
Woody Species Richness and Diversity Following Successional Stages at Jello-Muktar Dry Afromontane Forest, South-eastern Ethiopia

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Abstract: The study was carried out at 8⁰55'N-9⁰05'N latitude and 40⁰50'E-40⁰51'E longitude, at Jello-Muktar dry Afromontane forest South eastern Ethiopia to analyze changes in species composition, diversity and species richness under three successional stages. Three sites were selected each with 10 sample plots from each successional stage. The average distance between the plots was 200 m and the radius was 30m. In each plot, identification, counting and measurement of diameter at breast height (DBH) of all trees and shrubs (DBH≥10cm) was conducted. Comparison of richness (S) between sites and successional stages was analyzed by Chao2 estimator and Rarefaction was performed to compare species richness among sites and successional stages, for unequal number of individuals in sites. The Shannon-Wiener (H') and the Pielou indices (E) were used to assess the species diversity and evenness indices. A total of 114 species corresponding to 76 tree and 38 shrub species were recorded in the three successional stages. The MS forest was found to have the highest species richness followed by IS and ES successional stages. Analysis of Chao 2 estimator revealed that an average of 89.6% of the total species expected had been found for each successional stage. The MS sites were also found to have the highest mean H' and H'E indices. The Overall mean measure of evenness was about 0.86 which indicates that the relative homogeneity of the species in the samples was 86% of the maximum possible even population. Different conservation priorities should be implemented to maintain plant species at different successional stages.

Keywords: Richness, Successional Stages, South-eastern Ethiopia, Diversity, Dry Afro-montane

1. Introduction

Within an ecological community, the species composition will change over time as some species become more prominent while others may fade out of existence. As the community develops over time, vegetation grows taller, and the community becomes more established. This phenomenon was initially conceived as a natural process of ecological communities [13]. Communities with different plant composition can represent distinct mature stages in the same geographical area. The non-equilibrium hypothesis suggests that species richness should be higher at intermediate levels of disturbance [14] since conditions are not so adverse as to eliminate species. This hypothesis does not consider local physical factors such as soil and land relief and other

variations associated with the species microhabitats [9, 39].

However the initial floristic composition model [20] suggests that species from late stages may also be present in the stands initial successional process [10]. Today Tropical Afro-Montane Forests are under the state of secondary succession [17, 24] due to anthropogenic impacts of agricultural land expansion that changed the structure and composition of these forests [3, 37, 27]. But anthropogenic disturbances can result in a higher floristic diversity, biomass and density of woody vegetation than the original mature stages [8, 31, 38] when Tropical Afro-Montane Forests are not completely transformed to pastures or fields, intermediate level.

It had been reported that most of the studies were conducted with respect to successional patterns are from the

temperate forests and there is very little information in tropical forests [47]. Likewise, some early studies in Jello-Muktar were focused on soil fertility and timber utilization [34, 21]. No studies were conducted with respect to the variation in floristic composition of woody species under different successional patterns in Jello-Muktar forest. Indeed, there is a need to study and characterize changes in composition and diversity of woody plants under different successional stages which could be used as a national conservation strategy for the forest biodiversity. In this study comparison of sites representing different successional stages to describe changes in floristic composition, richness and diversity of the trees and shrubs with diameter at breast height (DBH) ≥ 10 cm under three successional stages within the Jello-Muktar forest, South-Eastern Ethiopia had been conducted.

2. Materials and Methods

2.1. Study Site

The study site is situated at $8^{\circ}55'N-9^{\circ}05'N$ latitude and $40^{\circ}50'E-40^{\circ}51'E$ longitude, about 342kms southeast of Addis Ababa. It covers a land area of about 1720 hectares. Its altitude ranges from 1900 to over 3310masl, having subtropical climatic condition with mean annual temperature of $10^{\circ}C$ and mean rainfall of 1220mm. Its length of growing period ranges from 210-270days [33].

It is part of the Chercher highlands in Harerghe with extensive mountain range separating the Rift system from the Eastern plateau and lowlands, having numerous micro-catchments with diversified bio-physical and socio-economic environments [36]. Anthropogenic processes due to shifting cultivation and forest clearing has led to continuous removal of soil materials that strongly affected the micro-climate and soil development of the area [21]. The study area is dissected by streams due to their erosive processes for prolonged period of time. The sub-watershed is within Wabi-shebele and Rift Valley drainage systems, drained by Chiro Qela and Jello perennial streams towards the Rift system while perennial streams like Welenso and Ula Quni and seasonal streams like Rukele Arba Feno and Dingete draining towards Wabi Shebelle drainage system [19].

2.2. Selection of Sites

Nine sites represented by three successional stages were selected as follows [4]: a) 3 disturbed sites from early stage (ES) of succession about 15 years which consisted of secondary vegetation; b), 3 sites from Intermediate stage (IS) of succession representing a transition between early and mature forests of 30 years and c), 3 sites from Mature stage (MS) succession with relatively well preserved sites of 45 years, characterized by the typical structure and cover of mature forest. Information about the time since last major disturbance (i.e., cutting, clearing and farming) obtained from interviews with key informants was used for the

selection of the secondary vegetation sites [4].

2.3. Plot Lay Out and Vegetation Sampling

A total of 90 sample plots were used for the three successional stages of the forest. *Ten sample plots* each with radius of 30m were laid in each site for each successional stage. The average distance between the plots was 200 m. In each of the plots, diameter at breast height (DBH) of all trees and shrubs (DBH ≥ 10 cm) was measured with diameter tape. Identification of woody plant species in each of the sample plot was conducted with the help of para-taxonomists and species difficult for identification in the field were pressed and taken to the National Herbarium, Addis Ababa University. Vernacular names of the plant species were recorded in the field. The nomenclature of the taxa followed Flora of Ethiopia and Eritrea (FEE).

2.4. Data Analysis

The number of individuals for each species was counted and the Shannon-Wiener (H') and the Pielou indices (E) were used to assess the species diversity and evenness as:

2.4.1. Species Diversity

The Shannon-Weaver's index (H') was used as measure of diversity and calculated as $H' = -\sum P_i \ln P_i$ where: i , is the proportion of the species relative to the total number of species (p_i) and \ln is a natural logarithm.

2.4.2. Species Richness (S)

Species richness as the number of species present in an ecosystem was calculated as: $S = S_n$ Where: n is number of species.

2.4.3. Species Evenness ($H'E$)

Species evenness $H'E$ is the proportion of individuals among species in an ecosystem and it is assessed by Shannon's equitability index and calculated as: $H'E = H'/H_{max}$ Where: H_{max} is defined as $\ln S$

An incidence-based species richness Chao 2 estimator based on the number of unique, and the number of duplicates was used to compare richness (S) between sites and successional stages [12]. Rarefaction analysis as performed to compare species richness among sites and successional stages for samples with different number of individuals [41]. The analysis was conducted by Estimate S v. 8.0 [11]. Since Shannon index is approximately normally distributed, making comparison with parametric tests is feasible and independent t-test was performed to evaluate the differences.

3. Results and Discussion

3.1. Floristic Composition and Species Richness

A total of 114 species (76 tree and 38 shrub species) corresponding to 51 families were recorded in the three successional stages (Tables 1-3). The number of species

richness recorded in this study of which 66.7% were trees is comparable to the numbers reported for other similar forest types [30, 32, 28] but higher than the total number of species recorded at Ades dry afro-montane forest of the same agro-ecology [34] and elsewhere in Ethiopia for studies from similar vegetation types [45, 29, 42, 1, 2]. It is also higher than the number of species reported from tropical dry forest in southwest Mexico [4] and in the temperate landscape of southern Chile [15]. This may be due to the presence of participatory forest management at Jello-Muktar forest. However, it is lower than the number of species reported for Senka meda with 139 species [43].

The family with the highest number of species were Fabaceae and Myrtaceae each with 7 species followed by Rosaceae (6), Myrsinaceae (5), Euphorbiaceae (5), Rutaceae (5), Flacourtiaceae (4), Oleaceae (4), Celastraceae (4), Papilionoideae (4), Verbenaceae (4), Apocynaceae (3), Araliaceae (3), Asteraceae (3), Flacourtiaceae (3), Moraceae (3), and Rubiaceae (3). These families represented 60.2% of the total species in the study site while the remaining families had 2 or 1 species and represented only 39.8% of the total species (Tables 1-3). The dominance of Fabaceae and Myrtaceae in terms of the number of species is in line with some studies reported for forests of other Tropical areas [22, 23, 4].

There also existed variation between successional stages in terms of the floristic composition of woody species at the family level. Twelve families namely: Asteraceae,

Cupressaceae, Myrsinaceae, Rosaceae, Sterculiaceae, Myrsinaceae, Sapindaceae, Sapotaceae, Flacourtiaceae, Hypericaceae, Fabaceae and Euphorbiaceae were recorded in all successional stages while the families of Balanitaceae, Bambusaceae, Bignoniaceae, Ebenaceae, Loganiaceae, Phytolacaceae, Pittosporaceae, Podocarpaceae, Sapindaceae and Vitaceae were only found in one of the three successional stages (Tables 1-3).

There were 28 families in the ES successional stage (Table 1). In this successional stage, 16 families were each represented by one species only while the rest were represented by at least two species. This may be due dispersal strategies of the species that can affect its germination according to some studies from tropical dry forests in ES where the seed bank is severely depleted or absent [25, 40]. In addition to the dispersal strategies of the species, other studies also reported that soil conditions, topography and microclimate of the forests can affect the species composition and succession dynamics [46, 26, 7, 16, 24, 4].

All the three sites of ES were dominated by species of *Vernonia amygdalina* and *Vernonia auriculifera*. Such species which are dominant in the ES sites are indicative of secondary succession and have a high capacity to colonize degraded areas resulting in distinct microclimatic changes and low water retention that could hamper the germination and establishment of typical of mature forests species [24, 4].

Table 1. Plant species Composition (DBH \geq 10cm) identified in three sites under ES successional stage at Jello-Muktar dry afro-montane forest, South-Eastern Ethiopia.

Family	Species	Life form	Successional Stages		
			ES		
			1	2	3
Agavaceae	<i>Dracaena steudneri</i>	Shrub	x		
Anacardiaceae	<i>Schinus molle</i>	Tree	x		
Apocynaceae	<i>Acokanthera schimperi</i>	Tree		x	
	<i>Carissa edulis</i>	Shrub		x	x
Araliaceae	<i>Cussonia holstii</i>	Tree		x	
	<i>Schefflera abyssinica</i>	Tree			x
Asteraceae	<i>Vernonia amygdalina</i>	Tree	x	X	x
	<i>Vernonia auriculifera</i>	Shrub	x		x
Balanitaceae	<i>Balanytus aegyptica</i>	Tree	x		
Boraginaceae	<i>Ehretia cymosa</i>	Tree			x
	<i>Cordia africana</i>	Tree		x	x
Cupressaceae	<i>Cupressus lusitanica</i>	Tree			x
	<i>Juniperus procera</i>	Tree	x	x	x
Euphorbiaceae	<i>Croton macrostachys</i>	Tree		x	
	<i>Macaranga kilimandsharica</i>	Tree	x	x	
	<i>Acacia decurrens</i>	Tree			x
	<i>Albizzia gummifera</i>	Tree			x
Fabaceae	<i>Calpurnia subdecandra</i>	Shrub			x
	<i>Calpurina aura</i>	Tree		x	
	<i>Leucena leucocephala</i>	Tree			x
Icacinaceae	<i>Dovyalis abyssinica</i>	Shrub	x	x	
	<i>Apodytes dimidiata</i>	Shrub		x	
Lamiaceae	<i>Ocimum lamifolium</i>	Shrub		x	
Meliaceae	<i>Lepidotrichilia volkensis</i>	Tree		x	
Moraceae	<i>Ficus sur</i>	Shrub		x	
	<i>Ficus thonningi</i>	Tree	x		
Myrsinaceae	<i>Myrsine africana</i>	Shrub		x	

Family	Species	Life form	Successional Stages		
			ES		
			1	2	3
Myrtaceae	<i>Eucalyptus saligna</i>	Tree		x	
	<i>Psidium guajava</i>	Tree		x	
Oleaceae	<i>Olea capensis</i>	Tree	x	x	x
Papilionoideae	<i>Erythrina abyssinica</i>	Shrub	x	x	
	<i>Erythrina brucei</i>	Tree			x
Passifloraceae	<i>Passiflora edulis</i>	Tree			x
Pittosporaceae	<i>Pittosporum abyssinicum</i>	Tree	x		
	<i>Rhamnus prenoids</i>	Tree	x	x	
Rhamnaceae	<i>Hagenia abyssinica</i>	Shrub	x		
	<i>Prunus africana</i>	Tree			x
	<i>Rosa abyssinica</i>	Tree	x	x	x
Rutaceae	<i>Vepris dainellii</i>	Tree	x		
Sapotaceae	<i>Aningeria altissima</i>	Tree	x	x	
Simaroubaceae	<i>Brucea antidysenterica</i>	Tree			x
Solanaceae	<i>Discopodium penninervium</i>	Shrub			x
Sterculiaceae	<i>Dombeya torrida</i>	Shrub		x	
Ulmaceae	<i>Celtis africana</i>	Tree			x
Verbenaceae	<i>Clerodendron myricoides</i>	Tree	x	x	
	<i>Premna resinosa</i>	Shrub			x

Species of *Juniperus procera*, *Rosa abyssinica*, *Olea capensis*, *Vernonia amygdalina*, *Vernonia auriculifera*, *Crotonon macrostachys*, *Apodytus diminiata* and *Prunus africana* were recorded in all of the successional stages while species of *Cussonia holstii*, *Balanytus aegyptica*, *Caesalpina decapetala*, *Delonix regia*, *Vitis vinifera*, *Euphorbia abyssinica*, *Leucena leucocephala*, *Strychnos mitis*, *Ekebergia capensis*, *Morus alba*, *Eucalyptus camaldulensis*, *Sizygeem guineense*, *Gardenia lutea*, *Fagaropsis angolensis*, *Vepris dainellii*, *Tecllea nobilis*, *Lippia adeonsis*, and *Euphorbia pulcherrima* were observed only in one of the three successional stages.

A total of 35 families were recorded in IS stage (Table 2) which accounts about 57% of the total number of woody species identified in this study. In IS successional stage the family of Proteaceae comprise the largest number of species (6) followed by Myrtaceae (5) and Oleaceae (4). Species of *Vernonia amygdalina*, *Vernonia auriculifera*, *Cupressus lusitanica*, *Juniperus procera*, *Croton macrostachys*, *Acacia decurrense*, *Apodytes dimidiata*, *Ocimum lamifolium*, *Ficus sur*, *Myrsine aricana*, *Pinus patula*, *Rumex abyssinicus*, *Prunus africana* and *Rosa abyssinica* were observed in all the three sites of IS (Table 2).

Table 2. Plant species Composition (DBH \geq 10cm) identified in 3 sites under IS successional stage at Jello-Muktar dry afromontane forest, South-Eastern Ethiopia.

Family	Species	Life form	Successional Stages		
			IS		
			1	2	3
Apocynaceae	<i>Carissa spinarum</i>	Shrub		X	
Aquifoliaceae	<i>Ilex mitis</i>	Tree	X		
	<i>Polyscias fulva</i>	Tree			X
Araliaceae	<i>Schefflera abyssinica</i>	Tree			X
	<i>Vernonia amygdalina</i>	Tree	X	X	X
Asteraceae	<i>Vernonia auriculifera</i>	Shrub	X	X	X
	<i>Vernonia leopoldii</i>	Shrub		X	X
Boraginaceae	<i>Ehretia cymosa</i>	Tree		X	X
	<i>Chata edulis</i>	Tree		X	
Celastraceae	<i>Maytenus arbutifolia</i>	Tree			X
	<i>Maytenus obscura</i>	Tree			X
Cupressaceae	<i>Cupressus lusitanica</i>	Tree	X	X	X
	<i>Juniperus procera</i>	Tree	X	X	X
Ebenaceae	<i>Diospyros abyssinica</i>	Tree			
Ericaceae	<i>Erica arborea</i>	Shrub		X	
	<i>Croton macrostachys</i>	Tree	X	X	X
Euphorbiaceae	<i>Macaranga kilimandsharica</i>	Tree			x
	<i>Acacia decurrense</i>	Tree	x	x	x
	<i>Calpurnia subdecandra</i>	Shrub	x		
Fabaceae	<i>Calpurina aura</i>	Tree		x	
	<i>Dovyalis abyssinica</i>	Shrub	x		
Flacourtiaceae	<i>Dovyalis vericosa</i>	Shrub		x	x
	<i>Flacourtia indica</i>	Shrub	x		
Icacinaceae	<i>Apodytes dimidiata</i>	Shrub	x	x	x

Family	Species	Life form	Successional Stages		
			IS		
			1	2	3
Lamiaceae	<i>Ocimum lamifolium</i>	Shrub	x	x	x
Lauraceae	<i>Ocotea kenyensis</i>	Shrub		x	
	<i>Persea americana</i>	Tree			x
Meliaceae	<i>Lepidotrichilia volkensis</i>	Tree		x	
Meliantaceae	<i>Bersama abyssinica</i>	Tree			x
Moraceae	<i>Ficus sur</i>	Shrub	x	x	x
	<i>Ficus thonningi</i>	Tree			x
	<i>Maesa lanceolata</i>	Shrub	x	x	
Myrsinaceae	<i>Myrsine africana</i>	Shrub	x	x	x
	<i>Myrsine melanophloeos</i>	Shrub	x	x	
	<i>Callistemon citrinus</i>	Tree			x
	<i>Eucalyptus camaldulensis</i>	Tree		x	
Myrtaceae	<i>Eucalyptus globulus</i>	Tree		x	
	<i>Eucalyptus saligna</i>	Tree	x		
	<i>Psidium guajava</i>	Tree	x		
	<i>Jasminum abyssinicum</i>	Tree			x
Oleaceae	<i>Olea africana</i>	Shrub		x	
	<i>Olea capensis</i>	Tree	x	x	
	<i>Olea europea</i>	Tree	x	x	
Oliniaceae	<i>Olina rochetiana</i>	Tree			
Papilionoideae	<i>Milletia ferruginea</i>	Tree	x	x	
Pinaceae	<i>Pinus patula</i>	Shrub	x	x	x
Poaceae	<i>Arundo donax</i>	Tree			x
Polygonaceae	<i>Rumex abyssinicus</i>	Tree	x	x	x
	<i>Rumex nurvosus</i>	Shrub		x	
Proteaceae	<i>Gravelia robusta</i>	Shrub	x	x	
	<i>Hagenia abyssinica</i>	Shrub	x	x	
	<i>Prunus africana</i>	Tree	x	x	x
Rosaceae	<i>Rosa abyssinica</i>	Tree	x	x	x
	<i>Rosmarinus offinalis</i>	Shrub		x	
	<i>Rubus apetalus</i>	Shrub			x
	<i>Rubus steudneri</i>	Shrub		x	
Rubiaceae	<i>Coffea arabica</i>	Shrub	x		
Rutaceae	<i>Clausena anisata</i>	Shrub	x	x	
Sapotaceae	<i>Aningeria altissima</i>	Tree	x		x
Simaroubaceae	<i>Brucea antidysenterica</i>	Tree		x	
Solanaceae	<i>Discopodium penninervium</i>	Shrub		x	
Sterculiaceae	<i>Dombeya torrida</i>	Shrub		x	
Ulmaceae	<i>Celtis africana</i>	Tree	x		
	<i>Clerodendron myricoides</i>	Tree	x		x
Verbenaceae	<i>Lippia adeonsis</i>	Shrub	x		
	<i>Premna resinosa</i>	Shrub		x	x

The MS successional stages had the highest number of families, 47 families comprising 77.2% of the total number of species in this study (Table 3).

Table 3. Plant species Composition (DBH \geq 10cm) identified in 3 sites under MS successional stage at Jello-Muktar dry afro-montane, South-Eastern Ethiopia.

Family	Species	Life form	Successional Stages		
			MS		
			1	2	3
Agavaceae	<i>Dracaena steudneri</i>	Shrub			x
Anacardiaceae	<i>Rhus glutinosa</i>	Shrub		x	x
Apocynaceae	<i>Acokanthera schimperi</i>	Tree	x	x	
	<i>Carissa spinarum</i>	Shrub	x		
Aquifoliaceae	<i>Ilex mitis</i>	Tree	x		
	<i>Polyscias fulva</i>	Tree		x	x
Araliaceae	<i>Schefflera abyssinica</i>	Tree	x	x	x
	<i>Vernonia amygdalina</i>	Tree		x	x
Asteraceae	<i>Vernonia auriculifera</i>	Shrub		x	
	<i>Vernonia leopoldii</i>	Shrub		x	
Bambusaceae	<i>Arundinaria alpina</i>	Tree	x	x	x
Bignoniaceae	<i>Jacaranda mimosifolia</i>	Tree			x

Family	Species	Life form	Successional Stages		
			MS	1	2
Boraginaceae	<i>Ehretia cymosa</i>	Tree		x	
	<i>Cordia africana</i>	Tree		x	x
Caesalpinioideae	<i>Caesalpina decapetala</i>	Tree		x	
	<i>Delonix regia</i>	Tree			x
	<i>Chata edulis</i>	Tree	x		
Celastraceae	<i>Maytenus addat</i>	Tree	x	x	
	<i>Maytenus arbutifolia</i>	Tree		x	x
	<i>Maytenus obscura</i>	Tree	x		x
Cupressaceae	<i>Cupressus lusitanica</i>	Tree			
	<i>Juniperus procera</i>	Tree	x	x	x
Ebenaceae	<i>Diospyros abyssinica</i>	Tree	x		x
Ericaceae	<i>Erica arborea</i>	Shrub	x		x
	<i>Croton macrostachys</i>	Tree	x	x	x
Euphorbiaceae	<i>Euphorbia abyssinica</i>	Tree			x
	<i>Euphorbia pulcherrima</i>	Tree			x
	<i>Macaranga kilimandsharica</i>	Tree		x	
	<i>Sapium ellipticum</i>	Tree	x	x	
	<i>Albizzia gummifera</i>	Tree		x	x
Fabaceae	<i>Calpurina aura</i>	Tree		x	
	<i>Entada abyssinica</i>	Shrub		x	
	<i>Dovyalis abyssinica</i>	Shrub	x		
Hypericaceae	<i>Hypericum revolutum</i>	Tree	x	x	
Icacinaceae	<i>Apodytes dimidiata</i>	Shrub	x	x	
Lamiaceae	<i>Ocimum lamifolium</i>	Shrub	x		
Lauraceae	<i>Persea americana</i>	Tree	x		x
	<i>Buddleja polystacha</i>	Tree		x	
Loganiaceae	<i>Strychnos mitis</i>	Tree		x	
	<i>Ekebergia capensis</i>	Tree		x	
Meliaceae	<i>Lepidotrichilia volkensis</i>	Tree	x		x
	<i>Bersama abyssinica</i>	Tree	x	x	x
Moraceae	<i>Ficus sur</i>	Shrub	x		
	<i>Morus alba</i>	Tree			x
	<i>Embelia schimpri</i>	Tree		x	
Myrsinaceae	<i>Myrsine africana</i>	Shrub	x	x	
	<i>Myrsine melanophloeos</i>	Shrub	x	x	x
	<i>Rapanea simensis</i>	Tree	x	x	x
	<i>Callistemon citirnus</i>	Tree	x		x
Myrtaceae	<i>Casuarina equisetifolia</i>	Tree			x
	<i>Psidium guajava</i>	Tree			x
	<i>Sizygeem guineense</i>	Tree			x
	<i>Jasminum abyssinicum</i>	Tree	x	x	x
Oleaceae	<i>Olea africana</i>	Shrub		x	
	<i>Olea capensis</i>	Tree		x	x
	<i>Olea europea</i>	Tree	x	x	
Oliniaceae	<i>Olina rochetiana</i>	Tree			x
Papilionoideae	<i>Milletia ferruginea</i>	Tree	x		
	<i>Erythrina brucei</i>	Tree			x
Passifloraceae	<i>Passiflora edulis</i>	Tree	x		
Phytolacaceae	<i>Phytolaca deodecandra</i>	Tree		x	
	<i>Pinus patula</i>	Shrub		x	x
Pinaceae	<i>Pinus radiata</i>	Tree		x	
	<i>Arundo donax</i>	Tree	x		x
Podocarpaceae	<i>Podocarpus falcatus</i>	Tree		x	
Polygonacea	<i>Rumex abyssinicus</i>	Tree	x	x	x
	<i>Rumex nurvosus</i>	Shrub			x
Proteaceae	<i>Gravelia robusta</i>	Shrub			x
	<i>Hagenia abyssinica</i>	Shrub		x	
	<i>Prunus africana</i>	Tree	x	x	x
Rosaceae	<i>Rosa abyssinica</i>	Tree	x	x	x
	<i>Rosmarinus offinalis</i>	Shrub		x	x
	<i>Rubus apetalus</i>	Shrub	x	x	
Rubiaceae	<i>Rubus steudneri</i>	Shrub		x	
	<i>Coffea arabica</i>	Shrub		x	

Family	Species	Life form	Successional Stages		
			MS		
			1	2	3
Rutaceae	<i>Gardenia lutea</i>	Tree			X
	<i>Rytigynia neglecta</i>	Tree		x	
	<i>Clausena anisata</i>	Shrub	x		X
	<i>Diphasia dainelli</i>	Tree	x		
	<i>Fagaropsis angolensis</i>	Tree			X
Sapindaceae	<i>Teclea nobilis</i>	Tree	x		
	<i>Dodonaea angustifolia</i>	Tree	x		
Sapotaceae	<i>Aningeria altissima</i>	Tree		x	
	<i>Mimusops kummel</i>	Tree		x	x
Simaroubaceae	<i>Brucea antidysenterica</i>	Tree	x		x
Solanaceae	<i>Discopodium penninervium</i>	Shrub	x	x	x
Sterculiaceae	<i>Dombeya torrida</i>	Shrub			
Ulmaceae	<i>Celtis africana</i>	Tree	x		
	<i>Clerodendron myricoides</i>	Tree		x	
Verbenaceae	<i>Premna schimperi</i>	Shrub	x		x
	<i>Premna resinosa</i>	Shrub	x		
Vitaceae	<i>Vitis vinifera</i>	Shrub			x

The study showed that an increasing trend in the total number of plant species from the early to the intermediate and mature stages following the natural sequence of successional stages that occurred subsequent to changes in land use system of the study area which is in line with the study reported for dry forests of Mexico [4].

The number of species that had been recorded in each of the successional stage ranges from 46-88 (Figures 1-3). The mature forest was found to have the highest species richness (88 species) followed by Intermediate stage (62 species) and Early stage of succession (46 species). The mature forest comprises 77.2% of the total number of species recorded in this study. The lowest number of species richness was recorded in ES1 sites (Figure 3) while the highest was in MS2 sites (Figure 1). There are bare lands in ES forest sites of this study and these could result in pronounced microclimatic changes and low water retention, which hinders the germination and establishment of typical of mature forests species as reported from elsewhere [4].

The number of species recorded in MS successional stage is almost twice more than the number of species recorded in ES succession. In this study, the number of species in MS sites was also higher than the IS sites which is not in line with the intermediate levels of disturbance (ILD) hypothesis [9, 6] but agreed with [5]. It had been reported from northern Chiloé Island [20] that the similarity in species between the successional stages predicts that the composition and community structure of plants change gradually, without total replacement of one community for another. Most Tropical Forest species may be found in all successional stages, but recruitment from MS could be lower in ES according to the initial floristic composition hypothesis [20] where each species had explicit environmental circumstances that limited its final richness and diversity. The number of species recorded in IS successional stage were equal to the total number species reported from Ades dry Afromontane forest [35].

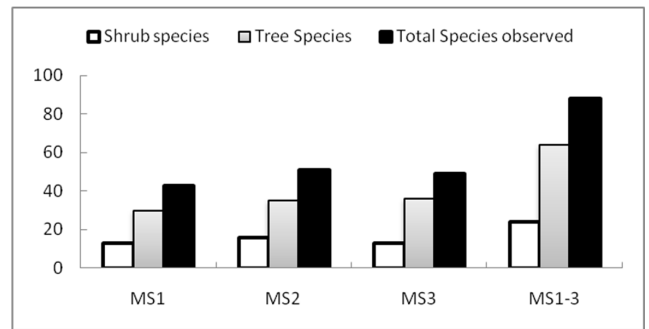


Figure 1. Number of Species observed in MS Sites.

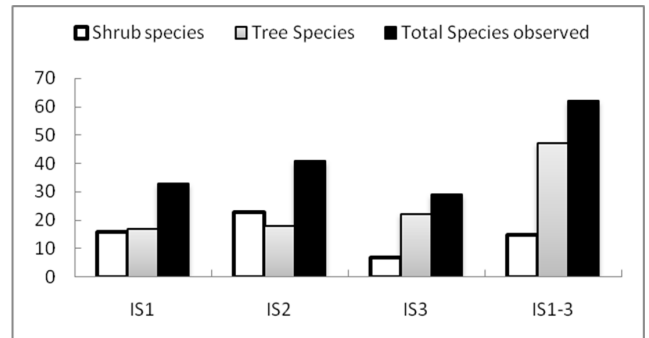


Figure 2. Number of Species observed in IS Sites.

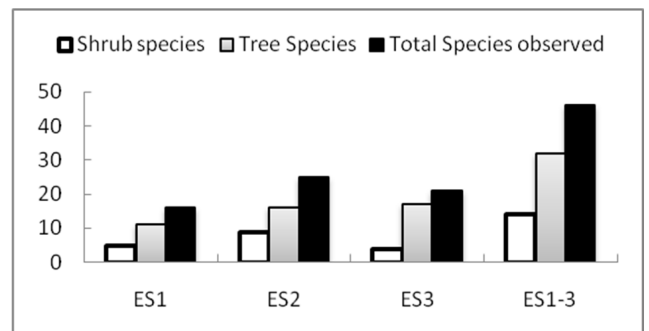


Figure 3. Number of Species observed in ES Sites.

Analysis of Chao 2 estimator showed that 92.6%, 92.5% and 83.6% of the species respectively were present in the mature stage, in the intermediate stage, and in the early stage. The expected number of species recorded in each site ranged from 40% for ES1 sites to 96.1% for MS3 sites (Figure 4). This study revealed that an average of 89.6% of the total species expected had been found for each successional stage and the number species observed was close to the expected number of species richness taking only those woody species

with DBH>10 cm. It is comparable to similar study from tropical dry forest in southwest Mexico [4].

The total number of species rarefied in each successional site ranged from 12 for ES1 sites to 49 for MS2 sites (Figure 4). The overall total species rarefied were 37, 55 and 65 respectively for ES, IS and MS successional stages. The total number of species rarefied in ES1 sites in this study was by far lower than the 57 rarefied species reported for other forests [4].

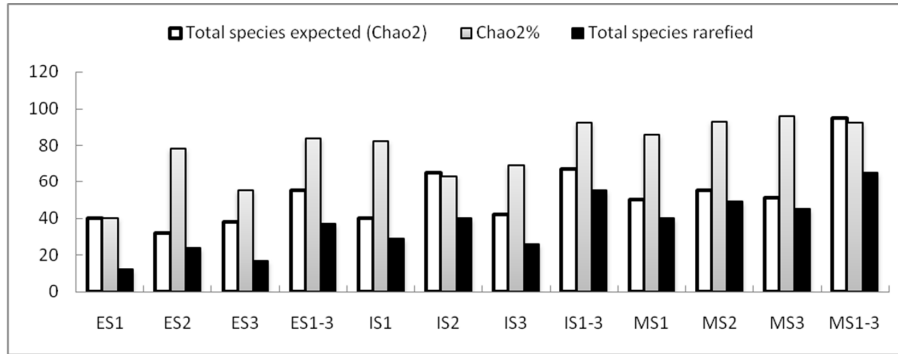


Figure 4. Expected and rarefied number of Woody plants for nine sites in 3 successional stages at Jello-Muktar dries afromontane forest, South-Eastern Ethiopia.

3.2. Abundance of Trees and Shrubs

In terms of the abundance of trees and shrubs, a total of 4990 individuals had been recorded. The highest and the lowest number of individuals were recorded in MS and ES successional stages respectively (Figure 5). A total of 2330 individuals were recorded in MS successional stages comprising about 46.7% of the total individuals observed. With respect to the number of individuals in each site, it

ranged from the lowest of 256 individuals for ES3 sites to the highest of 980 individuals for MS2 sites. The number of individuals recorded from the site of MS2 (980) was almost equal to the total number individuals observed in all ES sites (991). The number of individuals recorded in each successional stage of this study was higher than similar study reported for other dry tropical forests [4]. This could be due to geographic variation of the two forest types.

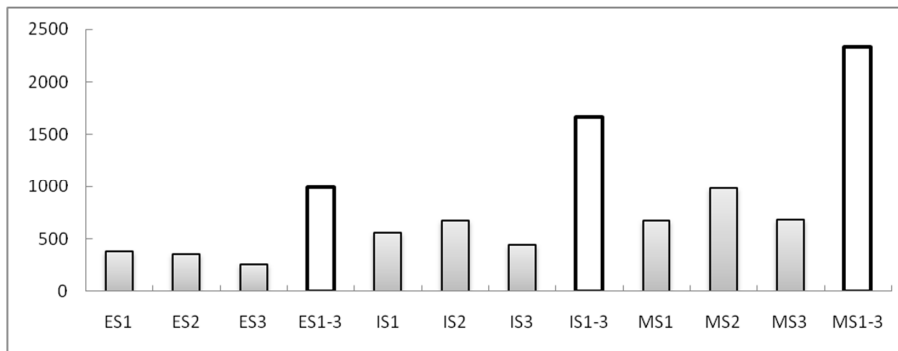


Figure 5. Abundance of Woody plants for nine sites (shaded bars) in 3 successional stages (Open bars) at Jello-Muktar dry afromontane forest, South-Eastern Ethiopia.

3.3. Species Diversity

Variation was also observed in Shannon index of diversity and Evenness indices between successional stages and among the sites. The index of Shannon-weiver ranged from 2.4 to 3.7. The highest mean Shannon-Wiener (3.7) was from MS2 sites (Figure 6) and the lowest was from sites of ES1 (2.4) indicating that MS had more species diversity than ES and IS sites. There was significant difference in H' among all the three sites of ES successional stages. Likewise sites of IS3 were significantly different from sites of IS1 and IS2

under IS succession. No significant variation was observed between MS1 and MS3 sites in MS succession. Overall there exist significant variation among ES, IS and MS successional stages (Figure 6). The overall mean Shannon-Wiener index of diversity for the three successional stages was 3.25 showing that the status of this forest under good diversity. The overall mean Shannon-Wiener index value recorded in this study was higher than the mean Shannon-Wiener Index of diversity of 2.82 reported for Ades dry afromontane forest of the same agro-ecology [35], Menagesha Suba Forest with H'=2.57 [18] and Ylat forest with H'=2.94 [44].

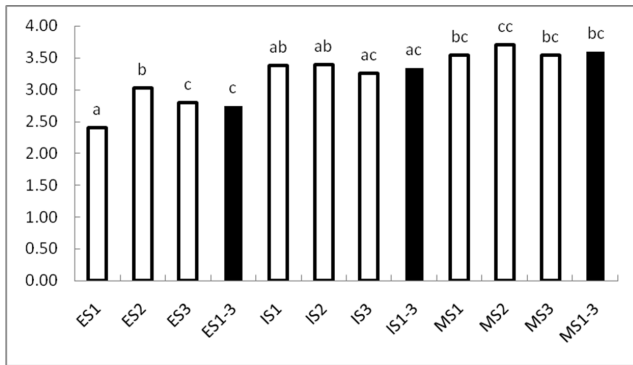


Figure 6. Shannon index of diversity for nine sites (Open bars) and three successional stages (shaded bars) of Jello-Muktar dry afro-montane forest, South-Eastern Ethiopia. NB. Different letters denote significant differences ($p < 0.05$) according to independent t-test.

3.4. Species Evenness

Evenness values also vary between successional stages (Figure 7). The lowest Evenness value of 0.67 was from sites of ES1 in ES successional stages. Sites of ES1 were significantly different from ES2 and ES3 sites of ES successional stage. In the IS successional stage, sites of IS3 were significantly different from IS1 and IS2 sites. With respect to MS successional stages, MS1 were significantly different from sites of MS2 and MS3. Comparison of Evenness values among sites from different successional stages showed that no significant differences was observed among sites of ES2, ES3, IS1 and IS2 in ES and IS successional stages on the one hand IS3, MS2 and MS3 from IS and MS successional stages on the other. The overall mean measure of evenness in this study was about 0.86. This means that the relative homogeneity of the species in the samples was 86% of the maximum possible even population. The lower Evenness in the ES1 sites shows a typical pattern of disturbed communities in which pioneer species achieve high relative importance values in relation to other species as suggested [37, 6].

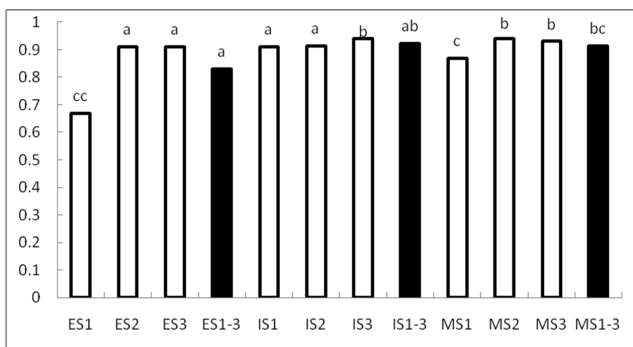


Figure 7. Evenness indices from nine sites (open bars) and three successional stages at Jello-Muktar dry afro-montane forest, South-Eastern Ethiopia. NB. Different letters denote significant differences ($p < 0.05$) according to independent t-test.

4. Conclusions and Recommendations

A total of 114 species (76 tree and 38 shrub species)

corresponding to 51 families were recorded in the three successional stages. The number of species that had been recorded in each of the successional stage ranges from 46-88. The mature forest was found to have the highest species richness (88 species) followed by Intermediate stage (62 species) and Early stage of succession (46 species). The mature forest comprises 77.2% of the total number of species recorded in this study. Variation was also observed in Shannon index of diversity and Evenness indices between successional stages and among the sites. The study showed that an increasing trend in the total number of plant species from the early to the intermediate and mature stages following the natural sequence of successional stages that occurred subsequent to changes in land use system of the study area.

Strategies and conservation priorities should be aimed at maintaining different successional plant communities with heterogeneous physiognomy in addition to mature forests in order to sustain regeneration processes and a high level of plant diversity.

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