Original article

Tree Species Growth Changes Over 16 Years in the Long-Term Dynamic Plots of Sakaerat Deciduous Dipterocarp Forest, Northeastern Thailand

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Received: August 3, 2009 Accepted: December 5, 2009

ABSTRACT

A census was carried out annually for 16 years (1984-2000) in four permanent long-term dynamic plots in the Sakaerat deciduous dipterocarp forest (SDDF), northeastern Thailand. The diameter at breast height (DBH, defined as 1.3 m above ground from the stem base) was measured for all trees having a DBH greater than or equal to 4.5 cm and growth rates of all existing tree species in each period in these stands were estimated. The studies revealed that all tree species investigated in each stand had different growth in terms of the absolute growth rate of basal area (AGR_{BA}) and the relative growth rate of basal area (RGR_{BA}). Several common tree species (*Albizia odoratissima, Cratoxylum formosum, Canarium subulatum, Lannea coromandelica, Pterocarpus macrocarpus, Shorea roxburghii, Shorea siamensis* and *Xylia xylocarpa* var. *kerrii*) were among the relatively fast growing species in all stands, whilst *Dillenia obovata, Diospyros mollis, Quercus kerrii* and *Shorea obtusa* were slow growing species, and overall, these latter tree species showed a greater reduction in stocking due to high mortality rates. The RGR_{BA} exhibited the same trend as the AGR_{BA}, and based on this rate, common tree species in all four stands were classified into nine different groups having significantly different RGR_{BA} values.

Keywords: absolute and relative growth rate, basal area growth, fast growing species, gain and loss in basal area, slow growing species, Sakaerat

INTRODUCTION

Forest management based on the sustained yield concept requires information on tree and stand growth. As the forest community undergoes change over time, the living tree component of the stands accumulates organic and inorganic substances as the result of physiological phenomena, in response to the governing environment for sustaining life. Growth expansion from this process results in an increase in size, volume and weight. Often, a forest community is composed of several tree species that have different responses to the various environmental conditions, as well as exhibiting different forms of population change during stand development. Forest management for timber yield always involves an evaluation of the tree merchantable volume by foresters, which is, in fact, the product of the stem size increase. The evaluation requires the measurement of both the tree basal area and stem height of each commercial species, whereas ecologists need to estimate stem and stand biomass regardless of the direct and indirect usage. Because of the difficulties in measuring the total stem height of standing trees in the natural tropical forest, usually, the diameter at breast height (DBH, defined as the stem diameter at 1.3 m above ground) is measured and used in all equations applied for the estimation of stem volume or other growth indices. Therefore, diameter increment measurements have been used to examine the dynamics of natural forests, as well as land use change (Lea *et al*., 1979; Day Jr., 1985; Conner and Day Jr., 1992). This is indispensable particularly for trees in tropical forests where tree size is more important than age for describing the dynamics of stands and the forest as a whole (Enright and Ogden, 1979), especially because the age of trees in tropical forests is difficult to measure accurately (Chambers *et al*., 1998). In addition, DBH is measured readily in the field without the risk of introducing non-sampling errors. However, DBH growth can vary substantially between and within tree species and also in relation to age, season and microclimatic conditions. Generally, instead of using DBH growth, the basal area, which can be derived from the measured DBH of trees, provides a more useful attribute in explaining tree growth and tree coverage of ground area. Furthermore, it is suitable for further derivation of tree stem volume, as well as tree weight or biomass, by using equations that may include other parameters, such as tree height and tree stem form factor, etc.

Stand growth and yield of tropical forests have been studied in some wet or moist forest communities (Wadsworth, 1987; Leslie, 1987; Manokaran and Kochummen, 1993; Milton, *et al*., 1994; Herwitz and Young, 1994; Condit *et al*., 1995; Silva *et al*., 1996; Poels *et al*., 1998; Finegan *et al*., 1999). A similar line of study is scarce in tropical dry forests, especially in deciduous dipterocarp forest (DDF) communities, with the few studies being not well documented. An understanding of stand growth and yield is essential for making decisions on sustained yield forest management, such as: 1) selecting tree species for logging, 2) identifying tree species for protection, 3) estimating cutting cycles and 4) prescribing silvicultural treatments necessary for accelerating the growth, yield and regeneration of the species. The main objectives of the current study were to estimate the annual basal area growth for each tree species and to observe the growth patterns, especially in the DDF community. This report forms part of a study into the long-term DDF dynamics using large-scale permanent plots in addition to other studies in the same stands of this forest community type in northeastern Thailand that have been reported in six preceding papers (Sahunalu, 2009a, b and Sahunalu, 2010a, b, c, d).

MATERIALS AND METHODS

Four permanent plots, each 1 ha in size in each of the four stands of the Sakaerat deciduous dipterocarp forest (SDDF) community were used as described in a previous report (Sahunalu, 2010d). The DBH of all trees greater than or equal to 4.5 cm, which had been identified to the species level, was obtained from repeated measurements at approximately yearly intervals. The dataset included all trees that had died, living tree species and the newly recruited individuals reaching the minimum DBH limit of 4.5 cm in every census. The DBH measurements and the calculations of the basal area (BA), absolute growth rate of basal area (AGR_{BA}) and relative growth rate of basal area (RGR_{BA}) were all performed according to the procedure described in the previous report on stand level investigation (Sahunalu, 2010d).

The total BA of each tree species was summed for each period using four separate pooled periods for every four years, totaling 16 years (1984 to 2000). These growth parameters provided the periodic total BA increment of each tree species, separated into two groups of tree species, namely those commonly found in all four stands (defined as common tree species in this paper) and those found scattered in only some of the four stands (defined as uncommon tree species in this paper). The growth rate parameters of each species were confined to both growth indices analyzed (AGR_{BA} and RGR_{BA}). Kruskal-Wallis's multiple comparison and Nemenyi's test statistics (Zar, 1999) were applied for grouping and significance testing of the ranking of the growth rates of the SDDF species.

RESULTS AND DISCUSSION

Growth of component tree species

The growth of the tree species in the four SDDF stands could be classified into two groups (common and uncommon tree species found in each stand) expressed in the form of absolute growth rate (AGR_{BA}) and relative growth rate of BA (RGR_{BA}) and are shown in Tables 1, 2, 3 and 4, respectively.

It was clear that there were large variations in the growth rates of tree species both among species and stands. The common tree species in the four stands exhibited a wide range in mean AGR_{BA}, with values of 99.65, 51.53, 46.04 and 25.36 $cm^2\ ha^{-1}\ y^{-1}$ in stands 1, 2, 3 and 4, respectively, but they were not significantly different (Kruskal-Wallis test, $p< 0.05$). However, among species, there was a tendency for substantial differences due to the large variations, but a statistical test was not performed for AGR_{BA}, due to the large differences in the initial BA of each tree species. The tree species that were not commonly found in all four stands or were scattered in some of the four stands (defined in this study as uncommon and rare species, respectively) also exhibited large variations due to the absence of those species in some stands. Some tree species were recorded only in the last census period, so that it was not possible to calculate their absolute and relative growth rates, nor was it possible to perform statistical tests on the variation of the AGR_{BA} of these tree species because of the same limitation. As the initial BA values were combined in the analysis and the RGR_{BA} estimate was obtained for those common tree species, the four stands with 27 common tree species were significantly different (Kruskal-Wallis test, $p< 0.05$) and could be categorized into two groups, with group 1 consisting of stands 1, 2 and 3 having mean RGR_{BA} values of 0.053, 0.073 and 0.072 y^{-1}, respectively, that were not significantly different using Nemengyi's test at $p < 0.05$ (Zar, 1999). The second group was composed of a single stand (stand 4) with a mean RGR_{BA} of only 0.042 y^{-1}. There was a highly significant difference (Kruskal-Wallis test, $p< 0.0001$) between the mean RGR_{BA} values among the common tree species, which could be classified into nine groups as shown in Table 5.

The two tree species with the highest and lowest mean RGR_{BA} values were *Canarium subulatum* and *Shorea obtusa*, respectively (Table 5). Other tree species

Table 1 Mean AGR_{BA} ($cm^2\ ha^{-1}\ y^{-1}$) values of common tree species[1] (DBH ≥ 4.5 cm) in the four stands. (D) = disappeared species. SD = standard deviation. Disappeared species were treated as having a zero change in basal area in the mean value calculation. Mean value of those species that appeared only in one stand was not evaluated. Time interval used for BA growth calculation of the newly recruited species varied accordingly to the year when those tree species were found.

Species	Stand				Mean ± SD
	1	2	3	4	
Albizia odoratissima (L.f.) Benth.	66.471	104.705	92.941	42.941	76.765± 27.643
Aporosa villosa (Wall.ex Lindl.) Baill.	5.882	1.765	52.353	-2.941	14.265± 25.647
Bauhinia sp.	14.706	18.235	68.824	7.059	27.206± 28.135
Canarium subulatum Guillaumin	69.997	95.882	77.059	28.824	67.941± 28.274
Careya sphaerica Roxb.	5.294	1.765	30.588	0.000	9.412± 14.288
Cratoxylum formosum (Jack) Dyer	18.235	51.765	334.118	33.529	109.412±150.430
Dalbergia cultrata Graham ex Benth.	41.765	27.059	1.176	-31.176	9.706± 32.005
Dalbergia oliveri Gamble	28.235	10.588	18.824	47.059	26.177± 15.678
Dillenia obovata (Blume) Hoogland	-28.824	1.765	2.941	3.529	-5.147± 15.802
Diospyros ehretioides Wall. ex G. Don	2.353	3.529	21.765	1.176	7.206± 9.754
Dipterocarpus intricatus Dyer	147.647	20.000	-5.294	31.765	48.530± 67.863
Gardenia sootepensis Hutch.	0.588	43.529	156.471	40.000	60.147± 67.101
Irvingia malayana Oliv. ex A.W.Benn.	51.765	49.412	50.000	14.118	41.324± 18.165
Lannea coromandelica (Houtt.) Merr.	66.471	142.941	263.529	3.529	119.118±111.885
Mitragyna rotundifolia (Roxb.) Kuntze	65.882	34.118	-40.588	48.824	27.059± 46.929
Morinda coreia Ham.	50.000	18.235	85.882	48.829	50.737± 27.663
Phyllanthus emblica L.	-4.118(D)	2.353	37.059	-2.941	9.118± 18.753
Pterocarpus macrocarpus Kurz	724.118	427.647	786.471	287.647	556.471±237.955
Quercus kerrii Craib	-869.412	21.176	-0.588	-300.000	-287.206±414.880
Shorea obtusa Wall. ex Blume	191.176	-807.647	-1314.118	-24.118	-488.677±697.880
Shorea roxburghii G. Don	1591.765	7.647	124.765	-1142.941	145.309±121.189
Shorea siamensis Miq.	201.176	1013.529	D	1378.824	648.382±655.050
Sindora siamensis Teijsm. & Miq.	41.176	-118.235	193.529	116.471	58.235±133.077
Syzygium cumini (L.) Skeels	7.059	14.706	12.353	4.706	9.706± 4.619
Terminalia chebula Retz. var. *chebula*	-5.294(D)	0.000	5.294	2.941	2.059± 2.564
Vitex peduncularis Wall. ex Schauer	27.059	11.765	13.529	10.588	15.735± 7.645
Xylia xylocarpa var. *kerrii* (Craib & Hutch) I.C.Nielsen	174.412	192.941	174.706	36.471	145.883± 73.349

[1] For the definition of common tree species, see Materials and Methods.

Table 2 Mean AGR_{BA} (cm^2 ha^{-1} y^{-1}) values of uncommon tree species1 (DBH ≥ 4.5 cm) in the four stands. (D) = disappeared species. SD = standard deviation. Disappeared species were treated as having a zero change in basal area in the mean value calculation. Mean value of those species that appeared only in one stand was not evaluated. Time interval used for BA growth calculation of the newly recruited species varied accordingly to the year when those tree species were found.

Species	Stand				Mean ± SD
	1	2	3	4	
Afzelia xylocarpa (Kurz) Craib	-	-	0.000	-	0.000
Antiaris toxicaria Lesch.	-2.353	-	-	17.176	7.412± 13.809
Antidesmaa ghaesembilla Gaerth.	0.588	-	-	-	0.588
Antidesma laurifolium Airy Shaw	-3.529	-	8.824	7.059	4.118± 6.681
Artocarpus lacucha Roxb.	-	-	23.529	-	23.529
Bauhinia malabarica Roxb.	60.000	-	-	-	60.000
Bauhinia saccocalyx Pierre	-	33.529	-	14.706	24.118± 13.310
Berrya cordifolia (Willd.) Burret	-	-	-	10.000	10.000
Bombax anceps Pierre var. *anceps*	-	-	26.154	-	26.154
Bombax insigne Wall.	10.000	20.000	-	10.000	13.333± 5.774
Buchanania lanzan Spreng.	26.667	3.529	2.000	-	10.732± 13.821
Canthium parvifolium Roxb.	-	10.000	-	-	10.000
Carallia brachiata (Lour.) Merr.	-	10.000	-	-	10.000
Catunaregam tomentosa (Blume ex DC.) Tirveng.	-	-	-40.909	-	-40.909
Cratoxylum cochinchinense (Lour.) Blume	-	-	10.000	-	10.000
Croton roxburghii N.P. Balakr.	-	42.500	20.769	-	31.635± 15.366
Dalbergia assamica Benth.	-	-	0.000	D	0.000
Dalbergia cochinchinensis Pierre	-	0.000	-	-	0.000
Dalbergia nigrescens Kurz	38.333	10.000	24.118	-	24.150± 14.167
Diospyros castanea Fletcher	-	0.000	-	-	0.000
Diospyros mollis Griff.	-10.588	-	-	2.941	-3.824± 9.566
Diospyros oblonga Wall.ex G.Don	-	-	10.000	-	10.000
Dipterocarpus intricatus Dyer	168.824	-	-5.294	31.765	65.098± 91.720
Erythrophleum succirubrum Gagnep.	-	-15.294	57.059	-	20.883± 51.161
Fernandoa adenophylla (Wall.ex G.Don) Steenis	-	-	0.000	-	0.000
Flacourtia sp.	0.588	-	70.000	-	35.294± 49.082
Garcinia cowa Roxb. ex DC.	-	20.000	-	-	20.000
Gomphia serrata (Gaertn.) Kanis	-	20.000	20.000	-	20.000
Grewia sp.	30.000	20.000	12.000	-	20.667± 9.018
Haldina cordifolia (Roxb.) Ridsdale	-	-	0.000	-	0.000
Hibiscus macrophyllus Roxb. ex Hornem.	-	-	1.111	-	1.111
Hymenodyctyon orixense (Roxb.) Mabb.	-	-	0.000	-	0.000
Ixora ebarbaata Craib	-	-	5.385	-	5.385
Kydia calycina Roxb.	7.647	5.294	-	-	6.471± 1.664
Lithocarpus polystachyus (Wall ex A.DC.) Rehder	20.000	43.529	-	-2.353	20.392± 22.944
Mallothus philippensis Mull.Arg.	-	10.000	-	-	10.000
Mangifera caloneura Kurz	1.176	212.941	10.000	-	74.706±119.797
Memecylon scutellatum Naudin	-	-	20.000	-	20.000
Morinda elliptica Ridl.	50.000	18.235	0.000	-	22.745± 25.303
Narigi crenulata (Roxb.) Nicolson	-	-	0.000	-	0.000
Nauclea officinalis (Pierre ex Pit.) Merr. & Chum	0.000	0.000	-	0.000	0.000
Nauclea orientalis (L.) L.	-	-	-	2.353	2.353
Parinari anamense Hance	-	13.529	65.882	22.353	33.921±28.028
Pavetta tomentosa Roxb.ex Sm.var. *canescens*	-	0.000	41.667	-	20.834±29.463

Table 2 (Cont.)

Species	Stand 1	Stand 2	Stand 3	Stand 4	Mean ± SD
Premna pyramidata Wall. ex Schauer	-	-	-	4.118	4.118
Rothmannia wittii (Craib) Bremek.	6.667	45.294	-	-	25.981±27.313
Semecarpus reticulata Lecomte	-	-	21.176	-	21.176
Siphonodon celastraneus Griff.	-	10.000	32.353	-	21.806±15.806
Spondias pinnata (L.f.) Kurz	-	-	-	2.222	2.222
Stereospermum neuranthum Kurz	-	-	-	18.235	18.235
Terminalia triptera Stapf	-	0.000	-	-	0.000
Ternstroemia gymnanthera (Wright & Arn.) Bedd.	-	-	3.846	-	3.846
Unidentified (Liana)	-6.471(D)	-	0.000	-	0.000
Unidentified 1	-	-	0.000	-	0.000
Unidentified 2	-	-	0.000	-	0.000
Unidentified 3	-	-	0.000	-	0.000
Vaccinium sprengelii (G.Don) Sleumer	-	-0.769(D)	-	-	0.000
Vitex canescens Kurz	-	7.647	-	-	3.824±5.407
Vitex pinnata L.	-	2.000	1.000	0.000	4.000±5.292
Wendlandia tinctoria (Roxb.) DC.	-	136.000	-	-	136.000
Xantolis cambodiana (Craib & Hutch.) I.C.Nielsen	-	0.000	6.923	-	3.462±4.895

[1] For the definition of uncommon tree species, see Materials and Methods.

Table 3 Mean RGRBA (y^{-1}) values of common tree species[1] (DBH ≥ 4.5 cm) in the four stands. Dash (-) = non-dominant tree species in those stands. (D) = disappeared tree species. SD = standard deviation. Disappeared species were treated as having a zero BA change in mean value calculation. Mean value for those species appearing only in one stand was not evaluated. Time intervals used for relative growth rate in BA of the newly recruited species varied accordingly to the time when those species were found.

Species	Stand				Mean ± SD
	1	2	3	4	
Albizia ordoratissima (L.f.) Benth.	0.130	0.047	0.060	0.026	0.066±0.045
Aporosa villosa (Wall. ex Lindl.) Baill.	0.011	0.054	0.175	-0.005	0.058±0.080
Bauhinia sp.	0.066	0.410	0.046	0.693	0.304±0.309
Canarium subulatum Roxb.	0.847	0.119	0.194	0.062	0.306±0.365
Careya sphaerica Roxb.	0.007	0.021	0.029	0.000	0.014±0.013
Cratoxylum formosum (Jack) Dyer	0.143	0.488	0.308	0.027	0.242±0.201
Dalbergia 1cultrata Graham ex Benth.	0.009	0.022	0.000	-0.009	0.006±0.013
Dalbergia oliveri Gamble	0.036	0.182	0.018	0.033	0.067±0.077
Dillenia obovata (Blume) Hoogland	-0.018	0.007	0.017	0.065	0.018±0.035
Diospyros ehretioides Wall. ex G.Don	0.002	0.011	0.062	0.017	0.023±0.027
Dipterocarpus intricatus Dyer	0.004	0.003	-0.0003	0.003	0.002±0.002
Gardenia sootepensis Hutch.	0.013	0.053	0.133	0.023	0.056±0.054
Irvingia malayana Oliv. ex A.W. Benn.	0.073	0,069	0.081	0.009	0.058±0.033
Lannea coromandelica (Houtt.) Merr.	0.064	0.164	0.182	0.122	0.133±0.052
Mitragyna rotundifolia (Roxb.) Kuntze	0.022	0.030	-0.015	0,015	0.013±0.020
Morinda coreia Ham.	0.040	0.008	0.026	0.017	0.023±0.014
Phyllanthus emblica L.	D	0.000	0.094	-0.074	0.005±0.069
Pterocarpus macrocarpus Kurz	0.047	0.034	0.042	0.039	0.041±0.005
Quercus kerrii Craib	-0.051	0.027	-0.001	-0.024	-0.012±0.033
Shorea obtusa Wall. ex Blume	0.013	-0.008	-0.016	-0.039	-0.013±0.021
Shorea roxburghii G. Don	0.006	0.003	0.034	-0.022	0.005±0.023
Shorea siamensis Miq.	0.037	0.029	D	0.018	0.021±0.016
Sindora siamensis Teijsm. & Miq.	0.009	-0.031	0.030	0.019	0.007±0.027
Syzygium cumini (L.) Skeels	0.023	0.066	0.008	0.024	0.030±0.025
Terminalia chebula Retz. var. *chebula*	D	0.000	0.100	0.058	0.040±0.049
Vitex peduncularis Wall. ex Schauer	0.014	0.065	0.057	0.011	0.037±0.028
Xylia xylocarpa var. *kerrii* (Craib & Hutch.) I.C. Nielsen	0.030	0.037	0.048	0.012	0.032±0.015

[1] For the definition of common tree species, see Materials and Methods.

Table 4 Mean RGRBA (y^{-1}) values of uncommon tree species[1] in the four stands. Dash (-) = non-dominant tree species in those stands. (D) = disappeared tree species. SD = standard deviation. Disappeared species were treated as having a zero BA change in mean value calculation. Mean value for those species appearing only in one stand was not evaluated. Time intervals used for relative growth rate in BA of the newly recruited species varied accordingly to the time when those species were found.

Species	Stand 1	Stand 2	Stand 3	Stand 4	Mean ± SD
Afzelia xylocarpa (Kurz) Craib	-	-	0.000	-	0.000
Antiaris toxicaria Lesch.	-0.020	-	-	0.030	0.005±0.035
Antidesma ghaesembilla Gaerth.	0.006	-	-	-	0.006
Antidesma laurifolium Airy Shaw	-0.054	-	-	0.038	0.030±0.080
Artocarpus lacucha Roxb.	-	-	0.105	-	0.105
Bauhinia malabarica Roxb.	0.000	-	0.179	-	0.179
Bauhinia saccocalyx Pierre	-	0.035	-	0.024	0.030±0.008
Berrya cordifolia (Willd.) Burret	-	-	-	0.405	0.405
Bombax anceps Pierre var. *anceps*	-	-	0.158	-	0.158
Bombax insigne Wall.	0.036	0.358	-	0.134	0.176±0.165
Buchanania lanzan Spreng.	0.043	0.082	-	-	0.061±0.020
Canthium parvifolium Roxb.	-	0.154	-	-	0.154
Carallia brachiata (Lour.) Merr.	-	0.134	-	-	0.134
Catunaregam tomentosa (Blue ex DC.) Tirveng.	-	-	-0.252	-	-0.252
Cratoxylum chochinchinense (Lour.) Blume	-	-	0.135	-	0.135
Croton roxburghii N.P. Balakr.	-	0.563	0.288	-	0.385±0.252
Dalbergia assamica Benth.	-	-	0.206	D	0.206
Dalbergia cochinchinensis Pierre	-	0.000	0.000	-	0.000
Dalbergia nigrescens Kurz	0.421	0.223	-	-	0.221±0.201
Diospyros castanea Fletcher	-	0.000	0.019	-	0.019
Diospyros mollis Griff.	-0.236(D)	-	-	0.017	0.009±0.012
Diospyros oblonga Wall. ex G.Don	-	-	0.021	-	0.021
Dipterocarpus intricatus Dyer	0.004	-	-0.037	0.003	-0.017±0.028
Erythrophleum succirubrum Gagnep.	-	-0.098	-0.042	-	-0.028±0.099
Fernandoa adenophylla (Wall.ex G.Don) Steenis	-	-	0.000	-	0.000
Flacourtia sp.	0.405	-	0.345	-	0.375±0.042
Garcinia cowa Roxb. ex DC.	-	0.000	-	-	0.000
Gomphia serrata (Gaertn.) Kanis	-	0.000	0.405	-	0.203±0.286
Grewia sp.	0.384	0.251	0.277	-	0.304±0.070
Haldina cordifolia (Roxb.) Ridsdale	-	-	0.000	-	0.000
Hibiscus macrophyllus Roxb. ex Hornem.	-	-	0.045	-	0.045
Hymenodictyon orixense (Roxb.) Mabb.	-	-	0.000	-	0.000
Ixora ebarbata Craib	-	-	0.116	-	0.116
Kydia calycina Roxb.	0.053	0.069	-	-	0.061±0.011
Lithocarpus polystachyus Wall. ex A.DC.) Rehder	0.000	0.064	-	-0.002	0.021±0.038
Mallotus philippensis Mull. Arg.	-	0.288	-	-	0.288
Mangifera caloneura Kurz	0.003	0.012	0.055	-	0.022±0.029
Memecylon scutellatum Naudin	-	-	0.693	-	0.693
Morinda elliptica Ridl.	0.693	1.386	0.000	-	0.693±0.693
Narnigi crenulata (Roxb.) Nicolson	-	-	0.000	-	0.000
Nauclea officinalis (Pierre ex Pit.)	0.000	0.000	-	0.000	0.000

Table 4 (Cont.)

Species	Stand 1	2	3	4	Mean ± SD
Merr. & Chun					
Nauclea orientalis (L.) L	-	-	-	0.030	0.030
Parinari anamense Hance	-	0.027	0.045	0.018	0.030±0.014
Pavetta tomentosa Roxb. ex Sm. var. *canescens* Craib	-	0.000	0.434	-	0.217±0.307
Premna pyramidata Wall. ex Schauer	-	-	-	0.025	0.025
Rothmannia wittii (Craib) Bremek.	0.183	0.114	-	-	0.149±0.049
Semecarpus reticulata Lecomte	-	-	0.042	-	0.042
Siphonodon celastraneus Griff.	-	0.182	0.040	-	0.111±0.100
Spondia pinnata (L.f.) Kurz	-	-	-	0.077	0.077
Stereospermum neuranthum Kurz	-	-	-	0.034	0.034
Terminalia triptera Stapf	-	0.000	-	-	0.000
Terstroemia gymnanthera (Wright & Arn.) Bedd.	-	-	0.096	-	0.096
Unidentified (Liana)	-0.265(D)	-	0.000	-	0.000
Unidentified 1	-	-	0.000	-	0.000
Unidentified 2	-	-	0.000	-	0.000
Unidentified 3	-	-	0.000	-	0.000
Vaccinium sprengelii (G.Don) Sleumer	-	-0.236(D)	-	-	0.000
Vitex canescens Kurz	-	0.085	0.000	-	0.043±0.060
Vitex pinnata L.	-	0.081	0.131	0.000	0.071±0.066
Wendlandia tinctoria (Roxb.) DC.	-	0.711	-	-	0.711
Xantolis cambodiana (Pierre ex Dubarb) P. Royen	-	0.000	0.107	-	0.054±0.076

[1] For the definition of uncommon tree species, see Materials and Methods.

Table 5 Mean RGRBA (y^{-1}) values of 27 common tree species1 in the four stands studied. Order is according to the mean rank from the Kruskal-Wallis multiple comparison test (Zar, 1999). Mean values with the same superscripts are not significantly different (Nemengyi's test, p<0.05). SD = standard deviation.

Rank No.	Species	Mean RGR_{BA} ± SD	Group
1	*Canarium subulatum* Guillaumin	0.306±0.365	a
2	*Bauhinia* sp.	0.304±0.309	ab
3	*Lannea coromandelica* (Houtt.) Merr.	0.133±0.052	abc
4	*Cratoxylum formosum* (Jack) Dyer	0.242±0.201	abcd
5	*Albizia odoratissima* (L.f.) Benth.	0.066±0.045	abcde
6	*Irvingia malayana* Oliv. ex A.W. Benn.	0.058±0.033	abcdef
7	*Shorea siamensis* Miq.	0.021±0.016	abcdef
8	*Dalbergia oliveri* Gamble	0.067±0.077	abcdef
9	*Pterocarpus macrocarpus* Kurz	0.041±0.005	abcdef
10	*Gardenia sootepensis* Hutch.	0.056±0.054	abcdef
11	*Xylia xylocarpa* var. *kerrii* (Craib & Hutch) I.C.Nielsen	0.032±0.015	abcdef
12	*Vitex peduncularis* Wall. ex Schauer	0.037±0.028	abcdef
13	*Aporosa villosa* (Wall. ex Lindl.) Baill.	0.058±0.080	abcdef
14	*Syzygium cumini* (L.) Skeels	0.030±0.025	abcdef
15	*Morinda coreia* Ham.	0.023±0.014	abcdef
16	*Terminalia chebula* Retz. var. *chebula*	0.040±0.049	abcdef
17	*Phyllanthus emblica* L.	0.005±0.069	abcdef
18	*Diospyros ehretioides* Wall. ex G. Don	0.023±0.027	abcdef
19	*Dillenia obovata* (Blume) Hoogland	0.018±0.035	abcdef
20	*Mitragyna rotundifolia* (Roxb.) Kuntze	0.013±0.020	abcdef
21	*Careya sphaerica* Roxb.	0.014±0.013	abcdef
22	*Sindora siamensis* Teijsm. & Miq.	0.007±0.027	bcdef
23	*Dalbergia cultrata* Graham ex Benth.	0.006±0.013	ef
24	*Shorea roxburghii* G.Don	0.005±0.023	ef
25	*Quercus kerrii* Craib	-0.012±0.033	ef
26	*Dipterocarpus intricatus* Dyer	0.002±0.002	ef
27	*Shorea obtusa* Wall.ex Blume	-0.013±0.021	f

[1] For the definition of common tree species, see the Materials and Methods section.

that could be grouped as having remarkably high mean relative growth rates in BA were *Bauhinia* sp. and *Lanea coromandelica*, with *Cratoxylum formosum* being intermediate in this group. The tree species having relatively low mean RGR_{BA} values were *Dalbergia cultrata, Shorea roxburghii, Quercus kerrii* and *Diptrocarpus intricatus*. The other 17 tree species could be grouped as having moderate mean RGR_{BA} values, as they were not significantly different from trees belonging to the fast and slow growing groups (Table 5). The difference in RGR_{BA} is attributable to the specific genetic characteristics of the species and the ability of trees to survive in the relatively harsh environment of the northeastern region of Thailand, which has a long dry season spell and prevailing poor soil conditions, in common with other tree species in tropical rain forests (Swain *et al*., 1987b).

The RGR_{BA} values for each common and uncommon tree species in all four stands (Tables 1 and 2) demonstrate clearly that these dominant tree species in SDDF, especially the legumes, such as *Albizia odoratissima, Pterocarpus macrocarpus, Xylia xylocarpa* var. kerrii and *Sindora siamensis* (Sahunalu, 2009a), all exhibit a notably high RGR_{BA} value, in the range 0.03-0.05 y^{-1}. On the contrary, several tree species that are the major trees found commonly in a DDF community, such as *Shorea obtusa, Shorea siamensis, Shorea roxburghii, Quercus kerrii* and *Dipterocarpus intricatus,* all have relatively low RGR_{BA} values, in the low range -0.0003 to 0.003 y^{-1}, although these tree species are all large, light-demanding species, and co-occur as the major canopy-layer trees in this SDDF type (Sahunalu, 2009a). Tropical forest tree species growing in relatively moist regions are reported to be light-demanding species and usually have greater relative growth rate values than other tree species (Lang and Knight, 1983; Swain *et al*., 1987a; Felfili, 1995). Nevertheless, these canopy trees occasionally may grow very slowly and have high mortality (Swain *et al*., 1987b). Many studies have emphasized the importance of crown illumination in the determination of growth increment in tropical moist forests (Clark and Clark, 1992; Silva *et al*., 1996) and Finegan *et al*. (1999) interpreted this as light availability (illumination and presence of lianas on tree crown) and the capacity of trees to utilize that light (crown form). It has been suggested by Wyatt-Smith (1995) that heavy hardwood group species have less ability to respond to increased light levels with increased diameter growth than the red meranti species group (*Shorea* spp.) in lowland dipterocarp forest. However, in an open canopy forest community, such as in SDDF in the present study, light availability is not a limiting factor in controlling the growth of tree species, as there is little overlap in most of the tree crown (Sahunalu, 2009a). Associations with some microorganisms, such as mycorrhiza and other symbiotic bacteria living inside and around the roots of most leguminous tree species, are probably the growth promoters for these tree species in a relatively dry climate with poor soil conditions.

Working on the prediction of growth in *Shorea javanica* forest in Java, Vincent *et al*. (2002) reported that crown form was the most effective predictor of growth, but initial girth and crown position only increased marginally the percentage of variance accounted for in the growth prediction. On dry sites, Rautiainen (1999) reported on the growth and yield prediction of sal (*Shorea robusta*) forest plantation in Nepal and noted that the competition index was a variable predictor of diameter increment of the stand. Importantly, the current analysis demonstrated clearly the density effects among trees of the same species, generally known as intra-specific competition. However, tree composition in a natural forest, as opposed to an artificial, monospecific, cultivated stand, entails numerous species, with competition among individuals of different species known as inter-specific competition, which is always more severe than among the same species for a given habitat.

CONCLUSION AND RECOMMENDATION

The tree species in each stand in the Sakaerat deciduous dipterocarp forest (SDDF) community had different expressions of growth in terms of absolute and relative growth rates in basal area (AGR_{BA} and RGR_{BA}, respectively). The AGR_{BA} of the component tree species differed among species and among stands. Several commonly found tree species growing in the four stands, such as *A. odoratissima, C. formosum, C. subulatum, L. coromandelica, P. macrocarpus, S. roxburghii, Sindora siamensis* and *X. xylocarpa* var. *kerrii,* were among the relatively fast growing tree species in all stands. In contrast, *Dillenia obovata, Diospyros mollis, Q. kerrii* and *S. obtusa* were found to be the slow growing tree species and overall these latter tree species showed a greater reduction in stocking due to high mortality rates. The RGR_{BA} showed the same trend as for the AGR_{BA} and therefore, based on the RGR_{BA}, the tree species found growing commonly in all four stands were classified into nine different groups having significantly different RGR_{BA} values. *C. subulatum* and *S. obtusa* were the tree species having the greatest and lowest RGR_{BA} values, respectively, together with a few tree species that tended to belong to both extreme groups. The remaining majority of trees species were classified as another group having intermediate RGR_{BA} values.

Based on the results of the analysis of change in tree species growth over the period of 16 y in SDDF, it would be possible to recommend management of this forest type on a sustainable yield basis, depending on which alternative was desired. For traditional forest management purposes, the growth of the major tree species in this forest type implied the possibility of yield regulation within the growth rate limitations of the species. However, the formulation of yield tables using volume tables that are necessary as a guide to the commercial harvesting operations would need additional details and analyses that were not included in this study, but would be available from basic information. Nevertheless, the major tree species in this DDF type, such as *S. obtusa, S. siamensis* and *D. intricatus* that used to be of commercial value did not have substantial value for timber or fuelwood production, as they are quite slow growing. An exception in this regard considering other possible commercial tree species were those belonging to the leguminous tree group, also of high value, such as *P. macrocarpus, Sindora siamensis* and *X. xylocarpa*. These species have potential for commercial timber or fuelwood production, whichever is more preferable in this forest type. However, the maintenance of the structural and species composition of this forest type should be taken into consideration whenever operations involving commercial harvesting are planned.

For conservation purposes, all fast growing tree species in this forest community can provide genetic material for future propagation in plantation forestry, for example as mother trees for seed collecting and as a genome for tree tissue culture. In fact, in situ gene conservation of all these tree species is likely to be most promising at this site, as this forest tract is considered to be one of the well protected areas, composed of a majority of dominant tree species of DDF and being the last piece of DDF in the northeastern region. On the other hand, rehabilitation of degraded the DDF type should be initiated using these fast growing tree species early in forest ecosystem restoration. Slow growing species are found mostly in the degeneration stage, due to their high mortality rates. Management options for these slow growing species could involve commercial selection harvesting and at the same time the promotion of regeneration of these species by a coppicing technique. Both coppicing of slow growing tree species and artificial regeneration by planting fast growing species could be undertaken separately or combined to achieve the goals of management strategies for both timber yield regulation and plant genetic conservation purposes.

ACKNOWLEDGEMENTS

The author expresses his thanks to the National Research Council of Thailand for financial support of this study. This paper was prepared during the author's tenure as a visiting professor at the Center for Southeast Asian Studies (CSEAS), Kyoto University, Japan (KUJ) in 2004-2005. He would like to render his special thanks to Professor I. Yamada of CSEAS and to his colleagues at KUJ, as well as to several other offices and people who assisted this study.

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