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COMPARATIVE ANALYSIS OF HILLSIDE DISTRIBUTION TO LANDLESS PEOPLE IN VEGETATION RESTORATION AT SELECTED WATERSHEDS OF KOLA TEMBIEN WEREDA

Guesh Assefa*, Meresa Weleslasie, Haftaye Hadush and Gebrekidan Abrha

Tigray Agricutural Research Institute; Abergelle Agricultural Research Center. P.O. Box 44, Abi Adi, Ethiopia.

***Corresponding Author: Guesh Assefa**

Tigray Agricutural Research Institute; Abergelle Agricultural Research Center. P.O. Box 44, Abi Adi, Ethiopia.

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ABSTRACT

In a community of having shortage of arable land like in the Tigray region, linking hillside distribution to the landless people and conservation is crucial. However, it has not been scientifically evaluated whether hillside distribution to landless people promotes vegetation restoration or not. Objective of the study was to evaluate the contribution of hillside distribution to landless people in vegetation restoration at three selected hillsides of kola Temben district. Parallel line transects were formed in each hillside area for vegetation inventory at 100 m interval. Rectangular sample plots of 20 m by 20 m for tree, 10 m by 10 m for sapling, 5*5 m for seedling and 1*1 m for herbaceous cover were used for sampling. Normalized Difference Vegetation Index (NDVI) was also used to detect the vegetation cover status of the hillsides before and after distribution. A total of 14 and 5 species belonging to 10 and 5 families in Chechah; 24 and 9 species belonging to 17 and 7 families in Sebako and 16 and 9 species belonging to 13 and 8 families in Weyni hillsides were found in distributed and undistributed hillsides respectively. Significant difference was seen between the distributed and undistributed hillsides in species richness, density and individuals of vegetation in Chechah; species richness, numbers of individual per plot and Shannon diversity in Sebako and number of individuals, species evenness and density in Weyni hillsides respectively. However, there was no significant difference on Shannon diversity and species evenness in Chechah; species richness, numbers of individual and diversity in Sebako and species evenness and density in Weyni hillsides respectively. There was a good regeneration status with higher vegetation height, DBH and canopy cover at the distributed hillsides than the undistributed in all sites. The NDVI result showed a slight improvement in vegetation cover in all hillsides. The area of improvement in Chechah, Sebako and Weyni accounted for 7.1%, 15.6% and 17% respectively. Since the distributed hillsides have showed a better performance in vegetation restoration, distributing other hillside areas to landless people should be widely promoted to restore degraded areas.

KEYWORDS: Hillsides, NDVI**,** vegetation regeneration and vegetation cover.

INTRODUCTION

Mountain and upland watersheds constitute 25% of the earth's land surface (UN general assembly, 2005). However, little understanding of mountain specificity by planners and policy-makers and the inability of development efforts to harness local niches have aggravated economic woes and threatened prospects for mountain development. Cultivation on the mountainous terrain has raised questions about the suitability of intensive land-use practices that threaten the condition of watersheds where land degradation is already high owing to the fragile ecosystem. Nowadays, degradation of land is a serious issue throughout the world, particularly in African countries. The severity of land degradation process makes large areas unsuitable for agricultural production, because the top soil and even part of the sub-soil in some areas has been removed, and stones or bare rocks are exposed at the surface (Badege, 2009). Removing vegetative cover on steep slopes for agricultural expansion, firewood and other wood requirements as well as for grazing space has paved the way to massive soil erosion (USAID, 2004).

The ever-increasing population in Ethiopia has increased pressure on natural resources. With no access to better quality lands and no off-farm employment opportunities, local people have removed forest and grass cover to fulfill their basic needs for food, fodder, fuel wood and timber. As in other areas of Ethiopia, Tigray faces twin problems of increasing population farming on limited land, with available land affected by degradation. The region has no more arable land that can be distributed to the rapidly increasing population, especially the current generation of landless youth. However, there is communally managed land, usually used for livestock grazing, forestry and collection of wood. These communal resources are also affected by severe degradation because of overgrazing, over-use of the woody resources and generally poor management.

In 1997 the Tigray regional administration passed the hillside guideline, intended to manage degraded hillside land. This promoted distribution of non-cultivable degraded communal land to be managed by individuals, who received the benefit of produce consumed or sold. Since 1997, the practice has been promoted by the Tigray Bureau of Agriculture and Rural Development (BoARD) and more communities are using this policy innovation in combination with technical interventions. Whilst this communal land only represents a small proportion of the land affected by degradation, the initiative has proved popular both by government and non-governmental support agencies (Amede et al., 2004).

Furthermore, over the past five years, the Tigray Regional Government (TRG) has piloted policy and investment programs to rehabilitate steep degraded hillsides into productive land, mainly through bench terracing. In a community of having shortage of arable land like in the Tigray region, linking hillside distribution to the landless people and conservation is crucial. However, it has not been scientifically evaluated whether hillside distribution to landless people promotes sustainable land management especially in vegetation restoration. Even though there are a lot of landless people in the region, hillside distribution to these people is not well expanded. Therefore, a clear understanding of the effectiveness of hillside distribution in vegetation restoration is helpful in bringing long lasting and appropriate natural resources utilization. The overall objective of this study was to evaluate the contribution of hillside distribution to landless people in vegetation restoration at the selected watersheds.

MATERIALS AND METHODS

Study Area Location

Geographically the study areas are found in Kola Tembien district which are located at ca.125 km away from Mekelle, the capital city of Tigray to the west. The district lays at 130, 39’, 34” to 130, 41’, 33” N and 380, 56’, 56”-380, 57’, 48” E with an altitude ranging from 911 m to 2553 m a.s.l. This study was specifically conducted at midland hillsides of Sebako (Smret Tabia), Chechah (Begashika Tabia) and Weyni (Dernetseb Tabia).

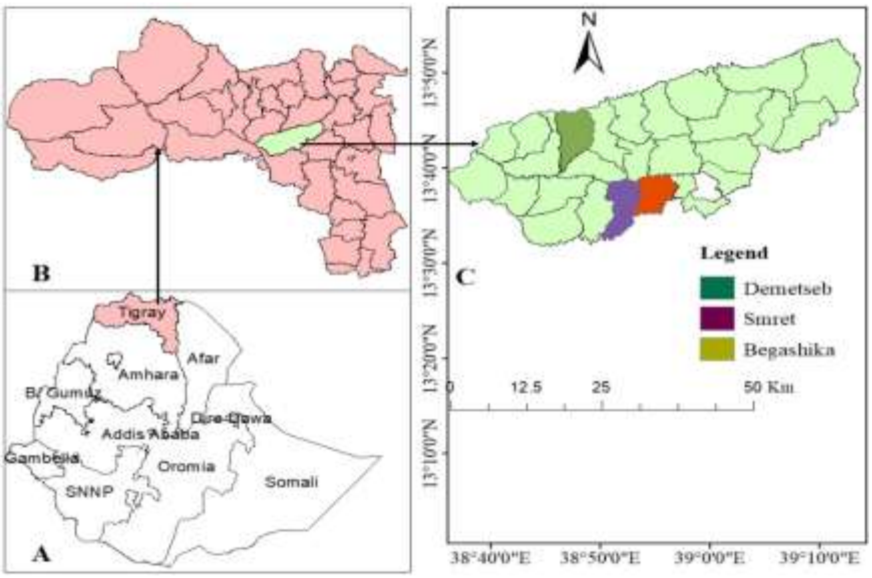


Figure 1: Location of the study area A) in Ethiopia B) in Tigray C) in Kola Tembien district.

The study areas are characterized as cool semi-arid agro-climatic zone. According to Kola Tembien Bureau of Agriculture and Rural Development (KTBARD, 201), the 10-year annual rainfall data (2007 to 2017), measured at the district weather station indicates that the mean annual rainfall is about 690 mm while the total annual rainfall ranged from 500 to 880 mm which is uni-modal. The average minimum temperature is 13.30C while the average maximum temperature is 29.8 0C. The average potential evapotranspiration is estimated at 137 mm. More than 80% of the total rainfall occurs during the main rainy season (from June to August) and sometimes it starts in May and stops in September.

Methods of Data Collection and Analysis

Three hillsides (Chechah, Sebako and Weyni) which have fully practiced hillside distribution to landless people were purposely selected from kola Temben Wereda. Age of the hillsides was five years after being transferred to the landless people. The hillsides were transferred to the landless people after soil and water conservation practices was made by the local community in the area such as bench terrace (in Chechah and Weyni) and stone bund (in Sebako). Parallel line transects were formed in each hillside area for vegetation inventory. Rectangular sample plots of 20 m by 20 m for tree, 10 m by 10 m for sapling and 5*5 m for seedling were used to sample woody species canopy cover, diversity, composition and structure of the vegetation along each transect at 100 m interval. Rectangular sample plots of 1 m by 1 m at each corner and center of the 20 m by 20 m were also formed for herbaceous species sampling. In addition to the vegetation inventory, Normalized Difference Vegetation Index (NDVI) was used to detect the vegetation cover status of the hillsides before and after distribution to the landless people. Multi-temporal medium resolution LANDSAT 8 imagery was used to archive temporal changes of NDVI (Normalized Difference Vegetation Index) for 2014 and 2019. The Landsat images were freely downloaded from USGS website (http://earthexplore.usgs.gov.) at path/row of 169/51. The images were acquired in the same season (January) to avoid the effect of seasonal variations (Kindu et al., 2013). Among the factors that could reflect the vegetation status, the NDVI could well reflect the changes of vegetation cover. Therefore, it is of great importance to study vegetation changes with NDVI (Jia et al. 2011; Meng et al. 2011; Liu et al. 2012).

Data analysis

Remotely sensed satellite image of Landsat 8 Operational Land Imager (OLI) was used to analyze the Normalized Difference Vegetation Index (NDVI) values using Geographical Information System (GIS) tools. The NDVI, which was proposed by Rouse et al. (1973), is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum to analyze whether the target area contains live green vegetation or not. Healthy vegetation absorbs most of the visible light that falls on it, thereby reflecting a large portion of the NIR. The NDVI value was generated using the following algorithm.

$$\mathrm{NDVI} = \frac{\mathrm{NIR-R}}{\mathrm{NIR+R}} \quad \text{or} \quad \mathrm{NDVI} = \frac{Band5-Band4}{Band5+Band4}$$

Where, NIR= Near Infrared and R= Visible red

The NDVI value falls between − 1 and + 1, where increasing positive values indicate increasing green vegetation and negative values indicate non-vegetated surface features such as water, barren land, ice, snow, or clouds (Sahebjalal and Dashtekian 2013). Descriptive statistical analysis was applied for the analysis of vegetation composition and structure. Independent t-test was used for diversity indices comparison using SPSS v20.

RESULTS AND DISCUSSION

Species Diversity, Composition and Structure

The analysis result showed that a total of 14 and 5 species belonging to 10 and 5 families were found in Chechah distributed and undistributed hillsides respectively. At Sebako site a total of 24 and 9 species belonging to 17 and 7 families were recorded in distributed and undistributed hillsides respectively. Similarly, at Weyni site 16 and 9 species belong to 13 and 8 families were recorded in distributed and undistributed hillsides respectively (Table 1).

Table 1: Total number of family and species recorded in the watershed.

	Vegetation Category	Begashika		Smrert		Dernetseb	
		Distributed	Undistributed	Distribu ted	Undistrib uted	Distributed	Undistributed
1	Total Species	14	7	24	9	16	9
2	Family	10	5	17	7	13	8
3	Tree Species	7	0	10	5	6	1
4	Shrub Species	7	2	11	4	10	8
5	Climber	0	0	2	0	0	0

The analysis result has revealed that species richness, density and individuals of vegetation in the distributed hillside were significantly different from the undistributed hillside of Chechah at 95% confidence (Table 2a). The species richness, density, individuals, DBH, height and canopy cover were higher in the distributed hillside than the undistributed (Table 2a and Figure 2). It was believed that the reason for the increment of species richness, density and individual was plantation of edible fruit trees by the landless people on the bench terrace and exclusion of the area from animal entrance. However, there was no significant difference on species Shannon diversity indices and species evenness.

Table 2a: mean + SE of species richness, individuals, density, evenness and density.

Land use	Chechah Hillside				
	Richness	individuals	Shannon	Evenness	Density
Distr.	$5.4^{a} \pm 0.84$	$26.8^{a} \pm 3.1$	$1.3^{a} \pm 0.14$	$0.7^{a} \pm 0.06$	$511.5^{a} \pm 60$
Undistr.	$3.1^{b} \pm 0.34$	$17.3^{b} \pm 3.1$	$.95^{a} \pm 0.06$	$0.9^{a} \pm 0.04$	$329.3^{b} \pm 59.6$
P-value	0.03	0.05	NS	NS	0.05

Means with the same letters across column are not significantly different (P $\geq$ 0.05); Distr. = distributed hillside, Undistr. = Undistributed hillside, NS= not significantly different.

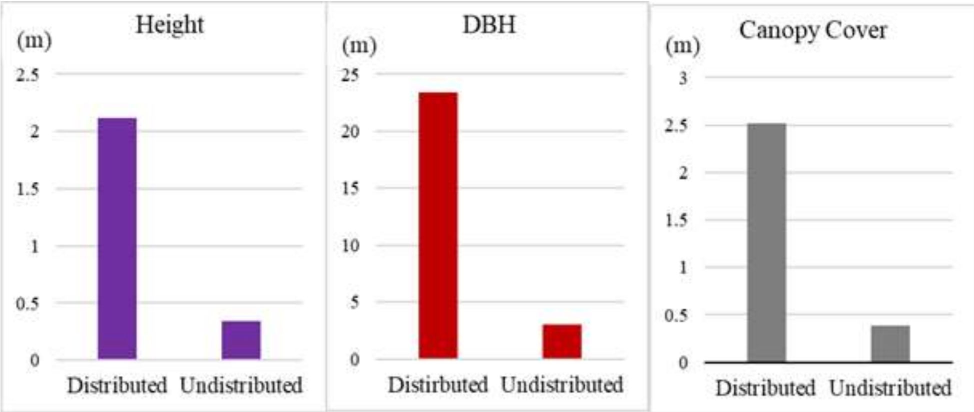


Figure 2: Illustration of plant height, DBH and canopy cover for distributed and Undistributed Hillsides Chechah site.

In Sebako site, the species richness, numbers of individual per plot and Shannon diversity were significantly different between the distributed and undistributed hillsides at P< 0.05 (Table 2b). However, there was no significant difference in species evenness and density. The Sebako distributed hillside showed higher species richness, number of individuals, species diversity, DBH, height and canopy cover than the undistributed hillside (Table 2b and Figure 3). This is because of the continuous follow up and protection of the area from animal entrance.

Table 2b: mean + SE of species richness, individuals, density, evenness and density.

Land use	**Sebako watershed**				
	Richness	**individuals**	**Shannon**	**Evenness**	**Density**
Distr.	$8.3^a \pm 1.3$	$41.1^a \pm 5.7$	$1.5^a \pm 0.16$	$0.6^a \pm 0.03$	$783^a \pm 109.9$
Undistr.	$4.3^b \pm 0.6$	$31.3^b \pm 5.1$	$1.0^b \pm 0.17$	$0.7^a \pm 0.1$	$596.8^a \pm 97.1$
P-value	0.03	0.02	0.05	NS	NS

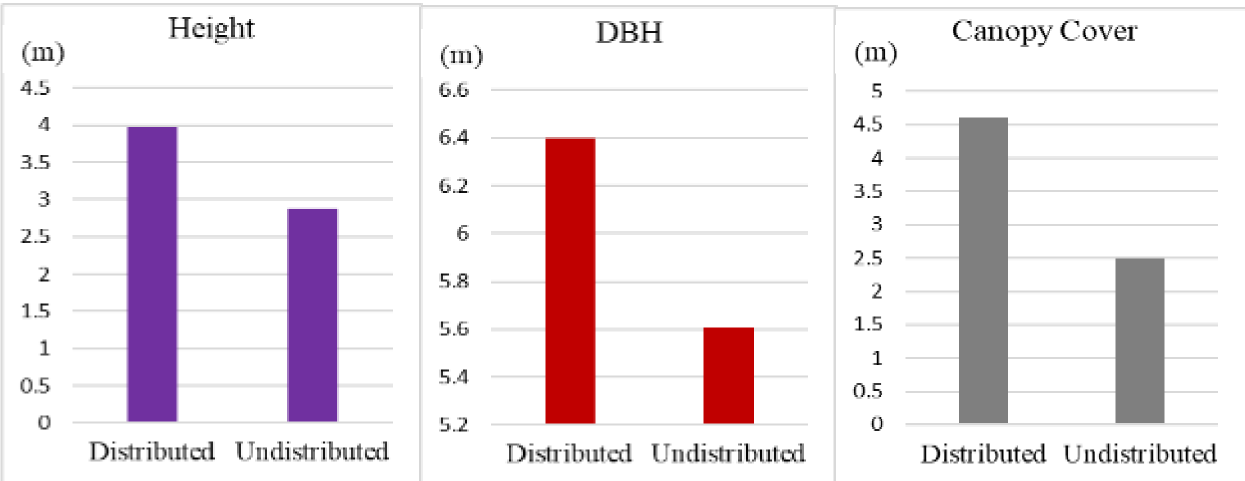


Figure 3: Illustration of plant height, DBH and canopy cover for distributed and Undistributed Hillsides Sebako site.

In the study area of Weyni hillside, there was significant difference in number of individual plots, species evenness and density at P<0.05 between the hillsides but not in species richness and Shannon (Table 2c). The distributed hillside has showed promising change in rehabilitation status as compared to the undistributed hillside. Higher vegetation density, evenness, height, DBH and canopy cover was observed in the distributed hillside (Table 2c and Figure 4). Similar to the Chechah site, the main reason for the vegetation increment and rehabilitation of the hillside was that plantation of edible fruit trees and useful shrubs by the landless people on the bench terrace and exclusion of the area from animal entrance.

Table 2c: mean + SE of species richness, individuals, density, evenness and density.

Land use	Weyni watershed				
	Richness	individuals	Shannon	Evenness	Density
Distr.	$5.7^{a} \pm 0.42$	$39^{a} \pm 3.2$	$1.3^{a} \pm 0.13$	$0.66^{a} \pm 0.05$	$742.8^{a} \pm 62.5$
Undistr.	$4.5^{a} \pm 1.2$	$12.7^{b} \pm 4.0$	$1.2^{a} \pm 0.31$	$0.85^{b} \pm 0.04$	$242.8^{b} \pm 77.1$
P-value	NS	0.001	NS	0.03	0.001

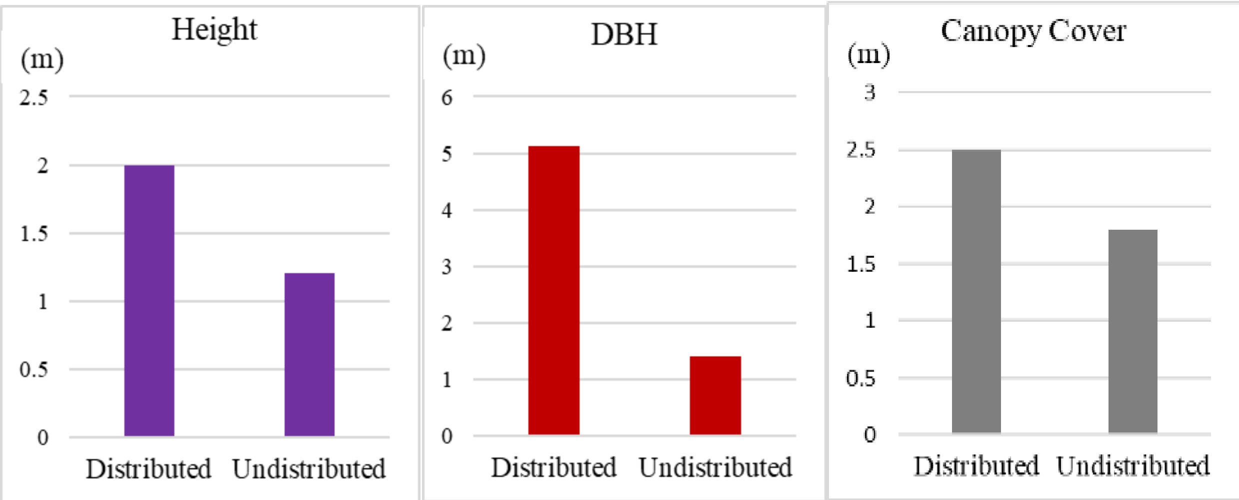


Figure 4: Illustration of plant height, DBH and canopy cover for distributed and Undistributed Hillsides Weyni site.

The average percentage cover of the herbaceous species for the distributed and undistributed hillsides is illustrated in table 3. Significant difference in grass cover was seen between the distributed and undistributed hillsides of all study sites. The herbaceous percentage cover interval for the distributed hillsides of Chechah, Sebako and Weyni was 71-99, 57-78 and 59-82 respectively. Whereas for the undistributed hillside, the percentage cover interval was 26-66, 18-22 and 20-30 respectively. The distributed hillsides have showed better herbaceous cover than the undistributed hillsides mainly due to the protection of the area from animal entrance and this will have a great contribution in increasing hay for animal feed and reduction of soil loss in the distributed hillsides. Study by Abesha (2014) indicated that, five years enclosure faced only slight erosion due to the reduced animal and human interference in the enclosures, the re-vegetating grasses reduced raindrop intensity and hindered detachment of soil particles that cause soil erosion. As physical observed in the distributed hillsides, the herbaceous species are the main sources of animal feed with cut and carry system used by the landless people.

Table 3: Herbaceous cover of the distributed and undistributed hillsides.

Land use	Grass cover (%)		
	Chechah	Sebako	Weyni
Distr.	$85.4^{a} \pm 5.1$	$64.3^{a} \pm 4.5$	$72.5^{a} \pm 3.1$
Unditr.	$50.0^{b} \pm 6.2$	$20.0^{b} \pm 1.2$	$25.3^{b} \pm 1.6$
P-value	0.00	0.00	0.00

Vegetation Regeneration status

The regeneration status of Chechah and Sebako hillsides indicated an inverted J shape with indication of healthy regeneration status. At both the distributed and undistributed hillsides higher number of seedlings than sapling and higher number of saplings than trees were observed in all the three hillsides which implies a good regeneration status (Fig. 5). The regeneration status of a forest is poor if the number of seedlings and saplings is much less than mature individuals (Aliyi et al, 2015). However, much number of seedlings, saplings and trees were observed at the distributed hillsides than the undistributed. There was good regeneration status at the distributed hillsides than the undistributed in all the three sites with minimum number of individual trees (Fig. 5).

In the distributed hillsides, higher emergence of seedling and sapling was observed. The distributed hillsides showed better potential of rehabilitation and reemergence than the undistributed hillsides. This is because, the distributed hillsides had continuous follow up and sense of ownership by the landless people. There were also additional activities in the distributed hillsides such as plantation of edible fruits and useful shrubs, conservation practices and management practices applied by the landless people to enhance the productivity of the hillsides for their livelihood improvement. The soil and water conservation practices implemented in the study area have resulted in a better restoration of the vegetation. The vigorous SWC activities performed throughout the country Ethiopia are also evidenced by EBI (2014) for the rehabilitation and restoration of degraded areas resulted in increased vegetation cover and enhancement of biodiversity. The implementation of different forms of SWC activities, such as stone terraces, soil bunds, contour ditches, moisture retention reservoirs and check dams are an optimal solution to reverse the vegetation degraded landscape of arid and semi-arid regions in Ethiopia (Hishe et al., 2017).

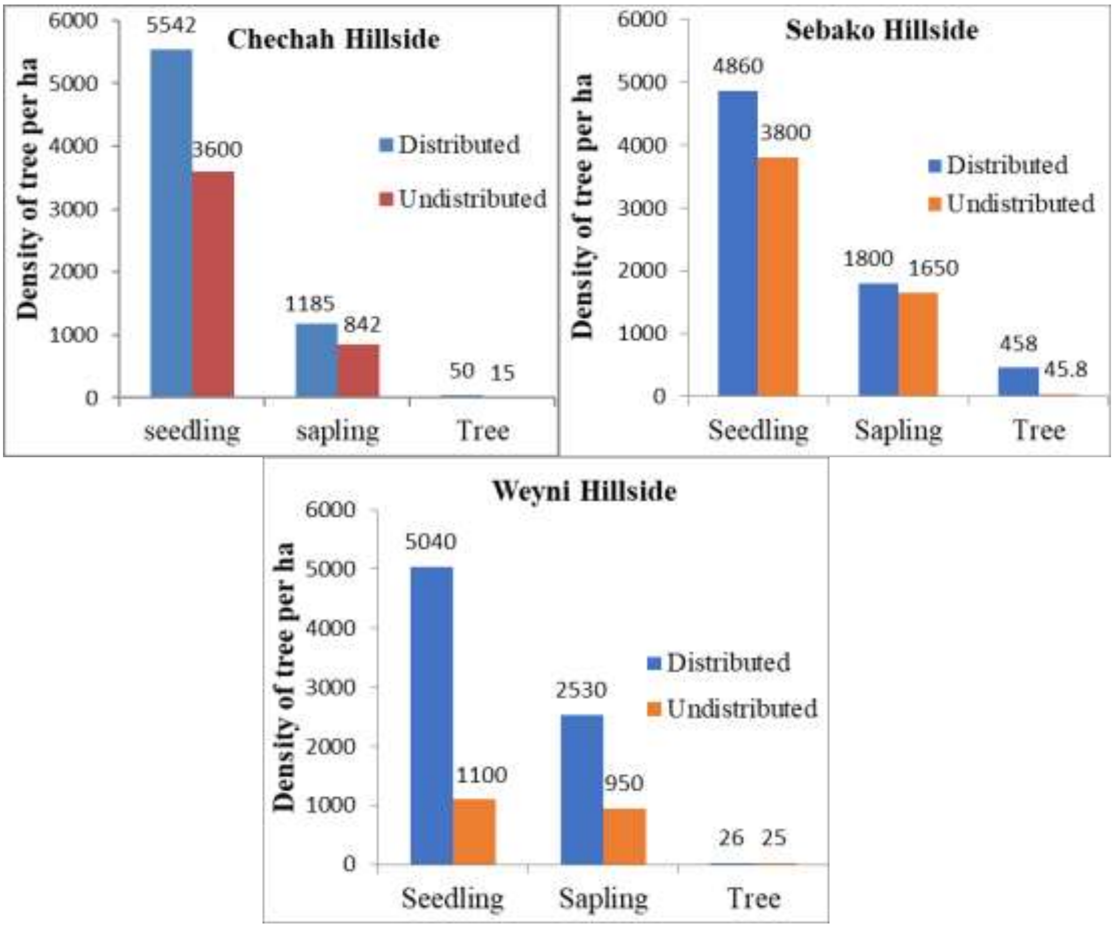


Figure 5: Regeneration status of vegetation at Chechah, Sebako and Weyni hillsides Respectively.

Vegetation Cover Change

The status of the vegetation cover before and after hillside distribution to landless people is illustrated below in figure 6. The NDVI map was generated by classifying the NDVI values in to three categories (<0.1, 0.1-0.2 and 0.2-0.3). The generated NDVI value of the three study sites laid in between 0.1 and 0.3 with an indication of barren areas, shrub and grass. Very low values of NDVI (0.1 and below) corresponds to barren areas of rock, sand, or snow. Moderate values represents shrub and grassland (0.2–0.3), while high values indicates temperate and tropical rainforests (0.6–0.8) (http://www.ospo.noaa.gov/Products/land/gvi/NDVI.html). Even though the NDVI values are low, the hillsides have shown some reemergence and regeneration of vegetation cover after the distribution.

In the five-year interval, a small increment in NDVI value was observed in Chechah hillside. During the 2014 study year, 93.61% of the study area had an NDVI value laid in between 0.1 and 0.2 while the rest 6.39% of the areas NDVI value was in between 0.2 and 0.3. Five years after the distribution (2019), the NDVI value was slightly increased by 7.11% from 0.1-0.2 into 0.2-0.3 i.e. during the 2014 study year, 6.39% of the total area had an NDVI value ranging from 0.2-0.3 and later in the 2019 the area with 0.2-0.3 NDVI value has increased in to 13.5% (Table 4).

Table 4: Vegetation cover change for Chechah site.

NDVI Value	2014		2019	
	Area in ha	Area in %	Area in ha	Area in %
0.1-0.2	4.14	93.61	3.83	86.5
0.2-0.3	0.28	6.39	0.60	13.5
Total	4.43	100	4.43	100

In the Sebako hillside, a slight vegetation development was observed in five-year interval after the distribution. Initially before the distribution, 2.95 ha of the area had an NDVI value ranging from 0.1-0.2 and only 0.25 ha of the area had NDVI value of 0.2-0.3. Five years after the distribution 0.5 ha of the area has increased its NDVI value from the first range (0.1-0.2) into the second range (0.2-0.3) (Table 5). Similar results reported that a rapid increase in NDVI value was observed in protected areas of Loess Plateau which was increased from 0.49 in 2000 to 0.61 in 2016 (Li et al. 2017).

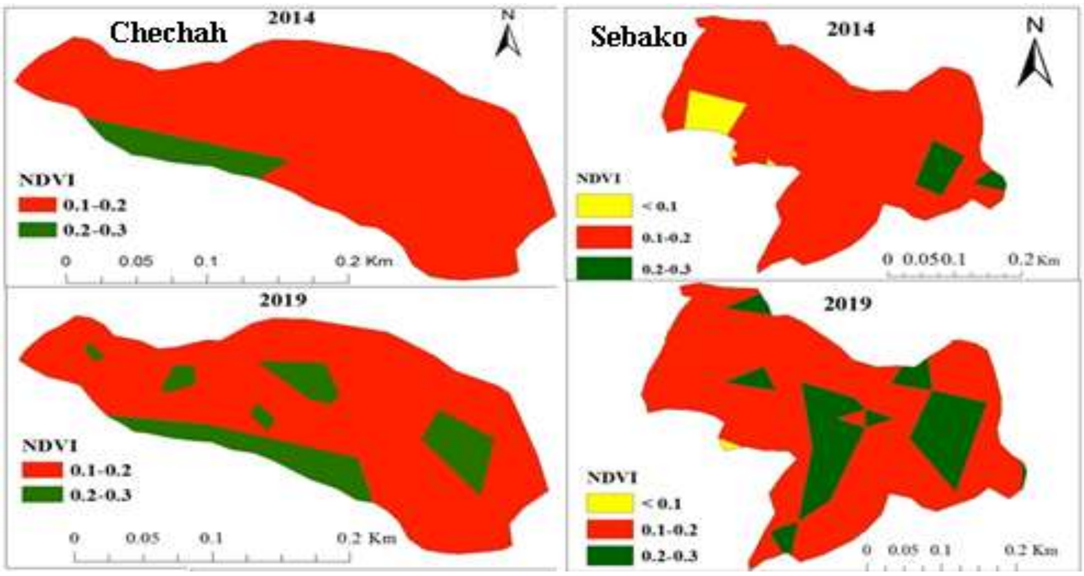
Table 5: Vegetation cover change for Sebako site.

NDVI Value	2014		2019	
	Area in ha	Area in %	Area in ha	Area in %
0.1-0.2	2.95	92.20	2.45	76.56
0.2-0.3	0.25	7.80	0.75	23.44
Total	3.20	100	3.20	100

The NDVI value for Weyni hillside was described in three categories (<0.1, 0.1-0.2 and 0.2-0.3. In the first study year (2014), NDVI value with < 0.1, 0.1-0.2 and 0.2-0.3 has covered an area of 0.53 ha, 11.10 ha and 0.52 ha respectively. But later in 2019 the amount of area covered by the above listed three NDVI value category becomes 0.03 ha, 9.53 ha and 2.59 ha respectively (Table 6). In other words, the area with NDVI value of <0.1 was decreased from 0.53 ha in 2014 into 0.03 ha in 2019. Similarly, the area with NDVI value of 0.1-0.2 was decreased from 11.10 ha in 2014 into 9.53 ha in 2019. This is because, five years after the distribution, the amount of area with NDVI value of 0.2-0.3 was increased by 2.07 ha. Similar result by Hongxue et al. (2018) was reported that, the area that have an NDVI value in between 0.2 and 0.4 decreased from 41.4% (2001) to 6.97% (2014) in Weihe River Basin. At the same time, the area of NDVI values between 0.6 and 0.8 increased, and the minimum and the maximum were 11.98% (2001) and 36.7% (2015) in Weihe River Basin.

Table 6: Vegetation cover change for Weyni site.

NDVI Value	2014		2019	
	Area in ha	Area in %	Area in ha	Area in %
< 0.1	0.53	4.28	0.03	0.24
0.1-0.2	11.10	91.46	9.53	78.53
0.2-0.3	0.52	4.26	2.59	21.23
Total	12.15	100	12.15	100



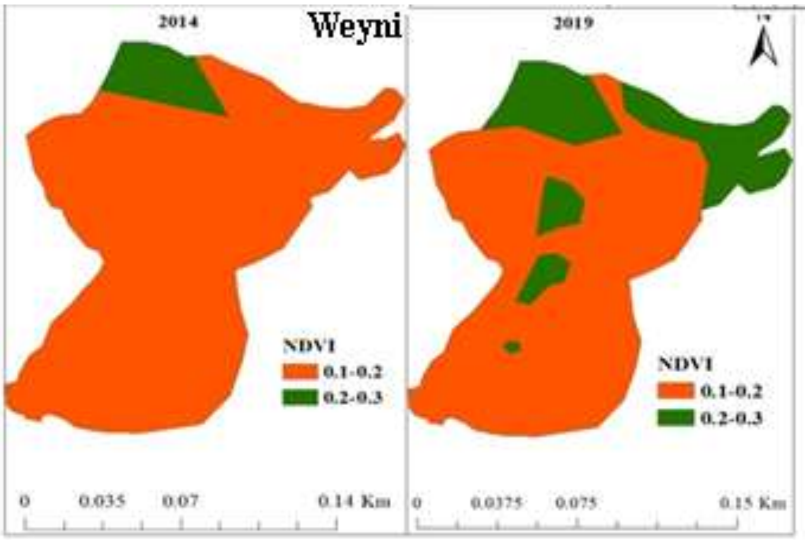


Figure 6: NDVI values for Chechah, Sebako and Weyni sites respectively before and after distribution.

Most of the vegetation cover in all hillsides showed slight improvement. The area of improvement in Chechah, Sebako and Weyni accounted for 7.1%, 15.6% and 17% respectively. The changes of the NDVI area in the three hillsides showed that the NDVI values were mainly concentrated in the range of 0.1–0.2. The NDVI values in the range of 0.1–0.2 decreased after the hillside distribution, while it increased in the range of 0.2–0.3 in all study sites. The most significant improvement was seen at Sebako and Weyni hillsides. The main reason is that tree plantation in both sites was higher than that of the Chechah site. The different SWC measures applied in the study area have also significance to the improvement of vegetation cover. In general, the distributed hillsides have showed a better improvement in vegetation cover than the undistributed hillsides. This can be taken as means for sustainable environmental utilization and it will have a great contribution to environmental rehabilitation. The implementation of SWC in the region as a strategy was to reduce run-off, improve soil fertility and finally reverse the degraded landscape and increase vegetation cover. When degraded landscape protected with different SWC practices, run-off will reduce, infiltration capacity will increase, which retain soil moisture and finally improve vegetation density (Hishe et al., 2017).

CONCLUSION AND RECOMMENDATION

Generally, as described in the results, distributing hillsides areas to landless people has brought better improvement in vegetation restoration and regeneration. Species richness, number of individuals and species diversity was higher in all distributed watersheds than the undistributed watersheds. The NDVI value has also showed an increment after the hillside was distributed to the landless people. Therefore, distributing hillside areas to landless people could be a better solution for vegetation regeneration and environmental rehabilitation so that land degradation will be minimized. In order to maintain the sustainability of the distributed watersheds, continuous follow up and maintenance of the physical soil and water conservation structures constructed in the hillsides is important. Since the distributed hillsides have showed a better performance in vegetation restoration, distributing other hillside areas to landless people should be widely promoted to restore degraded areas.

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