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Abstract

The productivity (biomass) in a successional series of former Swidden (rai) derived from the destruction of Dry Evergreen Forest in northeastern Thailand were investigated in the fall of 1976 at the Forest Experiment Station at Sakaerat Swidden of 1, 3, 6, 9 and 20 + years following the last crop were sampled. For comparison, a second-growth forest of indeterminate age was sampled in the same area. All former Swidden through 20 + years supported stands of _Saccharum sponteneum_ with varying amounts of either or both _Imperata cylindrica_ and/or _Eupatorium odoratum_ as Co-dominants. The biomass of these three species was roughly comparable during 9 yrs of succession, varying from 7.7 MT/HA. to 16.1 MT/HA. with a mean of 12.3 MT/HA (dry weight). By 20 + yrs., the biomass of these 3 species amounted to 7.8 MT/HA. but woody species had become dominant with a biomass of 39.2 MT/HA (dry weight). In contrast, the biomass of the second-growth forest was 269.6 MT/HA (dry weight).

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W.B. Drew,[1] S. Aksornkoae,[2] and W. Kaitpraneet[3]

Introduction

This paper is a report of cooperative ecological research project supported by the National Research Council of Thailand and the National Science Foundation of the United States.[4] The Department of Silviculture, Faculty of Forestry, Kasetsart University, and the Department of Botany & Plant Pathology, Michigan State University, also contributed in various ways to the project, especially in making available research facilities and personnel in Thailand and assistance with financial and secretarial matters at East Lansing.

The designated objectives of the investigation were to determine the productivity (biomass) of successional stages of forest regeneration following cessation of cultivation of swidden (rai) fields through "weedy" stages to early secondary forest, and to find out the sequence of nutrient cycling in the vegetation of such a successional array of fields. (The investigation

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4. NSF Grant No. INT76-17711. - Nation Research Council, Thailand.

of the minerals in the successional series of swidden will be reported in a separate paper.)

The field work was carried out during a 6-week period from 1 October to 14 November 1976, at the Forest Experiment Station, located on the Korat Plateau, Amphoe Pak Thong Chai, Changwat Nakon Ratchasima. Oven-drying, weighing and processing samples of vegetation for chemical analysis were done at the Soils and Plant Analytic Laboratory of the Faculty of Forestry, Kasetsart University. For determination of minerals in the samples of vegetation, the services of the Soils & Plant Testing Laboratory, University of Wisconsin (Madison) were contracted. We acknowledge with many thanks the helpfulness of many persons[5] who assisted us in the several laboratories and in the field at the Forest Experiment Station.

5. Special thanks are due to Mr. Preecha Khoorat, the Superintendent of the Forest Experiment Station at Sakaerat, and to Miss Maitreechit Honkanark, Soils & Plant Testing Laboratory, Kasetsart University, for their assistance in expediting field work and laboratory analyses respectively.

Resume of Important Investigations of the Regeneration and/or Productivity of Tropical Forests.

The regeneration of tropical forest ecosystems of the world has been summarized recently in Section 4 of Fragile Ecosystems, edited by Farnsworth and Golley (1973). Their focus has been directed especially toward the American tropics, but there is much material of relevance to tropical Asia. Indeed, they cite a report by Kira and Shidei (1967) which dealt with primary production and turnover of organic matter in forests of eastern Thailand, types which are ecologically quite different from the Dry Evergreen Forest of the Korat Plateau.

Williams (1965) has given a description of forest types in a regional survey of woody vegetation of Southeast Asia. A more detailed investigation of the floristic composition of the Dry Evergreen Forest in Thailand has been reported by Smitinand et al. (1968) who carried out their studies on a one-hectare plot at the Forest Experiment Station at Sakaerat. Another study of the floristic composition and structure of the Dry Evergreen Forest at Sakaerat has been done by Sabhasri et al. (1968) who investigated the variations in species along a transect from the adjoining Dry Diptercarp Forest type.

An intensive study of secondary succession from a denuded forest plot (20 x 20 m) cleared of vegetation one year previously to a field in a late stage of succession (26 years) was conducted by Sabhasri et al. at Sakaerat (1973). Abundance and frequency of species were estimated for the plots established one year after clearing, 5 years later on the same plot, in a field 12 years after the last crop and in a field 26 years after cultivation ceased. They found that several species, including both primary and secondary forest species, as well as grasses and herbs had become established the first year after clearing of the forest. By 5 years, the ubiquitous forb, Eupatorium odoratum, and the Elephant Grass (Saccharum spontaneum) had established dominance with scattered seedlings of forest species and ferns forming a ground layer. At 12 years after clearing, S. spontaneum had established complete dominance with saplings and seedlings of forest species, some of which were beginning to emerge from the grass canopy. Even 26 years after clearing, S. spontaneum was still dominant, but some tree species had attained considerable height and had developed canopies. The authors noted that had such an area been cultivated, fire would have been a factor at frequent intervals and might, in fact, have caused S. spontaneum to disappear more rapidly from the plant community. Parenthetically, it should also be noted that a farmer would tend to cut woody saplings and large seedlings as the swidden field was used for crops over a period of years, so that sprout shoots would have become an important element in forest regeneration as observed by Drew (1971) in the same region.

Biomass of Tropical Forests in Thailand and elsewhere in Southeast Asia

In a series of investigations between 1964 and 1971, Japanese and Thai ecologists studied various aspects of productivity of several forest types in Thailand, Cambodia and Malaysia. Kira et al. (1964) published the results of determining the biomass of a 40 x 40 m plot in a tropical rain-forest in southern Thailand. They found the total biomass for the trees to be 362 t/ha with another 3.6 t/ha added by the undergrowth. The same year, Ogino and Sabhasri (1964), using allometric means, estimated the standing crop biomass of a different forest type in northern Thailand.

Ogawa et al. (1965) reported upon the actual and estimated biomass of savanna, monsoon and Tropical Rainforest in Thailand. Standing crops varied from 291 t/ha (dry wt.) in gallery forest to 50-59 t/ha in savanna forests. For the tropical rainforest, values ranged from 318 t/ha to 396 t/ha in different stands.

Of more direct relationship to this project is the study of Sabhasri and Wood (1967) on forest biomass of different types, including Dry Evergreen Forest at Sakaerat. They determined from individual felled trees of the principal species and allometric tables using DBH, D^2BH and height, the total green weights of 40 different species of the Dry Evergreen Forest. They also attempted to establish a visual basis for determining the relative biomass of lianas which are difficult to separate where they have intertwined among the branches of trees. On 16 100 m^2 plots within a 40 x 40 m area, they cut and weighed the lianas. However, no actual means of estimating relative biomass of the lianas was achieved.

Kira and Ogawa (1969) have also investigated the problem of determining the biomass of lianas. In studies of tropical rainforest at Khao Chong, Thailand, they found that there is a degree of D^2BH-plant weight relationship for lianas but difficulty in harvesting these woody climbers makes the correlation less clear-cut as compared to trees. Thus, they suggested adding the weight of leaves and stems of lianas to that of the trees and to treat the totals as those of the trees alone. The results were quite good for leaves, but not for estimating the weight of the stems of lianas-tree branches correlation.

Sabhasri et al. (1968) have also studied primary productivity in the Dry Evergreen Forest at Sakaerat. Their data indicate that the total annual dry weight production (standing crop) in trees, undergrowth and climbers of the DEF was 9.6 t/ha. Finally, Sabhasri (1970) has studied the biomass of successional stages of the Lua forest fallow agriculture compared to old-growth forest of several types of northern Thailand. The weight of the standing crop of overstory species in old-growth forest was 650.7 t/ha green weight and 386.9 t/ha dry weight, whereas the undergrowth (and climbers) was 10.95 t/ha green weight and 4.2 t/ha dry weight. Root biomass was not calculated. He also found that over a 9-year period, the number of species present in the plots varied from 56 two years after cutting to 60 species nine years after cutting. None of the plots were located in the Dry Evergreen Forest type.

METHODS

A series of formerly cultivated fields (swidden) were located with different ages since the last crop was grown at the Forest Experiment Station at Sakaerat, Amphoe Pak Thong Chai, Changwat Nakon Ratchasima, Thailand. This area has been subject to shifting cultivation and fire for an indeterminate period of many years. Fields selected had vegetation of the following years since the last cultivation: 1, 3, 6, 9, 20+ and, in addition second-growth forest. The fields of 1-9 years had previously been selected for a study of the nitrogen content and minerals in the soil profiles, as reported by Preecha of the Applied Scientific Research Corporation of Thailand (ASRCT).

Although large plots of 100 to 500 m^2 had been originally planned, 25 m^2 plots were selected for the 1-9 year stages of the grass-Eupatorium fields, whereas 100 m^2 plots were utilized for the 20+ year area and the second growth forest. Constraints of time and budget led to employing a single plot per field. Through previous studies of Drew (1971) at Sakaerat, we had confidence that the size of the plots was appropriate, but we recognized that a minimum of 5 plots per age-group would have produced results more statistically sound. Circumstances beyond the control of the researchers limited our study.

In each 25 m^2 plot, all vegetation was harvested at ground level, separated in the field by species and the total mass weighed. The different species, or groups of species, were then sub-sampled, weighed for green weight, air-dried and packaged for determining oven-dry weight. By means of random numbers, 5 sub-plots in each 25 m^2 plot were selected to excavate to a depth of one meter in order to harvest all roots, rhizomes and other below-ground plant parts. Gross weights were obtained in the field after the dry soil had been removed as much as possible by shaking by hand. Later, sub-samples were carefully washed with water under pressure to remove as many of the remaining soil particles as possible, re-weighed, air-dried, and packaged for determining oven-dry weights. Finally, all seedlings were identified and counted for the entire 25 m^2 plot.

In the second-growth forest and the 20+ year old field, the height and DBH of all larger trees were measured; samples of bark, wood, branches and leaves were collected from each species; lianas were cut for samples of stems and leaves; and saplings, shrubs, grasses and herbs were completely harvested. Green weights for all categories and/or species were obtained in the field. Litter was sampled at randomly selected 5 one-square-meter plots and the roots, rhizomes, etc. were harvested from 4 one square-meter plots, randomly selected to a depth of 1 m. Sub-samples of all vegetation were then obtained for the determination later of oven-dry weights. Total weights of stems, branches and leaves of the larger trees (uncut) above sapling size were calculated from height and D^2BH data by allometric means developed for this forest-type at Sakaerat by Sabhasri and Wood (1967).

After air-drying and packaging in paper or plastic sacks, the samples of plant materials were delivered to the Soils & Plant Materials Laboratory, Department of Silviculture, Faculty of Forestry, Kasetsart University in Bangkok, for obtaining oven-dry weights, and preparing pulverized vegetation samples for chemical analysis for nitrogen and mineral nutrients at the University of Wisconsin (Soils & Plant Testing Laboratory, University of Wisconsin, Madison).

RESULTS AND DISCUSSION

A list of species identified in the sample plots is given in the Appendix, p. 27.

In the following Tables, the data for standing crop and below-ground biomass are listed by species for each of the 3 "weedy" dominants for the fields of from 1 to 20+ years after the last crop, but vines, lianas and other woody plants are grouped into separate categories for convenience. Non-living materials above-ground were also recorded by species, since, except for litter in the last two stages of succession investigated, the two grasses and Eupatorium provided essentially all of the dead vegetation. These non-living plant materials were counted as a part of the standing crop. Weights are recorded as metric tons per hectare.

The cropping history of each field sampled was not obtainable; but the data on standing crop suggest wide variations due to many possible factors influencing the character of vegetation found even one year after the last crop. The type of crop, such as corn, cassava, upland rice, castor beans, chilis, tobacco and sweet potatoes, the kind of subsequent crops, the care exercized to eliminate (cutting) sprouts and/or seedlings of woody species and the effects of fire are involved in the array of factors impinging upon the natural vegetation in any given area at a specific time after the last crop was harvested. In fact, such variations in standing crop biomass of a successional series of fields up to 27 years after the last crop in Mindanao, Philippines, were found by Kellman, as reported by Farnsworth and Golley, p. 119 (1973), to vary as much as 5 times in plots of the same age. Similarly, the numbers of species varied widely from 20 to 70, as on 7-year-old fields. Snedaker, as noted by Farnsworth and Golley, p. 122-123 (1973), has found large variation in biomass of successional vegetation at Lake Izabel, Guatemala, as, for example, in 32 different plots of 10-year-old fields where the extremes ranged from 10 t/ha to 210.3 t/ha. It is, therefore, very clear that many more areas must be sampled in the former swidden fields in the Sakaerat area before definitive statements can be made, especially with respect to the mean biomass of mid- and late stages of succession.

In this region of the Korat Plateau, three species compete for early dominance of former cultivated land. Our data indicate that Saccharum spontaneum, a tall cane-like grass developing from large, spreading rhizomes, is the more prevalent of these three species. Eupatorium odoratum, a sprawling, vigorously growing, pan-tropical composite, is also very prominent. As found by Sabhasri et al. (1974), S. spontaneum is the common dominant in abandoned swidden ("rai") in this area and, 12 years after the last crop, this grass may successfully supersede Eupatorium odoratum in dominance. Frequent fires, however, may reverse the dominance of these two species from Saccharum to Eupatorium. Imperata cylindrica is rarely dominant in this region (Sabhasri et al., 1974), but it often is a co-dominant with the other two "weedy" species. In our data, no Imperata was found in the 6-year-old field (Table III) or that of 20 $\pm$ years (Table IV). However, Imperata cylindrica can be a vigorous co-dominant with Saccharum as found in our 9-year-old field where Eupatorium, in turn, was less prominent (see Table IV).

The biomass data for the plots indicate an increase in tons/hectare the longer the period of succession after the last crop, beginning with the 9-year-old stage. During the early stages of succession from one to 9+ years, there is much variation due to the numerous factors discussed previously. However, the total biomass of the three "weedy" species remains roughly comparable, given the inherent variation, during this 9-year period (Table VI). The data from the field which was reputedly 3 years after the last crop suggest that unknown factors, or possibly even mis-information as to the actual age, many account for the substantially lower biomass in all categoreis. Regretably, little reliable information was known concerning the history of the field beyond the fact that the last crop grown was cassava. Other fields, such as that out-of-cultivation for one year, was last seeded to corn, one of the principal cash crops of the region.

Drew (1971) sampled 6 different fields (swidden) at Sakaerat by means of one 25 m^2 plot per area. All fields were approximately (10 $\pm$ 3) years after the last crop, but it proved impossible to obtain more accurate information. Green weights only were obtained from these fields, and the biomass from plot-to-plot was quite similar, as shown in the following data (Table VII).

Biomass (green weight) varied from 47.5 t/ha to 83.9 t/ha, with a mean value of 58.7 t/ha; but in 4 fields the results were very similar. Moreover, the data for a field of similar age in this study (Table IV) indicate a total green-weight biomass (50.7 t/ha) which is within the range of variation found in the earlier research (1971) in the same general area. These data, then, suggest considerable uniformity of vegetation in fields of about the same ages, due in part at least to the approximately comparable biomass of the 3 "weedy" species (Table VII) in the 6 fields. Variation in green-weight biomass ranged from 39.4 t/ha to 65.9 t/ha with a mean value of 46.2 t/ha.

A comparison of the biomass of the field of more than 20 years of age with that of the second-growth forest (Table VIII) indicates that once a canopy of trees becomes well established, the "weedy" dominants of early stages of succession disappear and the biomass thus consists mainly of trees and lianas. In the 20+ year-old stage, the canopy of invading trees was not yet closed ($\pm$ 35%), so that Saccharum and Eupatorium still contributed approximately 15% of the total biomass.

The biomass of the second-growth forest calculated in this study is 269.6 t/ha (dry weight). In contrast, Sabhasri et al. (1970) found that the standing crop of old-growth forest (not Dry Evergreen Type) in northern Thailand to be 386.9 t/ha. Ogawa et al. (1965) determined the biomass of Tropical Rainforest in southern Thailand to be 318-306 t/ha (dry weight), whereas that of Gallery Forest was 291 t/ha, and Savanna Forest 50-59 t/ha. While we were unable to sample a series of second-growth forest stands at Sakaerat, it appears that our data from the single 100 m^2 plot are quite comparable to those of Ogawa et al. (1965). Certainly the Tropical Rainforest would be expected to have a greater biomass due to 12 months of optimum growing conditions as contrasted to 4-6 months for the Dry Evergreen Forest. We do not have sufficient data for the biomass of the second-growth forest at Sakaerat to test the suggestion of Farnsworth and Golley, p. 123 (1973) that "biomass values for tropical second-growth also suggest an initial rapid period of production and then a decline in production rate......"

Species Changes with Succession

Lists of species of plants sampled in this study are given in the Appendix, p. 30.

In the field out-of-cultivation for one year, we found 6 species of trees at sapling stage and 7 species represented as seedlings. All 6 species of saplings were also present as seedlings along with an additional one. Of the 7 species of seedlings, 4 were of overstory trees (see graph, Table IX). It will also be noted that for the first 20+ years after the last crop, fields in this specific area generally have 4 or less species of trees of the mature overstory of the Dry Evergreen Forest; but of course, more extensive sampling would no doubt provide a sounder basis for drawing firm conclusions on this point. In his data from 1971, Drew found that the number of species of trees in 6 fields of comparable age of succession (10 $\pm$ 3 years) varied from 3 to 12 with a mean of 6.5, but records were not kept as to all identifications. Some seedlings, however, were definitely of overstory species.

The second-growth forest stand had 9 species of overstory trees plus, of course, 6 species of climbers (lianas) on a 100 m^2 plot. On the other hand, a survey by Smitinand et al. (1968) of the mature Dry Evergreen Forest at Sakaerat based on a one-hectare plot yielded 55 species of trees and 25 species of climbers (lianas). Again, increased sampling of the second-growth forest in our study would undoubtedly have yielded a larger number of species than found in our plot, but certainly not in the range of 55 species of trees.

The results of the study of Sabhasri et al. (1974) on succession on a denuded plot in the Dry Evergreen Forest at Sakaerat and former swidden ("rai") of 12 and 26 years after the last crop indicate a much larger number of species of trees becoming established as seedlings. Thus, for plots of 1, 5, 12, and 26 years, there were found 16, 12, 20 and 25 different species respectively, mostly of overstory trees from the closely adjacent Dry Evergreen Forest. The large number of tree seedlings at one and 5 years (recorded from the same denuded plot) seems to be due in large part to closer proximity of the 20 x 20 m plot to seed sources in the Dry Evergreen Forest, as well as to more sample areas with counts of seedlings taken on plots ranging from 400 m^2 (1 year), 16 m^2 (5 years), 48 m^2 (12 years) to 32 m^2 (25 years). In the final analysis, the number of species of trees and the number of individuals in any given swidden area depend as much on proximity to seed sources and frequency of fire as to husbandry of the field, crop grown, nutrient levels, etc.

SUMMARY

The research project on which this paper is based was aimed at determining the biomass of a successional series of swidden ("rai") fields up to and including a second-growth forest stand in the Dry Evergreen Forest type at the Sakaerat Forest Experiment Station, Amphoe Pak Thong Chai, Changwat Nakon Ratchasima, in the Northeastern part of Thailand. In this area of the Korat Plateau, swidden agriculture has been a way of life for many years, as indeed it has in many other areas in the world tropics. Hence, there are many hundreds of hectares of land in all stages of succession along with fields currently being cropped. Unfortunately, due to shifting population of farmers, the specific crop history of most swidden fields is not precisely known.

In our study, fields of known age of 1, 3, 6, and 9 years after cropping were identified. All of them supported stands of *Saccharum spontaneum* as the leading dominant with varying amounts of the two other co-dominants, *Imperata cylindrica* and *Eupatorium odoratum*. Plots of 25 m^2 were established in each field for clear-cutting of all vegetation to be weighed for fresh-weight and sub-sampled for oven-dry weights. All seedlings in the 25 m^2 were counted, and 4 $1 m^2$ quadrats were randomly selected for excavation to a depth of 1 m to measure the weight of the roots, rhizomes, etc.

The biomass of the three dominant "weedy" species remained roughly comparable during the 9 years of natural succession, varying from 7.7 t/ha to 16.1 t/ha, with a mean of 12.3 t/ha on a dry-weight basis. There was only a small and probably not significant increase in the biomass of the woody species in the plots. More extensive sampling of these and other fields might well have shown a significant increase in the biomass of woody species as a field aged; but so many factors are involved in determining the species composition within a field that it would be very difficult to find fields comparable in history of use in the region. By 20+ years after cultivation, the biomass of the "weedy" species of earlier stages is still important (7.8 t/ha dry-weight), but woody species have become dominant with a biomass of 39.2 t/ha dry-weight based on one 10 x 10 m plot. The total biomass has, of course, increased to 51.3 t/ha (DW) from a mean of 14.9 t/ha (DW) for the 1-9 year fields.

Species of seedlings during the 1-20+ year span did not increase notably in our plots; but again this result could well be modified by more extensive sampling. However, the number of individual seedlings increased substantially after 6 years, so that 49 were counted at 20+ years, whereas there were 28 at 9 years, and a mean of 13.7 for 1-6 years.

The second-growth forest of indeterminate age may have been a swidden area 50 or more years ago, but this fact is not wholly certain. There were no longer any of the three "weedy" species of early stages of succession, and the canopy was closed. Lianas were common but herbs and seedlings were very few. In the 100 m^2 plot, total biomass was found to be 269.6 t/ha (DW). Nine species of trees characteristic of the Dry Evergreen Forest were found, and 6 species of lianas and vines were present. The undergrowth was principally of saplings of the overstory trees, with about one herb (Zingiberaceae). In comparison with a mature stand of Dry Evergreen Forest, the number of species of trees and lianas especially is much less, since a study at Sakaerat of a one-hectare plot recorded 55 species of trees and 25 species of lianas and vines. Certainly the size of plot used by us, contributed to the recording of fewer species in a second-growth forest, but the species-richness of the mature forest suggests that for natural succession to attain a comparable stage of development from that of the second-growth stand which we studied requires a very long period of years, very possibly well in excess of 100.

TABLE I. Biomass of plant species in one-year old field, plot 25 m^2, sampled in 1976.

Category	Green Wt (t/ha)	Dry Wt (t/ha)
1. Standing Crop		
Saccharum spontaneum		
a. living stems & leaves	14.6	5.6
b. non-living stems & leaves	0.8m	0.6
Imperata cylindrica		
a. living leaves & stems	2.0	0.9
b. non-living leaves & stems	0.5	0.4
Eupatorium odoratum		
a. living stems and leaves	3.3	1.3
b. non-living stems & leaves	.0	.0
Vines	0.6	0.2
Woody spp.	1.6	0.8
Total Standing Crop	23.4	9.8
2. Below-ground Biomass		
a. Saccharum	8.0	3.2
b. Imperata	3.6	1.0
c. Eupatorium	1.8	0.8
d. Woody spp.	2.8	1.7
Sub total below ground	16.2	6.7
TOTAL BIOMASS	40.0*	16.5*

*Rounded off to nearest tenth

TABLE II. Biomass of plant species in three-year old field: plot 25M^2

Category	Green Wt (t/ha)	Dry Wt (t/ha)
1. Standing Crop		
Saccharum spontaneum		
a. living stems & leaves	4.0	1.4
b. non-living stems & leaves	0.1	0.04
Imperata cylindrica		
a. living leaves & stems	2.8	1.1
b. non-living leaves & stems	1.1	0.9
Eupatorium odoratum		
a. living stems & leaves	6.8	1.9
b. non-living stems & leaves	0.1	0.05
Vines	0.1	0.02
Woody spp.	0.02	0.02
Sub total of standing crop	15.0*	5.4*
2. Below-ground biomass		
a. Saccharum	2.2	0.6
b. Imperata	2.5	0.6
c. Eupatorium	3.8	1.1
d. Vines	---	---
e. Woody spp.	1.7	0.7
Sub total of below-ground biomass	10.2*	3.0*
TOTAL BIOMASS	25.1*	8.4*

*Rounded off to nearest tenth

TABLE III. Biomass of plant species in six-year old field: plot $25M^2$

Category	Green Wt(t/ha)	Dry Wt(t/ha)
1. Standing Crop		
Saccharum spontaneum		
a. living stems & leaves	7.5	3.2
b. non-living stems & leaves	2.1	1.6
Imperata cylindrica		
a. living leaves & stems	0	0
b. non-living leaves & stems	0	0
Eupatorium odoratum		
a. living stems & leaves	14.8	4.2
b. non-living stems & leaves	2.2	1.9
Vines	0.02	0.005
Woody spp.	1.2	0.5
Sub total standing crop	27.8*	11.4*
2. Below-ground biomass		
a. Saccharum	1.1	0.5
b. Imperata	0	0
c. Eupatorium	4.1	1.5
d. Woody spp.	2.4	1.2
Sub total below-ground biomass	7.6*	3.2*
TOTAL BIOMASS	35.4*	14.6*

*Rounded off to nearest tenth

TABLE IV. Biomass of plant species in nine-year old field: plot $25M^2$

Category	Green Wt(t/ha)	Dry Wt(t/ha)
1. Standing Crop		
Saccharum spontaneum		
a. living stems & leaves	13.3	5.6
b. non-living stems & leaves	1.1	0.8
Imperata cylindrica		
a. living leaves & stems	12.8	5.1
b. non-living leaves & stems	2.1	0.5
Eupatorium odoratum		
a. living stems & leaves	0.1	0.03
b. non-living stems & leaves	0.002	0.001
Vines	0.06	0.02
Woody spp.	1.16	0.53
Sub total standing crop	30.6*	12.6*
2. Below-ground biomass		
a. Saccharum	4.5	1.9
b. Imperata	9.0	2.1
c. Eupatorium	0.03	0.01
d. Woody spp.	6.6	3.2
Sub total below-ground biomass	20.1*	7.2*
TOTAL BIOMASS	50.7*	19.8*

*Rounded off to nearest tenth

TABLE V. Biomass of plant species in twenty plus year-old field: plot $100M^2$

Category	Green Wt(t/ha)	Dry Wt(t/ha)
1. Standing Crop		
<u>Saccharum spontaneum</u>		
a. living stems & leaves	6.5	2.4
b. non-living stems & leaves	1.7	1.1
<u>Imperata cylindrica</u>	0.0	0.0
<u>Eupatorium odoratum</u>		
a. living leaves & stems	5.8	1.8
b. non-living leaves & stems	0.02	0.01
Vines and lianas	0.06	0.02
Saplings and shrubs (understory)	1.4	0.6
Woody spp. (overstory)		
a. stems	68.7	41.7
b. branches	10.8	9.7
c. leaves	5.7	2.5
Litter	7.7	3.8
Sub total standing crop	108.4*	63.6*
2. Below-ground Biomass		
a. Saccharum	4.9	2.0
b. Eupatorium	2.0	0.6
c. Woody spp. (all trees, lianas, shrubs)	10.5	2.9
Sub total below-ground biomass	17.4*	5.5*
TOTAL BIOMASS	125.8*	69.1*

*Rounded off to nearest tenth

TABLE VI. Comparison of biomass of weedy species and woody species.

Age of Field	Biomass of 3** Weedy Species	Biomass of Woody Species	Total Biomass*
1 year	12.5	2.7	16.5
3 years	7.7	0.9	8.4
6 years	12.8	1.7	14.5
9 years	16.1	3.7	19.8
20+ years	7.8	39.2	51.3

* Metric tons/hectare, dry weight.

** Saccharum spontaneum, Imperata cylindrica, Eupatorium odoratum.

TABLE VII. Biomass (Green weight) of 10($\pm$ 3) year-old fields sampled in 1971.

Plot No.*	"Weedy" Dominants (t/ha)**	Total Green Wt (t/ha)
1	39.4	56.6
2	49.8	58.2
3	39.7	47.5
4	64.9	83.9
5	42.8	53.3
6	40.8	52.7
	$\overline{M}$ = 46.2	$\overline{M}$ = 58.7

*Plots were 25 m^2 in size.

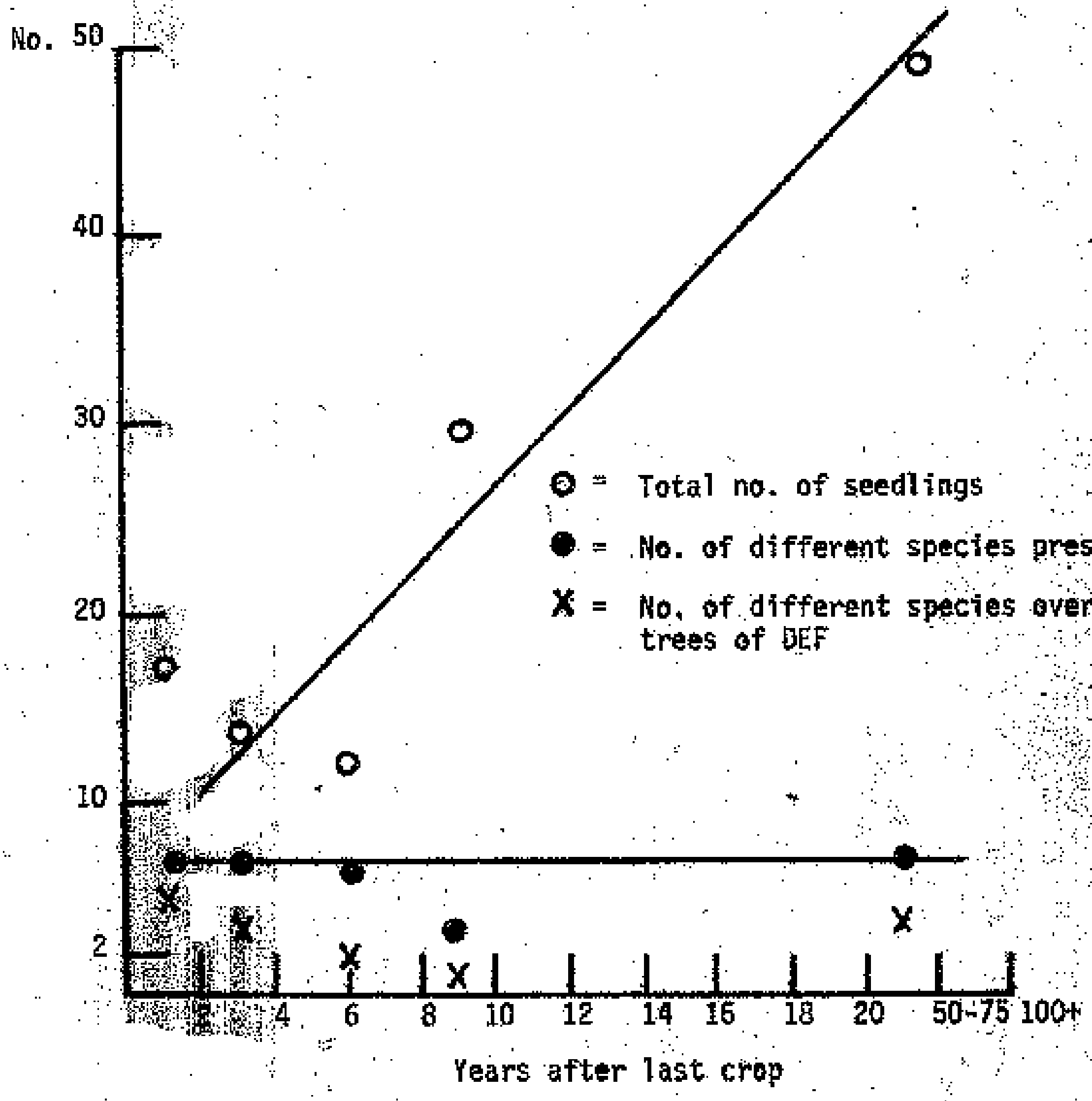
***Saccharum spontaneum*, *Imperata cylindrica*, *Eupatorium ordoratum*.

TABLE VIII. Second growth forest: plot $100M^2$

Category	Green Wt (t/ha)	Dry Wt (t/ha)
1. Standing Crop		
Woody spp.		
a. Overstory trees		
(1) stems	254.2	187.1
(2) branches	82.4	49.1
(3) leaves	15.1	7.0
Lianas	12.1	8.6
Understory saplings & shrubs	4.5	1.6
Herbs	0.05	0.02
Litter	10.0	6.5
Sub total standing crop	378.4*	259.9*
2. Below-ground Biomass		
Sub total below ground biomass	20.5*	9.7*
TOTAL BIOMASS	398.9*	269.6*

*Rounded off to nearest tents.

TABLE IX. Number of seedlings relative to ages of swidden.



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Appendix I

List of Species of Herbs, Lianas, Shrubs, Trees and Vines

Plot 1 (1 year)

a. Trees

Acacia sp.
Dalbergia oliveri
Erioglossum sp.
Ficus sp.
Melodorum fruticosum
Miliusa velutina
Urobotrya siamensis

b. Grasses

Imperata cylindrica
Saccharum spontaneum

c. Herbs, Shrubs, Vines

Eupatorium odoratum
Smilax sp.

Plot 2 (3 years)

a. Trees

Carissa carandas
Ixora sp.
Melodorum fruticosum
Miliusa velutina

b. Grasses

Imperata cylindrica
Saccharum spontaneum

c. Herbs, Shrubs, Vines

Dioscorea sp.
Ventilago sp.

Plot 3 (6 years)

a. Trees

Aganosma marginata
Aglaia sp.
Carissa carandas
Polyalthia erecta
Uvaria rufa

b. Grasses

Saccharum spontaneum

c. Herbs, Shrubs, Vines

Eupatorium odoratum
Smilax sp.

Plot 4 (9 years)

a. Trees

Knema conferta
Legume
Milletia sp.
Mitrephora sp.
Randia eucodon
Sterculia ornata

b. Grasses

Imperata cylindrica
Saccharum spontaneum

c. Herbs, Shrubs, Vines

Dolichos lablab
Eupatorium odoratum
Smilax sp.

Plot 5 (20+ years)

a. Trees

Carissa carandas
Erioglossum sp.
Ficus altissima
Grewia paniculata
Ixora sp.
Melodorum fruticosum
Memecylon ovatum
Miliusa velutina
Murraya sp.
Walsura sp.
Unidentified (3)

b. Grasses

Saccharum spontaneum

c. Herbs, Shrubs

Eupatorium odoratum

d. Lianas, Vines

Acacia sp.
Bauhinia horsfieldiana
Diploclisia sp.
Dioscorea sp.
Lygodium flexuosum
Smilax sp.
Tiliacora triandra
Ventilago sp.

Plot 6 (Second-Growth Forest)

a. Trees

Aglaia pirifera
Ardisia parvula
Cananga latifolia
Dialium cochinchinensis
Hydnocarpus ilicifolius
Lithocarpus sp.
Memecylon ovatum
Parkia streptocarpa
Walsura robusta

b. Lianas, Vines

Acacia sp.
Glossocarya sp.
Lygodium flexuosum
Strychnos chloropetala
Willughbeia sp.
Unidentified (6)

c. Herbs

Zingiberaceae (1)

Appendix II

List of Seedlings and/or Sprouts Counted in Plots

Plot 1 (1 year)		Number
Acacia sp.		3
Dalbergia oliveri		1
Erioglossum sp.		1
Melodorum fruticosum		4
Miliusa velutina		2
Urobotrya siamensis		1
Ficus sp.		5
	Total	17

Plot 2 (3 years)		
Carissa carandas		5
Ixora sp.		1
Melodorum fruticosum		1
Miliusa velutina		4
Similax sp.		1
Uvaria rufa		1
Ventilago harmandiana		1
	Total	14

Plot 3 (6 years)		
Aganosr . marginata		3
Carissa carandas		1
Ixora sp.		1
Miliusa velutina		1
Smilax sp.		3
Uvaria rufa		1
	Total	10

Plot 4 (9 years)		
Carissa carandas		25
Miliusa velutina		2
Uvaria rufa		1
	Total	29

Plot 5 (20+ years)		
Acacia sp.		8
Carissa carandas		15
Erioglossum sp.		2
Melodorum fruticosum		4
Miliusa velutina		13
Smilax sp.		3
Wulsura sp.		4
	Total	49

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* In Thai with English summary.