Original Research Article

Evaluation of Carbon, Nitrogen and Phosphorus Status and Variation across Disturbed and Intact Tropical Coastal Forest Sites

Abstract

This work aimed to evaluate the influence of tropical coastal forest disturbances, namely agriculture and livestock grazing, on soil fertility and nutrient cycling. The investigation done by evaluating differences in total carbon, total nitrogen and phosphorus as a function of land use. This work investigated and established the variation of soil nitrogen, total carbon and phosphorus across closed forest; crop-agriculture and livestock disturbed sites. The study provides useful information for local management strategies as it sets initial basic data on the soil status of Uzigua forest reserve after 50 years of crop-agriculture and livestock grazing pressure. Forty-seven (50m × 50m) quadrats were established on each land use for soil samples collection. Total nitrogen was analyzed by Kjeldahl acid-digestion, total carbon by the Walkley-Black procedures and phosphorus by Bray-II method. The mean values (percentage) were nitrogen = 16.07 ± 0.34, 1.75 ± 0.25, 6.5 ± 0.20; carbon =14.48 ± 0.23, 11.81 ± 0.13, 12.24 ± 0.30; phosphorus =14.12 ± 6.57, 17.74 ± 3.96, and 13.31± 2.86 for closed forest; agriculture disturbed and grazed sites respectively. There was a slightly lower amount of total carbon on crop agriculture disturbed sites than on the livestock grazed land uses. Carbon-nitrogen ratio was higher in closed forests than in the disturbed sites. The relationship between forest degradation and soil nutrient status is an indication that below-ground nutrient pools are mainly determined by activities, which disturb the above-ground biomass. To restore soil fertility status, it is important to establish the management of the disturbed sites through restoration of vegetation and minimize disturbances. Moreover, there is a need for research on how to improve the interplays across natural ecosystems, crop-agriculture and grazing schemes to minimize disturbances and sustain tropical coastal forests.

Keywords: Coastal forests; crop-agriculture; livestock grazing; soil disturbances; nitrogen; carbon; phosphorus.
Introduction

Although limiting forest disturbances is often viewed as essential for maintaining biodiversity, documentation show that there is incomplete, inconsistent, unreliable and limited information about the interplay of disturbance impacts on soils of forest ecosystems under various forms of land uses (United Republic of Tanzania [URT], 2015; FAO, 2015a). Research to support positive or negative impacts of disturbances on coastal forest soil nutrients content is lacking, especially in African countries including Tanzania (FAO, 2015a; FAO, 2010b). More specifically, comparative studies on the impacts of crop-agriculture and livestock grazing disturbances on the status and variation of soil chemical properties along the coastal forest ecosystems are poor. Hence, we conducted this study conducted to address this deficit. This was the first study at Uzigua Forest Reserve, which aimed to provide important initial information on soil status of the Uzigua forest following the past fifty years of anthropogenic encroachment and degradation, a condition requiring re-mapping of this forest in 2014-2017 and banning all anthropogenic activities as a step towards re-establishing a proper management scheme. This presented work investigated and established the variation of total nitrogen, total carbon and phosphorus across closed forest sites, crop agriculture and livestock grazed sites by using samples collected from Uzigua forest reserve. This forest has an area of 24,730 hectares and is a true representative of the disturbed coastal forests in Tanzania; still there is no existing documentation on soil health status after long-term disturbances. Findings from this study aimed to contribute to the establishment of a baseline that will be useful in mapping the dynamics of soil nutrients in the tropical coastal forest ecosystems to contribute to the information needed for management of forest after crop-agriculture and livestock disturbances (Deng, Sweeney and Shangguan, 2014).

This study was conducted in line with the understanding that forest ecosystems intimately linked to human life at both local and global levels (FAO, 2015a). The dependence of human life on forest ecosystems is evident (FAO, 2010b; FAO, 2015a, because forests play important roles, ranging from ecological functions (regulating the climate and water sources and by serving as habitats for plants and animals), and provision of goods (wood, food, fodder and medicines), recreation, spiritual values and other services (Wenhua, 2004; Pan et al., 2011; URT, 2015). Although forests are important in providing a wide range of services locally and globally, still they are under pressure of deforestation from increasing demand of land use-based products and
services, which frequently lead to different forms of forest conversion or degradation (Food and Agriculture Organization [FAO], 2012). Human based forest disturbances are brought mainly by selective harvesting, crop-farming livestock grazing, and damage by fire (FAO, 2010a; FAO, 2015b). In Tanzania, crop-agriculture and livestock grazing are the major agents of forest deforestation and disturbance causing massive loss of forest and forestry resources (URT, 2015). For example, deforestation has caused loss of forest area from 55 920 million ha in 1990 to 46 060 million ha in 2015 (FAO, 2015b).

Deforestation put Tanzania at the fifth position out of 10 countries in the world reporting the greatest annual forest area reduction (FAO, 2015b). The annual loss of forest in Tanzania was 372 000 ha, equivalent to 0.8 % of the country’s forestland use as per 2010 data (FAO, 2015a). This reported deforestation rate puts in jeopardy all efforts for sustainable management of forest ecosystems in the Tanzania. If not properly addressed, deforestation will continue to threaten the remaining 46 060 million ha (i.e. 52%) out of 88 850 million ha of the country’s total land use.

A number of the anthropogenic activities cause deforestation and conversion of forest ecosystems, which in turn result into soil degradation and loss of total nitrogen, organic carbon and phosphorus in the tropics (Barreto et al., 2016). Forest disturbances affect the properties of soils by causing loss of soil organic matter due to imbalance between materials entering and those leaving the ecosystem (Amlin, Suratman and Isa, 2014). Disturbances affect the interplay between inputs to soil organic matter by increasing or lowering decomposition of above-and belowground plant litter and animal excreta (Golluscio et al., 2009). Disturbance also affects outputs from soil organic matter pools by accelerating the mineralization and leaching of nutrients (Golluscio et al., 2009).

Deforestation and impacts on forest ecosystems along the coastal zone of Tanzania has been exacerbated by the rapid population growth of about 2.7% between the 2000s and 2010s (URT, 2016). This population increase is associated with the increased demand for crop and livestock production in the coastal zone of Tanzania. The current operations in crop-agriculture and livestock grazing cause forest ecosystem disturbance particularly in the coastal zone of the country. The problem is disturbing tropical coastal forests because anthropogenic activities are accelerated by climate change impacts forcing crop growers to expand their farms by
This pressure puts at risk the coastal forests that are the most affected forest ecosystems in Tanzania (Mligo, 2015).

Livestock grazing is putting more pressure on coastal forest ecosystems in 2010s than before because there is a massive shift of livestock grazing from central and northern parts of the country to the coastal zone searching pasture and water mainly for cattle (URT, 2016). For example, cattle population in the Pwani Region alone increased from 122,300 in 2002/2003 to 470,000 in 2011/2012 equivalent to an increase of 280% (URT, 2016). This increment puts more pressure on coastal forests located within 100 kilometers of the Indian Ocean, the zone where about 800 km² of forest ecosystems are located (Francis and Bryceson, 2001). Crop-agriculture, livestock grazing and climate change are currently threatening the biodiversity-rich coastal zone (IUCN, 2012). If not addressed now, the impacts will continue to affect this globally categorized biodiversity hotspot, which harbors about 1,500 of the world’s threatened 300,000 vascular plant species while records show that Tanzania coastal forest have already lost at least 70% of their primary vegetation (IUCN, 2012; Mligo, 2015).

Therefore, addressing the interplays between soil nutrients and vegetation in the disturbed sites of coastal forests is important in forest small sub-sector. The information on the status of soil health under crop-agriculture and livestock grazing forest disturbances are important in rescuing the remnant forests in management of tropical coastal forests. We conducted this study to test the following two hypotheses. (i) Closed forest sites have higher content of total carbon, total nitrogen and phosphorus than crop-agriculture and livestock disturbed sites. (ii) There is no significant variation of total carbon, total nitrogen and phosphorus between crop-agriculture and livestock grazing disturbed sites at 5% level of significance. The following question guided this research: how do total carbon, total nitrogen and phosphorus differ in closed forest sites from agriculture and livestock disturbed sites?

Material and Methods

Description of the Study Area
This study was conducted at Uzigua Forest Reserve (UFR), which is found in Mbwewe Ward in Bagamoyo District, Pwani region in the coast of Tanzania mainland (Figure 1). The forest covers an area of about 24,730 ha (URT, 2015). This forest is within 100 km of the coast of Indian Ocean and thus considered a coastal forest (Godoy et al., 2011). The Uzigua forest is supposed to be completely restricted from human use, serving for catchment and biodiversity conservation (URT, 2015). Unfortunately, this forest is overexploited by anthropogenic activities such as collection of fuel-woods, fodder, grazing pressure and encroachments for agriculture. These activities put UFR into among a few remaining coastal forests of Tanzania.

The impacts of disturbances on UFR is a challenge needing special conservation measures to rescue the diversity of plant species found in this ecosystem listed among the thirty-four (34) world biodiversity hotspots (IUCN, 2012; Mligo, 2015). Therefore, the UFR were purposely selected for this study because for the past fifty years, human activities such as production of crops took place without addition of any inputs and livestock grazing accelerated the degradation of UFR since the 1990s to the present. Indeed, the government has banned any anthropogenic activities in this forest from the year 2014, which have resulted in the abandonment of many farms and much grazing areas. Moreover, a little vegetation began to regenerate on the disturbed forest sites subsequent the stoppage of anthropogenic activities. Therefore, this forest provided good micro sites for studying comparatively the coastal forest disturbances, particularly on soil carbon (TC), nitrogen (TN) and phosphorus (P) status.

**Climate of the Study Area**

The UFR is located in the tropical and sub humid area with 700 mm to 1000 mm rainfall, with the temperature fluctuating within the annual mean of 24.3°C. The soils are well-drained, red, sand clay, loamy with brown friable top soils covered by more or less decomposed litter. The area is progressing with continuous hills ranging between 300 to 600 meters above sea level. This altitudinal range crated a wide range for coastal forests to harbor high diversity of forest trees species (Silayo, et al., 2006). However, the current climate change and human activities along the coast have greatly influenced temperature, rainfall, and the distribution pattern of plant species and their composition at large (Mligo, Lyaruu and Ndangalasi, 2009).
Figure 1: A map of study area (Ligate, Chen, & Wu, 2018)

**Sampling Design**

A systematic sampling design used in this study. To cover a representative sample of forested blocks and disturbed sites in UFR, the stratification approach was adopted from (Tomppo et al., 2014; URT, 2015). A comparison between impacts of disturbances on soils was studied under each site subjected to different land uses (LU). For comparing impacts of disturbance on soils chemistry, 47 random plots were established in the three major LU (i.e., closed forests (CFS) crop-agriculture (ADS) and livestock disturbed sites (DGS)).

**Data Collection**
Prior to intensive field data collection, reconnaissance surveys were conducted to get geographical coordinates, which were used to produce stratified different LU. We used satellite image interpretation to identify areas for ground study (Backéus et al., 2006). The LU classes were identified and developed by checking on the images and corresponding mean layer values, and normalized difference vegetation index (NDVI). The NDVI were used in LU classification together with support vector machine (SVM) classifier for processing images. The closed forest, agriculture and grazing lands were classified from mean layers. Site selection were conducted based on patterns of human activities (crop-agriculture and grazing) as supported by the maps. Conspicuous land-cover changes because of deforestation, agriculture and grazing were considered as the main criteria to obtain ADS and DGS for collection of soil samples (Peres, Barlow and Laurance, 2006).

**Soil Sampling**

Soil survey and sampling were collected from May to August 2016 at UFR sites. From each of the three strata (CFS, ADS, DGS), soil samples were collected using an Edelman auger at 1-30cm (topsoil) as adopted from (Curran et al., 2003; Aref, Atta and Ghamde, 2011; Berber, Tavşanoğlu and Turgay, 2015). During sampling, the attention was to make sure that soil samples were collected from disturbed and undisturbed sites (FAO, 2009). The soil samples in each quadrat were then mixed together to make one composite sample to eliminate variability. One hundred and forty one (141) soil samples were collected (47 soil samples at each LU) drawn at 50m × 50m sampling plots, which were stratified and purposively selected. Representative samples put into tightened double plastic bags, labeled and stored at 40°C to reduce further microbial degradation. Fresh air dry and oven dry weights were determined before subjecting soil samples to further laboratory analysis.

**Soil Sample Analysis**

Soil parameters TN, TC and P were analyzed by following the standard protocols for soil analysis as follows: (i) Determination of TN was done following the Kjeldahl acid-digestion procedures (Kjeldahl, 1883), (ii) Soil TC was analyzed by the Walkley-Black Procedures where by Potassium Dichromate (K_2Cr_2O_7) and concentrated Sulphuric acid (H_2SO_4) were used to produce the reaction and products as shown in this chemical reaction: 2Cr_2O_7^{2-} + 3C_0 +16H^+ \rightarrow 4Cr^{3+} + 3CO_2 + 8H_2O (Walkley and Black, 1934). In computing the results, a correction factor of 1.33 applied to adjust the organic carbon recovery because of incomplete oxidation in Walkley-
Black combustion procedures. (iii) Available phosphorus was determined by the Bray-II method (Bray and Kurtz, 1945). The Statistical Package for Social Sciences (SPSS) version 20.0 used together with MS-Excel computer program to run statistical analysis for getting mean and t-values at 5% significance level for TN, TC, and P between and across CFS, ADS and DGS.

Results

For comparing the differences between and across closed forests, agriculture and livestock disturbed sites; the following consistence were maintained in the presentation of results. The mean and t-values were kept constant in the order of TN (CFS vs. ADS), TN (CFS vs. DGS), and TN (ADS vs. DGS); TC (CFS vs. ADS), TC (CFS vs. DGS), TC (ADS vs. DGS); P (CFS vs. ADS), P (CFS vs. DGS) and P (ADS vs. DGS) for total nitrogen, carbon and available phosphorus consecutively.

Variation of Total Nitrogen across Land Uses

Total nitrogen variation between CFS vs. ADS was \( t = 11.66, p < .001 \). Due to the means values of TN between CFS and ADS, and the direction of t-value, we can conclude that there was a significance difference (%) of TN in CFS and ADS from 13.07 ± 0.34 to 11.75 ± 0.25, a difference of 1.32 ± 0.11; TN variation in CFS vs. DGS was: \( t = 2.21, p < .032 \), with a mean difference from 13.07 ± 0.34 to 12.57 ± 0.20, a variation of 0.50 ± 0.23; TN in ADS vs. DGS showed a variation of \( t = 5.34, p < .001 \), with mean difference from 11.75 ± 0.25 to 12.57 ± 0.20, i.e. 0.82 ± 0.15 TN-variation between ADS and DGS showed that TN in DGS is higher than in ADS.

Variation of Total Carbon across Land Uses

Total carbon differences between CFS vs. ADS was: \( t = 11.80, p < .001 \). Due to the mean values of TC between these two LU and the direction of t-value, a conclusion was drawn that there was significant difference (%) of TC from CFS to ADS (i.e. 14.48 ± 0.23 to 11.81 ± 0.13), a difference of 2.67 ± 0.23; the difference of TC between CFS vs. DGS was: \( t = 7.66, p < .001 \) with the mean values differing from 14.48 ± 0.23 to 12.24 ± 0.30, a significant difference of 2.24 ± 0.29, and TC in ADS vs. DGS was: \( t = 2.18, p < .035 \) and the mean difference was 11.81 ± 0.13 to 12.24 ± 0.30, showing a variation of 0.43 ± 0.19, this variation shows that there was less TC in ADS than in DGS.
Variation of Available Phosphorus across Land Uses

The available phosphorus variation between CFS vs. ADS was: \( t = 24.78, p < .001 \). Due to the means values of phosphorus between CFS vs. ADS, and the direction of the t-value, it was concluded that there was a significant difference of available phosphorus between these two LU from 13.12 ± 6.57 to 11.97 ± 6.96, a variation of 1.15 ± 0.93; variation of available P between CFS vs. DGS was: \( t = 4.04, p < .001 \), with the mean difference from 13.12 ± 6.57 to 10.12 ± 2.86, a difference of 3.00 ± 1.56 and variation in available phosphorus between ADS vs. DGS was: \( t = 1.54, p < .131 \), with a mean difference from 11.97 ± 6.96 to 10.12 ± 2.86, a difference of 1.85 ± 0.10.

Carbon-Nitrogen Ratio across Land Uses

Carbon-nitrogen ratio variation between CFS vs. ADS was: \( t = 3.97, p < .001 \). Due to the mean values of CN ratio between CFS vs. ADS, and the direction of t-value, it was concluded that there is a significant difference of CN ratio between these two LU i.e. from 8.62 ± 2.84 to 9.88 ± 2.91, a difference of 1.26 ± 2.77; variation of CN ratio between CFS vs. DGS was: \( t = 2.33, p < 0.02 \), with the mean difference from 8.62 ± 2.84 to 6.53 ± 2.06, a difference of 2.09 ± 0.57, and variation in CN ratio between ADS vs. DGS was: \( t = 2.94, p < .001 \), with a mean difference from 9.88 ± 2.91 to 6.53 ± 2.06, a difference of 3.35 ± 1.39.

Variation of TN, TC and P against Elevation

Between 300-390 m elevations, differences in each nutrient (percentage) were TN in ADS > CFS > DGS; TC was in the order of CFS > DGS > ADS while P was in the order of CFS > ADS > DGS. Between 391 to 447 m, TN was in DGS > ADS > CFS; TC was recorded in CFS > DGS > ADS; while P was in CFS > ADS > DGS orderly. At the elevation of 448-500 m, TN was DGS > ADS > CFS; TC order was TFS > ADS > DGS; P was DGS > CFS > ADS. Across the study sites, there were negative correlations between nutrients levels and elevations. This trend indicates that with increase in elevation there is unit loss of nutrients (Figure 2-1: a, b, c, d, e, f, g, h and i).
Figure 2: Correlation between nutrients levels (%) and elevation (masl×10^2) (a = TN in CFS vs. elevation, b = TN in ADS vs. Elevation, c = TN in DGS vs. Elevation, d = TC in CFS vs. Elevation, e = TC in ADS vs. Elevation, f = TC in DGS vs. Elevation, g = P in CFS vs. Elevation, h = P in ADS vs. Elevation and i = P in DGS vs. Elevation.

Correlation (R2) of TN, TC and P within Land Uses

The correlation (p = .05) between TN, TC and P within LU were:- (i) positive correlation between TN & TC in ADS (R^2 = 0.59); TN & TC in DGS (R^2 = 0.84); (ii) weak positive correlation between TN & TC in CFS (R^2 = 0.18); TN & P in CFS (R^2 = 0.14); TN & P in ADS (R^2 = 0.01); TN & P in DGS (R^2 = 0.12); TC & P in DGS (R^2 = 0.11); (iii) negative correlation between TC & P in CFS (R^2 = 0.07) and TC & P in ADS (R^2 = 0.17).

Correlation of TN, TC and P across Land Use

The correlation (p = .05) between TN, TC and P between LU showed both positive and negative relationships as follows: (i) strong positive correlation between: TN in CFS and ADS (R^2 = 0.62), TN in CFS and DGS (R^2 = 0.96), TN in ADS and DGS (R^2 = 0.61), TC in ADS and DGS (R^2 = 0.97), P in CFS and ADS (R^2 = 0.98), (ii) weak positive correlation between TC in CFS
and DGS \((R^2 = 0.09)\), TC in CFS and DGS \((R^2 = 0.15)\), (iii) weak negative correlation between P in CFS and ADS \((R^2 = 0.14)\) and P in ADS and DGS \((R^2 = 0.18)\).

**Discussion**

This discussion is presented on the basis that this work had some challenges emanating on the lack of baseline data about TN, TC and P status along the coastal zone of Tanzania. Hence, the discussion mainly focuses on the existing differences of soil nutrients and identifying the possible causes of variation under the hypothesis that disturbance type and associated cumulative severity affect the distribution and structure of forest vegetation and soil properties (Amato et al., 2011). To establish the variation, we based our discussion on closed forest sites as our control for comparison with the disturbed sites. Indeed, our findings suggest that disturbances cause impacts on above-ground and under-ground forest ecosystems hence causing differences in nutrients across different land uses (FAO, 2009; URT, 2015).

**Variation of Total Nitrogen across Land Uses**

Forests subjected to crop-agriculture and livestock grazing have different TN status. Closed forest sites contain a higher amount of TN than that found in ADS or DGS. It is explained that both crop-agriculture and livestock grazing contribute to making the soil susceptible to erosion and hence loss of nutrients (Golluscio et al., 2009), in which the impacts are not the same between agriculture and livestock disturbed sites as supported by the finding by that DGS had the lowest amount of TN across all the three LU. The low content of TN in DGS concurs with Golluscio et al., (2009); Xing et al., (2014); Zhong et al., (2014).

The findings suggest that disturbance reduces nitrogen mineralization, a process occurring in DGS and ADS than CFS because there is low moisture content following the fact that disturbances affect vegetation and thus land is exposed to solar radiation (Qu et al., 2016). These findings agree with other researches that low TN content in DGS (for example), is because livestock grazing decreases the input of organic matter and expose litter to photo-degradation (He et al., 2011; Salazar et al., 2000; Qu et al., 2016). Therefore, we establish that photo-degradation cause excessive loss of N from DGS than in ADS (Golluscio et al., 2009). However, the low content of TN in DGS is contrary to findings by Britton, Pearce and Jones, (2005); Bai et al., (2012). This controversial observation is that, we expected DGS to contain higher amount of TN because of inputs from livestock excreta mainly urine as documented in Hoogendoorn et al., (2010).
From our results, it seems that the small amount of N inputs from excreta does not make up for the amount lost because of disturbed biomass. Low return of N from grazing animals is explained in part by the fact that livestock grazing in these forest sites is mainly a free-range system, under which animals randomly grazed and therefore there is no guarantee of the return of nutrients from excreta in a particular piece of grazed land. The low amount of TN in DGS as compared to that in ADS explained by the fact that while grazing sites are left bare, cultivated farms have the advantage of harboring plant species (crops and weeds) that check soil erosion and photo-degradation. In addition, there is partial recycling of nutrients from crop residues and weed decomposition. Therefore, it is reasonable for DGS to contain relatively low amount of TN as compared to ADS and CFS (Zhong et al., 2014).

**Variation of Total Carbon across Land Uses**

Grazing within coastal forest ecosystems randomly done and so the current grazing system does not provide the redistribution of carbon and rapid increase in soil TC also reported in Kane, (2015). The low amount of TC in ADS and DGS proves that most degraded and depleted soils of agro-ecosystems contain lower soil organic carbon pool than those under natural ecosystems, as is supported in Lal (2012). The low amount of TC in ADS as compared to that in any of the other LU sites indicates that farming activities are responsible for soil carbon reduction supported in Syswerda et al., (2011) and Kane, (2015). In this view, farming accelerates soil heterotrophic activity and typically leads to carbon loss (Syswerda et al., 2011; Kane, 2015). Indeed it is possible that low amount of carbon in ADS and DGS is limited by nutrients, predominantly nitrogen and phosphorus in addition to other environmental constraints (Wang, Law and Pak, 2010).

Carbon depletion in the degraded coastal forest as represented by the Uzigua ecosystem is contributed by clearing and burning vegetation for farm preparation. It reported that farming in this way has been a common practice for over 50 years since independence in 1960s. During all these years, crop production had been characterized by conversion of forest into agricultural land without addition of mineral fertilizer or manure, so the natural nutrients pool is depleted (Lal, 2012). Although DGS showed a high amount of TC, yet it is below that found in CFS. This implies that grazing practices accelerated forest cover loss and hence affect carbon sinks above and below ground (Syswerda et al., 2011). The effect of livestock grazing in soil TC storage shows that herbivores may facilitate or depress TC deposition rates as compared to crop-
agriculture and closed forests (He et al., 2011). The impacts of livestock grazing in TC show that there is an indirect relationship between animal grazing activities above the ground and underground ecosystems as supported by Wardle et al., (2012). This relationship is explained by the difference in values of TC between CFS and DGS as supported by Golluscio et al., (2009); Britton et al., (2005); Bai et al., (2012).

**Variation of Phosphorus across Land Uses**

Available phosphorus is among the important nutrients in any ecosystem as it plays roles in driving cellular energy cycles and building the molecules of DNA and RNA in plants (Buendia, Kleidon and Porporato, 2010). The difference for P across CFS, ADS and DGS imply that ecosystem disturbances cause positive or negative impacts on the availability of this nutrient (Block, Knoepp and Fraterrigo, 2012). The results showed low content of P in ADS and DGS, which is explained by the fact that conversion of forest land into ADS and DGS reduces the amount of P because of the exposure of bare land to processes of soil runoff, erosion and percolation (Buendia et al., 2010). However, Groppo et al., (2015); Schmitz, Hawlena and Trussell, (2010) and Wardle et al., (2012) challenge the establishment of P decline in the livestock disturbed sites. This literature shows that livestock grazing supplements P by excretion and egestion processes contrary to our results. Therefore, our findings suggest that coastal forest disturbances affect the above ground biomass and hence lower the amount of P in soils supporting the findings of Bai et al., (2012).

**Carbon-Nitrogen Ratio across Land Uses**

Carbon-nitrogen ratio, as an important factor for determination of the capability of soil and storage of carbon varied from CFS to ADS and DGS in our studies of UFR like in a study by (Swangjang, 2015). The variation in CN ratio is important in forest ecosystem health because carbon plays an important role in the energy content (carbohydrate) of plant species and production of CO$_2$ in soil ecosystem and nitrogen is essential for plant growth (Pausch and Kuzyakov, 2012). This ratio plays a significant role in regulating soil organic matter mineralization (Swangjang, 2015). Therefore, this ratio has implications in soil fertility. The findings showed that soil CN ratio in the coastal forest decreased in the order CFS > ADS > DGS, possibly reflecting a higher degree of breakdown of humus stored in ADS and DGS as
compared to CFS (Kennedy, Yang and Cohen, 2010). However, these results contradict the trend in the CN ratio discovered by Zhang et al., (2016). Our results portray that as breakdown of organic matter proceeds, those easily decomposed materials disappear and nitrogen possibly get immobilized in microbial biomass and decay products supporting some findings in Kennedy et al., (2010). The process of breakdown and immobilization leaves behind more recalcitrant material characterized by slower decomposition rate because only a few microorganism such as fungi can break these materials (Zhang et al., 2016). These processes lowers the CN ratio in ADS and DGS than in CFS. The low CN ratio influences TN dynamics as it causes faster decomposition of organic matter and mineralization of nitrogen by microorganisms (Groppo et al., 2015). From our findings, we state that the impacts of converting land from native forests to ADS and DGS have contributed to affect microbial activities and thus forest disturbances are considered to degrade the rate of organic matter, which is the main source of nutriments in soils (Zhang et al., 2016).

The Variation of TN, TC and P across Land Uses

The differences in soil TN, TC and P across CFS, ADS and P as presented in this study generally indicate that activities such as crop-agriculture and livestock grazing contribute to different alteration of nutrients depending on the differences in LU. The lower amount of TN and TC found in ADS and DGS as compared to CFS agrees with the findings in Groppo et al., (2015). However, the trend of P was contrary to Groppo et al., (2015). In our study, these three nutrients declined from CFS to ADS and DGS. From this trend, it is evident that anthropogenic activities have a major contribution to variation in nutrient pools in forest ecosystems supporting the findings in Bai et al., (2012). Agriculture and livestock grazing activities affect the health status of soils by altering vegetation cover and the physical properties of soil (Eff, Eynolds and Elnap, 2005).

Lower content of the three nutrients in ADS and DGS across the study sites is the indicator that disturbed soils contained little organic matter because of inadequate vegetation life in the past years, which lead to a lack of humus and therefore low nutrient content (Aubault et al., 2015). The differences in nutrients status between ADS and DGS show that, although all disturbances cause impacts in soil properties, there are some degrees of variation between the category of
disturbances and any particular nutrient. For example, across all the nutrient states, DGS has the
least amount of any of the nutrients except TC, which was higher than that in ADS. The
difference in nutrients status across is used to explain that any conversion of natural forest lands
to artificial LU results into loss of nutrients such as TN and TC (Zhang et al., 2016).

**Correlation of TN, TC and P across Land Uses**

We found a positive correlation between soil TN and TC in this study. Such correlation was
significant especially in ADS and DGS than in other land uses. This relationship shows that TN
variation goes hand in hand with TC spatially and quantitatively as supported by Groppo et al.,
(2015). These findings suggest that there are some degrees of TN decline in the same direction of
TC in disturbed forest sites. These observations agree the existing documentations that loss of
vegetation because of human activities such as agriculture and livestock grazing affect bulk density,
and the decomposition organic matter and mineralization of soils nutrients are effected too
(Golluscio et al., 2009; Syswerda et al., 2011; Bai et al., 2012).

Such effects contributed to the nature of variation correlation we found in ADS and DGS in this
study. We observed weak positive correlation between TN and TC in CFS, TN and P in CFS, TN
and P in CAS, TN and P in DGS and, TC and P in DGS. These kinds of relationships show that
variations existing between these elements in these land uses are partially independent. Weak to
negative correlation between either TN and P or TC in CFS and ADS shows that TN or TC do
not increase or decrease to the same direction in agreement with Bai et al., (2012). However, the
weak correlation in variables is contrary with Block et al., (2012). This controversy could
emanate on different ecological systems with differing climatic conditions such as temperatures
and rainfall, which could affect TN, TC and P mineralization differently (Block et al., 2012).

In this article it is established that the variation of nutrients across land uses provide useful
information that clearing vegetation for various human activities contributes to physical losses of
organic compounds from leaching and other processes that may alter the nutrient content of litter
and returns to the soil and plants uptakes (Anzoni, Rofymow and Ackson, 2010). The
assumption that the loss of vegetation above the ground influences soil fertility status is also
supported by Xuluc-Tolosaa, et al., (2003) as leaf litter aboveground is the main input of
nutrients to the soil. Indeed, the amount of plant available nutrients affect natural and managed
ecosystems largely (Anzoni et al., 2010). Therefore, processes that disturbs vegetation can also
have a significant effect on nutrient cycles and nutrient limitation (Wang et al., 2010).

Conclusion
We conclude that the comparison of soil nutrients between closed forests, agriculture and
livestock disturbed sites of Uzigua Forest Reserve indicates that there are significant degrees of
variations in TN, TC and P content across different forms of land use. Although these differences
not directly defined as caused by human activities forest disturbances, the findings are useful to
establish relationships between nutrient status of intact coastal forests and that of sites subjected
to crop and livestock grazing. We partly suggests the interdependence of above and belowground
component of forests. Therefore, crop-agriculture and livestock grazing affect aboveground
biomass, which in turn affect the underground storage of nutrients. The study suggests that if
crop-agriculture and livestock grazing are to be integral part of coastal forest management,
the studies are needed to devise crop-agriculture systems and grazing stocking rates that will
sustain coastal forests. These activities should take place within limits, for example to take
advantage of nutrient cycling between grazed animals, crop residues and forest ecosystems.

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