SITE FERTILITY AND ITS INFLUENCE ON THE STOCKING OF DIPTEROCARP SPECIES IN THE TROPICAL RAIN FOREST OF PENINSULAR MALAYSIA

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AMIR HUSNI MOHD. SHARIFF & MILLER, H.G. 1992. Site fertility and its influence on the stocking of dipterocarp species in the tropical rain forest of Peninsular Malaysia. Foliar and soil chemical properties of both Pasoh and Tekam Forest Reserves are presented and discussed in relation to dipterocarp species composition, diversity and accumulated basal area. Analysis of variance (ANOVA) confirmed the significant difference between the two sites in terms of fertility and carrying capacity. This paper also highlights the care and consideration that the forest manager needs to undertake when carrying out silviculture treatments on fertile soils (volcanic derived soils).

Key words: Tropical rain forest - soil fertility - stocking - dipterocarp species

Introduction

An understanding of the various factors within the ecosystem that influence the floristic composition is vital in order to manage the forest resource and ensure optimum and perpetual production. Dipterocarpaceae, for example, is an important tree family in the lowland evergreen rain forest and the proportion it represents of the total volume profoundly influences the commercial value of the forest. The history and evolution of the Malayan Silviculture System clearly exhibits the care and consideration taken to enrich the forest with members of this family. Various systems, such as the Regeneration Improvement Felling (RIF), introduced in the 1900s, followed by poison girdling technique with sodium arsenate, were all aimed at cleaning the forest to give more room for natural regeneration of dipterocarp species. To further enhance dipterocarp richness in the forest, artificial regeneration was introduced in the form of enrichment planting. All these efforts clearly illustrate the intention of the Malaysian Forestry Department and Forest Research Institute Malaysia (FRIM) to enrich the forest with dipterocarp species for commercial purposes.

Study sites

For this study, two sites were selected. Both are main integrated research centres of FRIM, one being Pasoh Forest Reserve (PFR), Negeri Sembilan, while the other is Tekam Forest Reserve (TFR), Jengka, Pahang. These two reserves differ in geological formation and therefore offer good contrast in soil potential.

Pasoh Forest Reserve (PFR)

PFR is located in the southwestern part of Negeri Sembilan, about 85 *km* away from the capital city Kuala Lumpur. The reserve covers 592 *ha* with the surrounding reserved buffer zone of 1360 *ha*.

According to Morgan (1971), the climate of this area belongs to the Lipis type, characterised as having the lowest average annual rainfall in Peninsular Malaysia. The amount of rainfall in this area is about 1800 *mm* (Dale 1959, Sani 1983) while the mean annual temperature ranges from 24.5 to 27.2°*C*.

The geology of this area has been described by Khoo (1973, 1974, 1975 & 1976) and Loganathan (1980) as belonging to sedimentary rocks in the east and igneous rocks in the west. The topography is flat to undulating, mainly ranging between 75 to 150 *m* above sea level and only towards the eastern boundary does it rise to 600*m* where it adjoins low granitic hills. The vegetation of this area has been inventoried by Salleh (1968) and is typical of lowland rain forest as described by Wyatt-Smith (1961), being characterised by high percentage of red meranti groups.

Tekam Forest Reserve (TFR)

TFR lies immediately to the north of the Jengka Triangle in the state of Pahang, approximately 170 *km* to the northeast of Kuala Lumpur. This forest reserve covers an area of 12400 *ha* and the study was concentrated in the Tekam hydrological basin, an area of about 56.6 *ha* which has been the centre of many integrated research activities of FRIM over the past ten years.

The average annual precipitation in this area ranges between 2765 and 2980 *mm* (Abdul Rahim 1983), whilst the air temperature ranges from 24 to 29°*C* (Dale 1959).

The geology of the area varies from upper Triassic to lower Cretaceous and is associated with volcanism (Khoo 1977) and so is rich in tuffaceous minerals (based on the inventory of Sungai Tekai and Sungai Tekam area, Ibrahim unpublished). The area can be described as undulating to rolling to hilly with slope extremes of 35° and 2° and elevation ranging between 80 and 325 *m* above sea level.

Poore (1968) described the floristic composition of Jengka Triangle and pointed to the prevalence of members of the genus *Dipterocarpus* and genus *Shorea* of the red meranti group while the higher elevations are occupied by the seraya type (Hunting 1967).

Materials and Methods

Based on detailed and semi-detailed soil survey in TFR and PFR, respectively, five dominating soil types were selected from each reserve. Soils identified were based on the soil survey manual for soil surveyors in Malaysia (Paramanathan 1986). The soils selected from PFR were Padang Besar (PBR) (Orthoxic Tropudult), Bukit Tuku (BTU) (Aquic Paleudult), Awang (AWG) (Aquic Paleudult), Ulu Dong (UDG) (Typic Paleudult) and Chat series (Typic Paleudult) while for TFR they were Jengka (JKA) (Rhodic Paleudult), Tajau (TJU) (Typic Paleudult), Jeram (JRM) (Typic Paleudult), Jempol series (JPL) (Typic Paleudult) and Bungor (BGR) (Typic Paleudult) soil series.

A 2-*ha* plot oriented in north-south direction was laid out on each soil type and all trees 10 *cm* dbh were enumerated and identified at species level. For every 2-*ha* plot the accumulated basal areas of all species present, of the preferred species and of the acceptable species (as defined by Kochummen 1979) were calculated using a Fortran 77 (Ellis 1980) programme (written under the guidance of M. Court); the data were also sorted into families by both number of stems and basal area and into stem numbers within species and girth classes (at 30 *cm* intervals).

Each of the 2-*ha* plots, measuring 100 × 200 *m*, was then subdivided into 200 subplots, each 10 × 10 *m*, and using random tables (Rand Corporation 1955) ten subplots were chosen from every 2-*ha* plot for soil sampling. Ten bulk samples (one bulk sample being taken from five sampling points) were collected from each of the 2-*ha* plot to represent depths of 0 to 15 *cm* and 15 to 30 *cm*, samples being obtained using a screw auger. The samples from each sub-plot were thoroughly mixed to ensure uniformity and packed inside plastic bags for transportation to the laboratory for analysis. The soil samples were dried in the oven for a period of 48 to 72 hours at 60°C. The samples were crushed through a roller mill and the fraction that passed through a 2 *mm* sieve was collected for analysis. In the case of the determinations of N, total nutrients and micronutrients fine samples were used (sieved through 60 mesh size).

The pH was measured in water and 1 *N* KCl, in both cases the ratio of soil to liquid being 1:2.5, the measurements being made using a Corning 155 pH meter after shaking for an hour.

Kjedahl digestion procedure was adopted for total N(%) determination (Anonymous 1972) followed by semi-micro distillation using Buchii apparatus. Available P was determined by Bray and Kurtz's Method 2 (1945), measuring colorimetrically, with a Hilger Spekker, the molybdate-blue complex formed in the presence of ammonium molybdate with stannous chloride acting as reductant (Watanabe & Olsen 1965). Leaching with 1 *N* ammonium acetate buffered at pH 7 was adopted for extraction of available cations. For total cations and total P, Cu and Zn the perchloric:sulphuric acid mixture (1:1) digestion procedure was chosen (Lim 1975) with the subsequent determination procedures being as outlined for the sodium carbonate fusion method (Jackson 1958). Once extracted, the exchangeable K and total K were determined using a Corning 410 flame photometer,

while for Ca, Mg, Cu and Zn a Hitachi 170-30 atomic absorption spectrophotometer was employed.

In addition, foliage samples were taken from twelve selected dipterocarp species and two legume species, samples being taken from dominant trees (≥30 *cm* dbh) and only mature leaves 15 *cm* down the shoot were collected. The method of sample preparation prior to chemical nutrient determination as outlined by Yeoh (1975) was strictly followed. The classical Kjedahl method (Piper 1950) was adopted for N determination; for macronutrients (P, K, Ca and Mg) dry ashing technique was followed, while for micronutrients (Cu and Zn) a wet ashing procedure was used. P was determined colorimetrically by the formation of yellow vanado-molybdo-phosphate complex, measured using a Bausch and Lomb UV/VIS spectrophotometer, K by flame photometry while Ca and Mg by Hitachi 170-30 atomic absorption spectrophotometer (AAS) using strontium chloride to suppress the phosphate and sulphate ions as outlined by Wade and Johnson (1966). In the case of Cu and Zn, a Hitachi 170-30 AAS was used with the wavelength set at 324.8 and 213.8 μ respectively.

Data analyses

Analysis of variance (ANOVA) was carried out on the soil chemical data for the bulk samples to test for differences (F-test) between PFR and TFR in topsoils and subsoils (where n = 50) with least significant difference (LSD) set at the 5% level.

In terms of mean accumulated basal area of preferred species, acceptable species, dipterocarp species, preferred plus acceptable species and all species combined, ANOVA was again adopted for comparison between the two reserves using t-test for significant testing with LSD calculated at 5% significant level.

Results

In terms of stem density, the dipterocarps comprise 11.1% of the stands in PFR compared to 2.7% in TFR. There are as many as 17 species of dipterocarps in TFR (excluding two identified at genus level) in comparison to 36 in PFR (excluding one identified at genus level). In this study 13 species of dipterocarps are common to both reserves while four are exclusive to TFR and as many as 23 are found only at PFR (Table 1).

The ten most dominant individual species on each reserve are shown in Table 2. The four species at highest densities in TFR are *Elateriospermum tapos*, *Pometia pinnata*, *Nephelium lappaceum* and *Mallotus phillipensis* with a count of 9.1, 7.7, 5.0 and 4.9%, respectively. For the PFR, the dominating species are *Xerospermum intermedium* (2.6%), *Shorea leprosula* (1.9%), *Shorea ovalis* (1.7%) and *Shorea parvifolia* (1.4%).

The results of the significance test between preferred, acceptable, dipterocarp, preferred plus acceptable and all species basal area for TFR, PFR and TFR *versus* PFR are presented in Table 3.

Table 1. Dipterocarp species common to both reserves or exclusive to one

Species common to both reserves	Species exclusive to PFR	
D. baudiiolia	*A. costata*	*S. hopeifolia*
D. cornutus	*A. curtisii*	*S. kunstleri*
D. costulatus	*A. laevis*	*S. laevis*
D. gracilis	*A. megistocarpa*	*S. lepidota*
D. sublamellatus	*A. scaphula*	*S. macroptera*
H. dryobalonoides	*D. crinitus*	*S. materialist*
S. bracteolata	*H. dyeri*	*S. maxima*
S. guiso	*H. mengarawan*	*S. maxwelliana*
S. leprosula	*H. nervosa*	*S. pauciflora*
S. multiflora	*N. heimii*	*V. bella*
S. ovalis	*P. densiflora*	
S. parvifolia	*S. acuminata*	
V. pauciflora	*S. dasyphylla*	

Species exclusive to TFR

H. sulcata
S. assamica
S. curtisii
S. eurynchus

Note: S - *Shorea*, D - *Dipterocarpus*, P - *Parashorea*, V - *Vatica*, A - *Anisoptera*, N - *Neobalanocarpus* and H - *Hopea*
[Source: Amir *et al.* (1991)]

Table 2. The ten most common species in TFR and PFR based on 10-*ha* plot for each reserve, expressed as percentage of total stems

Dominant species in PFR	Dominant species in TFR
Alangium ridleyi (1.0%)	*Canarium littorale* f *rufum* (.5%)
Barrangtonia maingayi (1.1%)	*Canarium pseudosumatranum* (1.6%)
Dacryodes rugosa (1.3%)	*Elateriospermum tapos* (9.1%)
Ganua sp A (1.1%)	*Gymnacranthera bancana* (1.9%)
Ixonanthes icosandra (1.1%)	*Hydnocarpus wrayi* (2.5%)
Ochanostachys amentaceae (1.2%)	*Litsea erectinervia* (2.6%)
Shorea leprosula (1.9%)	*Mallotus phillipensis* (4.9%)
Shorea ovalis (1.7%)	*Nephelium lappaceum* (5%)
Shorea parvifolia (1.4%)	*Pometia pinnata* (7.7%)
Xerospermum intermedium (2.6%)	*Pseuduvaria macrophylla* (2%)

[Source: Amir & Miller (1991b)]

From Tables 3 and 4 it is evident that TFR is poorly stocked with dipterocarp species and that the commercial timbers were primarily non-dipterocarps. At PFR, the basal area of dipterocarp species is substantial (8.35 m^2 ha^1).

In the case of TFR versus PFR, a weak significant difference was observed between basal area of the preferred species ($P<0.1$) but none between acceptable species. However, the total basal area per *ha* (all species) and the basal area of the dipterocarps are highly significantly different between the two reserves ($P<0.001$).

When comparing the soils of the two reserves (Table 5), both the topsoil and subsoil of TFR are superior to the corresponding depths of PFR in all the nutrients, except exchangeable Ca, extractable Zn, and to a lesser extent, total Ca. Of the 14 parameters compared between the topsoils, nine are differential $P<0.001$ and one

is at $P<0.01$, whilst in the subsoils all the exchangeable and total amounts, including the available P and pH, differ significantly except total Ca. The high amounts of exchangeable bases at TFR are well demonstrated both by the amounts of cations and the pH values in water and in KCl, in soils from this reserve.

Table 3. Analysis of Variance (ANOVA) between the means of basal area ($m^2\ ha^{-1}$) of Preferred (Pre.), Acceptable (Acc.), Dipterocarp, Preferred plus Acceptable and All species composition within and between TFR and PFR (The significance is tested using the t-test and LSD is calculated at 5% significant level)

TFR Dipterocarp species	Preferred species	Acceptable species	Pre. + Acc. species	All species
2.73a	4.09a	8.52b	12.61c	30.99d

PFR Dipterocarp species	Preferred species	Acceptable species	Pre. + Acc. species	All species
6.92a	7.01a	8.35a	13.93b	25.52c

TFR vs PFR Species	Preferred species	Acceptable species	Dipterocarp species	Pre. + Acc. species	All species
Area					
TFR	4.09	8.52	2.73	12.61	30.99
	+	NS	***	NS	***
PFR	7.01	6.92	8.35	13.93	25.52

Note: Values in rows not sharing the same letter(s) are significantly different; +, *** and NS are significant at 10, 0.1% and Not Significant, respectively [Source: Amir & Miller (1991a)]

Table 4. Basal area composition of Preferred (Pre.), Acceptable (Acc.), Dipterocarp, Preferred plus Acceptable and total basal area and the mean value ($m^2\ ha^{-1}$) of TFR and PFR

TFR Soil series	Preferred species	Acceptable species	Dipterocarp species	Pre. + Acc. species	All species
TJU	1.519	12.269	0.659	13.788	32.595
JPL	7.480	6.569	5.408	14.049	37.432
BGR	4.355	7.705	2.312	12.060	28.312
JKA	5.090	7.356	3.506	12.446	31.878
JRM	2.019	8.694	1.758	10.713	24.709
Mean:	4.093	8.519	2.729	12.611	30.985
PFR					
PBR	7.760	9.738	9.427	17.498	27.518
BTU	5.568	5.113	6.390	10.681	21.248
UDG	7.423	5.490	7.390	12.913	25.709
AWG	8.041	4.280	10.136	12.321	26.032
Chat	6.237	9.983	8.425	12.220	27.067
Mean:	7.006	6.921	8.354	13.927	25.515

[Source:Amir & Miller (1991b)]

Table 5. Analysis of variance (ANOVA) between means of chemical soil properties of bulk samples between PFR and TFR in topsoils and subsoils, where n = 50 for each level (The means are compared using F-test. LSD calculated at 5% significant levels)

Topsoil: Available and exchangeable nutrients plus pH

Site	Av. P (ppm)	Ex. K	Ex. Ca	Ex. Mg	pH (water)	pH (KCl)
		← *meq* 100 g^{-1} soils →				
TFR	6.73	0.179	0.337	0.380	4.40	3.65
PFR	5.29	0.097	0.344	0.261	4.24	3.58
Sig. levels	***	***	NS	***	*	NS

Topsoils: Total soil nutrients

Site	N (%)	P (ppm)	K	Ca	Mg	Fe_2O_3 (%)	Cu (ppm)	Zn
			← *meq* 100 g^{-1} soils →					
TFR	0.094	294	5.05	3.03	3.08	2.07	12.17	28.70
PFR	0.077	143	2.47	2.68	1.84	0.97	7.42	33.20
Sig. levels	***	***	***	***	***	***	***	NS

Subsoils: Available and exchangeable nutrients plus pH

Site	Av. P (ppm)	Ex. K	Ex. Ca	Ex. Mg	pH (water)	pH (KCl)
		← *meq* 100 g^{-1} soils →				
TFR	4.34	0.137	0.170	0.329	4.57	3.77
PFR	5.29	0.097	0.344	0.261	4.24	3.58
Sig. levels	***	***	***	***	*	*

Subsoils: Total soil nutrients

Site	N (%)	P (ppm)	K	Ca	Mg	Fe_2O_3 (%)	Cu	Zn
			← *meq* 100 g^{-1} soils →				(ppm)	
TFR	0.056	207	8.41	1.70	4.55	2.79	9.38	13.80
PFR	0.047	122	2.29	1.63	1.91	1.54	5.85	23.80
Sig. levels	**	***	***	NS	***	***	***	***

Note: *, **, *** and NS are significant at 5, 1, 0.1% and Not Significant, respectively
[Source: Amir & Mona (1990)]

Discussion

The accumulated basal area at TFR averaged 30.99 $m^2 ha^{-1}$ of which 12.61 $m^2 ha^{-1}$ (40.7%) was classified as commercially valuable, the dipterocarps accounting for only 2.73 $m^2 ha^{-1}$. At PFR, by contrast, although the total basal area was only 25.52 $m^2 ha^{-1}$, of the 13.39 $m^2 ha^{-1}$ (54.6%) of commercially valuable timber the dipterocarps accounted for 8.35 $m^2 ha^{-1}$ (32.7%) (Table 3). The higher basal area at TFR is not surprising because it is generally a more fertile site than PFR (Table 5), the soils at TFR being mainly volcanic derived whereas at PFR they are primarily sedimentary and alluvial.

Comparison of the values of total basal area per *ha* obtained here with figures from tropical lowland evergreen rain forests elsewhere is shown in Table 6. The basal area at TFR is quite similar to the reported Indonesian figures and to that at Sungai Menyala Forest Reserve, Peninsular Malaysia, while the basal area at PFR is much lower than those figures from others sites with the exception of the poor

tierra-firme soils of Venezuela. In comparison to the figures from East Malaysia, the basal areas found in this study are generally much lower. This is to be expected since the soils in East Malaysia are generally more fertile with base status exceeding 10% (Gordon 1983) and a CEC over 16 *meq* 100 g^{-1} clay (Hamsawi & Jugah 1991). This is mainly attributable to the geology of East Malaysia which is mainly Tertiary (Leichti *et al.* 1960) while in Peninsular Malaysia it ranges from Triassic to Silurian and even Cambrian, although the latter is less extensive (Gobbett & Hutchinson 1973). The younger geological body of East Malaysia is the decisive factor in the difference in fertility status of the soils between the two regions.

Table 6. Plant biomass reported for various tropical lowland evergreen rain forests

Forest types	Location	Basal area $m^2\ ha^{-1}$	Plant biomass $t\ ha^{-1}$	Authors
L.R.F***	Venezuela	23.13	316	Jordan & Uhl 1978
L.D.F*	P. Malaysia	-	413[a]	Kira 1978
L.D.F*	P. Malaysia	-	475[a]	Kato *et al.* 1978
H.D.F**	P. Malaysia	-	811[b]	Gong & Ong 1984
L.D.F*	P. Malaysia	32.4	-	Manokaran & Kochummen 1987
L.R.F***	P. Malaysia			
1. Alluvial Forest		28.0	250	
2. M.D.F/L.R.F.		57.0	650	
3. Heath Forest		43.0	470	
4. Limestone Forest		37.0	380	
L.D.F*	Indonesia	36.8[a]	502[a]	Yamakura *et al.* 1986
L.D.F*	Indonesia	29.7	-	Kartawinata *et al.* 1981a
L.D.F*	Indonesia	37.5	-	Kartawinata *et al.* 1981b
M.D.F+	Indonesia	33.7	-	Riswan 1982
This study :				
L.D.F*	PFR	25.52	-	
L.D.F*	TFR	30.99	-	

Note : +, *, ** and *** are mixed dipterocarp forests, lowland dipterocarp forests, hill dipterocarp forests and lowland rain forests, respectively; basal area values without superscript indicate trees with dbhs > 10 *cm*, superscript a is dbh > 4.5 *cm*, b is > 1.6 *cm*

In terms of species density (based on 10-*ha* plot), the dominance at TFR of four particular species, namely *Pometia pinnata*, *Elateriospermum tapos*, *Nephelium lappaceum* and *Mallotus phillipensis*, is very conspicuous indeed when compared to PFR. The ratios between the two reserves (TFR:PFR) for the number of these species are 11:1 (393 to 35), 17:1 (496 to 28), 23:1 (255 to 11) and 84:1 (254 to 3), respectively (Amir 1989).

Interestingly, the basal area of dipterocarps in PFR is three fold higher than at TFR ($P<0.001$), despite the latter being a much more fertile site. The difference in basal area between the two reserves lies in the fact that PFR has 689 stems comprising 36 species while TFR has 139 stems comprising 17 species (excluding those classified at genus level) in the 10-*ha* plot (Figure 1 and Table 1). This accords with the observation of Proctor *et al.* (1983) in East Malaysia who recorded high diversity of dipterocarp species on poor soils. *P. pinnata*, according to Whitmore (1974), is capable of growing into large trees that invade the canopy layer and

respond well to gaps. Similarly *E. tapos* is a long-lived pioneer that also shows clumping characteristics (Ho *et al.* 1987) and is capable of attaining 39 *m* in height (Shaw 1975). *Nephelium lappaceum* is classified as a medium-sized tree with average height of 9 to 15 *cm* and requires shade during early life (Whithead 1959). The genus *Mallotus* has been indicated to have pioneering properties, notable examples being *M. paniculatus* (Whitmore 1973) and *M. griffithianus* (Wyatt-Smith 1966), while Shaw (1975) noted that *M. phillipensis* is capable of reaching 21 *m* in height. However, the true light requirement of this species has not been detailed.

It is believed that these four main species germinate under the canopy and respond well to gaps as and where they occur, in contrast to the dipterocarps that mostly require to germinate in gaps and are much slower growers. Thus, where these four species flourish they will have a head start following the creation of gaps and eventually suppress the dipterocarps. This is well supported by the distribution pattern of the dipterocarp species between the two reserves. There are as many as 23 species of dipterocarps exclusive to PFR compared to only four in TFR, while 13 are commonly found on both reserves (Table 1). The missing species on TFR are mainly *Shoreas* and *Dipterocarpus* renowned for their requirement for openings (Whitmore 1984). The light requirement of the red merantis (shoreas) has also been stressed by Sasaki and Mori (1981), who estimated their requirement to be between 50 to 80% of full sunlight. It is postulated that the rich fertile status of TFR gives a significant advantage to the four species mentioned above, enabling them to dominate the reserve, this being further assisted by their inherent physiological characteristics which, according to Huston and Smith (1987), is the key to the success in plant competition.

Furthermore, the poor fertility status of soils at PFR results in less above-ground biomass in comparison to TFR (Tables 3 and 4) causing less attenuation of light. Light is critical to most if not to all species, and dipterocarps in particular respond significantly to light (Sasaki &Mori 1981). By contrast, on fertile site (TFR) light attenuation increases and this will only favour strong competitors as indicated by the four main highlighted species above resulting in a lesser number of dipterocarp species as a result of competition and suppression.

On the basis of findings, it would seem that the silvicultural management of the natural forest of Malaysia should take into consideration site fertility in relation to dipterocarps regeneration and enrichment planting. It is strongly recommended that on fertile sites more seedlings or seeds of dipterocarps be introduced to enrich the forest in order to compensate for the competitive disadvantage of the dipterocarps on such sites where early growth of aggressive competitors is particularly marked.

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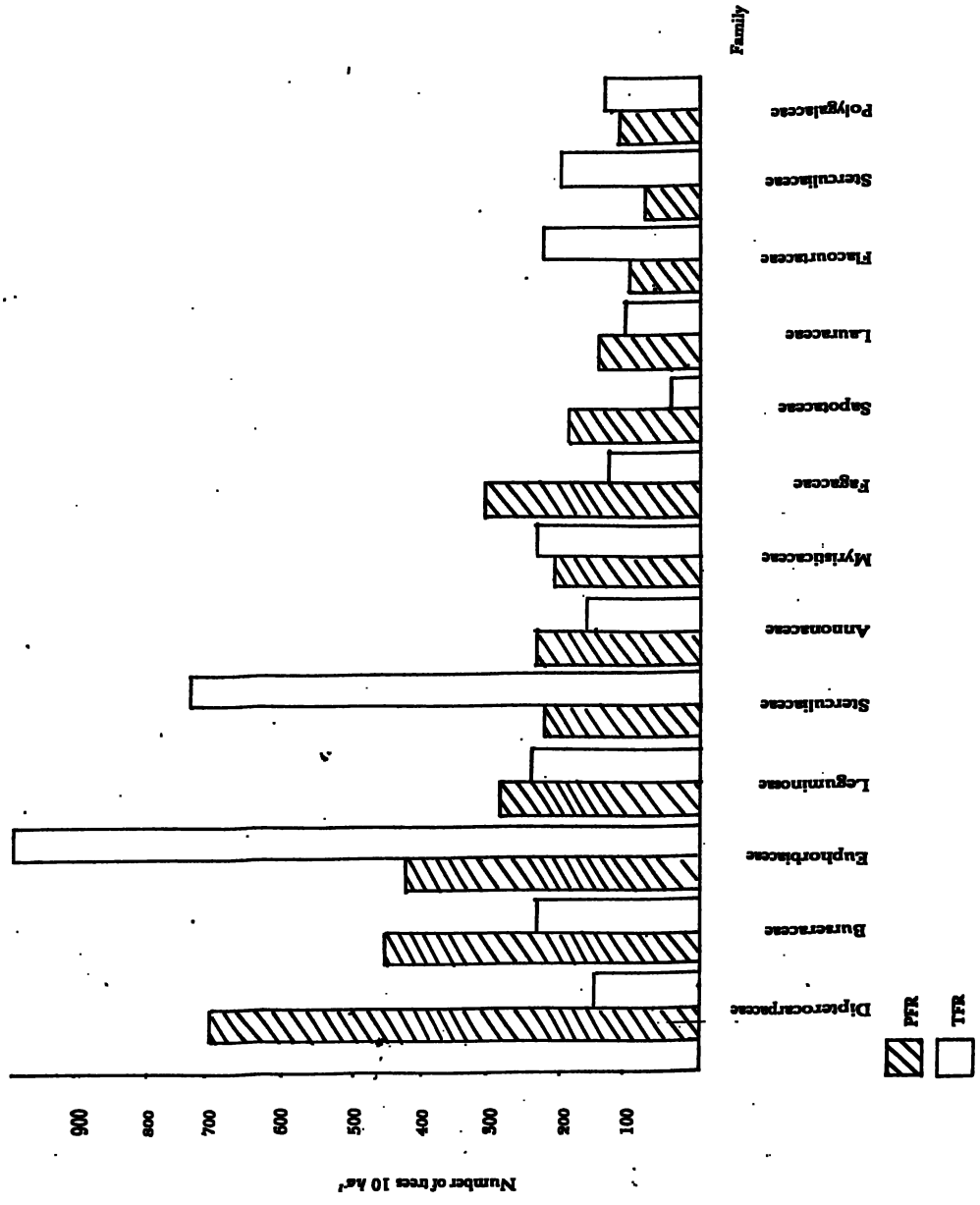

Figure 1. The most dominant families (of trees > 10 *cm* dbh) found oin PFR and TFR based on 10-*ha* enumeration at each site

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