Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.15, 2014

Effect of Human Settlement and Altitude on Rangeland Browse Woody Species Biodiversity and Productivity in Kafta-Humera Woreda, Tigray, Ethiopia

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Abstract
A research was conducted in Kafta-Humera districts of the Northern Ethiopia with the objective to determine the effect of human settlement on rangeland wood species productivity and biodiversity under three altitudinal ranges (600-1000, >1000-1400 and >1400-1800 m.a.s.l.) and along three distance intervals near (0-2 km), middle (2-4 km) and far (4-6 km) from settlement. The Statistical Package for Social Sciences (SPSS, version 16.0, 2013) was used to analyze the soil and vegetation data. In the study districts, a total of 46 woody species were identified. Browse biomass of woody species in the low, middle and upper altitude categories were, 180.47, 225.97 and 243.72 kg ha^{-1}, respectively. Browse biomass of woody species near, middle and far distance from settlement were, 145.30, 228.03 and 276.824 kg ha^{-1} respectively. Woody species diversity was increased with increasing altitude, and was significantly lower near to settlement than middle and far distance. Far distance from settlement had significantly higher in organic carbon, available phosphorus and available potassium than middle and near distance from settlement. The upper altitude had significantly higher organic carbon, organic matter, available phosphorus and available potassium than the lower and middle altitude. In conclusion, the study area was highly dominated by the thorny shrubs woody species. This implies that there is undergoing reduction biodiversity and productivity degradation. Therefore, appropriate plan of biodiversity conservation such as establishing, designing and implementations of watershed management for physical and biological conservation should be planned to minimize loss of biodiversity.
Keywords: Settlement, plant Species composition, plant species abundance, plant Species diversity, biomass production

1. Introduction

Plant species are highly damage due to high animal grazing pressure and human activities around human settlement areas (Brinkmann, 2009). Settlement influence the composition and abundance of woody plant species, patterns of soil nutrient redistribution and finally, these patterns influence the productivity and diversity of pastoral systems (Jefferey, 2007).

In Kafta - Humera satellite imagery in 2000 (before resettlement) and 2007 (after resettlement) was taken to know the degree of change in land use and cover related to settlement. The results of the spatio-temporal analysis showed decreased in woodland by 25.8% and an increased in arable land by 21.8%, and in 2011 after ten years arable land increased almost by 100%, woody vegetation cover reduced by 42% (Moti *et al*., 2011).

Settlements in Ethiopia have been studied widely. Though, most the studies have been focused more on the social and economic outcomes, planning and implementation (Pankhurst, 2005; Hammond, 2008). There has been rather not enough research undertaking at present time, to address some of the fundamental problems with the effect of human settlement on rangeland woody diversity, productivity and soil characteristics (Gebrehaweria, 2011; Moti *et al*., 2011).

Therefore this study was conducted with a general objective of determining the effect of human settlement on rangeland wood species productivity and biodiversity as well as soil characteristics in Kafta-Humera, in northern Ethiopia. And the specific objectives were:

- To determine the effect of human settlement on woody species composition, plant abundance and species diversity under three altitudinal range and distance away from human settlement in Kafta-Humera district of northern Ethiopia; and
- To investigate the effect of human settlement on rangeland woody biomass production and soil characteristics under three altitudinal ranges and distance away from human settlement in Kafta-Humera district of northern Ethiopia;

2. Materials and methods

2.1 Description of the Study Area

The study was conducted in Kafta-Humera District of Tigray National Regional State in north-western Ethiopia

(Figure 1).

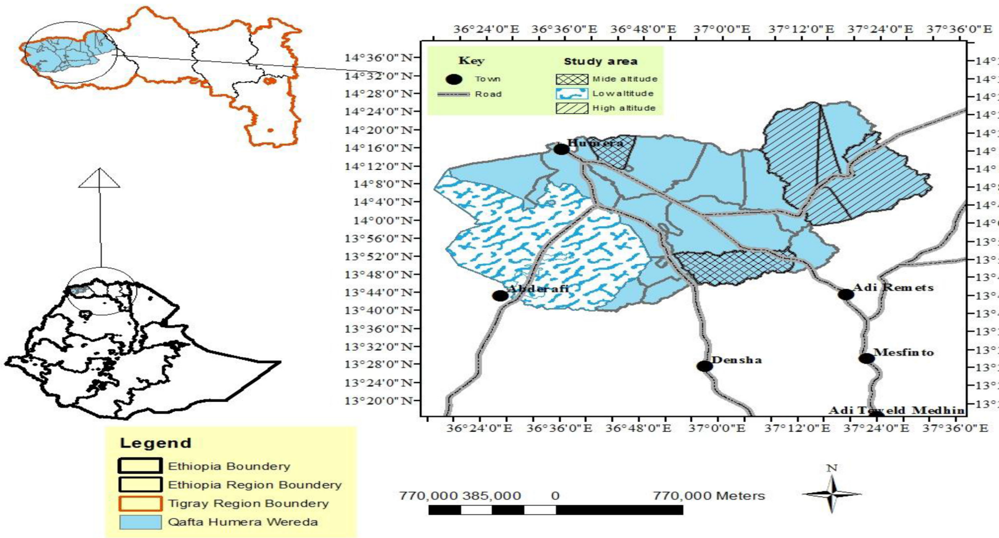

Figure 1: Location of Kafta-Humera, the study area

The District is located between $13^0$40'and $14^0$27'N, and $36^0$27'and $37^0$32'E. It covers an area of 160650 ha and its altitude ranges from 560 to 1849 m.a.s.l. The mean maximum temperature varied from 41.7^0C - 33^0C while the mean minimum temperature varied from 22.2^0C - 17.5^0C. The rainfall ranges from 448.8 -1102.5 mm (Hailesilassie, 1998; EARO, 2002).

2.2 Methods of Data Collection

Vegetation data were collected in a random sample area of 50 m x 50 m at each distance from settlements with in each altitude. Twelve quadrats were random taken at each distances, totaling 108 = (3 attitudes x 3 distances x 12 quadrats). Three composite soil samples in each distance from settlements under each altitudinal ranges were pooled and yielding a total of 27 soil samples.

2.3 Statistical Analysis

Ordination of sampling sites under the three altitude and three distances from settlements was done by multivariate techniques, using Conoco (Ter Braak, 1997). Ordination of woody species was done by a Principal Component Analysis (PCA). In addition, the correlations of soil parameters with the woody species were done using a Redundancy Analysis (RDA).

Woody species composition similarity among distance from settlements was estimated by the model Jaccard coefficient of similarity according to Krebs (1998). Biomass of selected browse woody species was estimated using the model of Petmak (1983). The diversity indices for woody species, plant abundance of each species and species evenness data were estimated using PAST software (Koleff *et al*., 2003).

To test differences in woody species diversity, plant abundance, soil characteristics and biomass production, a General Linear Model (GLM) was applied using SPSS software (version.16). Moreover, Jaccard coefficient of similarity (Magurran, 2004) was used to test the differences on species compositions similarities along altitudinal range and distance from settlement. Tukey multiple comparison was used to test significant differences among the means.

Soil analyses were done in Mekelle, Ethiopia Agricultural Research Center for organic carbon (OC), organic matter (OM), total nitrogen percentage (TN %), available potassium (K), available phosphorus (P), pH and percentage of soil textures (clay, silt and sand).

3. Results and discussion

3.1 Woody species composition

In the study area a total of 46 woody species have been identified. In the lower altitude of the study area, a total of 27 woody species were identified. *Acacia mellifera*, *Adonsonia digitata*, *Boswellia papyrifera*, *Dichrostachyus cinerea*, *Grewia bicolor* and *Termmalia brownii* were the most dominant woody species for all distance. In the middle altitude, *Acacia bussei*, *A. mellifera*, *D. cinerea*, *ziziphus abyssinica* and *Ziziphus spina-christi* were the top five dominant encountered woody species for all distance. *A. bussei*, *Carissa edulis*, *D.*

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cinerea, *Dovyalis abyssinica*, *Maytenus senegalensis* and *Senna singueana* were also common to the upper altitudes for all distance intervals (Table 1).

The ordination result showed a clear separation of the 9 sites for the woody species, as the distance interval from settlement in each altitudinal ranges are clustered separately (Figure 2a). The first and the second ordination axis explained cumulatively 98% of the total variance extracted by the PCA. The result of the sampling site x soil parameter using RDA showed higher relationships with woody species on the first and second ordination axis with a correlation coefficient of 0.998 and 0.993, respectively. The first and second ordination axis explained 95.5% for the total cumulative variance of woody species to soil relation extracted by the RDA (Figure 2b).

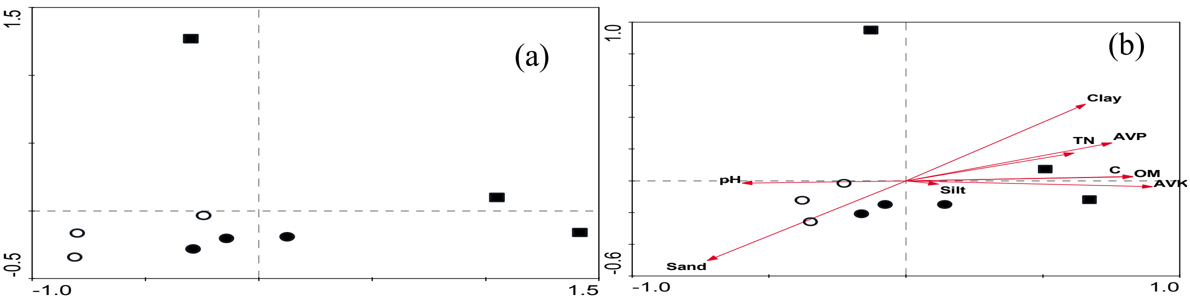

Figure 2: Ordination diagram of the 9 sample sites for woody species (a) and sampling sites x soil parameters for woody species (b) under 3 altitudinal ranges(open circles = low altitude; filled circles = mid altitude and filled squares = high altitude) in Kafta-Humera, Northern Ethiopia.

In the lower and middle altitude, *A. mellifera* and *D. cinerea* were the most dominant woody species near to the settlements. *A. bussei, D. cinerea, D. abyssinica* and *M. senegalensis* were the common woody species to the upper altitude near to the settlement (Table 1). Most of the dominant woody species in the study area were thorny woody species and comparatively their relative abundance was higher than of the other woody species. They can, therefore, be considered as the best indicators of intensively degraded rangelands of the area. This finding was in agreement with the study of Moti *et al*. (2011).

Table 1: List of woody species with their relative abundance (N0.25 ha^{-1}) under three altitudes (m.a.s.l.) and three distances from human settlement (km) in Kafta-Humera, northern Ethiopia

	Altitudinal Ranges								
	600-1000			>1000-1400			>1400-1800		
Woody species	0-2	2-4	4-6	0-2	2-4	4-6	0-2	2-4	4-6
Acacia abyssinica	0	0	0	5.4	11.3	8.4	7.4	9.3	15
Acacia bussei	1	0	7.3	13	7.8	14	16	2	12
Acacia mellifera	15.2	11.2	16.3	14	16.6	8.2	5.7	3	2
Acacia nubica	0	0	0	0	6	0	0	0	0
Adonsonia digitata	3	3	1	0	0	0	0	0	0
Albizia amara	0	0	0	4.5	4.7	7.4	0	0	0
Anogeissus leiocarpa	5.3	12.4	4.8	10.5	9.2	7.8	5.2	8.6	7.1
Balanitesa egyptiaca	3.8	6	9.2	13.3	0	8.5	0	9	0
Bosica angustifolia	4	0	0	0	7	7.5	0	3.5	4
Boswellia papyrifera	12	8.64	7.6	9.4	9.5	9.5	0	0	0
Bridelia cathartica	0	0	0	2	0	0	9	12.5	6.8
Capparis tomentosa	0	0	0	0	0	0	5.5	12	7
Carissa edulis	0	0	0	0	0	0	7	13	16
Combretum collinum	9.4	12.1	6.1	0	8.7	8	0	0	0
Combretum hartmannianum	6.7	6.8	11.8	13.7	18	0	6	6.1	6.3
Combretum Sp1.	4.5	6.5	18	0	0	0	10	8.3	9.9
Commiphora africana	1	0	9.6	0	0	0	0	0	0
Dalbergja melanoxyylon	6.3	14.7	5.9	13.8	10	10	0	0	0
Dichrostachys cinerea	17.1	18.5	21.1	18.8	17.1	19	12.7	27.5	23
Dodonea angustifolia	0	0	0	0	0	0	6.5	8.1	13
Dovyalis abyssinica	0	0	7	8	15.1	9.4	18	9.6	11
Erica arborea	2	0	0	0	0	0	0	0	0
Ficus glumosa	0	0	0	0	8	8	0	0	0
Ficus sycomorus	0	0	0	0	0	0	0	10.5	0
Gardenia ternifolia	0	0	0	0	0	0	4.5	6.1	6
Glumosa pittos	0	10.1	4	11	0	0	0	0	0
Grewia bicolor	0	27.5	11	4	5.7	8.1	0	0	0
Lannea frutcosa	3.7	6	7	9.5	6	5.7	5	7.8	6
Lonchocarpus laxiflorus	0	0	0	0	0	0	0	6	0
Maytenus obscura	0	0	0	0	0	0	4.3	9.5	0
Maytenus senegalensis	0	0	0	0	0	0	12.7	12.4	23
Nuxia congesta	0	8	2	0	5	4	0	6.3	1
Piliostigma thonningii	0	0	0	0	7.5	9	0	0	0
Pterocarpus lucens	0	0	8	0	0	0	0	0	0
Pterollobiu stellatum	0	0	0	0	0	0	5.8	6	8
Rhus nataliensis	0	0	0	0	0	0	5.1	7	7.4
Senna singueana	0	0	0	0	0	0	12	13.3	8
Table 1 continued									
Sterculia africana	4	6.5	0	7	0	11	0	0	0
Sterospermum kunthianum	1	2.5	10	0	8.3	11	4.6	6	10
Tamarindus indica	0	4	9.2	8	12.3	10	0	0	0
Termmalia brownii	9	8.8	5.3	0	0	0	0	0	0
Ximenia americana	6	0	3.5	8.3	0	0	5.3	10	7.3
Ziziphus abyssinica	0	6	0	7	21.5	10	2.5	5.5	7.3
Ziziphus spina-christi	7.5	5	10.8	12.3	9	11	3.6	8.8	12
Ziziphus mucronata	0	0	0	0	0	0	3	0	11

3.2 Browse species biomass production

3.2.1 Effect of distance on browse species biomass at different altitudinal ranges

Leaf browse biomass of woody species in the low altitude, far distance from settlement was significantly higher than near distance to settlement. In the middle altitude, leaf browse biomass of woody species near to settlement was significantly lower than of the other two distances. Leaf biomass of woody species in the upper altitude was significantly increased with distance from settlement increased (Table 2). This might be related with the browsing intensity of cattle and goats across to distance from settlement area.

3.2.2 The effect of altitude on browse woody species biomass

In all altitude, browse biomass were significantly increased with increased altitude (Table 2; $F_{2,99}$ = 11.97, P < 0.000). Browse biomass of woody species in the low, middle and upper altitude were, 180.47, 225.97 and 243.72 kg ha^{-1}, respectively (Table 2).

3.2.3 The effect of distance on browse species biomass

Browse biomass of woody species were significantly increased with distance increased from settlement (Table 2; $F_{2,99}$ = 49.70, P < 0.000). Browse biomass of woody species near, middle and far distance from settlement were, 145.30, 228.03 and 276.824 kg ha^{-1}, respectively (Table 2). This result could be related to the decreasing of browsing intensity animals and human activities with increasing distance from settlement.

Table 2: Effect of altitude and distances on Shannon diversity index, evenness, total plant abundance (N 0.25ha^{-1}), species richness and browse biomass (kg/ha) of woody species in Kafta-Humera rangelands, northern Ethiopia

	diversity	Evenness	Plant abundance	Species richness	biomass
Altitudinal ranges					
600-1000					
0-2	1.59^{b}	0.812^{a}	60.50^{b}	6.58^{b}	130.52^{b}
2-4	1.86^{a}	0.842^{a}	85.67^{a}	7.75^{b}	177.17^{ba}
4-6	2.01^{a}	0.785^{a}	88.17^{a}	9.67^{a}	233.72^{a}
>1000-1400					
0-2	1.71^{b}	0.866^{a}	104.25^{b}	7.16^{b}	146.053^{b}
2-4	2.17^{a}	0.896^{a}	175.42^{a}	10.58^{a}	244.835^{a}
4-6	2.34^{a}	0.899^{a}	190.17^{a}	11.58^{a}	287.032^{a}
>1400-1800					
0-2	2.08^{b}	0.837^{b}	130.58^{c}	9.50^{c}	159.342^{c}
2-4	2.30^{a}	0.896^{a}	187.83^{b}	11.00^{a}	262.094^{b}
4-6	2.30^{a}	0.918^{a}	209.00^{a}	11.00^{a}	309.721^{a}
Altitude (A)					
F (df= 2,99)	25.73	17.80	93.71	28.32	11.97
P	0.000	0.000	0.000	0.000	0.000
Distance (D)					
F (df= 2,99)	30.51	4.31	40.11	40.08	49.703
P	0.000	0.016	0.000	0.000	0.000
(A) * (D)					
F (df= 4,99)	2.24	2.78	3.21	4.30	1.03
P	0.07	0.031	0.016	0.003	0.393
Adjusted R^2	0.515	0.307	0.718	0.577	0.528

Df = degree of freedom, F-ratio = F test value, P value = probability value**,** A = Altitude, D = Distance. Means with the same letter in columns are not significantly different at P ≤ 0.05

3.2.4 Woody species similarity

In all altitude, species similarity was high between far and middle distance from settlement with in the same altitude range. less species similarity was recorded between low and high altitude distance intervals from settlement (Table 3).

Table 3: .Jaccard coefficient of similarity for woody species under three altitudes (m.a.s.l.) and three distance from human settlement (km) in Kafta-Humera rangelands, northern Ethiopia

	Altitudinal ranges								
	600-1000			>1000-1400			>1400-1800		
	0-2	2-4	4-6	0-2	2-4	4-6	0-2	2-4	4-6
600-1000									
0-2	-								
2-4	0.54	-							
4-6	0.67	0.68	-						
>1000-1400									
0-2	0.43	0.43	0.33	-					
2-4	0.42	0.42	0.43	0.54	-				
4-6	0.45	0.45	0.31	0.42	0.31	-			
>1400-1800									
0-2	0.28	0.29	0.33	0.38	0.31	0.27	-		
2-4	0.29	0.26	0.29	0.37	0.34	0.34	0.80	-	
4-6	0.31	0.32	0.33	0.31	0.34	0.30	0.84	0.85	-

3.4. Soil Parameters

3.4.1. The effect of altitudinal and distance on soil Parameters

3.4.1.1. The effect of distance on soil Parameters at different altitudinal ranges.

In the low altitude range, far distance interval was significantly higher in percentage of organic carbon and organic matter as well as available phosphorus and the percents of sand contents than near distance to settlement. In the middle altitude percentage of organic carbon and organic matter of soil were significantly lower in near distance than far distance from settlement. In the upper altitude, percentage of organic carbon and organic matter, available of phosphorus and available potassium of soil contents were recorded significantly higher in the far distance from settlement than near and middle distance from settlement (Table 4).

3.4.1.2. The effect of altitude on soil Parameters

Sand soil content had showed significant decreased with altitude increasing (Table 4; $F_{2,18}$ = 33. 07, P < 0.000). Whereas, clay soil content was increased with altitude increasing (Table 4; $F_{2,18}$ = 52.33, P < 0.000). In the lower altitude, pH value was recorded significantly higher than upper and lower altitudes (Table 4; $F_{2,18}$ = 6.16, P < 0.009). This is related to the fact that the pH value and sand soil increase with altitude decreases but clay soil content increase with altitude increase Abreha *et al.*, (2012). The higher sand content and pH value under lower altitude is probably caused by increasing run off and soil erosion, and soil compacted. Nitrogen percentage under low altitude was significantly difference from other altitudes. Under the upper altitude, organic carbon, organic matter, available phosphorus and available potassium had significant higher as compared to other two altitude ranges (Table 4). This is supported by the finding of Getachew *et al.*, (2007) in Borana rangelands, Ethiopia and Abreha *et al.*, (2012) in Tsegede Highlands, Northern Ethiopia. This results probably due to the availability of organic matter, higher standing biomass, soil moister and rainfall increasing with altitude range increasing.

3.4.1.3.The effect of distance on soil Parameters

In near distance to settlement, sand soil content had showed significantly higher than far distance from settlement (Table 4; $F_{2,18}$ = 3.65, P < 0.047). This result may be related to the high degree of soil erosion, high grazing pressures and human activities near to settlement than far distance from settlement. Organic matter and organic carbon had significant increased with distance increased from settlement. In far distance from settlement, available phosphorus and potassium were recorded significantly higher than that of the near and middle distance from settlement. Nitrogen Percentage had significantly higher in far distance from settlement than middle distances from settlement (Table 4; $F_{2,18}$ = 4.97, P < 0.019).

Table 4: Effect of altitudinal ranges and distance interval away from settlements (km) on physical and chemical soil Parameters in Kafta-Humera rangelands, northern Ethiopia

		pH	OC (%)	OM (%)	AVP.ppm	AVK.ppm	TN (%)	Sand (%)	Silt (%)	Clay (%)
	Mean									
Altitude (m.a.s.l)										
600-1000										
	0-2	7.45^{a}	1.06^{b}	1.83^{b}	0.61^{b}	1.42^{a}	0.09^{a}	53.33^{a}	16.33^{b}	30.33^{a}
	2-4	7.22^{a}	1.50^{ba}	2.58^{ba}	0.99^{ba}	1.43^{a}	0.08^{a}	48.67^{ba}	26.67^{a}	24.67^{a}
	4-6	7.09^{a}	2.10^{a}	3.62^{a}	1.28^{a}	1.96^{a}	0.10^{a}	42.00^{b}	27.00^{a}	31.00^{a}
>1000-1400										
	0-2	6.86^{a}	0.95^{b}	1.64^{b}	0.92^{a}	1.57^{a}	0.163^{a}	45.67^{a}	22.33^{a}	32.00^{a}
	2-4	6.73^{a}	1.34^{ba}	2.32^{ba}	0.95^{a}	1.78^{a}	0.129^{a}	36.33^{a}	16.33^{a}	47.33^{a}
	4-6	6.60^{a}	2.03^{a}	3.51^{a}	1.22^{a}	2.34^{a}	0.269^{a}	28.67^{a}	23.33^{a}	48.00^{a}
>1400-1800										
	0-2	6.87^{a}	1.59^{b}	2.75^{b}	1.44^{b}	1.87^{b}	0.210^{a}	17.67^{a}	21.33^{a}	61.00^{a}
	2-4	6.71^{a}	1.77^{b}	3.06^{b}	1.09^{b}	2.41^{b}	0.206^{a}	20.67^{a}	18.33^{a}	61.00^{a}
	4-6	6.53^{a}	2.57^{a}	4.44^{a}	2.10^{a}	3.39^{a}	0.311^{a}	16.33^{a}	23.00^{a}	60.67^{a}
Altitude (A)										
	F (df =2,18)	6.16	10.43	10.52	19.07	25.95	14.32	33.07	1.47	52.33
	p	0.009	0.001	0.001	0.000	0.000	0.000	0.000	0.255	0.000
Distance (D)										
	F (df =2,18),	1.66	35.97	36.21	18.17	25.98	4.97	3.65	4.03	1.50
	p	0.219	0.000	0.000	0.000	0.000	0.019	0.047	0.036	0.25
(A) * (D)										
	F (df =4,18),	0.02	0.22	0.23	3.75	2.44	0.99	0.85	4.35	2.38
	p	0.999	0.922	0.92	0.022	0.084	0.441	0.513	0.012	0.09
	Adjusted R^2	0.229	0.767	0.769	0.758	0.802	0.57	0.726	0.44	0.807

OC = Organic carbon; OM = Organic matter; AVP = Available phosphorus; AVK = Available potassium; TN = Total nitrogen.
Means with the same letters in columns are not significantly different at $P \leq 0.05$

4. CONCLUSION

In the study districts, a total of 46 species of woody species were identified. *A. bussei*, *A. mellifera*, *Anogeissus leiocarpa*, *Combretum hartmannianum*, *D. cinerea*, *Lannea frutcosa and Z. spina-christi* were the common dominant species for all altitude and distance. In all altitude, woody species diversity and abundance in far distance to settlements were significantly higher than near distance. In the lower altitude, all woody diversity parameters had significantly lower. Sand and pH value had also significantly higher but soil clay was significantly lower as compared to the middle and upper altitudinal ranges. Far distance from settlement had significantly higher in organic carbon, organic matter, available phosphorus and available potassium than to middle and near distance. The upper altitude had showed significantly higher in organic carbon, organic matter, available phosphorus and available potassium as compared to the lower and middle altitude. Under the present soil status, biodiversity and productivity circumstances of the areas near to settlement and middle distance intervals from settlement, preservation or return of habitats should be of greater concern because the best way to minimize biodiversity loss is to maintain the integrity of ecosystem function. Research related to rehabilitation and possible restoration strategies through soil seed bank under various altitudinal ranges and settlement areas should be considered.

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