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# Status of Native Woody Species Regeneration in the Plantation Stands of Yeraba Priority State Forest, Amhara Region, Ethiopia

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**Abstract**
The type of species, diversity, density, similarity and status of naturally regenerated woody plants under monoculture plantation stands of four exotic species (*Eucalyptus globules, Cupressus lustanica, Acacia decurrence* and *Acacia melanoxylon*) and the adjacent natural forest stand were investigated and compared to verify the hypothesis that plantation stands of exotic species can foster natural regeneration and to determine the status of regeneration and succession. A total of forty quadrate plots, with an area of 100m$^2$ (10 m × 10 m) for each, were established in all stands, i.e. eight plots in each plantation stand and the adjacent natural forest, independently. In each plot, naturally regenerated native species name and abundance were recorded. And numerical data on numbers of seedling were collected in a sub-plot (1m$^2$) lay within each major plot. A total of 31 species which belongs to 23 families were recorded. The diversity of understory woody plant regenerated species (*H'*) is 1.96, 1.80, 1.81, and 1.53 in the *Cupressus lusitanica, Eucalyptus globules, Acacia melanoxylon,* and *Acacia decurrence* plantations respectively and 2.05 in the natural forest stand. The density was 5790, 1510, 1090, 2590 and stems/ha in *Cupressus lustanica, Acacia melanoxylon, Eucalyptus globules* and *Acacia decurrence* plantations respectively, and 7950 stems/ha in the natural forest stand. Relatively high similarity of regenerated woody species composition (0.625) was found between the under-growths of the *Euc. globules* and *Ac. melanoxylon* plantation stands. There is disturbed status of natural regeneration and succession in all stands. The findings revealed that there is significant difference in undergrowth and succession between upper story species, mainly due to crown characteristics and stand density. Generally, plantation forests can foster natural regeneration and succession provided that there is an adjacent seed source and dispersal agents, and an appropriate management to protect the regeneration.
**Keywords:** natural regeneration; woody species diversity, plantation forest, Yeraba state forest

## INTRODUCTION

Ethiopia has the most highland areas of any country in Africa. These highlands have a large number of plants and animals found nowhere else in the world. The Ethiopian highlands are threatened by wide scale deforestation and erosion, partly a result of high population pressure. This is true at all levels of the highlands, but particularly in the "Dega" areas (an agroclimatic zone which lie between altitude 2300 to 3200masl) where growing conditions are often extreme (Mark, *et al*., 2002). Massive tree planting and reforestation programs were conducted in Ethiopia in the past decades to rehabilitate denuded areas and to protect and develop natural forests, especially the National Forest Priority Areas (NFPA), where large unified natural forests still exist. And almost all of the afforestation programs were focusing more on the plantation of exotic species mainly *Eucalyptus* and *Cupressus* species.

Amhara region, where more soil erosion and environmental degradation observed, was one of the regions where extensive afforestation and reforestation activities taken place as that of plantation campaign of the previous regime, the Dreg. And currently there are remnants of those forests containing over-matured trees grown densely. There is an opinion that draws attention to the harmful effects of such old plantation forests of exotic tree species to the environment, especially for the undergrowth. However, as the counterbalance for the opinion, different researches carried in tropical countries showed that the canopies of exotic trees can exert protective functions and nurse effect for the regeneration of natural forest (Feyera and Demil, 2002a). As evidence, with recently carried forest inventory, the existence of under canopy natural regeneration of native woody species were reported under the canopy of an old plantation forest at Yeraba Priority State Forest (Enyew and Gebeyehu, 2010). I the researcher also encountered the existence of regeneration of native woody species under the canopies of aged plantation forests, while I had field visits in different areas of the region. So this issue draws my attention and I wanted to do this research to confirm this fact through scientific investigation at one of the above mentioned remnant old plantation forest of NFPAs, Yeraba Priority State Forest. This forest comprising plantation stands of four exotic species.

In Ethiopia, there is poor biodiversity and ecosystem based research EFAP (1994). Especially information on seedling ecology and natural regeneration status and diversity of native woody species under plantation stands is limited (Feyera and Demel, 2002a). Despite the fact that plantation of exotic species have proved instrumental in the rehabilitation of degraded lands. Knowledge on the promoted indigenous species, the natural regeneration diversity and status of regeneration of the developing flora is lacking. This creates gap of knowledge to manage and conserve the understory biodiversity in plantation sites. The attention given to the conservation and sustainable use of these biological resources has been inadequate (IBC, 2005). In some areas, the under-canopy of old plantation sites are utilized as grazing field. In others, like that of the plantation areas of NFPAs, where there is protection and guarding, the natural under growth often cleared as a weed in cleaning the forest floor from fire hazard. Generally, there is undervaluation of such environmental resources due to low-level of awareness about the role of plantation ecosystems in promoting the natural regeneration.

Fortunately the current national and global perception is directed to the significance of a scientific way of exploration of the natural regeneration and diversity of adaptive woody species, especially under the canopy of plantations, protection of natural re-growth under plantation stands may in fact be a more effective and cheaper way to ensure long-term survival. And this is basic to the future transition of plantation forests to the natural ecosystem. Many scholars believe that such transition to be the shortcut and cheapest method of environmental rehabilitation than area closure, which needs longer period to rehabilitate and get with useful species (Bekele-Tessema, 2007). But the transition needs identification of the undergrowth species, their diversity and status of regeneration, an appropriate management of the under growth native vegetation and maintaining optimal condition for regeneration under the stand of upper-canopy species. In this research we investigated natural regeneration of native woody species under pure plantation stands of exotic species, at Yeraba Priority State Forest (YPSF) in Amhara region Ethiopia. The canopy species of this research were *Cup. lustanica* Miller (Cupressaceae), *Ac. melanoxylon, Ac. decurrence* and *Euc. globules* Labill (Myrtaceae), and an adjacent natural forest which is located within the plantation forest are used for comparison or control. In the present research the following hypothesis were tested. 1) Exotic tree plantations can foster the regeneration of native woody species. 2) The diversity and status of regeneration under each exotic species are similar.

The objectives of this study were to: 1) to determine the composition, density of the naturally regenerated woody species; 2) assess the regeneration status of woody species and compare the species composition (similarity) between stands; 3) to identify the differences in regeneration between stands.

## MATERIALS AND METHODS

### Materials

Sunto (Silva) compass, Jallow, Measuring tape (50m) were used for the alignment of transects and the spacing between quadrates. Wooden pegs and plastic rope is used to locate the corner points of the quadrate and sub-plot. Collar diameter of the regenerated plants and DBH of canopy trees measured using tree caliper. Centimeter marked wooden stick of length 3.5m was made at field and used to measure the height of regenerated plants. And Sunto hypsometer was used to measure the height of canopy trees. Scissors, News papers, Corrugated papers 'carton', Fiber rope and wooden sticks used to collect plant sample and press parts for identification. Clinometers and Altimeter were used to collect landscape data such as slope, aspect and altitude. Plastic paint was used to locate sampled stations or quadrates. Wireless internet apparatus (CDMA) was used to browse information. Scientific calculator, Lap-top computer and Microsoft Excel Soft-ware were used to compile and organize the data and to make analysis and Microsoft Word was used for writing. Goggle Earth was used to download the satellite picture of the area. And Hewlett Printer, Photocopier, paper, tonner, carbon, fix pencil, pen, marker, ruler etc… were used at the field and in office.

### Description of the study area

The study was carried at YPSF. This forest is located 295 km North of Addis Ababa on the way to Bahir Dar, in East Gojam Zone of Amhara National Regional State (ANRS), Ethiopia. This forest is located at geographical reference of $10^{0}$18'35''N latitude and $37^{0}$45'29''E longitude. The altitude ranges between 2400 masl to 2551 masl. The forest covers a total area of 315 hectares. There are different land uses bordering the forest namely 'Aygereb pasture land' in the East, 'Abedeg pasture land' in the West, 'Engich got' farm land at the North and the main asphalt road and a small village 'Chemoga' at the South. The landform of the study area is characterized by undulating plain topography, and dominated by gentle slopes and a localized moderate steep slopes ranging from 2-15%. The study area is located at the lowest boundary of 'Moist Dega' agroclimatic zone (National Atlas of Ethiopia (NAE)) (Azene, 2005), and has a uni-modal type of rainfall pattern. The mean annual rainfall is recorded to be 1200 mm. The mean annual temperature, according to the 'Management plan' survey (Enyew and Gebeyehu, 2010), is 16$^{o}$C. The months May to October are the rainy months. The soil is Nitosol and is red in color, good physical properties, stable structure, deep rooting volume, and high moisture storage volume (EMA, 1988). This zone is zone of high agricultural activity with Barley, Wheat, and Pulses as main crops. One cropping season only. There is old history of land use with high erosion damages.

In the vicinity, the grassland is heavily overgrazed. There are few forests left and the acute scarcity of fuel wood in many places means that dung is being used instead. *Juniperus procera*, form dominant but broken forest stands, with medium sized trees. With this canopy, indigenous tree species such as *Croton macrostachys,* *Ekebergia capensis, Olea africana, Hagenia abyssinica, Pygeum africana* etc are found. As an area rehabilitation measure, exotic species like *Cupressus lusitanica, Acacia decurrence, Ac. melanoxylon* and *Eucalyptus globules* etc are successfully introduced as artificial plantations in to this area (Sjoholm, 1989). Descriptions and other relevant information about these species can be found in the works of Azene *et al.* (1993) and Fichtl & Admassu (1994). The study site, YPSF, is composed of these four mentioned exotic plantation species. And all stands are aged, more than 20 years. And the research investigates the condition of the undergrowth within these four species, and uses the natural forest stand, which is located at the center of these stands, for comparison.


Figure 1 Satellite image of Ethiopia. And the location of Yeraba Priority State Forest is pointed with yellow pin. (Google 2010 Accessed May 25, 2011).

**Sampling design and data collection**

**Sampling design**

The field study was conducted from January to March 2011. In the vegetation census the forest was classified in to four types of plantation stands (*Cupressus lusitanica, Acacia decurrence, Acacia melanoxylon* and *Eucalyptus globules*). And the Natural forest stand which is located within the plantation forest was taken as a reference for comparison. For vegetation data collection, as (Dwivedi, 1993) recommended a systematically designed sampling survey technique of parallel line transect with quadrates method were employed. And as Dagnachew (2001) tested and recommended the design for such assessment, sample quadrate measuring 10 m by 10 m (100 $m^2$) were laid down at 100 m intervals from each other along the transect lines. And the spacing between two adjacent transect lines was also 100 m. In each major quadrate plot, one subplot (1 m by 1m) was established. This subplot was laid at the centre of the major quadrate plots and used to count very small seedlings. As Anne (2004) suggested, 10 sample quadrates were established for each stand, and a total of 50 sample quadrates were established. Quadrates were placed more than 50 meters far from the border to avoid edge effect.

**Data collection**

During field assessment, the quadrates were marked using plastic rope and four wooden pegs. Within the major quadrate plot, all types of naturally regenerated native plant species encountered were identified and listed. Plant identification was carried out in the field using identification keys of Useful Trees and Shrubs for Ethiopia (Azene, *et al*., 1993; 2007) and Honeybee Flora of Ethiopia (Fichtl and Admassu, 1994). And for species which were difficult to identify in the field, voucher specimens of the plant were collected and identified in the National Herbarium of Ethiopia, Addis Ababa University. In counting and measuring, the individual plants were categorized in to growth stages of Germinant ($\leq$0.5 m ht.), seedlings (0.51-1 m ht.), and saplings (i.e. small saplings of 1.01-2 m, and juveniles of 2.01-3 m ht.) and counted and recorded accordingly. Counting and measuring of very small/ minute but abundant seedlings was carried out in the subplot. This classification was used to balance the samples across size classes, because the number of individuals expected to decline with increasing stem height or diameter size and it helps to see the population structure clearly. The categorization considers the life form and taxonomic structure of a few of the woody plants.

**Methods of Data Analysis**

Species Richness '*S*', Diversity '*H*'', Evenness '*E*'', and Status of the Natural Regeneration of native woody species under each stand, were analyzed using commonly used biodiversity measuring formulas and methods. And the results were compared between stands to evaluate the condition of regeneration under each stand, and the similarity 'JCS' (Jacard's Coefficient of Similarity) of the undergrowth between stands were compared.

A computer program, *Microsoft Excel,* was employed to make computation and analysis for diversity, evenness, abundance and status of growth and to draw graphs, curves and tables. The measurements and methods employed in this research are expressed as follows:

***The Species richness*** is measured to know how much number of different kinds of organisms present in each stand; and from the results to compare between stands species composition. Species richness computed simply by counting the number of types of native woody species (taxa) regenerated in a stand (S'). And the Margalef index "R" (Margalef, 1958), were used to compute the species richness for each stand. This index takes the total observed individuals 'N' as one factor in the computation. And the formula is as follows:

$$R=(S'-1)/\ln N \quad \ldots\ldots (1)$$

Where, R is Margalef index of species richness;
*S*' is number of taxa or species;
N is number of individuals.

Thus, the higher the R index value, the richer is the stand in species.

***The diversity of species*** is computed to know how diverse (in kind and abundance) the species present in each stand. Or to know how much is the average degree of uncertainty in predicting to what species an individual chosen at random is from the population of a collection of species. Species diversity is analyzed by using the most popular of metrics Shannon-Wiener Diversity Index (*H'*) (Kent and Coker 1994). And the formula is as follows:

$$H' = -\sum_{i=1}^{S} P_i \ln P_i \quad \ldots\ldots (1)$$

Where, *H'* is observed diversity;
*S* is the number of species;
$p_i$ is the proportion of the individual species to the total, $n_i$/N (where, $n_i$= the abundance of the individual species; and N is the total abundance); and
'Ln' is Natural Logarithm.

Thus the higher the *H*' value, the diverse the undergrowth in the stand.

***Evenness*** is a measure of how similar species are in their abundances (Anne, 2004). And as a heterogeneity measure, it describes the *equitability of species abundance* in the community (Dagnachew, 2001 cited Alatalo 1981 and Molinari 1989). Evenness is calculated using Shannon Evenness index (*E'*) (Krebs, 1989). And the formula of evenness index is as follows:

$$E' = H'/H'_{max} \quad \text{or} \quad E'=H'/\ln S \quad \ldots\ldots (2)$$

Where, *H'* is observed diversity;
$H'_{max}$ is equal to natural logarithm of richness, ln *S*.

Thus, an assemblage in which most species are equally abundant is one that has high evenness. And it is conventional to equate high diversity with high evenness (equivalent to low dominance of one or few species) (Magurran, 2004).

***The Density of species*** expresses how many members of that particular specie are found in the forest. Or it expresses the abundance of the specie in that forest. And it is computed as the division of the number of plants of a certain species by the area surveyed expressed in hectare, and the formula is as follows:

Density = total # of stems of the species/ sampled area in ha

***The frequency of species*** (%): expresses how frequent the species is observed in all samples. In other words it explains its distribution over the forest. And it is derived from the division of the number of quadrates of occurrence of a species to the total quadrates sampled multiplied by 100. And the formula is:

Frequency %= (# of quadrates with the plant/Total # of quadrates sampled) × 100

To compare the differences in species abundance between stands one of the best known and most informative methods, the Rank/Abundance Plot (or Dominance/Diversity Curve) or Whittaker plots using $Log_{10}$ scale (Krebs, 1989). The rank/abundance using Log10 scale is plotted as a graph. In this graph species are plotted in sequence from most to least abundant along the horizontal (or x- axis) and their relative abundances are typically displayed in a *$log_{10}$ format* (on the y axis).

These plots are often the best way of illustrating differences in *evenness* and *species richness.* Contrasting patterns of *species richness* are clearly displayed from the *rank*. When there are relatively few species all information concerning their relative abundances is clearly visible, whereas it would be inefficiently displayed in a histogram format (Wilson 1991). Furthermore, they highlight differences in *evenness* amongst assemblages (Nee *et al*., 1992). And their *diversity* and *Evenness* can be identified from their regression slope. The more the steepness of the regression slope the *least diverse* and the *less even* the stand.

***The Similarity*** analysis is used to identify the highly similar and or dissimilar stands in their understory plant composition. The similarity is analyzed using a statistical measure of similarity Jaccard's Similarity Coefficient (JSC) (Krebs 1989). The Jacard index for two sets, set A and set B, is defined as the cardinality of their intersection divided by the cardinality of their union.

Mathematically,

J(A,B)=[AnB]/[AUB]

The **status of natural regeneration** of native woody species in a stand or in a forest as a hole can be determined from population structures. Population structure refers to the distribution of individuals in arbitrarily defined Diameter or height classes. In this study I follow the height class distribution of regenerates. Then the values evaluated by using *height class histograms, (*Height class vs. % proportion of density). The height classes $\leq$0.5m for Germinant, 0.51-1m for seedlings, 0.01-3m for sapling are used. But to see the structure clearly the sapling class divided in to two, 1.01-2m and 2.01-3m. And from the population structure one of the two types of regeneration status will be determined: good regeneration status or poor regeneration status. Those Species which possess high number of individuals in the lower height classes, particularly in the first class, are considered to have good regeneration potential. Whereas, other species which possess either no or few number of individuals is in poor regeneration status. From this analysis, the species which show good regeneration or hampered regeneration status in each stand or for the forest as a hole will be described.

## RESULTS AND DISCUSSIONS

**Floristic composition and richness:** List of the naturally regenerated woody species found in a stands of the plantations and the natural forest stand in Yeraba state forest are described in Table 1. A total of 31 woody species with 22 families and 1893 individuals as a hole were recorded, in 50 sample quadrates, growing under plantation stands and in the natural forest stand. Concerning the life form of the plants according to the classifications of Fichtl and Admassu (1994), among the 31 native woody species recorded 9 species are trees, 12 species are shrubs/small trees, 7 are shrubs, and 2 species are shrub/woody climbers (Table 1).

The type genes /taxa of naturally regenerated native woody species encountered in each stands were assessed and listed (Table 2). The species composition in different stands ranged from 11 to 27 species. And the species taxa for each stands is: 19 in *Cupressus lusitanica*, 15 in *Acacia melanoxylon*, 15 in *Acacia decurence*, 11 in *Eucalyptus globules* and 27 in the Natural forest stands. The highest number of species was found in the Natural forest stand. Whereas among plantation stands, the highest number of species was recorded in *Cup. lusitanica* stand, and the least species are recorded in *Euc. Globules* stand. And concerning plant families, the highest 14 recorded under *Cup. lusitanica* stand and the least is *Euc. globules* (7 families). The natural forest stand contained 19 families. Among the 31 identified woody species, 9 species were only recorded in the Natural forest stand.

Table 1. List of the naturally regenerated woody species found in 50 samples.

| No | Species name | Family | Local name (Am) | Total | Plant Life Form |
|---|---|---|---|---|---|
| 1 | *Acacia abyssinica* Hochst ex Benth. | Fabaceae (Leguminosae) subfamily Mimosoideae | Nech girar | 2 | T |
| 2 | *Albizia schimperiana* Oliv. | Fabaceae (Leguminosae) subfamily Mimosoideae | Sessa | 2 | T |
| 3 | *Allophylus abyssinicus* (Hochst.) Radlk. | Sapindaceae | Ambus | 62 | T |
| 4 | *Apodytes dimidiata var. acutifolia* (A. Rich.) Boutique | Lcacinaceae | Dong | 7 | T |
| 5 | *Combretum molle* (R.Br. Ex Don.) Engl. & Diels | Combretaceae | Abalo | 180 | T |
| 6 | *Croton macrostachyus* Hochst. ex Del. | Euphorbiaceae | Bisana | 5 | T |
| 7 | *Hagenia abyssinica* (Bruce) J.F.Gmelin | Rosaceae | Koso | 5 | T |
| 8 | *Prunus africana* (Hook.f.) Kalkm. | Rosaceae | Homa/ Tikur enchet | 64 | T |
| 9 | *Rhus glutinosa* sub sp. *neoglutinosa* (M. Gilbert) M. Gilbert | Anacardiaceae | Ash'qamo | 13 | T |
| 10 | *Acacia lahai* Steud. & Hochst. ex Benth. | Fabaceae (Leguminosae), subfamily Mimosoideae | Cheba/ tikur girar | 3 | S/Ts |
| 11 | *Buddlega polystachya* Fresen. | Buddlejaceae (also often put in Loganiaceae, as in the flora of Ethiopia) | Anfar | 3 | S/Ts |
| 12 | *Clausena anisata* (Willd.) Benth. | Rutaceae | Limich | 639 | S/Ts |
| 13 | *Discopodium penninervium* Hochst. | Solanaceae | Aliba | 17 | S/Ts |
| 14 | *Dombeya torrida* (J. F. Gmel) P. Bamps | Sterculiaceae | Wulkifa | 1 | S/Ts |
| 15 | *Dovyalis abyssinica* (A. Rich.) Warb. | Flacourtiaceae | Korshim | 14 | S/sT |
| 16 | *Dracaena steudneri* Engl. | Agavaceae | Merko | 2 | S/sT |
| 17 | *Maesa lanceolata* Forsk. | Myrsinaceae | Kil abo | 134 | **S**/Ts |
| 18 | *Maytenus obscura* (A. Rich.) Cuf. | Celastraceae | Atat | 175 | S/Ts |
| 19 | *Ritchiea albersii* Gilg. | Capparidaceae | Dingai seber | 12 | S/Ts |
| 20 | *Rhamnus prinudes* L'Herit. | Rhamnaceae | Gesho | 14 | S/Ts |
| 21 | *Vernonia amygdalina* Del. in Caill. | Asteraceae | Girawa | 16 | S/Ts |
| 22 | *Argyrolobium schimperianum* Hochst. ex. A. Rich. | Fabaceae (Leguminosae: Papilionoideae sub family | Amedmado | 16 | S |
| 23 | *Clerodendron myricoides* (Hochest.) R. Br. ex Vatke | Verbenaceae | Misirech | 33 | S |
| 24 | *Lantana trifulia* L. | Verbenaceae | Kessie | 27 | S |
| 25 | *Osyris quadripartita* Decn. | Santalaceae | Qeret | 33 | S |
| 26 | *Phytolacca dodecandra* L'Her. | Phytolaccaceae | Endod | 3 | S |
| 27 | *Rubus apetallus* Poir. | Rosaceae | Injori | 13 | S |
| 28 | *Vernonia auriculifera* Hiern. | Asteraceae | Gengorita | 156 | S |
| 29 | *Carrisa edulis* (Forsk.) Vahl | Apocynaceae | Agam | 73 | S/C |
| 30 | *Rosa abyssinica* Lindley | Rosaceae | Qega | 6 | S/C |
| 31 | ????? | ???? | Tedamich** | 163 | T |
| | Number of total individuals sampled (=1893) | | | | |
| | Number of species (=31) | | | | |
| | Number of families (= 22) | | | | |

T= tree; S/sT= shrub or small tree; S= shrub; S/C =shrub or woody climber (lians); (Am) is local name of species in Amharic.

**The species name of "Tedamich" (Am) cannot be identified yet.

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Table-2. Population and total density of naturally regenerated woody species sampled under each forest stand.

| No | Species name | Density of Individuals in stands (density/ha) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Natural forest stand | | *Cup. lustanica* stand | | *Ac. melanoxylon* stand | | *Ac. decurrence* stand | | *Euc. globules* stand | |
| | | Total # in samples | Dt/ha | Total # in samples | Dt/ha | Total # in samples | Dt/ha | Total # in samples | Dt/ha | Total # in samples | Dt/ha |
| 1 | *Acacia abyssinica* | 2 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | *Albizia schimperiana* | 2 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | *Allophylus abyssinicus* | 57 | 570 | 1 | 10 | 0 | 0 | 2 | 20 | 2 | 20 |
| 4 | *Apodytes dimidiata* var. *acutifolia* | 7 | 70 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | *Combretum molle* | 44 | 440 | 1 | 10 | 59 | 590 | 40 | 400 | 36 | 360 |
| 6 | *Croton macrostachyus* | 0 | 0 | 0 | 0 | 1 | 10 | 0 | 0 | 4 | 40 |
| 7 | *Hagenia abyssinica* | 5 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | *Prunus africana* | 41 | 410 | 0 | 0 | 16 | 160 | 3 | 30 | 4 | 40 |
| 9 | *Rhus glutinosa* sub sp. *neoglutinosa* | 4 | 40 | 5 | 50 | 0 | 0 | 4 | 40 | 0 | 0 |
| 10 | *Acacia lahai* | 1 | 10 | 1 | 10 | 1 | 10 | 0 | 0 | 0 | 0 |
| 11 | *Buddlega polystachya* | 0 | 0 | 2 | 20 | 0 | 0 | 1 | 10 | 0 | 0 |
| 12 | *Clausena anisata* | 326 | 3260 | 159 | 1590 | 4 | 40 | 150 | 1500 | 0 | 0 |
| 13 | *Discopodium penninervium* | 15 | 150 | 0 | 0 | 1 | 10 | 1 | 10 | 0 | 0 |
| 14 | *Dombeya torrida* | 1 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 15 | *Dovyalis abyssinica* | 14 | 140 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 16 | *Dracaena steudneri* | 2 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | *Maesa lanceolata* | 2 | 20 | 132 | 1320 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | *Maytenus obscura* | 45 | 450 | 103 | 1030 | 4 | 40 | 17 | 170 | 6 | 60 |
| 19 | *Ritchea albersii* | 0 | 0 | 9 | 90 | 3 | 30 | 0 | 0 | 0 | 0 |
| 20 | *Rhamnus prinudes* | 12 | 120 | 2 | 20 | 0 | 0 | 0 | 0 | 0 | 0 |
| 21 | *Vernonia amygdalina* | 0 | 0 | 1 | 10 | 2 | 20 | 1 | 10 | 12 | 120 |
| 22 | *Argyrolobium schimperianum* | 4 | 40 | 5 | 50 | 0 | 0 | 7 | 70 | 0 | 0 |
| 23 | *Clerodendron myricoides* | 12 | 120 | 5 | 50 | 8 | 80 | 5 | 50 | 3 | 30 |
| 24 | *Lantana trifulia* | 3 | 30 | 7 | 70 | 7 | 70 | 5 | 50 | 5 | 50 |
| 25 | *Osyris quadripartita* | 9 | 90 | 20 | 200 | 0 | 0 | 4 | 40 | 0 | 0 |
| 26 | *Phytolacca dodecandra* | 3 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 27 | *Rubus apetallus* | 5 | 50 | 3 | 30 | 1 | 10 | 2 | 20 | 2 | 20 |
| 28 | *Vernonia auriculifera* | 4 | 40 | 60 | 600 | 41 | 410 | 17 | 170 | 34 | 340 |
| 29 | *Carrisa edulis* | 11 | 110 | 60 | 600 | 2 | 20 | 0 | 0 | 0 | 0 |
| 30 | *Rosa abyssinica* | 1 | 10 | 3 | 30 | 1 | 10 | 0 | 0 | 1 | 10 |
| 31 | Tedamich (local name in Amharic) | 163 | 1630 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Number of total individuals (=1893) | 795 | | 579 | | 151 | | 259 | | 109 | |
| | Number of species (=31) | 27 | | 19 | | 15 | | 15 | | 11 | |
| | Number of families (= 22) | 19 | | 14 | | 11 | | 12 | | 7 | |
| | Density /ha | | 7950 | | 5790 | | 1510 | | 2590 | | 1090 |

(#=indicates the total number of individuals encountered in the 10 samples taken in each stand; Dt=Density ha$^{-1}$.

**Species richness computation Using Margalef index:**

Table 3. Species richness R (Margalef index) under five forest stands at Yeraba.

| No | Stand | S' | N | S'-1 | LnN | R |
|---|---|---|---|---|---|---|
| *1* | *Cup. lusitanica* | 19 | 579 | 18 | 6.36 | 2.83 |
| *2* | *Ac. melanoxylon* | 15 | 151 | 14 | 5.02 | 2.69 |
| *3* | *Ac. decurrence* | 15 | 259 | 14 | 5.56 | 2.52 |
| *4* | *Euc. globules* | 11 | 109 | 10 | 4.69 | 2.13 |
| 5 | Natural forest | 27 | 795 | 26 | 6.68 | 3.89 |

S'=number of taxa; N=total population in a stand; Ln=natural logarithm; R= Margalef species richness index.

The result showed that, the Natural forest stand is richer in regenerated species than plantation stands (R=3.89). And from plantations stands *Cup. lustanica* is richer than others (R=2.83). *Euc. globules* is the least stand in species richness (R=2.33) (Table 3). In this estimator, as Gesesse (1996) indicated, the presence and distribution (abundance) of *rare species* affects the species richness estimate. The existence of these rare species made the richness result higher. For example the *Natural forest* stand has contained 9 rare species which are not found on the plantation stands. Among plantation stands, the *Cup. lustanica* stand contained 2 rare species and one of these rare species, *Maesa lanceolata*, was with high abundance. So the result becomes higher in *Cup. lustanica* stand than other plantation stands.

Even though the discovery made in this research varies with some of the types of canopy species (*Ac. melanoxylon* and *Ac. decurrence*), the species richness and floristic composition was compared with other similar studies carried at Central Ethiopian highlands, at Menagesha-Suba forest Western Showa region, at Belete state forest Western Oromiya region and Munesa Shahemene State forest at Southern Oromyia. In these studies *Cup. lusitanica* and *Euc. Globules* were one of the canopy trees used for investigation.

The total species richness result of Yeraba PSF is similar in number with that of the Central Ethiopian highland where Mulugeta (2004) totally discovered 33 woody species under four plantation stands of exotic species (*Cup. lusitanica, Pinus patula, Eucalyptus saligna*) and an indigenous species *Cordia africana*. And it is also nearly similar with that of the discovery of Feyera and Demel (2001), where 37 native woody species recorded under *Cup. lusitanica*, *Euc. Globules*, *Pinus patula, Pinus radiata* and an indiginus coniferous species *Juniperous procera* at Menagesha-Suba forest. But my result is far less than that of Belete State Forest where Shiferaw (2006) discovered 47 species under *Eucalyptus grandis* and adjacent natural forest; and that of Feyera (1998) who discovered 56 woody species under *Cup. lusitanica*, *Euc. Globules, Euc. Saligna*, *Pinus patula* and an indigenous *Cordia africana* plantation and adjacent natural forest at Munessa Sahsemene forest project.

**Density and frequency of regenerated species:**

***Density*:** The density of understory regenerated woody plants was variable among the various plantation stands (Table 2). The highest density of regenerated understory woody plants (5790 plants $ha^{-1}$) was recorded in the *Cup. lustanica* stand and the lowest (1090 plants $ha^{-1}$) in the *Euc. globules* stand. The density of naturally regenerated woody species in the adjacent natural forest stand was 7950 plants $ha^{-1}$, which is higher than that of plantation stands. To know whether there is a significant difference between stands in total density of species regenerated under each stand Mean Separation analysis is used and the result is described as follows (Table 4).

Table 4: Result of the significance difference analysis between stands in total regeneration density of native woody species, using Mean Separation Analysis LSD.

| Nº | Treatment | Mean population | Difference from control | LSD | |
|---|---|---|---|---|---|
| | | | | 5% | 1% |
| 1 | Natural stand | 79.5 | 0 | 23.50 | 31.45 |
| 2 | Cup. lustanica | 57.9 | $-21.6^{ns}$ | | |
| 3 | Ac. melanoxylon | 15.1 | -64.4** | | |
| 4 | Ac. decurrence | 25.9 | -53.6** | | |
| 5 | Euc. globules | 10.9 | -68.6** | | |

**=significant at 1% level, *=significant at 5% level, ns= not significant

The three stands have negatively significant in density; this huge difference may arise due to the interference of illegal grazing and felling that disturb and damage most seedlings. These stands are located at the far northern end of the forest where such disturbance is sporadic, as farmers say, and it is a major problem for guarding.

***Frequency*:** The most frequently found species (frequency >50%) are described in the following table (Table 5). Out of the 31 species 4 of them have frequency between 25-50% and 23 of them have less than 25% frequency (*i.e.* they are at the fourth quartile class of frequency). And the least frequent species (having 1% frequency) are *Apodytes dimidiate var. acutifolia, Hagenia abyssinica*, *Acacia abyssinica, Dracaena steudneri,* and *Dombeya torrida.* This means out the fifty sampled quadrates these species were encountered only in one quadrate. This implies that these particular species are rare and may become extinct from the area in the near future. Therefore, due attention should be given to treat and manage the regeneration of these 23 species as a target to biodiversity conservation.

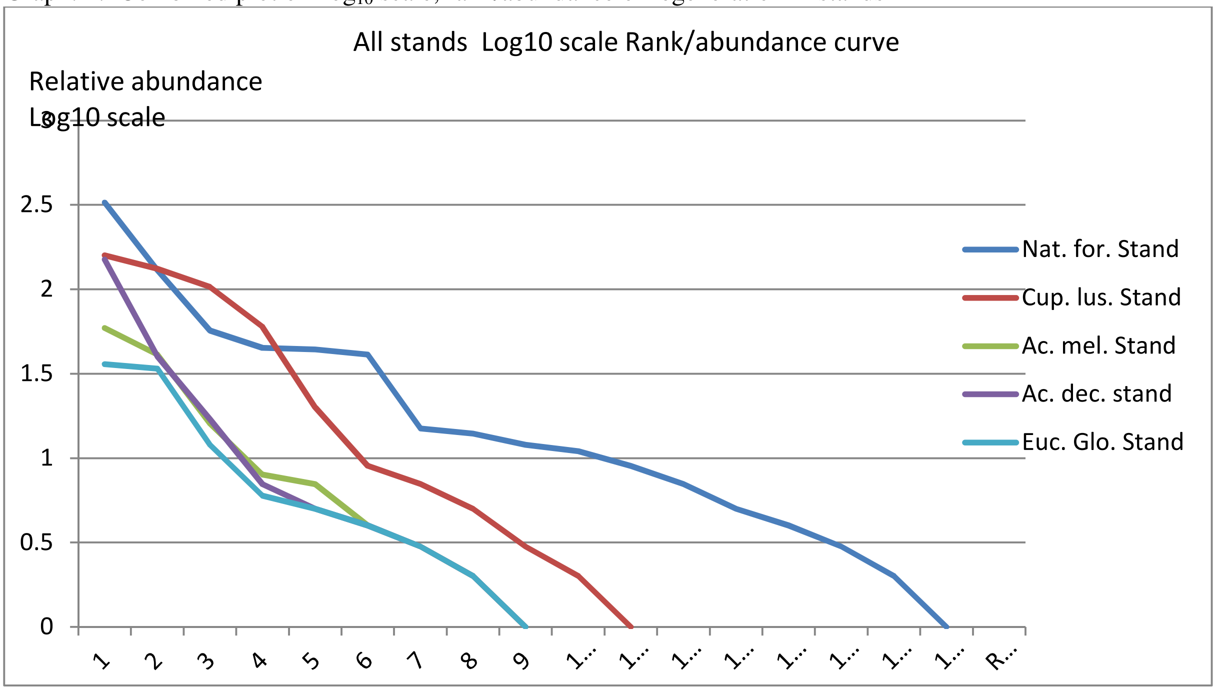
Table 5: List of the four most frequently found species (F ≥50%) in all sampled stands at Yeraba PSF.

| No | species | Local name (Am) | Total sampled | # of quadrates with the plant.* out of 50 sampled plots | Frequency F (%) | Remark |
|---|---|---|---|---|---|---|
| 1 | *Vernonia auriculifera* | Gengerita | 156 | 36 | 72 | |
| 3 | *Combretum molle* | Abalo | 180 | 30 | 60 | |
| 2 | *Maytenus obscura* | Atat | 175 | 30 | 60 | |
| 4 | *Clausena anisata* | Limich | 639 | 25 | 50 | |

*# of quadrates with the plant out of 50 sampled plots.

The difference in species abundance between stands is compared using Rank/Abundance curve ($Log_{10}$ scale) based on the population encountered in sampling. And the result summary is presented in Graph 1. The *rank/abundance* plot using $log_{10}$ scale result is plotted in the following graph (Graph 1). In this species are plotted in sequence from most to least abundant along the horizontal (or x) axis. Their abundances are typically displayed in a $log_{10}$ format (on the y axis).

Graph: 1. Combined plot of $Log_{10}$ scale, rank/abundance of regeneration in stands




Therefore, to evaluate differences in species abundance between the undergrowth assemblages of stands, a comparison of the value of the relative abundance $log_{10}$scale (Y-axis) on the graph was made, and the natural forest exhibited $log_{10}$ scale of relative abundance 2.513. Then the species in the Natural stand were more abundant than other stands. Among the plantation stands, naturally regenerated native woody species under the *Cup. lustanica* stand were more abundant, whereas, under the *Euc. globules* stand were the least. The *Cup. lustanica* and *Ac. decurrence* stands were nearly similar.

**Diversity of species:**

The result of Species diversity indexes (*H'*) of stands revealed that generally Natural forest stand was more diverse (2.05) and *Ac. decurrence* was the least (1.53). Among plantation stands, the natural regeneration of native woody species in the *Cup.lusitanica* stand was more diverse (1.96) and in *Ac. decurrence* stand was the least (1.53). This can be shown from the linear regression slope of rank/abundance curve, where *Ac. decurrence* stand exhibited (-0.239) slope and was the least diverse in naturally regenerated woody species (Table 6).

Table 6: Linear Regration slope analysis of each stand rank/abundance curve.

| Nº | stand | Trend line* (linear regression) | Linear regression slope (R) | Rank in regression slope steepness |
|---|---|---|---|---|
| *1* | *Cup. lusitanica* | Y=-0.231x+2.544 | -0.231 | 2nd |
| *2* | *Ac. melanoxylon* | Y=-0.212x+1.921 | -0.212 | 3rd |
| *3* | *Ac. decurrence* | Y=-0.239x+2.077 | -0.239 | 1st |
| *4* | *Euc. Globules* | Y=-0.188x+1.721 | -0.188 | 4th |
| 5 | Natural stand | Y=-0.128x+2.308 | -0.128 | 5th |

And from their regression slope their *diversity* and *Evenness* can be identified. The more the steepness of the regression slope the *least diverse* and the *less even* the stand. Even though *Ac decurrence* and *Ac. melanoxylon* stands had similar number of species (taxa) their diversity varied. This is because the species abundance (ni) range is very wide (1-150) in *Ac. decurrence* than that of *Ac. melanoxylon* (1-59). For example the highest dominant species in *Ac. decurrence* stand, *Clausena anisata* dominates with 58% proportion of the population (pi=0.58). While the highest in *Ac. melanoxylon* stand, *Combretum molle* dominates with 39% (pi=0.39). But the logarithm ln(pi) figure became less in *Ac decurrence* stand that influenced the *H'* result negatively. Exceptionally highly abundant species like *Clausena anisata* in *Cup.lusitanica,* in *Ac. decurrence* and in the Natural forest stand; and *Combretum molle* in *Ac. melanoxylon* and in *Euc globules* stands*,* with high relative abundance influenced the *H'* value of each stands negatively. The result suggests that, the presence of species with exceptionally high abundance reduces the *H*' value of a stand. because as Emiru *et al*. (2006) wrote the Shannon diversity index was highly influenced by the number of dominant and rare species present, and the number of species represented by very small number of individuals also affected the diversity.

**Evenness (E'):**

The evenness (or similarity in proportion of abundance of naturally regenerated native woody species in a stand; or the equitability of species), as a heterogeneity measure, results is indicated in the table (Table 8). Here the result shows the abundance of regenerated species under *Euc. globules* stand is relatively even (0.75) than other stands, because there is narrow abundance range between regenerated species (10-360 individuals $ha^{-1}$) (Annex-1). And evenness under that of the *Ac. decuurence* stand is the least (0.57). Among the plantation stands, the same *Euc. globules* and *Ac. decuurence* stands exhibited similarly the highest and the least result respectively. In the *Euc. globules* stand assemblage the most dominant species (*Combretum molle*) comprised 33% proportion of the total population of regenerates. This contrasts with that of the *Ac. decurrence* stand in which the most dominant species (*Clausena anisata*) represented 58% proportion of the sample population in the stand. From the regression slope of the rank/abundance plots (Table 7) we can observe *shallower slope* (-0.188) in the *Euc.globules* stand which show its higher evenness in assemblage among plantation stands. And the Natural forest stand exhibited low evenness (0.62) due to the existence of a wide range in abundance between species (*i.e*. 10-3260 individuals $ha^{-1}$). In the natural forest some species were exceptionally dominant and distributed in huge number over the stand, like *Clausena anisata* 3260 individuals $ha^{-1}$, and *Tedamich* (Am.) 1630 individuals $ha^{-1}$. As I mentioned above, here also the width of the range in abundance do have an effect on the evenness *E*' of a stand. The presence of extremely dominant (abundant) species can affect the evenness. The more the relative abundance of species differs, the lower the evenness (Emiru *et al*., 2006 cited Avena, 2000,).

Table 7: Summary of average plot value of Richness, Shannon-Wiener diversity, Evenness and Density in five forest stands.

| No | Stand | Total population sampled (N) | Density $ha^{-1}$ | Richness | | Diversity (*H*') | Evenness (*E*') |
|---|---|---|---|---|---|---|---|
| | | | | (*S*') | R | | |
| 1 | *Cup. lustanica* | 579 | 5790 | 19 | 2.83 | 1.96 | 0.67 |
| 2 | *Ac. melanoxylon* | 151 | 1510 | 15 | 2.69 | 1.81 | 0.67 |
| 3 | *Ac. decurrence* | 259 | 2590 | 15 | 2.52 | 1.53 | 0.57 |
| 4 | *Euc. globules* | 109 | 1090 | 11 | 2.13 | 1.80 | 0.75 |
| 5 | Natural forest | 795 | 7950 | 27 | 3.89 | 2.05 | 0.62 |

**Similarity in species composition between stands.**

Jacquard's Coefficient of Similarity in species composition of naturally regenerated woody species between stands is presented in Table 8.

Generally, the similarity between *Ac. melanoxylon* and *Euc. globules* stands is the higher (JCS=0.625) than all stands including the natural forest. And among plantation stands the maximum Jaccard's similarity index value in regenerated species is exhibited between *Ac. melanoxylon* and *Euc. globules* stands which is 0.625, while the least (JCS=0.429) is exhibited between *Cup. lustanica* and *Euc. globulus* stands. When we examine the similarity of plantations with the natural stand, *Cup.lusitanica* stand showed higher similarity (JCS=0.533), and

*Euc. globules* show the least (JCS=0.310) (Table 9). The number of common species shared by any two stands ranged between 8. Table 8: Jaccard's Coefficient of Similarity in species composition of naturally regenerated woody species between stands.

| stand | *Cup. lustanica* | *Ac. melanoxylon* | *Ac. deccurence* | *Euc. globulus* | Natural forest |
|---|---|---|---|---|---|
| *Cup. lusitanica* | 1.000 | 0.545 | 0.619 | 0.429 | 0.533 |
| *Ac. melanoxylon* | | 1.000 | 0.500 | 0.625 | 0.400 |
| *Ac. deccurence* | | | 1.000 | 0.529 | 0.448 |
| *Euc. globulus* | | | | 1.000 | 0.310 |
| Natural forest | | | | | 1.000 |

**Status of natural regeneration**

Forestry literatures' indicated that "a naturally regenerated stand of trees, even on forests where there is not human interference, may have thousands of seedlings per hectare in the beginning, the number decreases as the plants grow, at first rapidly, then more slowly. As plants reach the maturity stage only a few hundred of trees per hectare are remaining. This continuous decrease in tree number is mostly the result of rigorous natural selection. Most vigorous or best adapted trees are most likely to survive the intense competition for light, moisture and nutrients. This process is not entirely a steady and progressive selection of the fittest; at the same time natural accidents eliminate trees at random (Anna-Lisa, 1981). If there is an additional human interference and management failure on top of this natural process, things grow worsening for the natural succession through regeneration. The status of the natural regeneration under the canopies of forests can be revealed from the Height Class Distribution histograms of the species.

**Structure of regeneration of most frequent (common) species:** Common species are those species which are available regenerated in all stands (most frequent) and relatively most abundant. In this study, the Height class *vs*. Population proportion % histogram of the four highly frequent species, listed top to down according to their frequency of occurrence in the sampling (Table 5), are plotted. Analysis of frequent species can give better clue about the regeneration status of major species in the forest.

Table 10: - Population distribution of naturally regenerated common (frequent) species at their growth stages.

| no | Species | Stand | Total density $ha^{-1}$ | Proportion % in Growth stage | | | |
|---|---|---|---|---|---|---|---|
| | | | | Germinant (≤0.5m) | Seedling (0.5-1m) | Sapling (1.01-2m) | Sapling (2.01-3m) |
| 1 | *Vernonia auriculifera* | *Cup. lusitanica* | 600 | 100 | 0 | 0 | 0 |
| | | *Ac. melanoxylon* | 410 | 58.53 | 14.63 | 26.83 | 0 |
| | | *Ac. decurrence* | 170 | 64.71 | 17.65 | 25 | 0 |
| | | *Euc. globulus* | 340 | 26.47 | 38.23 | 35.29 | 0 |
| | | Natural forest | 40 | 25 | 25 | 25 | 25 |
| | | Total=> | **1560** | **1050** | **230** | **280** | |
| 2 | *Combretum molle* | *Cup. lusitanica* | 10 | 100 | 0 | 0 | 0 |
| | | *Ac. melanoxylon* | 590 | 83.05 | 10.17 | 6.77 | 0 |
| | | *Ac. decurrence* | 400 | 100 | 0 | 0 | 0 |
| | | *Euc. globulus* | 360 | 69.44 | 0 | 30.56 | 0 |
| | | Natural forest | 440 | 79.55 | 9.09 | 6.82 | 4.55 |
| | | Total=> | **1800** | | | | |
| 3 | *Maytenus obscura* | *Cup. lusitanica* | 1030 | 94.17 | 5.58 | 0 | 0 |
| | | *Ac. melanoxylon* | 40 | 0 | 25 | 75 | 0 |
| | | *Ac. decurrence* | 170 | 58.82 | 11.76 | 17.65 | 11.76 |
| | | *Euc. globulus* | 60 | 50 | 33.33 | 16.67 | 0 |
| | | Natural forest | 450 | 28.88 | 20 | 31.11 | 20 |
| | | Total=> | **1750** | | | | |
| 4 | *Clausena anisata* | *Cup. lusitanica* | 1590 | 69.18 | 19.5 | 11.32 | 0 |
| | | *Ac. melanoxylon* | 40 | 100 | 0 | 0 | 0 |
| | | *Ac. decurrence* | 1500 | 65.33 | 16 | 13.33 | 5.33 |
| | | *Euc. globulus* | 0 | 0 | 0 | 0 | 0 |
| | | Natural forest | 3260 | 55.21 | 25.77 | 11.35 | 7.67 |
| | | Total=> | **6390** | | | | |

Based on the above table (Table10) the following graphs are plotted for common species, and the regeneration status can be shown from the population structure at each growth stage (Graph 2).

## CONCLUSION

The result of this research evidenced that forest plantations can be used to catalyses the regeneration of native woody species, thereby increasing biological diversity. But there should be seed sources in the vicinity of the plantations and the area should be protected from grazing and human interference. And appropriate management of the regeneration is very crucial to maintain succession. The study revealed there is difference in the type of taxa, diversity, evenness and density of naturally regenerated native species among the plantation stands of exotic species; this may be due to their crown architecture and density, which is related to the amount of light passing to the lower floor to enhance regeneration and growth. Some species are rare and may come extinct in the area, and some others are new in the area. The rarity of species may be due to climate change. As Seppala *et.al*. (2009) indicated, narrowly endemic species that are limited by non-climatic factors (e.g. soil conditions) may be at risk of extinction under climate change.

The new species, as farmers indicated, were known to the local farmers as lowland species "Yekola tekil" and they were not familiar to this area. This may suggest that the climatic change related to the environmental disorder may push this species beyond their usual location, or the lower periphery of the Moist Dega agroclimatic boundary may shifted up to higher altitudes. Seppala *et.al* (2009) indicated that the distributional changes of species toward higher latitudes and elevations have been well documented and correlated with climate warming.

After climate change, dominant endemic species may no longer be adapted to the changed environmental conditions of their habitat, affording the opportunity for introduced species to invade, and to alter successional patterns, ecosystem function and resource distribution (Seppala *et.al*, 2009).

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