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Utilitarian separations of woody species, Proxy of Ecological versatility and procurement for Forest administration

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The natural forests in north western Ethiopia have been dwindling at an alarming rate. However, church forests are found as a spot in each community serving as unique and conspicuous *in situ* conservation of indigenous species. Five church forests with adjacent degraded forests were surveyed to investigate the functional distance and diversity. Fifty woody species were identified both from the church and adjacent degraded forests and have 34 species in common ($S_j = 0.68$). Eleven new species were recorded in the adjacent degraded forest, but five species which were found in the church forest disappeared. The average functional distances between woody species were 22.3 ± 14.4 (mean \pm SD) and 23.8 ± 17.0 for church and adjacent degraded forests, respectively. Dominant woody species were functionally dissimilar. Functional distances between 10 minor of the church and 10 dominant of adjacent degraded forest species were significantly different ($\chi^2 = 12.24$, $P = 0.01$), suggesting that minor species have offered insurance. Passenger species and some of the dominant species in the church forest have also offered insurance. Functional distance which is a cumulative effect of functional attributes is a proxy for ecological elasticity to disturbances and helps in forest management decisions.

Key words: Church forests, degraded forests, ecosystem, functional attributes, relative abundance, resilience.

INTRODUCTION

The natural forests in north western Ethiopia has been dwindling at an alarming rate (Mamo et al., 2006; Gole et al., 2008) due to conversion to arable lands, overgrazing, and excessive utilization for fuelwood and construction triggered by increasing population growth (Haugen, 1989; Taddese, 2001; Zeleke and Hurni, 2001). However, church forests are found as a spot in a landscape in each community (that is, the lowest administrative unit in the region) and mostly represent the original natural forest of

the area (Wassie et al., 2005). The degraded natural forests may be composed of a combination of species from the original natural forest and additional new species. The church forests are unique and conspicuous spots serving as an *in situ* conservation, mainly for indigenous trees and shrubs in north western parts of Ethiopia. Though, the churches are mainly built as congregational sites of worship, burials, meditating and religious festivals, they often provide exclusive, secured habitats for plants, animals and microorganisms (Wassie, 2002; Wassie et al., 2005). The reason why church forests survive the intensive deforestation in the region is that, as many people remain adherents to the Orthodox faith which espouses protection of woodland within its

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territory, they are reluctant to degrade such areas. Nevertheless, some disturbances such as spot clearing for burial purpose and selective logging for the maintenance of the churches are occasionally carried out. Due to differences in intensity of disturbances, species composition in church and degraded forests may thus be different even if they are located at short distances. Disturbance is thus one of the key factors that shape the structure of vegetation (Rusch et al., 2003; Westoby et al., 2002). Although, a few traits have a general association with responses to disturbance, some studies have documented that plant attributes are specific to a particular disturbance (Girme, 2001; Walker et al., 1995).

The functional attributes of species have pivotal roles for the ecosystem function of a given species assembly (Delarum et al., 2010) and help to predict changes in vegetation and biodiversity in response to changes in environmental factors and land-use shifts at regional and global scales (Rusch et al., 2003). It is now generally accepted that the structure of species assemblages may be as important as the concept of species richness (Naeem and Wright, 2003; Petchey and Gaston, 2006; Petchey et al., 2007; Griffin et al., 2009). This approach signifies the importance of functional diversity than biodiversity (Dalerum et al., 2010). There is thus an increasing interest in quantifying functional diversity. Holling (1973) has introduced the perception of ecosystem resilience as a means to investigate ecological processes. Such ecological resilience can be regarded as a measure of how much disturbance an ecosystem can tolerate without altering its original state (Gunderson, 2000) or amount of disturbance that a species assembly can take up without varying its ecological utility (Walker, 1995). Dominant species of a natural forest are few in number, and they are responsible for performing the bulk of photosynthesis, transpiration and nutrient uptake (Peterson et al., 1998). Dominant species would be functionally dissimilar to each other (Walker et al., 1999). Minor species, which constitute a smaller proportion of the species abundance in the ecosystem are similar to the dominant species in ecological functioning, but react in a different way to environmental requirements and disturbance; as a result they offer insurance to the vegetation after a certain interruption (Walker, 1995; Walker et al., 1999; Bengtsson et al., 2000).

Identifying dominant and minor species and functional distances between the dominant and minor species in a vegetation, therefore, helps to predict the possible structures of a forest and the likelihood of such occurrence (Archibold, 1995; Peterson et al., 1998; Walker et al., 1999). Despite the potential of the church forest in understanding the history of the original ecosystem, consequences of disturbance and resilience mechanism studies are rare (Wassie et al., 2002, 2005, 2010) and absent particularly in relation to functional

diversity. Thus, the objectives of the study were to: 1) identify dominant and minor woody species and their functional attributes both in the church and degraded forests, 2) estimate functional diversity of the forests and functional distances between pairs of woody species, and 3) examine how minor species in the church forests have offered resilience for the adjacent degraded forest.

MATERIALS AND METHODS

Study area

The study was conducted in Awabel district of East Gojam administrative zone in Amhara national regional state, Ethiopia. Each community (the lowest local administrative unit) has its own church which is mostly surrounded by natural forests. We selected five churches with natural forest that have adjacent degraded forests for this study: Yeleb Lideta (10° 09' N, 37° 59' E), Yeterbina Gebreal (10° 09' N, 38° 02'), Tsid Mariam (10° 08' N, 37° 58' E), Mehir Abo (10° 06' N, 37° 59' E) and Mekides Mariam (10° 07' N, 38° 00' E). The elevation of the study area ranges from 1100 to 3200 m above sea level. The annual rainfall and mean annual temperature is about 1100 to 1400 mm and 21°C, respectively.

Sampling

Five churches together with five adjacent degraded forests were randomly selected. The five selected churches were: Yeleb Lideta, Yeterbina Gebreal, Tsid Mariam, Mehir Abo and Mekides Mariam. Twelve circular plots with a radius of 5.64 m (100 m² area) (approximately 10% of the total area of each church forest) were randomly distributed in each of the church and adjacent degraded forests, a total of 60 plots were established in each of the forest types. Circular plots were used to avoid edge effects (Magurran, 2004). All woody species were recorded. However, seedlings were recorded in a subplot (1 m radius) established in each of the circular plots.

Estimating functional distance and functional attributes

As shown in Table 1, the most important plant functional attributes such as life form, height, leaf area, leaf life time, and fruit type (Archambault, 1998; Walker, 1995; Walker et al., 1999) were used to estimate the functional diversity of the two forests and functional distance between pair of woody species. Some of the attributes play vital role in performing photosynthesis and biomass accumulation by receiving more light for longer periods. Fruit type influences seed dispersal, storage and germination potential and mechanism which in turn have great impact on the regeneration and dominance of a species (Ngulube et al., 1997; Teketay, 1997; Vanclay et al., 1997; Eriksson et al., 2003). These functional attributes and botanical names for each species were identified in the field according to "Flora of Ethiopia and Eritrea" (Edwards et al., 2000; Hedberg and Edwards, 1989; Hedberg et al., 2006). Specimens were collected for species which were not identified in the field and identified at the National Herbarium at Addis Ababa University. The functional distance was estimated following Walker (1995) and Walker et al. (1999) equation:

$$FD_{ij} = \frac{1}{2} \sum_{k=1}^n |A_{ik} - A_{jk}|$$

Table 1. Functional attributes and values attached to each attribute.

<u>Functional value</u>	<u>Height (m)</u>	<u>Leaf area (cm²)</u>	<u>Growth form</u>	<u>Leaf life time</u>	<u>Fruit type</u>
1	0-5	0-10	Shrub	Deciduous	Berry
2	5-10	10-20			Drupe
3	10-15	20-30	Shrub/tree	Semideciduous	Nut
4	15-20	30-40			Capsule
5	> 20	> 40	Tree	Evergreen	Pod

Source: Walker et al. (1999) and Rutina et al. (2005). Note that the two conifer species lack fruits. *Cupressus lusitanicus*, which has dry seeds, is in the table classified as having nut, while *Juniperus excelsa*, which has fleshy seeds, is in the table classified as having a berry.

Where A_{ij} and A_{ik} are the attribute values of species j , k for attribute i , and I is the total number of attributes being considered.

We also classified functional similarity intervals using ecological distance (ED) as functionally similar ($0 \leq ED \leq 6$), similar to average ($7 \leq ED \leq 14$), average to dissimilar ($14 \leq ED \leq 33$) and dissimilar ($ED > 33$) following Walker et al. (1999). Jacard's similarity coefficients (Magurran, 2004) were used to determine the similarities of woody species based on their abundance. The relative abundance of each species (Krebs, 1999; Smith and Smith, 2001) in both church and adjacent degraded forests was compared using a Z test of two proportions in Minitab software version 16.0. Then, a Chi-square test was used to compare the functional distances among the ten most dominant species of the church forest and between the ten least dominant (minor) of the church forest and the ten most dominant species of the adjacent degraded forest.

RESULTS

Relative abundance and similarity of woody species

Fifty woody species have been identified from both the Church and adjacent degraded forests. Fifteen woody species were significantly more abundant in the church forests than in the degraded forests ($P < 0.05$). Similarly, seven woody species were significantly more abundant in the adjacent degraded forests than in the church forest. Five woody species, *Cordia africana* Lam, *Dracaena steudneri* Engel., *Jasmiun abyssinicum* Hochst. ex DC., *Malva verticillata* L. and *Olea europaea* L. ssp. *Cuspidata* which were found in the church forest have disappeared in the adjacent degraded forest. Eleven new woody species, *Acalypha fruitcosa* Forssk., *Clausena anisata* (Willd.) Benth., *Combretum molle* R.Br. ex G.Don, *Dodonaea angustifolia* L.F., *Ekebergia capensis* Sparrm., *ficus plamta* Forssk., *ficus vasta* Forssk., *Myrsine Africana* L. and *Rhus glutinosa* A. Rich. which were not found in the church forest have been recorded in the adjacent degraded forest (Table 2). Most of the woody species which were dominant in church forests had reduced in abundance in adjacent degraded forests. The similarity between the church and the adjacent forests as a whole was the highest ($S_j = 0.68$) of all indexes (Table 3).

On average, similarity index was higher among church

forests ($S_j = 0.52$) compared to adjacent degraded natural forest ($S_j = 0.34$). Mekdes church forest and its adjacent degraded forest were the most dissimilar ($S_j = 0.18$).

Functional distance and diversity

The functional distances between woody species ranges from 0 to 72 and 0 to 81 and church and adjacent degraded forests, respectively (Appendix 1 and 2). The total number of functional distances between woody species in the church and adjacent forest was 737 and 926, respectively. The average functional distances between woody species were 22.3 ± 14.4 (mean \pm SD) and 23.8 ± 17.0 for church and adjacent degraded forests, respectively (Appendix 1 and 2). Out of the total functional distances in the church forests, 14% (106) pairs were functionally similar, 26% (193) pairs were similar to average, 38% (277) pairs were average to dissimilar and 22% (161) pairs were dissimilar for the church forests (Figure 1A). In the degraded adjacent forests, 17% (154) pairs were functionally similar, 23% (215) pairs were similar to average, 33% (304) pairs were average to dissimilar and 27% (253) pairs are dissimilar (Figure 1B). We found significant variation among the four functional distance groups in the distribution of functional distances of the 10 most dominant species in the church forest ($\chi^2 = 21.40$, $P < 0.001$) and between 10 minor of the church and 10 dominant adjacent degraded forest species ($\chi^2 = 12.24$, $P = 0.01$) (Table 4). The average dissimilar ($14 \leq ED \leq 33$) and dissimilar ($ED \geq 33$) functional groups combined represent 87% of the total functional distances in the church forest (Table 4).

Only the rest 20% of the functional distances among the ten most dominant woody species of the church forest lies in similar to average ($6 < ED \leq 14$) and similar ($0 \leq ED \leq 6$) functional ranges (Table 4). Whereas, the functional groups for average to dissimilar ($14 \leq ED \leq 33$) and dissimilar ($ED \geq 33$) combined have captured only 66% ($\chi^2 = 12.240$, $P = 0.01$) of the functional distances between the ten minor species of the church forest and the ten most dominant woody species of the adjacent degraded forests. Five woody species (*Carissa spinarum*

Table 2. Woody species identified and their relative abundance and functional attributes.

Species	Relative abundance (%) in 120 plots		Mature leaf area (cm ²)	Height at maturity (m)	Growth form	Leaf life time	Fruit type
	Church	Adjacent					
<i>Acacia abyssinica</i> Hochst. ex Benth.	15 ^a	28 ^a	0-5	20	Tree	Semi-deciduous	Pod
<i>Acacia nilotica</i> (L.) Willd. ex Del.	17 ^a	20 ^a	0-5	2-14	Shrub/tree	Evergreen	Pod
<i>Acalypha fruticosa</i> Forssk.	0 ^a	3 ^a	>40	2-5	Shrub	Semi-deciduous	Capsule
<i>Acanthus pubescens</i> (Oliv.) Engl.	32 ^a	30 ^a	>40	0-5	Shrub	Deciduous	Capsule
<i>Albizia gummifera</i> (J.F. Gmel.) C.A.Sm.	8 ^a	18 ^a	0-5	15	Tree	Evergreen	Pod
<i>Asparagus racemosus</i> Willd.	0 ^b	7 ^a	0-5	7	Shrub	Semi-deciduous	Berry
<i>Bersama abyssinica</i> Fresen.	2 ^b	15 ^a	>40	2-5	Shrub	Semi-deciduous	Capsule
<i>Buddleja polystachya</i> Fresen.	15 ^a	8 ^a	>40	4-12	Tree	Semi-deciduous	Capsule
<i>Calpurnia aurea</i> (Ait.) Benth..	58 ^a	18 ^b	0-5	2-5	Shrub	Semi-deciduous	Capsule
<i>Capparis micrantha</i> A.Rich.	53 ^a	13 ^b	0-5	0-5	Shrub	Semi-deciduous	Capsule
<i>Carissa spinarum</i> L.	58 ^b	83 ^a	5-10	0-5	Shrub/tree	Evergreen	Berry
<i>Clausena anisata</i> (Willd.) Benth.	0 ^b	15 ^a	0-5	0-5	Shrub	Evergreen	Capsule
<i>Clerodendrum myricoides</i> (Hochst.) Vatke	18 ^a	3 ^b	0-5	0-5	Shrub	Evergreen	Capsule
<i>Combretum molle</i> R.Br. ex G.Don	0 ^a	2 ^a	20-30	2-5	Shrub	Evergreen	Capsule
<i>Cordia africana</i> Lam.	13 ^a	0 ^b	300	15-20	Tree	Deciduous	Drupe
<i>Croton macrostachyus</i> Del.	32 ^a	27 ^a	150	25	Tree	Deciduous	Nut
<i>Cupressus lusitanica</i> Lindl. ex Parl.	8 ^a	7 ^a	0-5	35	Tree	Evergreen	Dry seed
<i>Cussonia holstii</i> Harms ex Engl.	3 ^a	7 ^a	20-30	0-5	Shrub	Evergreen	Nut
<i>Dodonaea angustifolia</i> L.f.	0 ^a	5 ^a	5-10	0-5	Shrub	Evergreen	Capsule
<i>Dombeya torrida</i> (J.F.Gmel.) P. Bamps	8 ^a	17 ^a	100	12-15	Shrub/tree	Semi-deciduous	Capsule
<i>Dracaena steudneri</i> Engl.	3 ^a	0 ^a	>40	5-10	Shrub/tree	Evergreen	Capsule
<i>Ehretia cymosa</i> Thonn.	8 ^a	7 ^a	15	0-5	Shrub	Semi-deciduous	Capsule
<i>Ekebergia capensis</i> Sparrm.	0 ^a	3 ^a	>40	20-30	Tree	Evergreen	Capsule
<i>Eucalyptus globulus</i> Labill.	3 ^a	2 ^a	30-40	30	Tree	Evergreen	Capsule
<i>Euclea racemosa</i> Murr. ssp. <i>schimperi</i>	3 ^a	8 ^a	10-15	3-5	Shrub/tree	Evergreen	Drupe
<i>Euphorbia abyssinica</i> J.F.Gmel.	35 ^a	3 ^b	0-5	10	Shrub	Evergreen	Capsule
<i>Ficus palmata</i> Forssk.	0 ^a	5 ^a	>40	20-30	Tree	Deciduous	Berry
<i>Ficus vasta</i> Forssk.	0 ^b	8 ^a	>40	>20	Tree	Deciduous	Fig, berry
<i>Grewia ferruginea</i> Hochst. ex A. Rich.	60 ^a	7 ^b	>40	0-5	Shrub	Evergreen	Capsule
<i>Hibiscus micranthus</i> L.f.	12 ^a	2 ^b	6-30	0-5	Shrub	evergreen	Capsule
<i>Jasminum abyssinicum</i> Hochst. ex DC.	18 ^a	0 ^b	20-30	5-10	Shrub	Semi-deciduous	Nut
<i>Juniperus excelsa</i> M.Bieb.	8 ^a	2 ^a	0-5	40	Tree	Evergreen	Fleshy seed
<i>Justicia schimperiana</i> (Nees) T. Anders.	40 ^a	5 ^b	36-40	0-5	Shrub/tree	Evergreen	Capsule
<i>Malva verticillata</i> L.	7 ^a	0 ^b	20-30	2-5	Shrub	Evergreen	Capsule

Table 2. contd.

<i>Maytenus senegalensis</i> (Lam.) Exell	58 ^a	40 ^b	0-5	0-5	Shrub	Evergreen	Berry
<i>Myrsine africana</i> L.	0 ^a	5 ^a	0-5	0-5	Shrub	Evergreen	Capsule
<i>Ocimum urticifolium</i> Roth	8 ^a	7 ^a	0-5	1-2	Shrub	Semi-deciduous	Capsule
<i>Olea europaea</i> L. ssp. <i>cuspidata</i>	17 ^a	0 ^b	30	10-20	Tree	Evergreen	Nut
<i>Olinia rochetiana</i> A. Juss.	0 ^b	8 ^a	0-5	0-5	Shrub	Evergreen	Capsule
<i>Osyris quadripartita</i> Decn.	12 ^a	18 ^a	0-5	0-5	Shrub	Evergreen	Drupe
<i>Phytolacca dodecandra</i> L'Hérit.	23 ^a	3 ^b	0-5	2-5	Shrub	Evergreen	Capsule
<i>Pittosporum viridiflorum</i> Sims	30 ^a	13 ^b	20-30	0-5	Shrub/tree	Semi-deciduous	Pod
<i>Prunus africana</i> (Hook.f.) Kalkm.	3 ^a	7 ^a	0-5	0-5	Shrub	Evergreen	Pod
<i>Protea gaguedi</i> J.F.Gmel.	25 ^a	30 ^a	0-5	2-15	Shrub	Evergreen	Pod
<i>Pterolobium stellatum</i> (Forssk.) Brenan	48 ^a	18 ^b	50	40	Tree	Evergreen	Drupe
<i>Rhus glutinosa</i> A.Rich.	0 ^b	12 ^a	24	3-10	Shrub/tree	Evergreen	Drupe
<i>Rosa abyssinica</i> Lindley	2 ^a	10 ^a	0-5	0-5	Shrub	Evergreen	Drupe
<i>Schefflera abyssinica</i> (A. Rich.) Harms	5 ^a	13 ^a	>40	10-30	Tree	Evergreen	Capsule
<i>Terminalia schimperiana</i> Hochst.	5 ^a	15 ^a	20-30	2-5	Evergreen	shrub	Capsule
<i>Vernonia amygdalina</i> Del.	8 ^a	15 ^a	>40	3-10	Shrub/tree	Evergreen	Capsule

Figures with different superscripts indicates that the relative abundance of a species is significantly different ($P < 0.05$) in church and degraded forests.

L., *Maytenus senegalensis* (Lam.) Exell, *Calpurnia aurea* (Ait.) Benth., *Justicia schimperiana* (Nees) T. Anders and *Osyris quadripartite* Decn. out of the most dominant 10 woody species of the adjacent degraded forest had similar ecological distance (Appendix 1 and 2).

DISCUSSION

The similarity index shows that church forests are more similar to each other than adjacent degraded forests, suggesting that disturbance can create more dissimilar forests. Our result revealed that functional diversity of the degraded natural forest had increased only by 6% after disturbance considering the church forest as a reference. However, Abebe et al. ('under review') has

reported higher species diversity for church forest compared to adjacent degraded forest using the same plots of these forests. A slightly higher mean and standard deviation of functional diversity for the adjacent degraded forest compared to the church forest indicates that disturbance may some how increase functional diversity. However, this occurs at moderate level of disturbance as reported in other studies (Delarum et al., 2010). This study indicates that functional diversity is less sensitive to disturbance than species diversity. This study thus contributes to the increasing interest in quantifications of functional diversity (Petchey et al., 2007; Bracken et al., 2009; Dalerum et al., 2009). The findings of this study must be cautiously interpreted not to diminish the role of the church forest in maintaining intact natural forest of indigenous species. The relative abundance of the species

confirms that rare species are many in number and few in abundance and dominant species are few in number but covers most of the area. It agrees with the ecological concept which claims that dominant species are few in number and minor or tail species are many in number, but less dominant (Peterson et al., 1998; Walker et al., 1999).

The result reveals that dominant species are functionally dissimilar to each other, supporting previous findings which claimed that differences in functional niches allow these species to be co-dominant (Walker et al., 1999; Peterson et al., 1998). This implies that less disturbed natural forests have high functional diversity that can play a vital role in avoiding competition among species. This also signifies the advantage of natural forest or mixed plantations compared to monoculture plantations. The functional distances between the

Table 3. Similarity in species abundance among the possible pairs of church forests (Chf) and adjacent degraded forests (Af).

Chf	Adf	Yeleb		Yeterbina		Tsid Mariam		Mekides		Mehir	
		0.68	Chf	Af	Chf	Af	Chf	Af	Chf	Af	Chf
Yeleb	Chf	1.00	0.63 (18)	0.63 (20)	0.49 (17)	0.47 (15)	0.38 (11)	0.53 (17)	0.22 (9)	0.49 (17)	0.35 (13)
	AF		1.00	0.52 (20)	0.38 (13)	0.31 (10)	0.35 (9)	0.33 (11)	0.25 (9)	0.31 (11)	0.41 (13)
Yeterbina	Chf			1.00	0.47 (16)	0.50 (15)	0.36 (10)	0.48 (15)	0.30 (11)	0.46 (16)	0.37 (13)
	AF				1.00	0.36 (12)	0.36 (10)	0.52 (16)	0.41 (14)	0.42 (15)	0.33 (12)
Tsid Mariam	Chf					1.00	0.65 (10)	0.62 (16)	0.23 (14)	0.48 (15)	0.34 (11)
	AF						1.00	0.46 (11)	0.37 (7)	0.31 (10)	0.29 (8)
Mekdes	Chf							1.00	0.18 (7)	0.50 (16)	0.36 (12)
	AF								1.00	0.40 (14)	0.39 (12)
Mehir	Chf									1.00	0.50 (13)
	AF										1.00

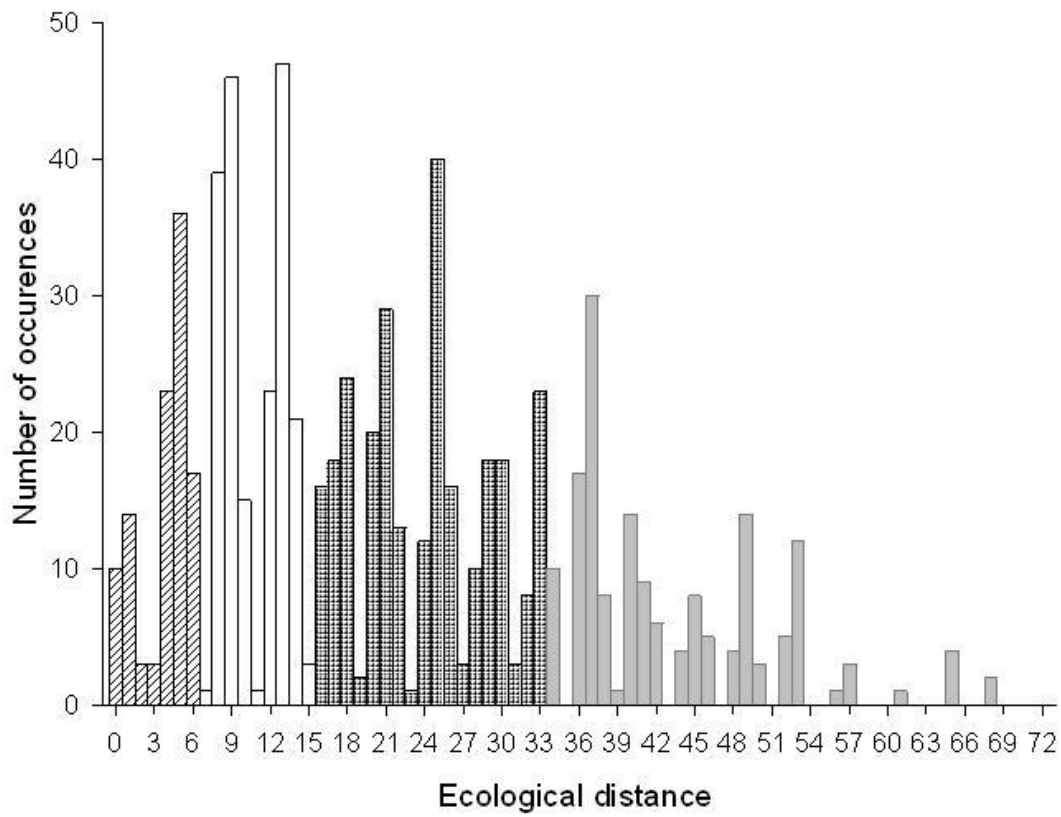
minor species of the church forest and the dominant species of the adjacent forests suggests that minor species of the church forest have shown tendency of offering insurance in the adjacent degraded forest. The result also confirms that new comer (passenger species) have offered insurance after disturbance. However, some species (*C. spinarum*) which are dominant in the church forest have still remained dominant in the adjacent forest. On the other hand, five species (*C. africana*, *D. steudneri*, *J. abyssinicum*, *M. verticillata* and *O. europaea* ssp. *cuspidate*) which were rare in the church forest were totally absent in the adjacent degraded forest. Their timber quality and sensitivity to browsing made these species extinct locally due to animal and human disturbances. In sum, dominant species and rare species may be functionally similar, but may not be necessarily different in responding to disturbance. Minor species, which offer insurance

regenerate in different ways, that is, by seed banks, seedling banks, seed rain or underground stumps (Teketay, 1997; Argaw et al., 1999; Eriksson et al., 2003; Wassie and Teketay, 2006; Wang et al., 2009). About 82% of the species, which are not found in the church forests, have capsule fruits and the rest 12% have berry fruits.

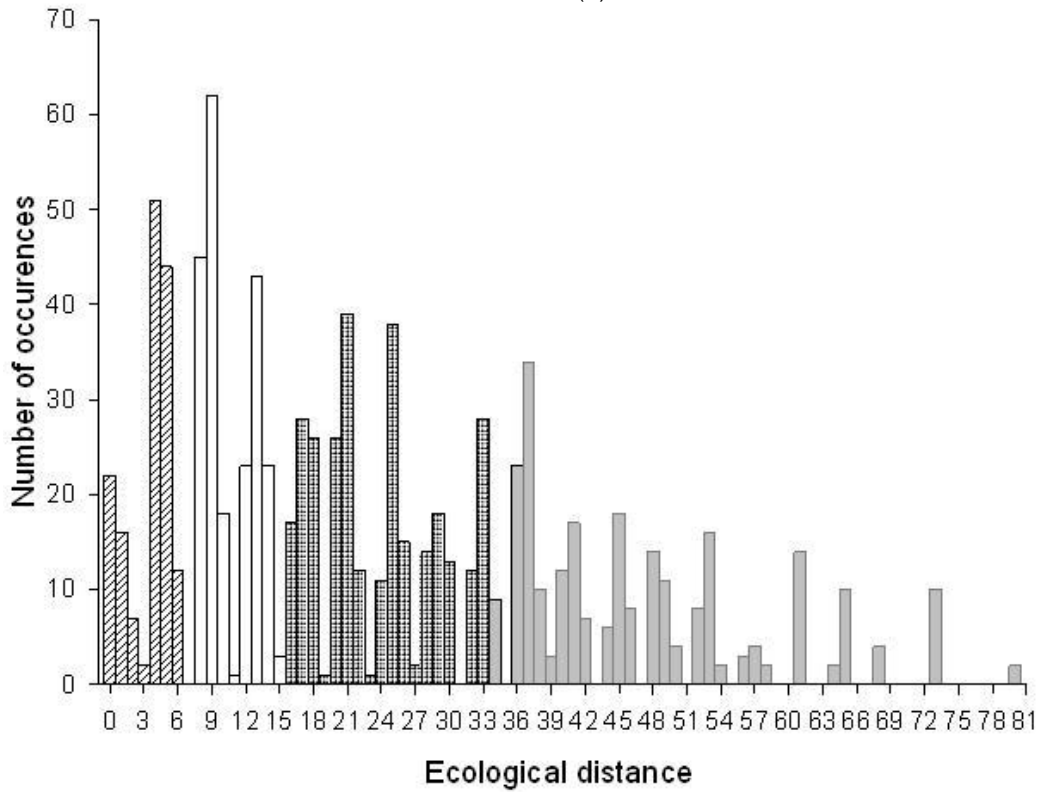
The seed germination strategy and dispersal methods might have contributed to the existence of those species. Tiny seeds from capsule are highly dependent on wind for dispersal and wind dispersal is more limited in the church forests compared to the open adjacent degraded forests. The main disturbances observed in the area were combinations of human disturbances mainly for wood products (that is, fuelwood and construction) and intensive browsing by animals. However, other disturbances such as fire, mineral and water stress, shed, wind, pest, disease and other natural disturbances such as climate change could also

be possible causes (Vanclay et al., 1997; Meers et al., 2010). Most of the dominant species in the adjacent degraded forest, except *C. spinarum* are not preferred by animals as a forage or by people for different uses (Bekele-Tesemma et al., 1993). *C. spinarum* which is preferred as browse for animals and for its excellent fire wood is abundant both in church and adjacent degraded forests. Its unique potential and adaptation has helped to perfectly respond to the disturbances and offer insurance. Its sharp thorns are important for resisting browsing pressure. Its amorphous big underground root also helps to produce multiple sprouts after grazing or cutting by people or damage by animals. This suggests that a single species with unique ability in responding to disturbances can also offer insurance for the ecosystem after disturbances.

The result lends hand to the general understanding that disturbance is among the most



(A)



(B)

Figure 1. Frequencies of ecological distances for all species pairs in the church forest. Groupings reflect apparent clusters of frequent ecological distances (light hashed, white bars, striped, and grey bars); the lower the ecological distance, the more functionally similar are the two species.

Table 4. Functional distances between 10 most abundant species in the church forest, and between 10 minor church and 10 dominant adjacent degraded forest species.

Functional similarity	Functional distance pairs between species	
	Church dominant	Church minor versus adjacent dominant
Similar ($0 \leq ED \leq 6$)	3	14
Average to similar ($6 < ED \leq 14$)	4	20
Average to dissimilar ($14 < ED < 33$)	19	37
Dissimilar ($ED \geq 33$)	19	29
Total pairs	45	100
χ^2	21.40	12.24
P-value	< 0.001	0.01

important key factors shaping the ecologies of the vegetation and attributes that confer success under disturbance are central (Rusch et al., 2003; Girme, 2001; Westoby et al., 2002). Functional diversity which is a cumulative effect of functional attributes is a proxy for ecological elasticity to disturbances. Thus, the concept of functional distances between species may be used as criteria to determine the functional distances between species for plantation and conservation purposes. It can also be used to predict changes in vegetation driven by anthropogenic disturbance such as land-use shifts and climate changes at local, regional and global scales.

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Appendix 2. contd.

<i>Osyris quadripartita</i>	38	17	36	29	24	44	8	8	6	8	48	65	33	9	32	25	9	45	5	21	20	8	10	41
<i>Phytolacca dodecandra</i>	30	9	32	21	20	40	4	4	14	4	52	65	33	9	28	21	5	41	9	17	16	4	10	33
<i>Pittosporum viridiflorum</i>	18	13	12	17	8	12	8	8	14	8	16	29	29	5	8	9	5	25	9	13	12	8	6	29
<i>Protea gaguedi</i>	29	8	33	20	21	41	5	5	21	5	57	68	36	12	29	22	6	42	14	18	17	5	13	32
<i>Pterolobium stellatum</i>	21	4	37	16	25	37	9	9	25	9	61	56	24	16	25	22	10	30	18	18	21	9	13	20
<i>Prunus africana</i>	23	26	53	22	41	13	49	49	25	37	33	18	10	38	17	18	44	4	24	22	37	37	31	18
<i>Rosa abyssinica</i>	26	13	40	17	28	32	12	12	2	12	36	53	21	13	28	21	13	33	1	9	24	12	14	29
<i>Schefflera abyssinica</i>	22	25	48	21	36	8	52	52	38	36	36	17	17	41	12	13	45	1	33	25	32	36	34	17
<i>Terminalia schimperiana</i>	34	13	20	25	8	28	8	8	14	0	40	53	37	5	16	9	5	33	9	21	4	0	6	37
<i>Vernonia amygdalina</i>	29	18	21	22	9	9	25	25	19	9	25	30	30	14	5	0	18	14	14	20	5	9	13	30