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Catchment and Community Vegetation Classification for Plant Management in Temcha Watershed (TW) of Amhara Region, Ethiopia

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ABSTRACT

In landscape ecology, plants have traditionally been the focus of so much research because plants are producers and the knowledge on them influences the detailed components of watershed. The status of the vegetation in a watershed had largely been studied by using satellite images. Such kinds of works did not indicate the type of plants that exist in the area hence inventory-based approach is critically important. Nested quadrants were used to collect all vascular plant species encountered in each quadrat. Accordingly, 20 m X 20 m size quadrats established for tree and shrub inventory. For seedlings, saplings and herbaceous layers, 3m x 3 m sub quadrats one at each corner and one at the center of each 400 m 2 quadrats were established within the main quadrats. We used Shannon Wiener diversity index, Shannon's evenness index and species turnover (β-diversity) for measuring the diversity and similarity of plants in separate communities and catchment. Frequency, dominance and density measurements were used to identify ecologically important plants in TW.The study resulted a total of 220 vascular plants showed the potential of the remnant patches of forest for future plant based management. The community and catchment classification are helpful to manage the plants based on species distribution and location specific approach in the watershed.

Keywords: patches of forest; plant community; catchment vegetation; Temcha Watershed;

1. INTRODUCTION

Management of watershed requires all actions in the watershed from small erosion control projects to large-scale restoration of the landscape. In landscape ecology, plants have traditionally been the focus of so much research because plants are producers (IK, 1992) and the knowledge on them influences the detailed components of watershed including soil and water conservation practices, integrated pest and nutrient management, crop diversification and livestock production (Nimachow *et al.*, 2011).

Globally, forests range from closed to open formations and cover 31 % (4 billion hectares) of the total land area (FAO, 2010a). This calculation is based on FAO's definition of forest as a piece of land of more than 0.5 hectares, with more than 10 % tree crown cover (or equivalent stocking level) and trees reaching a minimum height of 5 meters at maturity *in situ* (FAO, 2000). Besides the presence of a number of isolated large-sized trees, even on farmlands, or patches of forests around churchyards and religious burial grounds in Ethiopia, it is difficult to establish the precise cover of the past as well as the present forest vegetation (Friis, 1986; Tamrat Bekele 1993). However, the recent data on forest resources as reported in FAO (2010b) with new definition puts Ethiopia among countries with forest cover of 10-30 %. According to this report, Ethiopia‘s forest cover is 12.2 million ha (11 %). In addition to this, a recent, national forest cover estimate is about 15.5 percent based on the adopted forest definition REDD+ Secretariat (MEFCC, 2015).

Forests on account of high population increase which have resulted in extensive clearing for agricultural use, overgrazing, exploitation of existing forests for fuel wood, fodder, construction materials, unsustainable exploitation of wood for timber, overgrazing and civil unrest (Bongers *et al.*, 1988; Demel Teketay, 1996; Moon and Tamirat Solomon, 2019). Therefore, vegetation study in Temcha Watershed (TW) could provide first hand real experience on the current status of the use of natural resources and could help future management initiatives.

Watershed based developmental intervention in the study district and throughout the country was performed by the local communities assisted by government Agricultural office follwed the recurrent droughts and the subsequent famine in the 1970s and 1980s (Yasir Mohamed and Makonnen Loulseged, 2008). However, the status of the vegetation had largely been studied by using satellite images (Carr, 1998; Woldamlak Bewket, 2002; Solomon Gebreyohannis *et al.*, 2010, 2014). Such kinds of works did not indicate the type of plants that exist in the area. Therefore, inventory-based approach is critically important in order to provide basic information about the plant species present currently and those that are in decline in the recent past but with potential to be used in future watershed management.

2. MATERIALS AND METHODS

Study Area Description

The study was undertakeninTWfound in Machakel and Dembecha Districts along the Abay River basin. The river originates from the south-west direction of Choke Mountain and drains in to Abay River after the slope. The watershed targeted for the study is delineated by using Arc GIS 10 software. The watershed lies in between $10^{0}23$‘ to $10^{0}41$‘N latitude and $37^{0}16$‘ to $37^{0}45$‘ E longitude which constitutes 73, 054 hectares of land. Administratively, the study area falls in Dembecha District (Western Gojjam) and Machakel District (Eastern Gojjam) in Amhara Regional State. It is about 345 km far from the capital city, Addiss Abeba to the North West and 285 km from the regional capital city, Bahardar to the South East (Figure 1). Temcha Watershed is fully covers 10 of the 24 kebeles (sub district) and partially four additional kebelesin Machakel District. It also covers eight of 29 Kebeles and partially five additional kebeles in Dembecha District. Temcha River naturally divded Dembecha District from Machakel District.

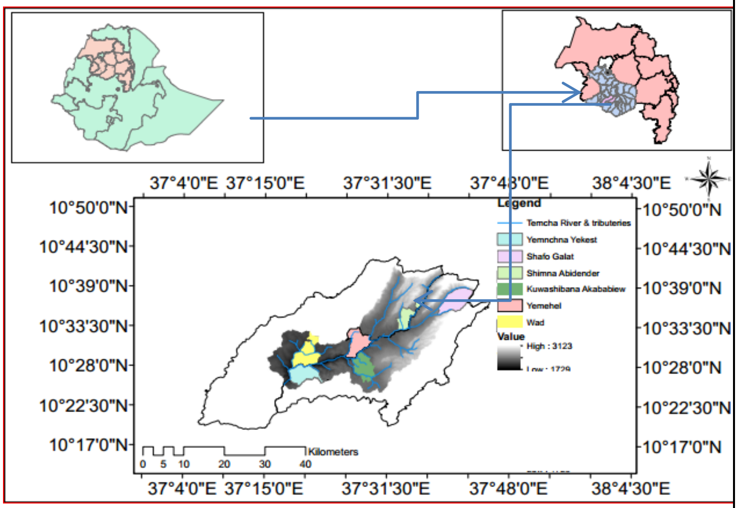


Figure 1 Map of Ethiopia showing regional states, districts, Temcha Watershed and sampled kebeles (Developed using ArcGIS 10).

Vegetation data collection

Nested quadrants were used to collect all vascular plant species encountered from eighty six (86) sampling quadrats placed systematically along a line transect in purposively selected patches of forest found in the Eastern and Western direction of Temcha river (Table 1). Accordingly, 20 m X 20 m size quadrats established for tree inventory in the way described by Kent and Coker (1992). For shrub including seedling, saplings and herbaceous layers, 3m x 3 msub quadrats one at each corner and one at the center of each 400 m^2 quadrat were established. Following Haile Adamu *et al.* (2012), woody plants were categorized as seedlings (height < 1.5 m), saplings (height between 1.5 m and 3 m) and mature plants (height > 3 m). Diameter of each woody species having a diameter of ≥ 2.5 cm at Breast Height (DBH) 1.3 m above ground was measured using a tree caliper.

The heights of all individuals of woody species with DBH ≥ 2.5 cm and height greater than 3 m was measured with a hypsometer (Nikon Laser Rangefinder Forestry Pro). The heights of lianas were not measured due to the difficulty in tracing individual lianas as they got interwoven with similar or other individuals. Cover abundance values of trees, shrubs, herbs and grasses were estimated following modified 1 - 9 Braun-Blanquette scales as converted by van der Maarel (1979).Additional tree and shrub species within 10 m distance from the plot's boundaries were recorded as present.The specimens collected were identified using the relevant volumes of the Flora of Ethiopia and Eritrea and other taxonomic works and by comparing them with specimens already authenticated and deposited in the National Herbarium.

Vegetation data analysis

The percent canopy/foliage cover was transformed to ordinal scales and assigned to one of the nine cover-abundance classes according to the modified 1-9 Braun-Blanquet scale (van der Maarel, 1979). The scales are 1 ≤ 0.1 %, 2 = 0.1 to 1 %, 3 = 1 to 2 %, 4 = 2 to 5 %, 5 = 5 to 10 %, 6 = 10 to 25 %, 7 = 25 to 50 %, 8 = 50 to 75 %, and 9 >75 %. The three-column data, abundance or cover, were imported to R Package 3.2 (R Core Team, 2015) and matrified to carry out the analysis for various parameters.

Frequency, density, basal area and dominance of woody species.

Frequency is defined as the probability or chance of finding a species in a given sample area or plot and is expressed as the total number of quadrats in which individuals of a given species were recorded divided by the sum total number of the quadrats taken in the study area (Kent and Coker, 1992).

$$\text{Frequency} = \left(\frac{\text{The number of plots where a species occur}}{\text{The total plots used during the study}}\right)$$

$$\text{Relative Frequency} = \left(\frac{\text{Frequency of a species}}{\text{Total frequency of all species}}\right) \text{x } 100$$

Woody species density in this study is expressed as number of individuals of a species per hectare as indicated in Kent and Coker (1992).The total species density, which is expressed as the sum total of all individuals of all species in a hectare was also computed. The relative density was calculated using the following formula:

$$\text{Density} = \left(\frac{\text{The number of individuals of a species}}{\text{The total number of all indivuduals}}\right) (\text{DBH} \geq 2.5 \text{ cm})$$

$$\text{Relative Density} = \left(\frac{\text{The density of a species}}{\text{The total density of all indivuduals}}\right)(\text{DBH} \geq 2.5 \text{ cm}) \text{x } 100$$

Basal area (Ba) (in m^2 per hectare) was measured as the cross-section area of a tree at breast height of trees and it was computed using this formula (3.14 d^2 /40,000) or ($0.0000785d^2$).

$$Dominance = \left(\frac{Basal\ area\ of\ each\ species}{Total\ basal\ area\ of\ all\ species}\right)(DBH \geq 2.5\ cm)$$

$$Relative\ Dominance = \left(\frac{Basal\ area\ of\ each\ species}{Total\ basal\ area\ of\ all\ species}\right)(DBH \geq 2.5\ cm) x\ 100$$

DBH and height class distributions

The population structure of the study as the density distribution of individuals in arbitrarily defined DBH or height classes were carried out for woody species based on most widely used DBH and height classes in Ethiopia (e.g. Tamrat Bekele, 1993; Ermias Lulekal, 2014).

Endemic species

Endemic species to the Flora area (Ethiopia and Eritrea) were identified based on the Flora of Ethiopia and Eritrea volumes (Vol. 1-8). The IUCN threat status of species endemic to Ethiopia was determined by comparing them with Ensermu Kelbessa *et al.* (1992) and Vivero *et al.* (2005).

Importance value Index (IVI)

Importance Value Index (IVI) of woody species computed by adding relative density, relative frequency and relative dominance (Mueller-Dombois and Ellenberg, 1974).

Diversity measurements, similarity of the community and catchment vegetation

Floristic diversity, richness and evenness indices of the study area, sites and plant communities were calculated using R Package 3.2 (R Core Team, 2015) based on the following formula. Here quadrats grouped into clusters based on floristic similarity and species abundance in order to define distinct plant community types. Identified communities were further refined in a synoptic table where species occurrences were summarized as synoptic cover-abundance values (van der Maarel *et al*., 1987).

The Shannon Wiener diversity index is one of several diversity indices used to measure diversity (Krebs, 1999).

Shannon –Wiener Diversity Index, (H') is calculated as follows:

H'= $-\sum_{i=1}^{s} pilnpi$,

Where H´ = Diversity Index; s i = the number of species, Pi = the relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community (ni/N, where ni is the number of individuals of a species, N - total number of individuals in a community), lnPi = natural logarithm of this proportion.

Shannon's evenness index (J) was calculated using the formula**:**

Shannon's evenness index (J) = H'/H'max = $-\sum_{(I=1)}^{s}$ pilnpi / ln S

Where, J = evenness; H' = Shannon-Wiener Diversity Index; S = total number of species in the sample. The value of evenness index falls between 0 and 1. The higher the value of evenness index, the more even the species is in their distribution within the given area (Kent and Coker, 1992).

Species richness was calculated as: $Species\ Richness = \frac{(S-1)}{Log\ N}$

Where S = total number of species; N = total number of individual of all species. In species richness higher, the value more is the diversity.

Sorensen's similarity coefficient used to measure the pattern of species similarity among communities identified in Temcha Watershed between (Kent and Coker, 1992). This was calculated using the following formula: (Ss), Ss = 2a/ (2a+b+c),

Where, a = number of species common to both forests compared; b = number of species in one forest; and c = number of species in the other forest.

Species turnover (β-diversity) measures the change in species composition from place to place among set of habitats or along environmental gradients (Whittaker, 1972) and can be calculated based both on presence/absence and abundance data.

$$\beta - \text{diversity} = \frac{\text{b} + \text{c}}{2\text{a} + \text{b} + \text{c}}$$

Where a = the number of shared species in two sites I.e., a and b, b = the number of species unique to site b and c = the number of species unique to site c.

A high β–diversity index indicates a low level of similarity among areas, while a low beta diversity index shows a high level of similarity (Økland, 1990)

Table 1.**Number of line transects and quadrats on the selected patches and kebeles at different leg of Temcha Watershed (LC= Lower Catchment; MC= Middle Catchment; UC= Upper Catchment)**

Catchment	LC		MC		UC		Total
Altitude range	1784 – 1970 m		1886 – 2067 m		2243 – 2862 m		
Forest Patch	Yemnchna Yekest	Wad	Kuashibana Akababiew	Yemehel	Shimna Abidender	Shafo Galat	-
No. of Line transect	5	3	4	5	3	4	24
Plot range	1-18	19 – 27	28 - 42	43 – 60	61 – 72	73 – 86	1-86
No. of plot	18	9	15	18	12	14	86
Total area sampled(hectar)	0.72	0.36	0.6	0.72	0.48	0.56	3.44
Study area	36 ha	27.91ha	30.6 ha	44.9 ha	28.2 ha	31.5 ha	198 ha

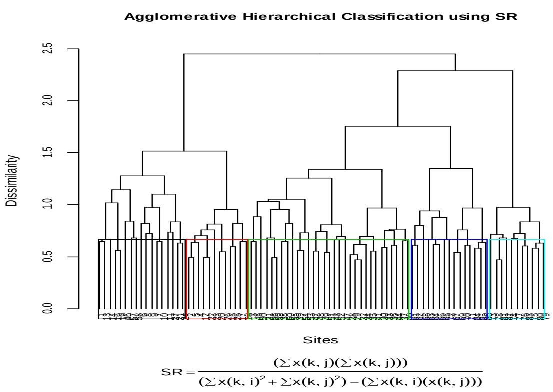
3.RESULTS and DICUSSIONS

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

Plant community types in Temcha Watershed

The TW has five communities based on 60 % information remain in Agglomerative Hierarchical classification using similarity ratio in R software and the communities were named based on high synoptic cover abundance value (Figure 2 and Table2).

The description of plant community involves the analysis of species diversity, evenness and similarity (Whittaker, 1975). The patches of forests in TW are classified in to five communities. These plant community formations may be due to wide altitudinal variation in the study patches of forests stretching over a range of 1078 m elevation. Hedberg (1964) and Hamilton (1982) indicated that wide altitudinal variation affects atmospheric pressure, moisture and temperature in an area accompanied by varying degrees of differences in microclimatic conditions resulting in variations in plant community structure.



*C indicates community and the number indicates the quadrat

*C1 = 1, 6, 7, 8, 9, 10, 11, 13, 14, 16, 19, 21, 24, 27, 46, 57 and 58

*C2 = 2, 4, 5, 12, 15, 17, 18, 20, 22, 23, 25 and 26

*C3 = 3, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 59 and 60

*C4 = 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 84, 85, and 86

*C5 = 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83

Figure 2 Plant community (C) identification in TW by agglomerative hierarchical classification using similarity ratio in R

Catchment classification

The catchment vegetation approach in TW classifeied the vegetation in to three catchment based on the location of the patch as lower catchment (Wad and Yemnchna Yekest) contained a total of 27quadrat, 109plant species and stretched to 1784-1970 m, middle catchment (Yemehel and Kwashibana Akababiw) witha total 33quadrat, 114 plant species and stretched to 1886-2067 m, and upper catchment (Shimna Abidender and Galat Shafat) with a total 26quadrat, 105 plant species and stretched to 2243-2862 m (Figure 3).

Figure 3 Temcha Watershed and sub districts that contain forest patches in the lower catchment (Wad and Yemenchna Yekest), middle catchment (Kwashebana Akababiw, Yemehel) and upper catchment (Galat Shafat, Shemina Abidender)

Table 2 Synoptic cover abundance value of species reaching a value of >3.1 in at list one community type in TW (C = Community)

Scientific name	C1	C2	C3	C4	C5
Phoenix reclined	**3.88**	4.83	0.52	0.00	0.00
Clausena anisata	**3.12**	0.50	1.10	1.47	0.00
Acacia senegal	2.47	**8.25**	0.00	0.00	0.00
Croton macrostachyus	3.41	**6.00**	5.23	3.67	0.00
Albizia schimperiana	0.00	0.00	**5.74**	2.20	0.00
Ehretia cymosa	0.41	0.00	**3.26**	0.00	0.00
Prunus africana	2.35	0.00	1.42	**3.33**	0.00
Hypoestes triflora	0.29	0.00	0.90	**3.40**	1.45
Maesa lanceolata	1.06	2.92	1.65	2.80	**7.00**
Kniphofia foliosa	0.00	0.00	0.00	0.00	**5.18**
Acacia etbaica	1.12	5.33	0.00	0.00	0.00
Buddleja polystachya	0.18	0.25	1.90	1.13	4.18
Carissa spinarum	2.41	3.58	2.06	1.53	0.00
Discopodium penninervium	0.00	0.00	0.10	1.53	3.45
Dombeya torrida	0.18	0.00	0.84	2.73	4.91
Maytenus gracilipes	0.00	0.00	0.00	3.13	1.91
Nuxia congesta	1.76	2.58	1.32	0.53	4.73
Rosa abyssinica	0.24	1.00	0.39	2.00	4.36
Satureja paradoxa	0.00	0.00	0.00	0.00	3.55

Proportion of quadrats and plant species found in identified plant communities in geographically separated patch of forests in TW

The patches of forests found in TW were categorized in to three catchments based on the location of forests and five community classification based on similarity ratio were compaired based on total quadrat shared and plant shared are presented in (Table 3).

Table 3.Distribution of quadrats and number of shared plants from identified plant community at different catchments in the watershed (S= species richness, H'= Shannon-Wiener Diversity, SP = Shared plant, SQ = shared quadrat, TQ = total quadrat

Community type, quadrat distribution, total plant and diversity				Lower catchment: total quadrat 27, total plant 109			Middle Catchment: total quadrat 33, total plant 114			Upper catchment: total quadrat 26, total plant 105		
Community type	TQ	S	H'	SP	SQ	% SP	SP	SQ	% SP	SP	SQ	% SP
Phoenix reclinata - Clausena anisata (C1)	17	105	4.20	95	14 (82.4 %)	90.47	71	3 (17.6 %)	67.6	49	0	46.66
Acacia senegal - Croton macrostachyus (C2)	12	67	3.70	67	12 (100 %)	100	40	0	59.7	26	0	38.8
Albizia schimperiana - Ehretia cymosa (C3)	31	111	4.10	68	1(3 %)	61.26	109	30 (97 %)	98	62	0	55.85
Hypoestes triflora - Prunus africana (C4)	15	82	4.02	47	0	57.31	65	0	79.26	82	15 (100 %)	100
Maesa lanceolata - Kniphofia foliosa (C5)	11	75	3.90	26	0	34.6	41	0	54.66	75	11 (100 %)	100

C= Community

From the communities identified, *Phoenix reclinata- Clausena anisata* community had high species richness and evenness with diversity value of 4.2. Species diversity increases when the populations have more even abundances and vice versa (Maguran, 1988; Lean and Maclaurin, 2016). Ninety percent of the 105 plant species in this community were collected from the lower catchment areas. However, due to the fact that some of these plants also grow in a wide range of altitudes, more than half of these plants (67 %) and close to half (47 %) were collected from the middle and upper catchments respectively. Of the total number of quadrats (17), 14 (82.4 %) and three (17.6 %) quadrats were located in the lower and middle catchments. However, *Acacia senegal - Croton macrostachyus* community type has lowest diversity with the diversity value of 3.7. All the quadrats in this community were found in the lower catchment. In spite of this, from the total plant species (67), 59.7 % and 38 % of the plants were collected from middle and upper catchments.

In the study, more similarity was observed in between *Phoenix reclinata – Clausena anisata* community and *Albizia schimperiana - Ehretia cymosa* community. This is because these two communities are geographically close to each other and have many overlaps in plant species composition. According to Condit *et al.* (2002), small differences in species composition across plant communities may show adaptations of species to similar environmental conditions coupled with efficient dispersal of the species forming the communities. On the other hand, the least species similarity was recorded between *Maesa lanceolata - Kniphofia foliosa* community and *Acacia senegal - Croton macrostachyus* community. All quadrats in these two communities were exclusively distributed in the upper and lower catchments respectively. However, due to the presence of plants which grow in an extended altitude some plants collected in these two communities are also collected from the other catchments. Consequently, the two communities share very low similarity due to geographical separation than any of the other communities.

The community classifications fitted with the catchment classification based on the percentage of quadrats and species shared in these two systems of classification. For instance, the quadrats laid in the lower catchment and upper catchment comprised different community types that shared limited similarity of plants than the other community. There is also high beta diversity in between upper catchment vegetation and lower catchment vegetation that further strengthened the assertion that there is limited similarity among them.

In general, the proportion of quadrats and plants shared with the five communities and three-catchment vegetation identified by the location of the patches in Temcha Watershed indicated that plant community formations are mainly affected by altitude. According to Chen *et al.* (2003), species composition of forests was also affected by environmental heterogeneity, regeneration success and competition.

To adequately capture the variation of plant diversity in different communities and catchment vegetation, functional traits related to diversity like productivity, competitive ability, reproduction, disturbance tolerance, life history, and tolerance to habitat instability of plants (Biswas and Mallik, 2010) might demand further investigation in the study area.

Floristic composition

Two hundred twenty plant species distributed in 169 genera and 76 families were collected in the study area. Of these, 193 plant species were collected from the sampled quadrats and the remaining 27 plant species were collected outside the quadrats. The woody plant species accounted for 2/3 of the total plant species collected i.e., 149 plants (75 shrubs, 55 trees and 19 plants are lianas). The herbs accounted for 71 plant species including 6 herbaceous climbers. The observed diverse flora of TW is in line with the patterns of species richness documented in East African montane forests (Coetzee, 1978). More specifically plant diversity in TW are due to an extended altitude (1784 – 2862 m a.s.l) and presence of different vegetation types along the river.

Among the families present, the highest number of species was recorded in the family Fabaceae (10.9 %) and Asteraceae (10 %). Similarly, the family Fabaceae is the richest family in species composition in the Flora area followed by Poaceae, Asteraceae and Euphorbiaceae (Ensermu Kelbessa and Sebsebe Demissew, 2014). The family Fabaceae was also the richest family reported by Abiyot Berhanu *et al.* (2016). The family Asteraceae is also known as the richest family in other parts of Ethiopia (Haile Yineger *et al.*, 2008; Abiyou Tilahun *et al.*, 2011; Ermias Lulekal, 2014).

From the collected plants, 17 plant species are endemic (7.7 % of total) to the Flora of Ethiopia and Earitrea (Table 4). Among the total endemics, eight species are herbs, six species are shrubs; and three species are trees. These plants were distributed in three catchments i.e., 29.40 % of the plants were found in lower catchment, 58.80 % in mid and 76.47 % in upper catchments (Table 4).

Table 4 Endemic species in Temcha Watershed(EN = Endangered, Lc = Least concerned, NT= near threatened, VU = vulnerable, LC = lower catchment, MC = middle catchment, UC = upper catchment)

Scintific name	Family	Local Name	Catchment present	Habit	IUCN threat level
Acanthus sennii	Acanthaceae	KOSHESHILA	MC, UC	S	NT
Cussonia ostinii	Araliaceae	CHAKMATIE	LC	T	NT
Cynoglossum coeruleum	Boraginaceae	YEDMET AYEN	MC	H	-
Echinops kebericho	Asteraceae	KEBERICHO	MC	S	VU
Echinops longisetus	Asteraceae	GONGOBIL	UC	S	Lc
Erythrina brucei	Fabaceae	KORCH	UC	T	Lc
Kalanchoe densiflora	Crassulacae	ENDAHULA	ALL	H	-
Kniphofia foliosa	Asphodelaceae	ASHEGDYE	UC	H	-

Laggera tomentosa	Asteraceae	AMEDMADO	MC, UC	H	-
Mikaniopsis clematoides	Asteraceae	AMEDO HAREG	UC	H	Lc
Millettia ferruginea	Fabaceae	BIRBIRA	ALL	T	Lc
Rhus glutinosa	Anacardiaceae	ASHEKAMO	ALL	S	VU
Satureja paradoxa	Lamiaceae	METITE	UC	H	NT
Solanecio gigas	Asteraceae	BOZE	MC, UC	S	Lc
Trifolium decorum	Fabaceae	WAJMA	MC	H	-
Urtica simensis	Urticaceae	SAMA	ALL	H	Lc
Vernonia rueppellii	Asteraceae	TIKUR GENGERTA	UC	S	Lc

Woody species frequency

The top most frequent species in TW are *Croton macrostachyus* (62.79), *Bersama abyssinica* (46.51) &*Maesa lanceolata* (45.35). *Croton macrostachyus* (70.37), *Acacia senegal* (62.96) &*Phoenix reclinata* (59.26) are the top three frequent species in lower catchment. The top three frequent species in middle catchment are *Calpurnia aurea* (87.88), *Albizia schimperiana* (81.82) &*Croton macrostachyus* (72.73) Species such as *Dombeya torrida* (61.54), *Maesa lanceolata* (57.69) &*Bersama abyssinica* (57.69) are the most frequent species in the upper catchment.

The most frequently encountered species in the study area (in many quadrats) are *Croton macrostachyus* collected from 54 quadrats and distributed in the Flora region between 500-2350 m altitudes; *Bersama abyssinica* collected from 40 quadrats and distributed in the Flora region between 1700-2715 m altitudes and *Maesa lanceolata* collected from 39 quadrats being distributed in the Flora region between 1350-3000 m altitude. The frequency of these species might be attributed to their occurrence along wide altitudinal ranges as indicated in the Flora of Ethiopia and Eritrea (Sebsebe Demissew, 1995; Hedberg *et al.,* 1989; 2003). High frequency of a species always depends on a number of factors that relate to habitat preference, adaptation, degree of exploitation and availability of suitable conditions for regeneration (Rey *et al.,* 2000).

Data on frequency of distribution of plants provided information about the nature of the forest in addition to species distribution. For example, *Croton macrostachyus*, *Maytenus arbutifolia, Maesa lanceolata* and *Bersama abyssinica* were plants with high frequency in the study area. These plants are gap fillers and pioneer woody species in disturbed sites, secondary forests and forest edges of the DAF and MAF (Tamrat Bekele, 1993; Townsend, 2000; Gemedo Dalle and Masresha Fetene, 2004; Azene Bekele, 2007; Friis *et al*,. 2010; Ermias Lulekal, 2014; Abiyot Berhanu *et al.*, 2017). The three catchments also shared this scenario because either of the above-mentioned plants were also in the top ten highest frequency woody plants and distributed homogeneously throughout the three catchments. The frequency distribution also showed the presence of plants heterogeneously distributed across the catchments. For example, *Acacia senegal, Mimusops kummel and Podocarpus falcatus* were found only in the lower catchment.

Woody species density

The overall woody plant species density in the pooled patches was 1475 Ind. ha^{-1} The top three highest density species are *Croton macrostachyus, Maesa lanceolata* & *Albizia schimperiana.*When compared with other study sites in DAF, the values are greater than the density of Dense forest, 138 individuals ha^{-1} (Ermias Lulekal, 2014), Adelle (898 individuals ha^{-1}) and Boditi forest (498 individuals ha^{-1}) (Haile Yineger *et al*., 2008) and less than Zengena forest (2, 202 individuals ha^{-1}) (Desalegn Tadel *et al.,* 2014). According to Whittaker *et al.* (2003), variations in density distributions can be attributed to variations in topographic gradients and habitat preferences of species forming the forest, and the degree of anthropogenic influences. Another reason for the large number of individuals per hectare than in the other comparable forests could be due to the fact that the forest is not closed. The emergent trees in all different communities in TW are very few creating an opportunity for other species to grow.

The density of woody species in the three catchments showed great variability among them. The lower catchment has larger woody species density (2201 ind. ha^{-1}) than the middle catchment (941 individuals ha^{-r}) and upper catchment (721 ind. ha^{-1}). These may be due to differences in habitat preferences of plants in the Watershed or it might also indicate that the lower catchment has a better vegetation cover than the two catchments. The top 10 woody plant density report in the three catchments showed habitat preferences of selected plants like *Acacia senegal* (147 ind. ha^{-1}), *Albizia schimperiana* (137 ind. ha^{-1}) and *Maesa lanceolata* (95 ind. ha^{-1}), which are preferred in the lower, mid and upper catchments respectively.

The largest density of the woody species and other plants are mainly found in the middle DBH and height classes. The density of plants in the next higher diameter and height classes declined considerably suggesting that there is interference or anthropogenic disturbance attributed to the unplanned and unsustainable exploitation of woody species in the forest by the local people not only for domestic consumption but also for generating income (Alemnew Alelign *et al.,* 2007).

Larger density of plants below the middle DBH class in this study area also indicates the historical management of the selected patches of forests. All patches of forests found along the river are open access areas and provide most of the charcoal and firewood used in the rural centers. The unsustainable exploitation of the forest patches by the local communities has critically affected species evenness of the woody plants and population structure. The evidences were shown by the very low density of woody plants in higher diameter classes above the middle and high dominance of individuals below the middle diameter and height classes.

Basal area (BA) of Woody species

Total BA of woody species in the pooled patches with DBH ≥ 2.5 cm was 83.23 m^2 ha^{-1}. The top three dominant tree species in the pooled patches of forest are *Croton macrostachyus* (9.31 m2 ha-1), *Prunus africana* (8.72 m^2 ha^{-1}) &*Albizia schimperiana* (5.55 m^2 ha^{-1}) The total BA in LC was 103.94 m^2 ha^{-1} and the dominant tree species are *Albizia gummifera* (11.24 m^2 ha^{-1}), *Croton macrostachyus* (11.15 m^2 ha^{-1}) &*Acacia senegal* (7.78 m^2 ha^{-1}) The total BA in MC was 69.09 m^2 ha^{-1} and the dominant tree species are, *Albizia schimperiana* (17.25 m^2 ha^{-1}), *Croton macrostachyus* (13.80 m^2 ha-1) & Ficus sur (4.81 m^2 ha^{-1}) The total BA in UC was 46.21 m^2 ha^{-1} and the dominant tree species are *Prunus africana* (23.97 m^2 ha^{-1}), *Apodytes dimidiata* (6.52 m^2 ha^{-1}) &*Croton macrostachyus* (2.54 m^2 ha^{-1}).

Woody plant species recorded and grouped in the higher DBH classes contributed most for the total BA and hence about 52.7 % of the total basal area were contributed by ten large-sized tree species, i.e. *Croton macrostachyus*, *Prunus africana*, *Albizia schimperiana*, *Ficus sur*, *Albizia gummifera*, *Acacia abyssinica*, *Millettia ferruginea*, *Syzygium guineense*, *Acacia senegal* and *Apodytes dimidiata*. These species provide functional significance to the patches of forests in the area because BA is closely proportional to leaf area and foliage mass than are the other common structural measures (McCune and Grace, 2002).

The BA of forests in TW is considerably lower than Tara Gedam forest (115.4 m^2 ha^{-1}) (Haileab Zegeye *et al.*, 2011), Wof-Washa forest (102 m^2 ha^{-1}) (Tamrat Bekele, 1993) and higher than in similar forest fragments such as Kuandisha Afromontane forest (15.3 m^2 ha^{-1}) (Abiyot Berhanu *et al.*, 2017), Jibat forest (50 m^2 ha^{-1}) (Tamrat Bekele, 1993), Denkoro forest (45 m^2 ha^{-1}) (Abate Ayalew *et al.*, 2006). The lower total BA is mainly attributed to lower DBH of woody species (Tamrat Bekele, 1993). The basal area of woody species reported from Tara Gedam and Wof -Washa is higher than the present study area. The most appealing reason is that Tara Gedam forest and Wof-Washa forest have seasoned and large-sized trees, which have long been protected by the church and forest guards. Moreover, according to Alemayehu Wassie *et al.* (2005), churches and monasteries harbor many of the forests with the oldest and large-sized individuals of trees in North Gondar.

The top ten highest basal area woody plants in TW were also distributed in the three catchments. For example, *Albizia gummifera* (11.24 m^2 ha^{-1}) and *Croton macrostachyus* (11.15 m^2 ha^{-1}), *Albizia schimperiana* (17.25 m^2 ha^{-1}) and *Croton macrostachyus* (13.80 m^2 ha^{-1}) and *Prunus africana* (23.97 m^2 ha^{-1}) and *Apodytes dimidiata* (6.52 m^2 ha^{-1}) constituted the largest basal area in the lower, middle and upper catchments, respectively. Contributions of WEPs for highest basal area in different catchments were also substantial.

Importance value index (IVI)

The top ten highest IVI value recorded in this study was for *Croton macrostachyus* (81.21), followed by *Maesa lanceolata* (52.21) (Table 5). Whereas, the highest IVI value of woody species was documented for *Croton macrostachyus* followed by *Acacia senegal*, *Albizia schimperiana* followed by *Croton macrostachyus* and *Prunus africana* followed by *Maesa lanceolata* in the lower, middle and upper catchments respectively(Table6).

Table 5 IVI values of top ten woody plants in Temcha Watershed

No	Plant species	Relative Density	Relative frequency	Relative Dominance	IVI value
1	*Croton macrostachyus*	7.05	62.79	11.36	81.21
2	*Maesa lanceolata*	4.84	45.35	2.02	52.21
3	*Bersama abyssinica*	4.06	46.51	1.24	51.81
4	*Albizia schimperiana*	4.10	39.53	6.77	50.41
5	*Nuxia congesta*	3.94	33.72	2.52	40.18
6	*Pavetta abyssinica*	3.44	36.05	0.69	40.17
7	*Prunus africana*	2.07	25.58	10.65	38.29
8	*Vernonia amygdalina*	2.23	33.72	0.94	36.89
9	*Ficus sur*	1.65	29.07	5.24	35.96
10	*Acacia abyssinica*	2.51	26.74	3.80	33.06

Table 6 IVI values of top ten highest woody plants in the three catchments (IVI = important value index)

Lower catchment		Middle catchment		Upper catchment	
List of species	IVI	List of species	IVI	List of species	IVI
Croton macrostachyus	87.06	*Albizia schimperiana*	117.82	*Prunus africana*	82.26
Acacia Senegal	76.64	*Croton macrostachyus*	102.46	*Maesa lanceolata*	73.03
Phoenix reclinata	70.10	*Calpurnia aurea*	89.68	*Dombeya torrida*	72.26
Pavetta abyssinica	55.42	*Carissa spinarum*	57.15	*Bersama abyssinica*	64.42
Carissa spinarum	54.33	*Bersama abyssinica*	57.10	*Pavetta abyssinica*	62.62
Albizia gummifera	54.16	*Ehretia cymosa*	56.84	*Rosa abyssinica*	58.05
Calpurnia aurea	50.98	*Ficus sur*	55.96	*Buddleja polystachya*	53.70
Nuxia congesta	49.58	*Vernonia amygdalina*	52.73	*Vernonia rueppellii*	51.61
Syzygium guineense	48.85	*Pavetta abyssinica*	49.25	*Croton macrostachyus*	48.83
Acacia etbaica	47.59	*Buddleja polystachya*	45.80	*Calpurnia aurea*	46.69

One hundred nine woody plant species were analyzed using Importance Value Index (IVI) and each of these obtains different values. According to Mueller-Dombois and Ellenberg (1974) and Curtis and McIntosh (1950), the relative ecological significance and/or dominance of a tree species in a forest ecosystem could best be identified from IVI analysis. The top four species with highest IVI values were *Croton macrostachyus* (81), *Bersama abyssinica* (52), *Maesa lanceolata* (52.2) and *Albizia schimperiana* (50). The values for *Croton macrostachyus* and *Albizia schimperiana* are due to High relative frequency and relative basal area values whereas *Maesa lanceolata* and *Bersama abyssinica* are due to high relative frequency. The larger IVI value arisen from basal area is an important structural measurement for the ecological services that the plant provides (McCune and Grace, 2002) and hence *Croton macrostachyus* and *Albizia schimperiana* are ecologically very important plants in the area. In addition, Thus, in this investigation, the IVI results also confirmed that these four species are the most important / dominant species in the study area.

Among the 109 Plants recorded only from the riverine forest, the three species with highest IVI values in decreasing order are *Celtis africana* (19), *Ficus sycomorus* (94) and *Mimusops kummel* (50). Thus, these plants are ecologically very important in the riverine vegetation along TW as previously indicated (Friis *et al.,* 2010). IVI values of additional riverine plant species include *Phoenix reclinata* (13), *Syzygium guineense* (21) and *Salix subserrata* (82) have also been indicated by an earlier work as the important species found in TW (Friis *et al.,* 2010). Moreover, species like *Myrsine melanophloeos, Olea europaea* subsp. *cuspidata, Dovyalis caffra, Dregea schimperi, Ricinus communis, Hypericum revolutum, Opuntia ficu-indica, Psidium guajava, Hippocratea africana* had the least IVI values with rare occurrences.

The IVI value reports in each catchment were helpful to select ecologically important plants, accordingly. From the top ten IVI values registered, *Croton macrostachyus* and *Acacia senegal* were ranked 1st and 2nd from the lower catchment. Similarly, *Albizia schimperiana* and *Croton macrostachyus* and *Prunus africana* and *Maesa lanceolata* were ranked in the first and second positions in the mid and upper catchments.

Diameter at breast height (DBH) distribution

The density of trees and shrubs in Temcha Watershed across seven DBH classes indicated a relatively high density of individuals in DBH class 20.1 - 50 cm (649) and DBH class 10.1 - 20 cm (418). The lowest proportion of individuals was recorded in DBH class >140 cm (Figure 4). All DBH classes were represented by some individual plant species. However, the highest density was concentrated in DBH classes below 50 cm. The highest DBH was recorded for *Ficus ingens* (191 cm), *Albizia gummifera* (159 cm) and *Prunus africana* (143 cm). In general *Ficus ingens, Albizia gummifera, Prunus africana, Ficus sycomorus, Apodytes dimidiata* and *Schefflera abyssinica* were found to be the dominant large-sized trees in Temcha Watershed with DBH >110 cm.

The value obtained from a comparison of the ratio of density distribution of trees or shrubs in DBH > 10 cm and DBH > 20 cm in TW is 0.6. As indicated in Figure 12, the density of individuals in the pooled patches of forest is high in DBH class of 20-50 cm. This value is much less than that of researches conducted in some of the forest priority areas like Chilimo (2.6) and Menagesha Suba (2.3) (Tamrat Bekele, 1993), Mana Angetu (2.09) (Ermias Lulekal *et al.*, 2008), Dindin (1.99) (Simon Shibru and Girma Balcha, 2004) and Denkoro (1.90) (Abate Ayalew *et al.,* 2006). The results indicated that the different patches of the forests in TW have not been benefiting from close management and protection on account of being recognized as important forest priority areas in Ethiopia.

The highest DBH measurement in this study reached to 191 cm, 159 cm and 143 cm for *Ficus ingens*, *Albizia gummifera* and can reach up to 45 m (GTZ 2003; Haile Yineger *et al.*, 2008; Haileab zegeye *et al.*, 2011; Desalegn Tadele *et al.*, 2014). Tamrat Bekele (1993) and GTZ (2003) also indicated that in undisturbed forests, tree species such as *Prunus africana*, *Juniperous procera*, *Schefflera abyssinica*, *Albizia shimperiana*, *Ekebergia capensis*, *Celtis africana*, *Croton macrostachyus* and *Cordia africana* were reported to reach a DBH of between 80 - 270 cm and a height of 30 - 46 m in the DAF. Nevertheless, the above species in the present study *Prunus africana* and their heights being less than 32 m. This is relatively much less than those mature tree species found in undisturbed forests. In the undisturbed forests, the DBH of mature trees usually reaches up to 270 cm while their height showed DBH between 30 -143 cm and heights between 16 - 31 m. These comparisons also indicated that the forest patches in the current study showed some sort of disturbances. In general, Tamrat Bekele (1993) and Friis *et al.* (2010) indicated that in disturbed forests, the upper canopy species except few of them are usually removed for various purposes and only short stature trees in the middle and lower canopy with a DBH of less than 50 cm and height less than 21 m remain in the forest.

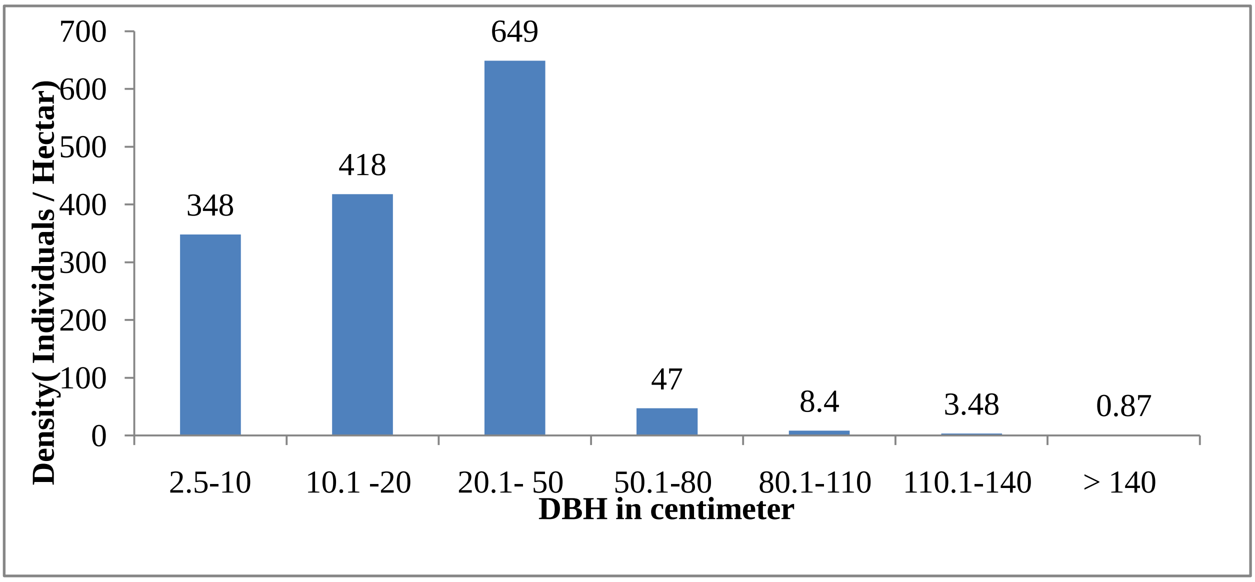


Figure 4. Density of woody species in different DBH class

Height class distribution

The density of trees and shrubs in Temcha Watershed across the ten height classes showed a similar pattern to DBH classes. The majorities of individuals in this study were grouped in the lower height classes (< 10 m) with the highest distribution in the second height class and gradually decreases up to the sixth class until it eventually stops thereafter (Figure 5). No plants were recorded for heights greater than 31 m. Some of the emerging woody plants in the forest were *Phoenix reclinata* (31 m), *Ficus sycomorus* (30 m), *Prunus africana* (30 m), *Podocarpus falcatus* (25 m), *Albizia gummifera* (25 m) and *Apodytes dimidiata* (25 m).

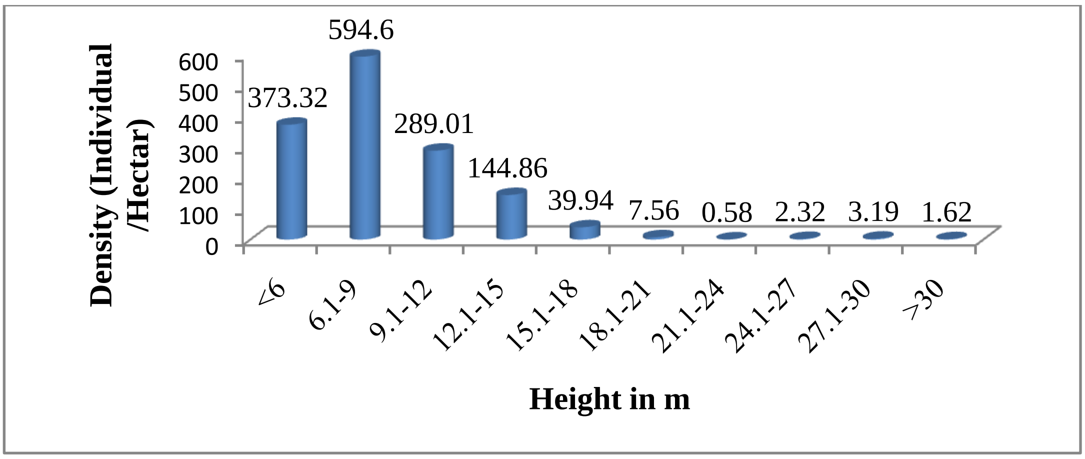


Figure 5 Distribution of overall woody species density in 10 height classes (m)

Population structure

Three general patterns of population structure were recognized after making graphs for the most common tree species (Figure 6 A-C).

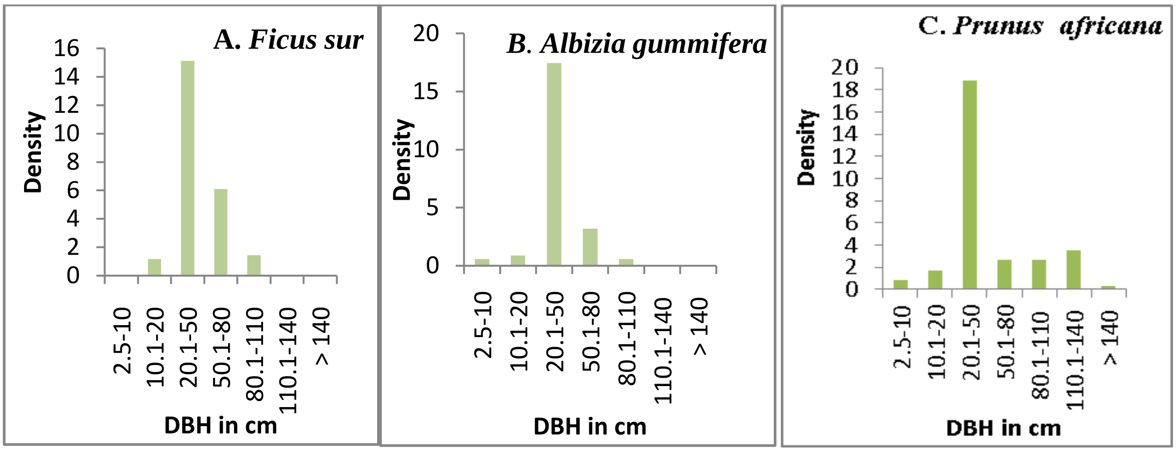


Figure 6(A-C). Representative population structure patterns of each tree species in the study area

The density distribution of individuals of all woody species in the various diameter classes were not uniform in TW, but it showed a progressive trend of decline. The number of individuals decreased with increasing diameter classes, suggesting a more or less inverted J-shaped population structure, an indication of stable population structure or healthy regeneration status. This conclusion agrees with those of other researchers (Simon Shibru and Girma Balcha 2004; Alemnew Alelign *et al.*, 2007; Haileab Zegeye *et al.*, 2011). However, the researcher noted that some species were not in healthy regeneration status because of compensation effect.

Interpretation of the general population pattern needs caution. The pertinent reason with the observed population patterns of the forest patches was the "compensatory effect;" where populations of one species compensates for the missing populations of another species in various DBH and height classes (Ducey, 2010). In this study, the individual tree species structural pattern revealed that they lacked individuals at various DBH or height classes. The various patterns of population structure of trees eventually resulted in three different population patterns. The patterns of species population structure are indications of the variations in population dynamics in the forest (Popma *et al.*, 1988). Practically, it can give an estimate of the regeneration status of woody species (Demel Teketay, 2005a).

Different population patterns of tree species result due to various factors such as selective cutting, disturbance, shade-intolerance and life history strategy (Bin *et al.*, 2012, Ambachew Getnet *et al.*, 2019). Similarly, population structure analysis of woody species in TW and the existing facts showed the following three major representative patterns of density distribution of trees across different DBH classes.

Ficus sur population pattern

This population pattern is also shared by *Combretum molle*, *Schefflera abyssinica*, and *Juniperus procera*. The pattern indicates the absence of individuals in the first or second DBH class, but occurs in the next three or four DBH classes and also absent in the last three or two classes of the highest DBH classes. This pattern indicates hampered regeneration caused by heavy human pressure on the species leading to scarcity of mature individuals that can serve as seed sources in the forest. Similar findings were also reported by Simon Shibru and Girma Balcha (2004); Dereje Denu (2006).

In general, this pattern may have been the result of lack of regeneration and establishment of populations of a species after a major disturbance such as clear-cutting for agriculture, grazing land or settlement, leaving few mature individuals as shade trees (Friis, 1986). Similarly, deforestation has been suggested as a factor hampering natural regeneration and seedling establishment in tropical forests, and hence influencing diversity and structure of plant communities (Getaneh Gebeyehu *et al.*, , 2019). Another probable reason may be the life history strategy where mother trees negatively influence germination of seeds and establishment of seedlings under their canopies (White, 1983; Bin *et al.*, 2012) including by producing allelochemical, grazing of the seedlings. This pattern has been rarely reported for some tree species including *Juniperus procera* and *Erythrina brucei* in the highly disturbed forests of the DAF (Tamrat Bekele, 1993; Desalegn tadele *et al.*, 2014).

Accordingly, the low density of *Juniperus procera* might be related to the very poor regeneration capacity under its own canopy (Tamrat Bekele, 1993), whereas that of *Ficus sur* might be related to the lack of specific environmental conditions, mainly river courses, which the species needs to regenerate (Chapman and White, 1970). White (1983) also stated that *Juniperus procera* is a light-demanding species that does not commonly regenerate under its own shade, and therefore shows low density in closed forests.

Albezia gummifera population pattern

This pattern represented the second population structure and is shared by *Cordia africana, Acacia abyssinica, Acacia etbaica,* These plants did not reach maturity to provide mature seeds in the next generation. This indicates the phenomenon of secondary forest development or cutting of higher DBH classes. Generally, the absence of large-sized individuals might indicate that the forest has long history of anthropogenic disturbance. It shows high frequency in lower DBH classes followed by a gradual decrease and absence of representative individuals after the middle-size DBH classes. It suggests good reproduction and bad recruitment (Ermias Lulekal *et al.*, 2008; Getaneh Gebeyehu [b] et al., 2019).

Prunus africana population pattern

This population pattern was shared by *Apodytes dimidiata* and *Syzygium guineense*. It represents Gauss-type distribution pattern. It shows low frequency in the first and second DBH classes, a gradual increase in the middle class followed by a decrease in density towards the higher classes. Such population structure indicates poor reproduction (Tamrat Bekele, 1993), and a decline in some big trees. Selective cutting of large-sized individuals for various purposes, mainly timber for construction, could be the reason for decline in some large-sized tree.

Acacia senegal, Albizia schimperiana, Allophylus abyssinicus, Celtis africana, Croton macrostachyus, Dombeya torrida, Dracaena steudneri, Ehretia cymosa, Euphorbia abyssinica, Maesa lanceolata, Millettia ferruginea, Nuxia congesta, Phoenix reclinata and Pittosporum viridiflorum. In this population pattern the species occur in the first four and five DBH classes and absent in the rest of the higher DBH classes.

Species diversity evenness and richness of the plant communities

Comparison among the identified plant communities of pooled patches of forests in TW showed the highest value of overall species richness (111) for community 3, species diversity (Shannon Wiener diversity index) (4.2) for community 1, and species evenness index (0.91) for communities 1 and 4 (Table 7).

Table 7 Overall species richness, diversity and evenness values of the five plant communities identified in TW (S = Species richnes, H' = Shannon-Wiener Diversity Index, J = Shannon's evenness index)

Community type	(S)	(H')	(J)
Phoenix reclinata - Clausena anisata (1)	105	4.2	0.91
Acacia senegal - Croton macrostachyus (2)	67	3.7	0.88
Albizia schimperiana - Ehretia cymosa (3)	111	4.1	0.87
Hypoestes triflora - Prunus africana (4)	82	4.0	0.91
Maesa lanceolata - Kniphofia foliosa (5)	75	3.9	0.90

Similarity between plant communities in Temcha Watershed

Overall species similarity analysis of the five plant communities showed more floristic similarity (0.40) between communities 3 (*Albizia schimperiana - Ehretia cymosa*) and community 1 (*Phoenix reclinata - Clausena anisata*) than between any of the other pairs of communities. The least species similarity with any other community was recorded for *Maesa lanceolata - Kniphofia foliosa* and *Acacia senegal - Croton macrostachyus* communities (0.15) (Table 8).

Table 8Sorensen's similarity and dissimilarity* analysis of floristic composition of plant communities in TW

Community types	1	2	3	4	5
Phoenix reclinata - Clausena anisata (1)		**0.62***	**0.60***	**0.66***	**0.76***
Acacia senegal - Croton macrostachyus (2)	0.38		**0.70***	**0.74***	**0.85***
Albizia schimperiana - Ehretia cymosa (3)	0.40	0.30		**0.61***	**0.71***
Hypoestes triflora - Prunus africana (4)	0.34	0.26	0.39		**0.62***
Maesa lanceolata - Kniphofia foliosa (5)	0.24	0.15	0.29	0.38	

Beta diversity of pairwise comparisons of vegetation in three catchments

A high β–diversity index among the catchments was found through pairwise comparison of vegetation in between lower catchment and upper catchments. This was indicating a low level of similarity among areas or communities. A low beta diversity index was found between lower and middle catchments and upper and middle catchments showing high level of similarity (Table 9).

Table 9 Pairwise comparison of vegetation in lower, middle and upper catchments

Catchment type	Lower	Middle	Upper
Lower			
Middle	0.62		
Upper	0.70	0.65	

4. CONCLUSIONS

The six patches of forest in TW comprised many plant species including endemic species. These patches of the forest were classified into five different plant communities with different Shannon Wiener diversity, richness and evenness values. These patches were also classified in to three catchments based on the location of the patches using altitude as major parameter as lower catchment vegetation, mid catchment vegetation and upper catchment vegetation. These two systems of classification (community types and catchment) might provide an option for future management.

Results of density of woody plant species in the three catchments showed variations among the catchments. The lower catchment has the highest density (2201 ind. ha^{-1}) than the rest. The upper catchment has large number of endemic plant species accounted to 76.47 % of the total endemic plants collected from the TW. This solid fact emphasized the importance of the upper catchment in terms of number of endemic plant species even though the overall woody plant density was relatively very small (721 ind. ha^{-1}).

The overall vascular plant inventory analysis, disclosed the existence of plants that grow in a wide altitudinal range and habitat preferences. *Croton macrostachyus*, *Bersama abyssinica*, *Maesa lanceolata* and *Albizia schimperiana* are the most homogeneously distributed in more than 40 % of the quadrats and these plants have the highest relative frequency throughout the three catchments. The density distribution report disclosed the above-mentioned plant species have the highest density in the pooled patches of forests as well as in the separate catchments. The presence of these plant species showed similar patterns of species distribution in both plant community and catchment classification of the vegetation in TW. However, some plants prefer the lower catchment than the others do and it is true for the others too. In general, the population structure, DBH and height measurement of woody plants in the pooled patches of forests indicated that the patches were highly exposed to anthropogenic disturbances.

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