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PLANT LIFE FORM CLASSIFICATION AND DISTRIBUTION AT SUBA SEBETA FOREST, ETHIOPIA

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ABSTRACT: A study focusing on altitudinal distribution of life forms of vascular plants was conducted in Suba Sebeta Forest, located 40 km west of Addis Ababa in Oromia National Regional State. The objective of the study was to document the life form composition of Suba Sebeta Forest based on life form spectrum. In the study, a systematic sampling method was employed to collect vegetation data from 48 (20 m x 20 m) plots. These entire quadrats included 16 (5 m x 5 m each) subplots to incorporate all life form types. Vegetation classification was done based on Raunkiaer's major life form groups. R-Software (Version 2.15.1) Package was used to classify the life forms. The data were collected along altitudinal gradients, ranging from 2400 to 2870 m a.s.l. A total of 135 species belonging to 67 families were recorded from the study area; the results showed that Asteraceae was the dominant family accounting for 15.6% of the total record. Analysis of life form spectrum showed Phanerophytes as the dominant life form contributing 48 species (35.6%) followed by Hemicryptophytes (34 species, 25.18%), Chamaeophytes (22 species, 16.30%), Therophytes (20 species, 14.81%) and Geophytes (11 species, 8.15%). Correspondence analysis between life form and environmental gradients showed no significant relationship between life forms and soil pH while altitudinal difference affects the life form distribution. These life form variabilities along altitudinal gradient lay the foundation for further studies for monitoring of changes relating to climate change.

Key words/phrases: Life form, Life form spectrum, Raunkiaer, Suba Sebeta Forest.

INTRODUCTION

The vegetation cover of an area has a definite structure and composition developed as a result of long-term interaction of biotic and abiotic factors (Peters, 1996). Several quantitative measures are employed to describe the structure of plant communities with much ecological precision, qualitative characters such as species richness, life form spectrum, and vertical disposition of species. Raunkiaer (1934) described communities of different climatic zones or phytoclimatic zones of the earth on the basis of life form spectrum or biological spectrum. Any change in the life form composition

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away from its phytoclimatic zone is considered as an indicator of alteration in vegetation either due to biotic or edaphic factors or both. However, recently, the natural structural complexities of plant communities are being affected mostly due to reckless anthropogenic activities.

Excessive utilization of forest resources and over grazing have resulted in changes in the life form composition of plant communities (Reddy *et al*., 2002; Verma and Shukla, 1993). Life form classification is a powerful instrument employed for several purposes like land management and climate control. It also provides a way of summarizing our knowledge of understanding on life form pattern. Life form composition of vegetation to a certain extent is an indicator of the climate, and is also helpful to compare geographical distribution and to identify widely distributed plant communities (Muhammad, 2012). Plant life forms differ in every climate zone on the basis of altitude. Long-lived life forms, such as Phanerophytes, dominate in tropical zones and Hemicryptophytes dominate in arctic or alpine zones, whereas short-lived life forms such as Therophytes are most frequent in deserts. Raunkiaer (1934) reported the existence of three types of life forms with respect to the different climate zones of the earth: Phanerophytic in tropics, Therophytic in deserts and Hemicryptophytic in cold temperate zone. Cain and Castro (1959) and Shimwell (1971) also reported Hemicryptophytes as indicators of temperate zone climate while Therophytes and Geophytes are indicators of desert climate and Mediterranean climate, respectively. Vegetation profile of the component species indicates the phyto-climatic condition of an area and is employed commonly in community structural description through profile diagrams (Unwin, 1989; Ashton and Hall, 1992; Chen, 1995; Pignatti, 1995; Sahunalu and Dhanmanonda, 1995; Visalakshi, 1995).

Similarities of plants in structure and form indicate their adaptive mechanism to a given area. Whenever such similar plants grow close together, they become strong competitors since they are adapted to use the environmental resources in the same manner. According to Mueller-Dombois and Ellenberg (1974), plants of the same life form growing together are likely to compete directly for the same space. Variation in life forms along altitudinal gradients has been used for a better interpretation of vegetation and species richness patterns in relation to environmental gradients. Life form diversity creates ecological opportunity and this positive feedback culminates in the high biotic diversity that is found in tropical forests. Variation of species composition along altitudinal gradient also correlates with ecological plasticity. The distribution with altitude of every plant species gives an idea of its ecological plasticity. The life forms of plants include species, which have similarities in the complex of ecological conditions and thus are reflections of their habitat characteristics (Angelova and Tashev, 2005).

Several factors such as environment, periodic phenomena, and community development influence life forms. On the other hand, internal ecosystem functioning can be influenced by an already established life form. Solbrig (1993) described life forms as single character based functional groups, yet even at this level there are some similarities in life history and resource use that lend coherence to the categories. This is perhaps expected if life forms are the result of evolutionary forces that lead to ecological convergence (Bocher, 1977).

The vegetation resources of Ethiopia have been studied by different scholars (Logan, 1946; Pichi-Sermolli, 1957; von Breitenbach, 1962; 1963; Westphal, 1975; Chaffey, 1979; Friis *et al*., 1982; Friis, 1986; Tewolde Berhan Gebre Egziabher, 1988; Friis and Mesfin Tadesse, 1990; EFAP, 1994; Teshome Soromessa and Sebsebe Demissew, 2002). Although, many studies have been done on the vegetation classification and different ecological parameters, researches that relate to plant life form are scanty if not none at all in Ethiopia. However, the current global climate change scenario necessitates study of life forms in every climatic zone. This study focuses on vegetation classification based on Raunkiaer life form spectrum along an altitudinal gradient in the Suba Sebeta Forest. In addition, the study aims at documenting the life form composition of Suba Sebeta Forest based on biological life form spectrum for a better understanding of the vegetation characteristic.

MATERIALS AND METHODS

Description of the study area

Suba Sebeta Forest is located 40 km southwest of Addis Ababa. Geographically, it lies between 38°31' and 38°35' E and 9°89' and 9°00' N in Oromia National Regional State. The forest is found in West Shewa Zone and is part of the central plateau with altitudinal range of 2200-3385 m a.s.l. (Afework Bekele, 1994) (Fig. 1). The forest is found on the southwestern slopes of Mt. Wochacha, which is a massive dead volcano mountain with an elevation of 3385 m a.s.l. The mountain sides are generally steep with ravines cut by streams and rivers. The southern base of the mountain is at 2200 m and flanks the Becho plains. The Suba Sebeta Forest is one of the remnant patches of dry Afromontane forest in Ethiopia. This type of forest together with grassland and woodland once had formed a vegetation mosaic across the Ethiopian plateau. The forests and woodlands occur on the better drained soils of the mountains and sides of the valleys while the grassland occupies the heavy clay soils of the valley bottoms.

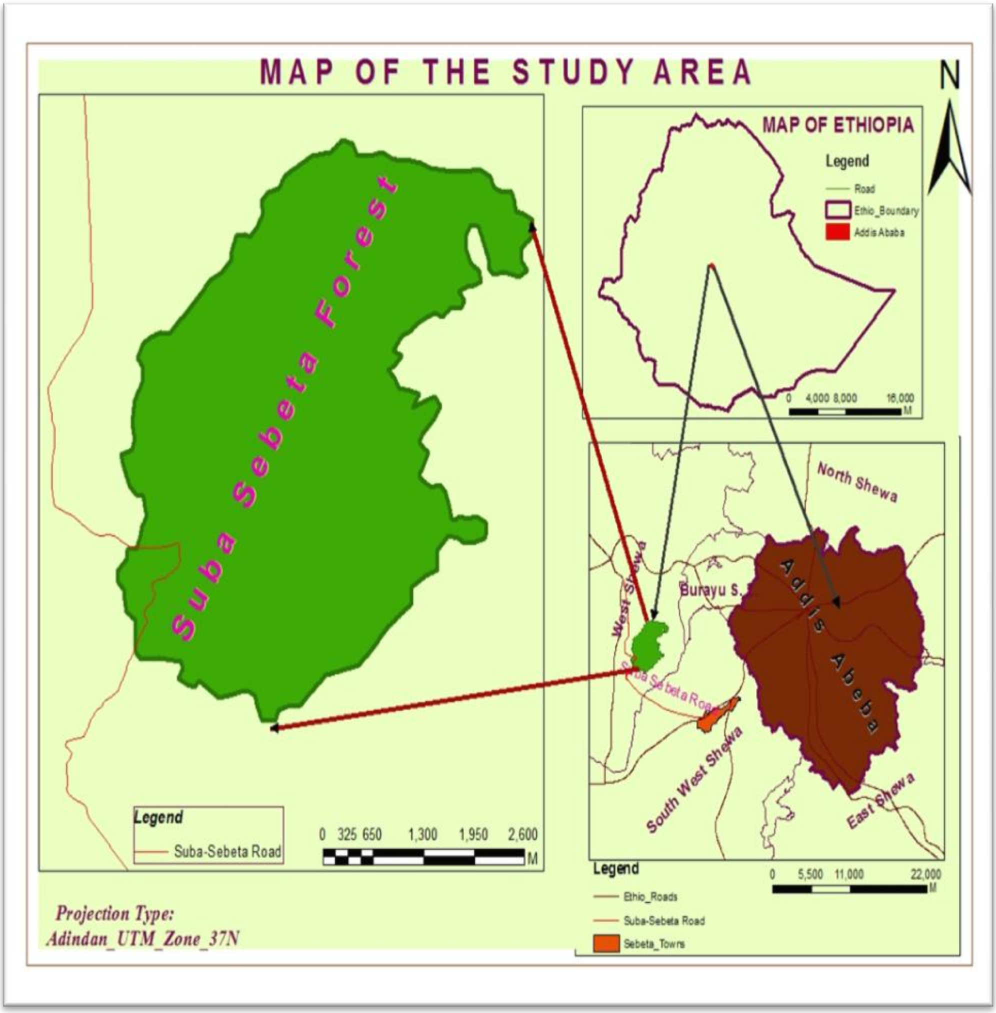

Fig. 1. Map of the study area.

Data collection

A reconnaissance survey of the vegetation was made in October 2013 in order to obtain an impression of the vegetation and topographic features. Actual field data were collected from October to November 2013. Vegetation and environmental data were collected in sample quadrats placed along transect lines, which were systematically laid. A total of 48 quadrats, at every 10 m altitudinal drop, were laid along transect lines between 2400-2870 m a.s.l. All woody plant species including trees and shrubs were recorded in 20 m × 20 m quadrats while herbaceous species were recorded in 16 sub quadrats (5 m × 5 m) that systematically cover the entire main quadrat.

Information on habit, habitat, vegetation type, the nature of perennial bodies was recorded so as to draw a life form spectrum, following the concept of Raunkiaer (1934). In the construction of life form spectra each species was assigned to a single life form.

Physiographic variables such as altitude and geographic coordinates were measured for each quadrat using GPS. Specimens of all vascular plant taxa were collected, pressed, dried and brought to the National Herbarium (ETH), Addis Ababa University, for identification. The specimens were dried in the dryer, kept in a deep freezer for 72 hours and identified referring to the volumes of Flora of Ethiopia and Eritrea as well as reference collections.

Soil sample

Soil samples were taken from five spots in each plot, from the four corners and from the centre. The weight of soil from the five spots was 250–300 g. Separate soil samples were taken from 0–15 cm depth of soil layers from each spot. The samples were mixed thoroughly, air dried and passed through a 2 mm mesh sieve to remove the stone pieces and the debris.

Data analysis

All the plant species recorded were grouped into different life forms based on criteria outlined by Raunkiaer (1934), and Mueller-Dombois and Ellenberg (1974). Also, a simple metrics was used to analyze proportions of life forms following Pharswan *et al*. (2010).

The percentage of life form was calculated using the following formula:

$$\%\ \text{Life form} = \frac{\text{Number of species in any life form}}{\text{Total number of species of all life forms}} \times 100$$

Soil pH analysis

The combined soil sample was subjected to pH analysis which was performed in the eco-physiology laboratory of the Department of Plant Biology and Biodiversity Management, College of Natural and Computational Sciences, Addis Ababa University. Soil pH was measured by mixing 20 grams of soil sample and 20 ml of distilled water (1:1 ratio), and stirring for 30 minutes in a 100 ml beaker. The soil-water mixture was kept for 5 minutes and the reading was taken with a Jenway 3345 Digital pH meter.

RESULTS

Life form composition

A total of 135 vascular plant species were recorded in Suba Sebeta Forest belonging to five major life form groups. The percentage of species belonging to each life form category relative to the total number of species is presented in Fig. 2. The largest life form were Phanerophytes represented by 48 species (35.5%) followed by Hemicryptophytes (34 species, 25.2%), Chamaeophytes (22 species, 16.3%), Therophytes (20 species, 14.8%) and Geophytes (11 species, 8.2%).

The 135 species recorded in the study belong to 67 families. The dominant families were Asteraceae (21 species, 15.6%), followed by Fabaceae (8 species, 5.9%), Lamiaceae (6 species, 4.4%), Apiaceae, Rubiaceae, Scrophularaceae each represented by 5 species each (3.7%).

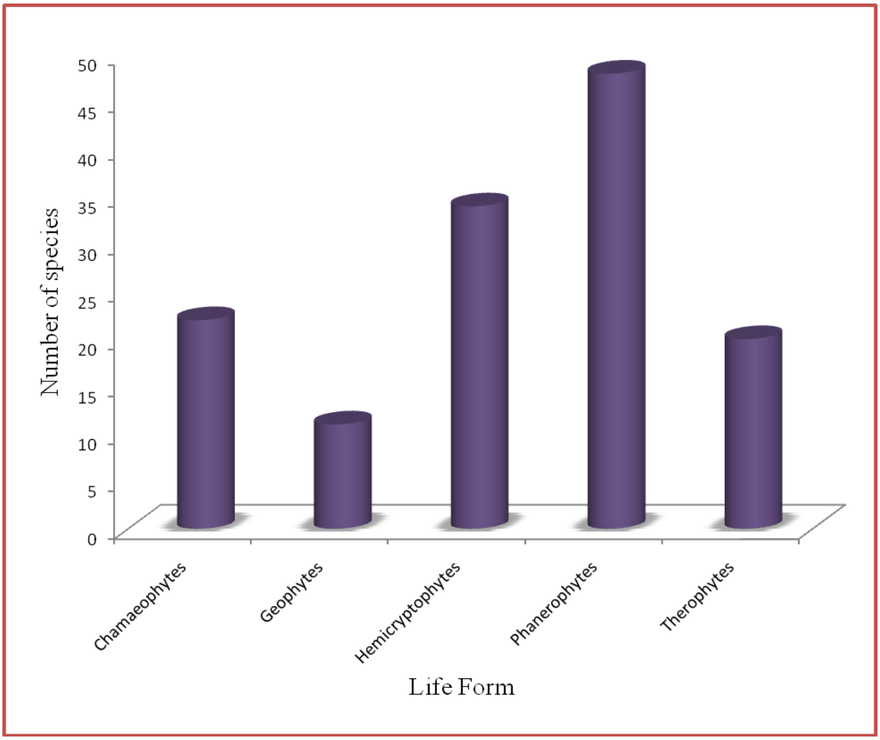

Fig. 2. Number of species per life form in Suba Sebeta Forest.

The family Asteraceae (15.6%) is represented by all the five major life form groups (Table 1). The representative species in this family include *Tagetes minuta* – Therophyte, *Lactuca inermis* – Hemicryptophyte, *Sonchus bipontini* – Geophyte, *Solanecio gigas* – Chamaeophyte and *Vernonia wollastonii* – Phanerophyte. Fabaceae with 5.9% is the next diverse family represented by Therophyte – *Trifolium simensis*, Chamaeophyte – *Dolichos sericeus* and Phanerophyte – *Albizia schimperiana*. Hemichryptophytic and Geophytic life forms are not represented in Fabaceae.

Table 1. Dominant species in the five major life form groups and their percentage contribution in Suba Sebeta Forest.

Life form	**Dominant species**	**%life form contribution**	**Growth form**
Phanerophyte	*Bersama abyssinica*	43.8%	Tree
	Dovyalis abyssinica		Shrub
	Dovyalis verrucosa		Shrub
	Jasminum abyssinicum		Shrub
	Juniperus procera		Tree
	Maytenus gracilipes		Shrub
	Maytenus undata		Tree
	Myrsine africana		Shrub
	Olea europaea L. subsp. *cuspidata*		Tree
	Olinia rochetiana		Tree
	Podocarpus falcatus		Tree
	Scolopia theifolia		Shrub
	Sideroxylon oxyacanthum		Shrub
	Teclea nobilis		Shrub
Hemicryptophyte	*Adiantum poireti*	25%	Herb
	Asplenium monanthes		Herb
	Cyperus tenuispica		Herb
	Geranium arabicum		Herb
	Kalanchoe petitiana		Herb
	Mimulopsiss olmsii		Herb
	Oplismenu shirtellus		Herb
	Sanicula elata		Herb
Chamaeophyte	*Achyranthes aspera*	15.6%	Herb
	Hypoestes triflora		Herb
	Lobelia giberroa		Herb
	Mikaniopsis clematoides		Herb
	Solanecio gigas		Herb
Therophyte	*Agrocharis melanantha*	12.5%	Herb
	Cynoglossum coeruleum		Herb
	Galiuma parinoides		Herb
	Impatiens hochstteteri		Herb
Geophyte	*Cynoglossum amplifolium*	3.1%	Herb

Life form similarity among plots

The cluster analyses resulted in five clusters (Fig. 3). The data matrix contains 48 quadrats and 135 species.

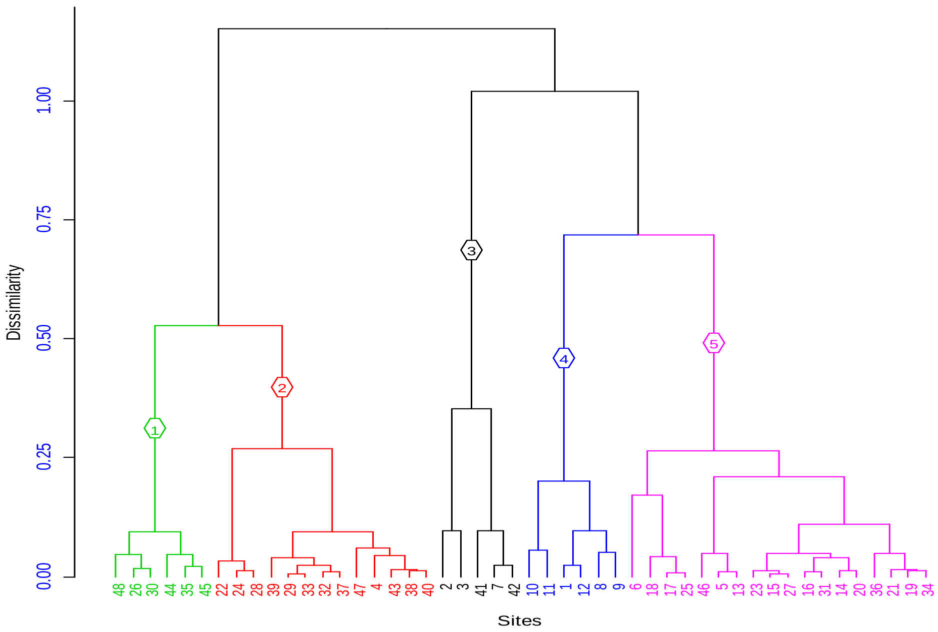

Fig. 3. Dendrogram outputs of the life form data obtained from hierarchical cluster analysis. The plot code and arrangement of plot along the dendrogram based on their cluster group.

C1: (Plots 1, 8, 9, 10, 11, 12)

C2: (Plots 2, 3, 7, 41, 42)

C3: (Plots 4, 22, 24, 28, 29, 32, 33, 37, 38, 39, 40, 43, 47)

C4: (Plots 5, 6, 13, 14, 15, 16, 17, 18, 19, 20, 21, 23, 25, 27, 31, 34, 36, 46)

C5: (Plots 26, 30, 35, 44, 45, 48)

Relation between altitude and soil pH

A negative correlation between soil pH and altitude was obtained. The soil pH ranged between 5.6 and 7.3 (Fig. 4). The lower pH (i.e., 5.6) indicating acidic soil was recorded at a high altitude (i.e., 2870 m a.s.l.). The highest pH (i.e., 7.3) indicating a more or less neutral soil was recorded in soils from the lower altitude (i.e., 2570 m a.s.l.).

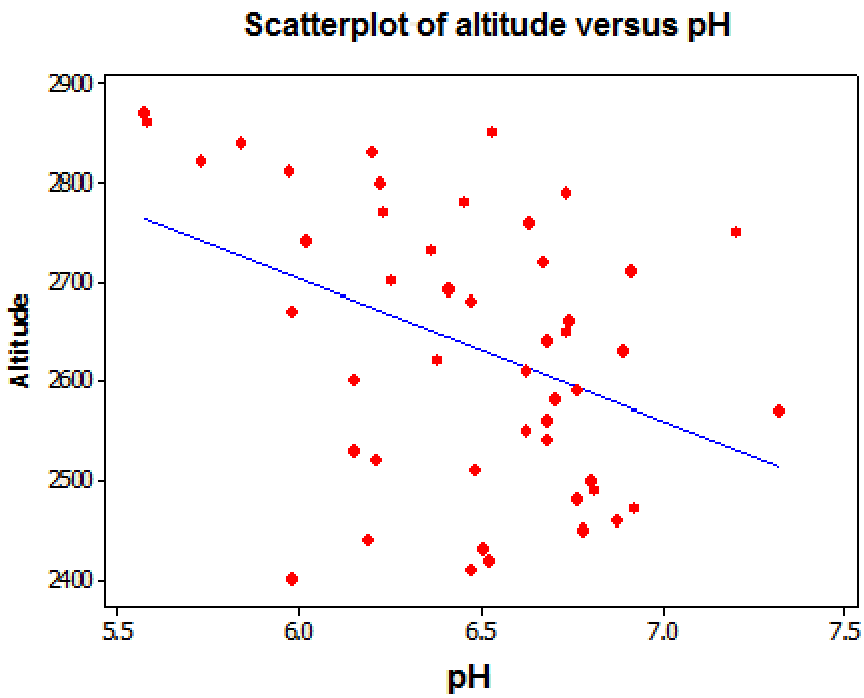

Fig. 4. Relation between altitude and soil pH.

Endemic plants and their life form in Suba Sebeta Forest

Endemic plant species that were collected from Suba Sebeta Forest and their life forms contribution in the study area is given in Table 2.

Table 2. List of endemic plant species and their life form in Suba Sebeta Forest.

No.	Species name	Family	Life form	Growth form
1	*Cirsium schimperi*	Asteraceae	Geophyte	Herb
2	*Conyza nana*	Asteraceae	Hemicryptophyte	Herb
3	*Jasminum stans*	Oleaceae	Phanerophyte	Shrub
4	*Laggerato mentosa*	Asteraceae	Chamaeophyte	Shrub
5	*Maytenus addat*	Celastraceae	Phanerophyte	Tree
6	*Mikaniopsis clematoides*	Asteraceae	Chamaeophyte	Climber
7	*Millettia ferruginea*	Fabaceae	Phanerophyte	Tree
8	*Satureja paradoxa*	Lamiaceae	Hemicryptophyte	Herb
9	*Solanecio gigas*	Asteraceae	Chamaeophyte	Herb
10	*Vernonia leopoldii*	Asteraceae	Chamaeophyte	Shrub

DISCUSSION

In this study, out of the 135 species, 48 belonged to the Phanerophytic life form. The dominant Phanerophyte life form includes the two important Gymnosperms, *Juniperus procera* and *Podocarpus falcatus* which are characteristic species of the dry Afromontane forests. Tree and shrubby angiosperms like *Olea europaea*. subsp. *cuspidata*, *Olinia rochetiana*, *Myrsine africana* and *Rosa abyssinica* also belong to this life form. The Hemicryptophytes also have great contribution to the life form spectrum. The most probable factor to this life form composition must be the humid nature of Suba Sebata Forest. Most Hemicryptophytes are herbaceous in habit that includes *Thymus schimperi*, *Veronica simensis* and *Rubia cordifolia*.

The Chamaeophytic life form in Suba Sebeta Forest is represented by the shrub *Hypericum quartinianum* and the herb *Mikaniopsis clematoides*, which carpeted the ground at higher altitudes. Other herbs belonging to the same group include *Achyrospermum schimperi*, *Hypoestes triflora* and *Solanecio gigas*. Chamaeophytes are indicators of alpine vegetation (Muhammad, 2012). In the life form composition, Therophytes and Geophytes have great contributions comprising 20 and 11 species each, respectively. Therophytes are annuals that include *Agrocharis melantha*, *Dichrocephala chrysanthemifolia* and *Cynoglossum coerulem* which reproduce through seeds and complete their life cycle in a short period of time. Geophytes are represented by *Cynoglossum amplifolium*, *Arisaema enneaphyllum* and *Scadoxus multiflorus*.

Asteraceae is the largest family and genus in terms of endemicity contributing 6 species (60%) that belong to Chamaeophytic, Hemicryptophytic and Geophytic life forms. The remaining four families contain one species each and altogether covered 40% of the overall endemicity. From these four families, three of them belong to Phanerophytic life forms and one is Hemicryptophytic life form. There are also species that are endemic to the Flora of Ethiopia and Eritrea. These near endemic species include *Kalanchoe petitiana*, *Thymus schimperi* and *Veronica simensis* that occurred in Hemicryptophytic life form while *Plectocephalus varians*, *Sideroxylon oxyacanthum* and *Erucastrum pachypodum* are found in Geophytic, Phanerophytic and Therophytic life forms, respectively.

The life form of plant species is usually a constant character (Mueller-Dombois and Ellenberg, 1974) and life forms are species-specific. But some species show different life forms when growing under very different environmental conditions. Plants of the same life form growing together are likely to compete directly for the same space. The anthropogenic factors are so pervasive that there is scarcely any tropical forest in the world in which human activities have not left their mark on life form diversity (Denslow and Padoch, 1988; Goldhammer, 1992). In this study, *Prunus africana* showed two different life form strategies: a Chamaeophytic and Phanerophytic type. This result indicates that *Prunus africana* developed two life forms in the same forest to cope up with environmental influence that may be caused by human activity. The human activities in this species include removing the bark of the tree for traditional medicine, using the tree for timber production, as source of material for building local houses, fuel wood and making charcoal. This explanation is strongly supported by the works of Legesse Negash (2002).

The highest similarities of life form cluster along altitude were recorded between Phanerophytic and Hemichryptophyte life form. These life forms were similar due to their presence under similar soil pH range and altitude. Soil pH and altitude were correlated negatively and as the altitude increased pH value decreased or became slightly acidic. Great life form cluster differences were created between clusters three and cluster one which were dominated with Phanerophytic and Chamaeophytic life forms, respectively. Chamaeophytic life forms show increasing trend in the higher altitudes while Phanerophytes have a decreasing trend in higher altitudes. From this result, Chamaeophytic life forms are better adapted in slightly acidic soil than Phanerophytes. The second difference in distribution was also observed between the Therophytic species which are mostly confined to lower altitudes and the Chamaeophytic life forms that are abundant at higher altitudes. The third one was between Therophytes and Hemichryptophytes, which may be due to altitude, soil moisture and the soil pH differences.

The diversity and distribution of life forms is usually correlated with climatic heterogeneity (Cowling *et al*., 1994) decreasing with increasing altitude (Montana and Valiente-Banuet, 1998; Pavón *et al*., 2000). Results of the present study indicate that altitude is the main factor influencing life form composition. Most species in the present study are ephemerals that complete their life cycle just in a short period of time. The predominance of annuals at low altitudes can partly be explained by soil disturbance (Klimes, 2003). The more intense or the more frequent the disturbance is, the lower the proportion of long-lived life forms.

The results from Klimes (2003) confirm that Chamaeophytes show an increasing trend towards higher altitudes. The work of Muhammad (2012) concluded that Chamaeophytes are generally the most common life form both in high altitudes and high latitudes. At higher altitude precipitation is high resulting in leaching of the upper surface, which leads to increasing of soil acidity. With increasing altitude, temperature will typically decrease and the corresponding precipitation will increase (Barry, 1981; Ineson *et al*., 1998; Shen *et al*., 2013). Plants absorb dissolved nutrients in the soil water and the nutrient solubility depends largely on the pH value. Hence, the availability of elements varies at different pH levels.

CONCLUSION

This study contributes basic data on life form composition and life form spectrum of vascular plants at Suba Sebeta Forest. In order to provide baseline information for subsequent studies, a total of 135 species were identified and assigned to 67 families. The family Asteraceae was the most dominant followed by Fabaceae and Lamiaceae, respectively. The study of biological life form spectrum more accurately describes the vegetation physiognomy, since each plant is counted by its life form. The life form spectrum was dominated with Phanerophyte (35.56%) followed by Hemicryptophytes (25.18%), Chamaeophytes (16.30%), Therophytes (14.81%) and Geophyte (8.15%). Altitudinal variation played a great role in life form distribution and composition in the study area. At higher altitudes, Chamaeophytic life form was dominant while Hemicryptophytes were well distributed. Cluster analysis of the vegetation data of the forest produced five communities each of which have its own indicator and dominant life form type. The distribution of these plant life form communities in the forest was influenced by environmental factors and biotic stresses which are derivatives of the life form of plant and composition. While it is believed that this study is a pioneer attempt, further elaborated studies to correlate the species distribution with chemical and physical characteristics of soils and other environmental influences should be undertaken.

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