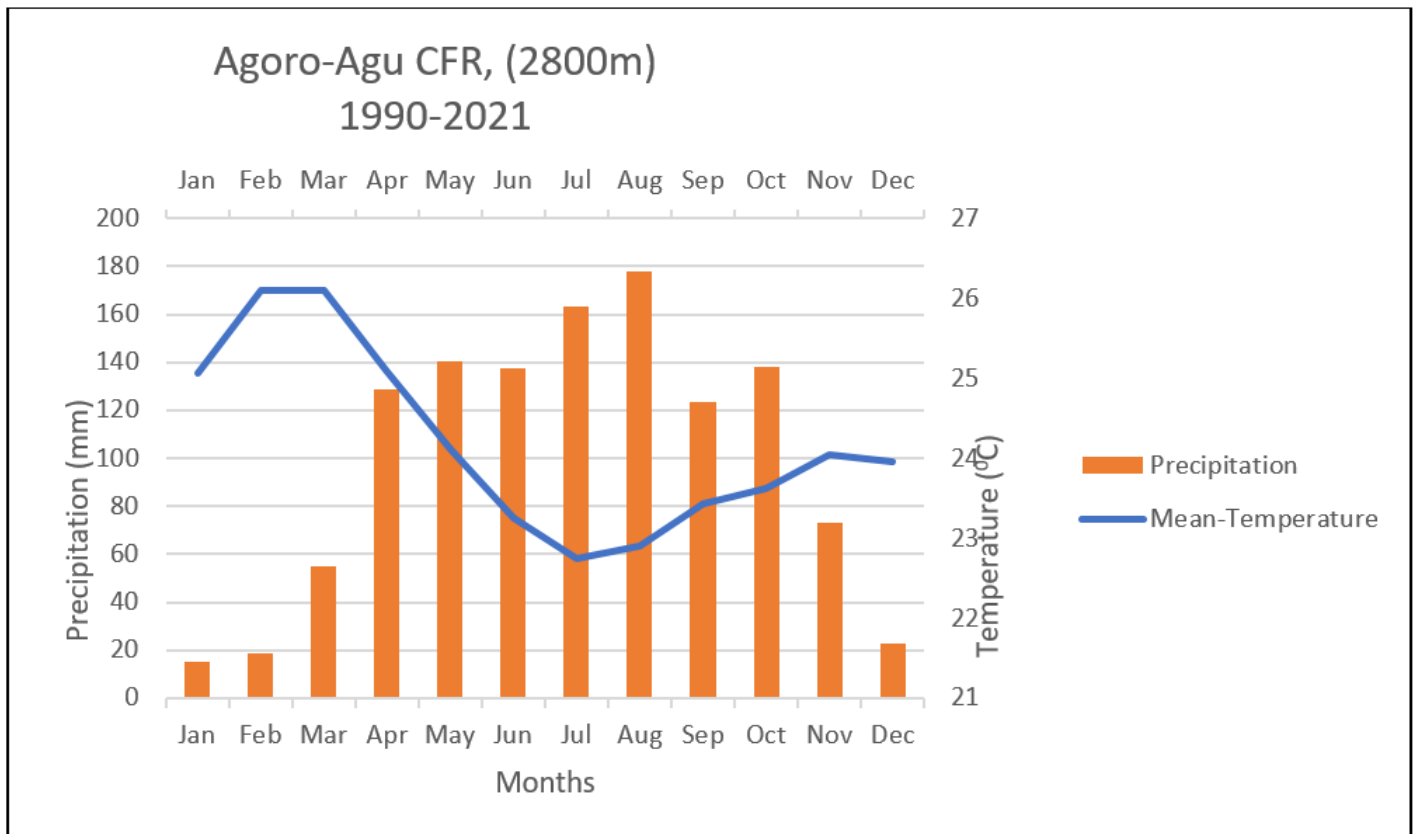


Figure 1

*Average Rainfall and Temperature of Agoro-Agu CFR (1990-2021).*

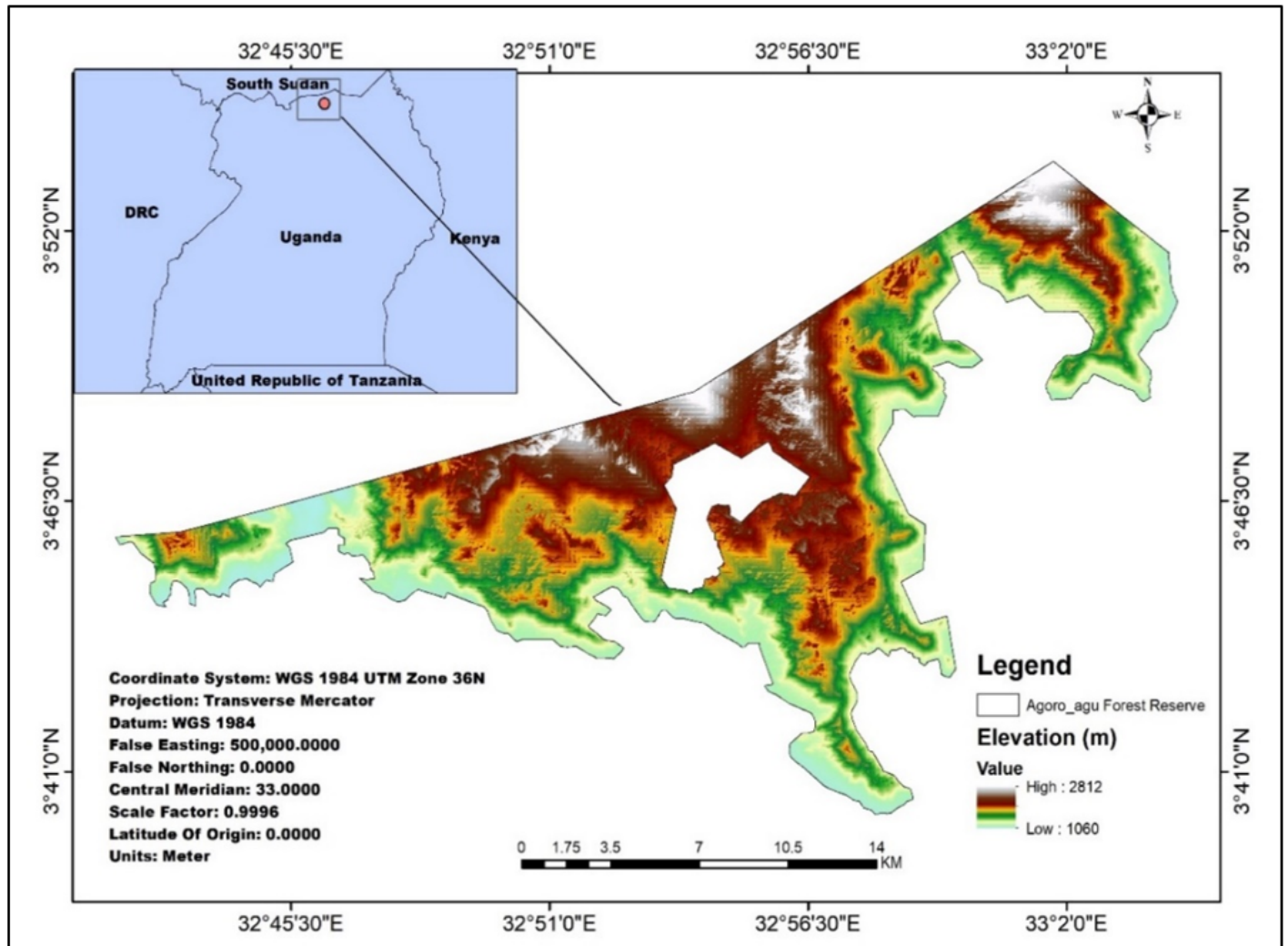


Figure 2

*Location Agoro-Agu CFR in Northern Uganda.*

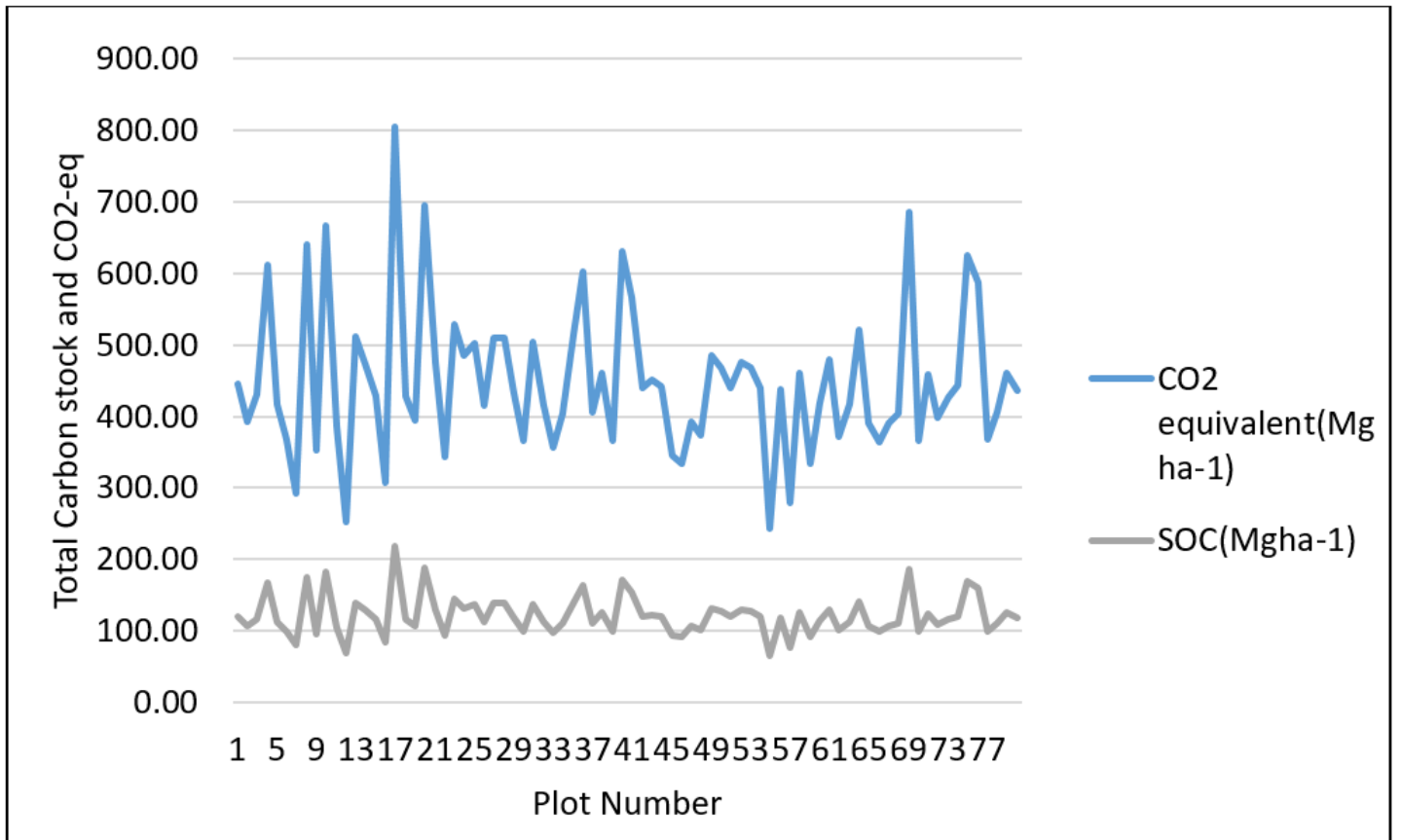


Figure 3

*Total carbon stock (TC) and CO<sub>2</sub>-eq per plot*

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