THE EFFECTS OF IRRIGATION ON THE GROUND FLORA OF A DECIDUOUS DIPTEROCARP FOREST AT HUAI HONG KHRAI

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL IN
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DATE 24 MONTH MARCH YEAR 1994

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ชื่อเรื่องวิทยานิพนธ์ ผลของการให้น้ำต่อพืชพื้นล่างในป่าเต็งรังบริเวณห้วยฮ่องไคร้

ชื่อผู้เขียน นางสาวสุทธาธร สุวรรณรัตน์

วิทยาศาสตรมหาบัณฑิต สาขาการประเมินความเสี่ยงทางด้านสิ่งแวดล้อมในระบบนิเวศเขตร้อน

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บทคัดย่อ

ปริมาณน้ำในดินเป็นปัจจัยสำคัญประการหนึ่งซึ่งมีผลต่อลักษณะและโครงสร้างของป่า ดังนั้นถ้าหากมีการให้น้ำแก่ป่าเต็งรังซึ่งเป็นป่าผลัดใบ กลุ่มสังคมพืชในป่าน่าจะเปลี่ยนไปคล้ายกับสังคมของพืชที่อาศัยอยู่ในพื้นที่ที่มีความชื้นสูงกว่าป่าเต็งรัง ได้ทำการศึกษาผลของการให้น้ำแก่ป่าเต็งรังในบริเวณศูนย์ศึกษาเพื่อการพัฒนาห้วยฮ่องไคร้อันเนื่องมาจากพระราชดำริ ซึ่งได้รับการให้น้ำในช่วงฤดูแล้งมาเป็นเวลา 8 ปี โดยทำการสำรวจชนิดและปริมาณของพืชพื้นล่างในแปลงตัวอย่างขนาด 1x1 ตารางเมตรจำนวน 80 แปลงใน 4 พื้นที่ ได้แก่บริเวณสันเขาและหุบเขาในพื้นที่ที่ให้น้ำกับบริเวณสันเขาและหุบเขาในพื้นที่ที่ไม่มีการให้น้ำ โดยทำการเก็บข้อมูลทุก 3 เดือนในช่วงฤดูแล้งและทุกเดือนในช่วงฤดูฝน ในการศึกษามวลชีวภาพและปริมาณผลผลิตขั้นปฐมภูมิ ได้ทำการศึกษาเฉพาะบริเวณพื้นที่สันเขา โดยใช้แปลงตัวอย่างขนาด 2x2 ตารางเมตรจำนวน 15 แปลงในแต่ละพื้นที่

จากการศึกษาพบว่าจำนวนชนิดของพืชพื้นล่างบนสันเขาทั้งสองพื้นที่เท่ากับ 39 ชนิด

ส่วนในบริเวณหุบเขาของพื้นที่ที่ให้น้ำและไม่ได้ให้น้ำมีจำนวนชนิดเท่ากับ 52 และ 63 ชนิดตามลำดับ ความหลากหลายทางชีวภาพ (Hill's number, N1 และ N2) และความสม่ำเสมอในการกระจาย (Evenness, Modified Hill's ratio) ของสังคมพืชพื้นล่างพบว่ามีค่าสูงสุดในบริเวณหุบเขาของพื้นที่ที่ไม่ได้รับน้ำ (36.2, 31.5, 0.9 ตามลำดับ) และต่ำสุดในบริเวณสันเขาของพื้นที่ที่ได้รับน้ำ(16.3, 11.3 และ 0.7) เปอร์เซ็นต์ของพืชที่มีวงชีวิตมากกว่าหนึ่งปีจากจำนวนพืชทั้งหมดในบริเวณสันเขาของพื้นที่ที่ได้รับน้ำมีพืชกลุ่มนี้น้อยกว่าพื้นที่ที่ไม่ได้รับน้ำ (66.67% และ 76.92% ตามลำดับ) แต่ในบริเวณหุบเขาของทั้งสองพื้นที่มีปริมาณใกล้เคียงกัน (86.54% ในบริเวณที่ให้น้ำและ 84.37% ในบริเวณที่ไม่ได้รับน้ำ) อย่างไรก็ตามในพื้นที่ที่ได้รับน้ำพบว่าพืชพวกนี้สามารถเจริญได้ดีกว่าพื้นที่ที่ไม่ได้รับน้ำ จากการศึกษาพบว่าดรรชนีความคล้ายคลึงกัน (Similarity,Sorensen'sindex) ของพื้นที่ที่ให้น้ำและไม่ได้ให้น้ำเท่ากับ 0.74 ในบริเวณหุบเขา และ 0.62 ในบริเวรสันเขา การศึกษาเกี่ยวกับปริมาณมวลชีวภาพและผลผลิตขั้นปฐมภูมิแสดงให้เห็นถึงผลของการให้น้ำได้อย่างชัดเจน ส่วนของพืชที่มีชีวิตในพื้นที่ที่ได้รับและไม่ได้รับน้ำมีปริมาณสูงสุดในเดือนกันยายน(155.536 และ84.541 กรัมต่อตารางเมตรตามลำดับ) ในขณะที่ส่วนของพืชที่ตายมีปริมาณสูงสุดในเดือนมีนาคมในพื้นที่ที่ให้น้ำ (239.710 กรัมต่อตารางเมตร) และสูงสุดในเดือนมิถุนายนในพื้นที่ที่ไม่ได้รับน้ำ (183.256 กรัมต่อตารางเมตร)การที่ผลของการให้น้ำต่อสังคมพืชพื้นล่างไม่ชัดเจนเท่าที่ควรอาจเนื่องจากประสิทธิภาพของระบบการให้น้ำ

Thesis Title The Effects of Irrigation on the Ground Flora of a Deciduous Dipterocarp Forest at Huai Hong Khrai

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M.S. Environmental Risk Assessment for Tropical Ecosystems

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Abstract

Soil moisture is one of the most important factors affecting the structure and species composition of forests. Therefore if more water is put into a degraded deciduous forest, the species composition of the forest should change to a more mesic community. The study site for this thesis was at Huai Hong Khrai Royal Development Study Center, Doi Saket, Chiang Mai province, in an area that has been irrigated for 8 years. Eighty permanent quadrats ($1 \times 1\ m^2$) were used for a ground flora survey at 4 different sites: irrigated ridge and gully and non-irrigated ridge and gully. All the ground plants

rooted in each quadrat were identified and given abundance scores every 3 months during the dry season and every month during the rainy season. On the ridge of both sites another 15 (2 x 2 m^2) quadrats were laid out for a study of biomass and productivity. Every 2 months 1 m^2 of the above-ground standing crop was harvested. The living and dead standing crop was separated, dried and weighed.

The number of species recorded at both the irrigated and non-irrigated ridges was 39 while in the irrigated and non-irrigated gullies the number was 52 and 64 species respectively. The highest species diversity (Hill's number, N1 and N2) and evenness (Modified Hill's ratio) occurred in the non-irrigated gully (36.2, 31.5 and 0.9 respectively) and lowest in the irrigated ridge (16.3, 11.3 and 0.7 respectively). Perennial species in the irrigated site comprised only 66.67% of the total species, while in the non-irrigated ridge the figure was 76.92%. However in the gully sites the percentage of perennials was similar (86.54% in irrigated and 84.37% in non-irrigated area). The similarity (Sorensen's index) of IG and NIG was 0.74 while between IR and NIR was a little bit lower, 0.62. However all of the species occurred in all study sites were typical to deciduous dipterocarp forest. The study of biomass and productivity showed the effects of the irrigation more clearly. The total biomass at all 4 collection times was higher in the irrigated sites. The living standing crops at both sites were highest in

September (155.536 g/m^2 in the irrigated site and 84.541 g/m^2 in the non-irrigated site). The dead standing crop in the irrigated area was highest in March (239.710 g/m^2) but in the non-irrigated area it peaked in June (183.256 g/m^2). The limited effects of irrigation may be due to the inefficiency of the irrigation system.

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ABBREVIATIONS

IR	Irrigated ridge
NIR	Non-irrigated ridge
IG	Irrigated gully
NIG	Non-irrigated gully
PP	Primary Production
NPP	Net primary production
GPP	Gross primary production

1. INTRODUCTION

The area of primary forest in Thailand is decreasing rapidly due to many human activities. In 1950 about 32 million ha of Thailand was forested, but by 1985 the forest area had been reduced to only 14.4 million ha; a rate of deforestation of about 1.44% per year (Flaherty and Filipchuk, 1993). The Northern part of Thailand contains the highest forest cover, but also has the highest rate of deforestation. The main factors causing deforestation are commercial logging and the practice of shifting cultivation. After logging, some areas are cleared for agriculture and housing, whilst others are degraded and become secondary forest. When lowland primary forest is disturbed or degraded, it is quite often replaced by deciduous dipterocarp forest dominated by *Shorea* spp. The secondary forest is itself also further disturbed by local people gathering firewood and agricultural expansion. Many environmental impacts follow. Loss of forest cover, especially on steep slopes and in watershed areas increases runoff and soil erosion. The frequency of floods in the rainy season and drought during the dry season is increased. Many wildlife species are depleted to seriously low levels and some go locally extinct.

Therefore one important question is how can primary forest be rapidly regenerated. The best way to restore the forest is via natural succession (Lugo, 1990, Aronson,*et al.*, 1993), but there are 4 types of activities that can help accelerate this process; 1) reducing environmental stressors (e.g. controlling fire, grazing, etc.), 2) adding materials (e.g. planting or seeding, adding water or fertilizer), 3) accelerating or decelerating ecosystem processes (e.g. accelerating seed input by attracting seed vectors) and 4) changing site conditions (e.g. changing drainage, reducing light input by shading). Irrigation can contribute to at least 2 of these activities. It can increase the available water in the forest and at the same time decrease fire frequency.

The Huai Hong Khrai Royal Development Study Center in Doi Saket, Chiang Mai was the study site for the project described in this thesis. Eight hundred rai of its deciduous dipterocarp-oak forest has been irrigated during the dry season for about 8 years, but little scientific research has been done to determine the effects of this treatment.

The species diversity of forest plant communities seems to increase with increasing annual rainfall (Gentry, 1982), because soil moisture is one of the most important factors affecting the structure and composition of forests. Deciduous forest is particularly sensitive to soil moisture. Such forest has a sparse canopy and a ground flora dominated by grasses and sedges which are suitable fuel for fire during dry season. The organic matter and water holding capacity of the soil is low and the soil cannot maintain enough water to satisfy the transpiration needs of the vegetation during the dry season. Therefore if more water was added to deciduous forest during the dry season, the forest should become more productive, develop a higher species diversity and perhaps become more mesic community.

Changes in forest structure can be detected by vegetation analysis. However, in forest regeneration, it takes quite a long time for the tree community to change. Therefore, in this project only the ground flora community, which changes faster, was studied. Irrigation should cause the relative frequency of perennial plant species in the ground flora community to increase and that of annual species to decrease, because irrigation will reduce fire and this should allow perennial species to spread, whilst annual species will find it more difficult to compete with the perennials.

Another factor studied in this project was the biomass and productivity of the ground flora community. Because the area was watered during dry season, the period of available water was prolonged. Therefore, the vegetation should have a longer time to grow and the biomass and productivity of the irrigated area should increase. The quality of soil in the area should also improve because higher primary productivity will cause greater input of organic matter into soil.

The aims of the research present here were: 1) to compare the species composition of the ground flora communities between irrigated and non-irrigated deciduous dipterocarp-oak forest and 2) to compare the primary productivity and standing crop biomass of the ground flora in these 2 area and determine their effects on the percentage organic matter in soil.

2. LITERATURE REVIEW

Tropical deciduous forest is a kind of forest that is mainly affected by seasonal drought and fire. Deciduous dipterocarp forest is the most widespread forest type in Thailand, it occupies 47% of the whole forest area (Stott, 1988).

Normally deciduous dipterocarp forest grows where annual rainfall is between 1,000 - 1,500 mm, there is a dry season of 5 - 7 months (October/November to March/April or May) and for more than half of the year (up to nine months) evapo-transpiration exceeds precipitation (Stott, 1986). Maximum daily temperature always exceed 20°C. Fires are common. They destroy soil organic matter and decrease the water holding capacity of soil. Therefore during the dry season, soil moisture is not enough for the vegetation to retain their leaves and leaf shedding occurs. The forest is dominated by six deciduous tree species of the family Dipterocarpaceae; *Dipterocarpus intricatus, D. obtusifolius, D. tuberculatus, Shorea obtusa, S. roxburghii* and *S. siamemsis.*

Although fire is common in this kind of forest, it is not a necessary factor to maintain its environment. For example in areas with shallow sandy soil, rocky out crops and on steep slopes, Barrington (1931) states that fire protection may have no appreciable effect on the vegetation.

There is only a single-layered open canopy in this forest which allows high light intensity at ground level. The trees have biological characteristics which enable them to resist drought and fire, such as thick, hard and rough bark, with the same protection and numerous dormant buds on the root collar for coppicing after fire (Stott, 1986).

The ground flora of this forest is also able to survive drought and fire. The ground flora, most of which is perennial, is at its maximum density during the later part of rainy season (September - November) and absent during dry season (February - May). Several monocot herbs produce their flowers during the peak of dry season before their leaves appear, e.g. *Murdannia scapiflora* (Roxb.) Roy. (Commelinaceae) and *Curcuma zedoaria* (Berg.) Rosc. (Zingiberaceae) (Maxwell, 1992). Example of adaptation to drought and fire are the hemicryptophytes (the dominant grasses and grass-like bamboos) and geophytes (e.g. ground orchids, such as the genus *Habenaria* and members of the Zingiberaceae). They have perenating organs, either underground or protected at the soil surface by a dense mat of dead matter. The members of these groups also recover very fast after fire, such as *Arundinaria pusilla* (Gramineae) which is known to resprout within 14 days after burning (Stott, 1988).

Soil moisture is one of the most important factors affecting the structure and composition of the forest and in tropical regions species richness seems to increase with increasing annual rainfall. For every 1,000 mm of rainfall, the community gains about 50 tree species (Lugo, 1988). Therefore if more water were added to a deciduous forest, especially the anthropogenically induced ones, the vegetation community should change to a more mesic community.

Irrigation is a new technique to aid recovery of degraded forest. By watering an area, at least two benefits should arise. Irrigation will increase available water in the soil and at the same time, reduce fire. One experiment was conducted in Panama by Wright and Cornejo (1990). The neotropical forest area was irrigated continuously to discover whether moisture stress is responsible for the timing of tree flowering. The results showed that irrigation has no effect on flowering periodicity. Another experiment was a pilot project of the Dhammanat Foundation in Mae Soi, Chom Thong, northern, Thailand. The water was dispersed evenly over a small area. After 1-2 years the study area showed some differences compared to the non-watered control area, with the species diversity of the ground flora higher and more perennial plant species in the watered area, but the density of the ground flora and the rate of organic matter decomposition showed no significant differences (Elliott, 1991).

Forest irrigation has also been used as a method to remove nutrients from waste water. This system also adds nutrients to the forest. For example an experiment on the effects of feedlot runoff on a southern Illinois (USA) forest watershed (Pinkowski, 1982 and Pinkowski *et al.*,1985) found that after watering the area with feedlot runoff, the vegetation community, both tree and herbaceous, became more similar to moist sites. The species diversity of herbaceous species increased significantly.

Aronson *et al.* (1993) suggested several characteristics of ecosystems that can be used as indicators of ecosystem structure and function which allows changes of that ecosystem to be monitored e.g. perennial and annual species richness or above-ground phytomass, which can be used to determine ecosystem structure, while soil organic matter, rain use efficiency or length of the water availability period can be used as indicators of ecosystem function.

In tropical regions, most forest studies have mainly concentrated on tree communities. There have been very few studies of the ground flora communities. Therefore most of the techniques used in ground flora studies have been developed in temperate countries.

The most commonly used sample unit used to survey the ground flora is the quadrat. This is a simple square or rectangular sample area for detailed examination. Quadrats may be used to select a "typical" sample or repeated over an area. They may be positioned regularly (separated usually by five times their own width) or randomly (McLean and Cook, 1968).

The size of quadrats used depends on the scale of the vegetation being studied. In general a quadrat size up to 0.25 m^2 is suitable for herbaceous vegetation, while sizes larger than 1 m^2 are required for work with woody species (Causton,1988). The size of the sample plot also depends on the vegetation type. A plot of 1-25 m^2 is regarded as adequate for sampling herbaceous vegetation, while in small scrub, a plot of 25-100 m^2 is preferred and in forest, plots of 200-500 m^2 are used for tree, with appropriate sizes substituted for the shrub and herb layers, (Goldsmith, *et al.*, 1986). For example, in Coed Nant Lolwyn, mid-Wales (U.K.), the ground flora in a deciduous woodland was surveyed by using 0.25 m^2 quadrats at 200 random sample points (Causton, 1988). The density of each species was recorded in each quadrat in this study, as a measure of the abundance of the ground flora.

However, this technique has some disadvantages in that the definition of an individual depends on the morphology of the species concerned. For example, many shoot of grasses may probably join together underneath the soil by stolen and should be count as 1 individual, this is very difficult to prove that they are the same individual or not. In the Welsh study, 100 species of flowering plants, ferns and bryophytes were recorded. In the study by Okali and Onyeachusin (1991) of ground flora communities in a plantation and natural forest in Omo forest reserve, Nigeria, ten 1 m^2 quadrats were distributed randomly in 50 x 50 m^2 permanent plots in each area and all vascular plants less than 100 cm tall were recorded and their density used as an abundance score. The total number of species, and recruitment and extinction of species in the ground flora were higher in the forest than in the plantation, but density of plants and seasonal fluctuation in the density were higher in the plantation than in the forest.

Various measurements are made within quadrats. The most simple one is presence or absence of species (which is suitable for areas where species number is increasing markedly) or the vegetation can be quantified in terms of density, cover, biomass, basal area, etc.

Cover is the proportion of ground covered by a species and should be envisaged as a vertical projection of each species on to the ground (Goldsmith, 1991). Cover can be expressed as a percentage or placed in ranges of value, e.g. the "Domin" scale which was used on the continent of Europe and in the British National Vegetation Classification. This scale is "pseudoquantitative" but is easily and quickly used in field. It also produces satisfactory ordinations and classifications (Goldsmith, 1991 and Goldsmith *et al.*, 1986).

Generally the primary production of arid land such as grassland increases with the water available, (Sala *et al.*, 1988). In the study of Issaree (1982), the primary production of a degraded forest area and dry evergreen forest mainly came from the understory layer rather than the tree canopy layer.

Production is the weight or biomass of organic matter assimilated by an organism or community over a given period of time. Primary Production (PP) is the production of organic matter by photosynthesis which can be expressed in two ways: gross primary production (GPP) and Net Primary Production (NPP), (Chapman, 1986). GPP is very difficult to measure therefore the one that is commonly used in plant ecology is NPP.

NPP is the amount of organic matter incorporated by a plant or an area of vegetation over a period of time. One formula that is generally used to calculate NPP is;

$$P_N = \Delta B + L + G$$

when P_N = Net Primary Production

ΔB = Change in biomass during the period $t_1 - t_2$

L = Plant losses by death and shedding during $t_1 - t_2$

G = Plant losses by grazing , etc.

In practice it is quite difficult to determine NPP from this formula. Therefore in the present field studies NPP was obtained by;

$$P_N = B_2 - B_1$$

when P_N = Net Primary Production

B_1 = Biomass at time t_1

B_2 = Biomass at time t_2 (Jager and Harrison, 1982)

Or another method that was suggested by Long and Mason (1983), used in a study of salt marsh flora is;

$$P_N = W_{1(max)}$$

when P_N = Net Primary Production

$W_{1(max)}$ = Maximum biomass recorded during the year

With the assumption that; 1) there is no carry-over of biomass from one year to the next and 2) no death occurs before the maximum biomass is achieved.

A common method used to determine the biomass or production of small plants is harvesting. Chapman (1986) suggested that a standard error in the order of 10% of the mean is an acceptable level of accuracy for ecosystem studies. However, another factor that should be considered is that this method is destructive. It should be used only when production is an important factor of concern.

3. STUDY SITES

Huai Hong Khrai Royal Development Study Center is located in Doi Saket District, Chiang Mai, Thailand at an altitude of about 500m. It was set up in 1983. The main purpose of the center is to demonstrate sustainable development of agriculture and forestry. The annual rainfall in the area is about 1450 mm (average of 1985-1992 rainfall data). The driest months are January, February and March (monthly rainfall less than 10mm). The maximum and minimum temperature during the year is about 40 and 12°C, respectively. Mean temperature throughout the year is about 25°C. (Fig.1)

The research site for this thesis was located in an area earmarked for forest development, which is covered by deciduous dipterocarp-oak forest. The forest development area covers about 800 rai, (128 ha). The area had been irrigated in the dry season every year since 1985. There are two irrigation systems in this area: 1) a check dam system on each stream and 2) an irrigation pipe which waters the area during the dry season. The purpose of these irrigation systems was to maintain soil moisture during the dry season to protect the forest against fire and promote the establishment of a more mesic forest ecosystem.

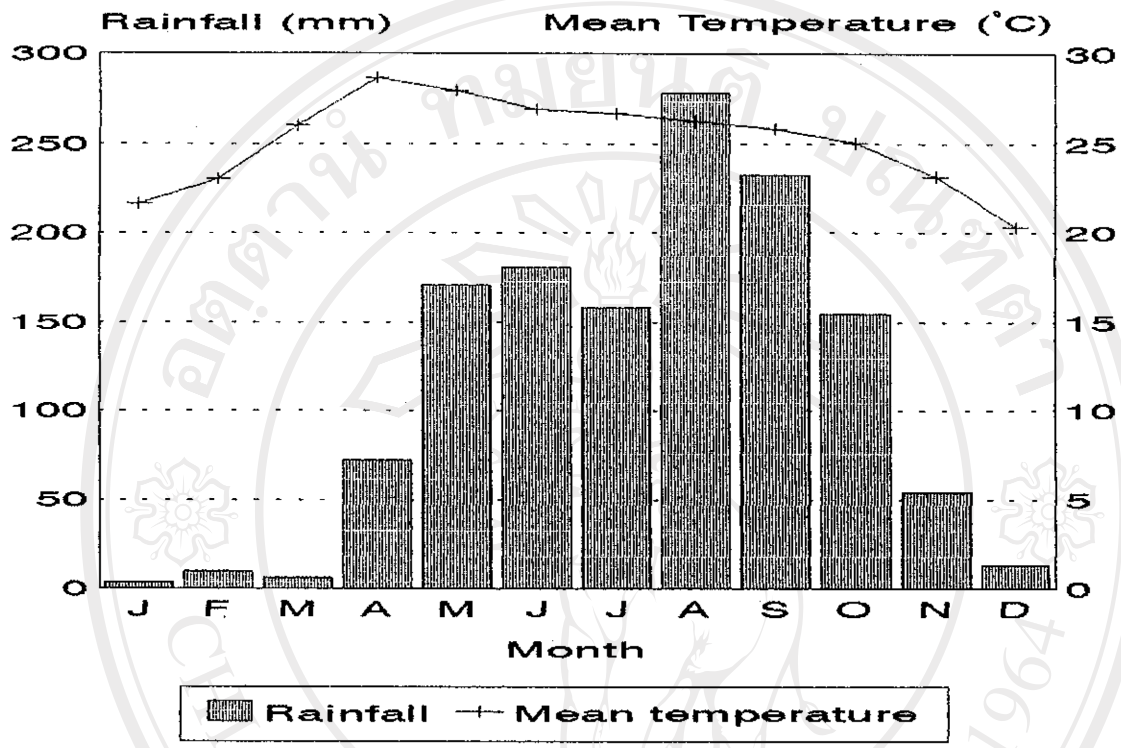

Figure 1 Monthly rainfall and mean temperature (average from Huai Hong Khrai office record, 1985 - 1992)

The irrigation pipes were laid along the tops of the ridges in the area. The water was released by gravity through small holes every 2 meters along the pipe (Fig. 2). During February, March and April water was released twice a week and the quantity of water released each day was 600 - 800 m^2. This amount of water is equivalent to only about 11 -15 mm of rainfall per dry season, assuming that the water spreads evenly across the whole site.

There were 2 study sites; an irrigated area and an adjacent non-irrigated area (the control site). Each study site was further divided into ridge sites, which should get the greatest effect from irrigation and the gully sites, which were further away from the pipe but should collect the water from the whole area. Four transects (50 m long) were established, one each along an irrigated ridge (IR), non-irrigated ridge (NIR), irrigated gully (IG) and non-irrigated gully (NIG) for a ground flora survey. Another 2 transects

Figure 2. Pipes laid along the ridge of the irrigated area.

(100 m long) were established for determination of productivity and biomass on the IR and NIR.

Transects for the ground flora survey had the following characteristics:

Irrigated Ridge (IR)

The transect was laid out about 10 meters from and parallel to the pipe (10 meters from the ridge). The aspect was 50° northwest and slope steepness was 40%. The altitude was 500 m.

Non-irrigated Ridge (NIR)

The transect was laid out about 10 meters from the ridge in the non-irrigated area. The aspect was 30° northeast and slope steepness was 20%. The altitude was 520 m.

Irrigated Gully (IG)

The transect was laid out about 5 meters from the bottom of the gully in the irrigated area. The gully lay in an east to west direction. The altitude was 490m

Non-irrigated Gully (NIG)

The transect was laid out about 5 meters from the bottom of the gully in the non-irrigated area. The gully lay in an east to west direction. The altitude was 510m.

Transects for biomass and productivity study had the following characteristics:

Irrigated Ridge (IR)

The transect was laid out along the ridge next to the irrigation pipe.

Non-irrigated Ridge (NIR)

The transect was laid out along the ridge crest of the non-irrigated area.

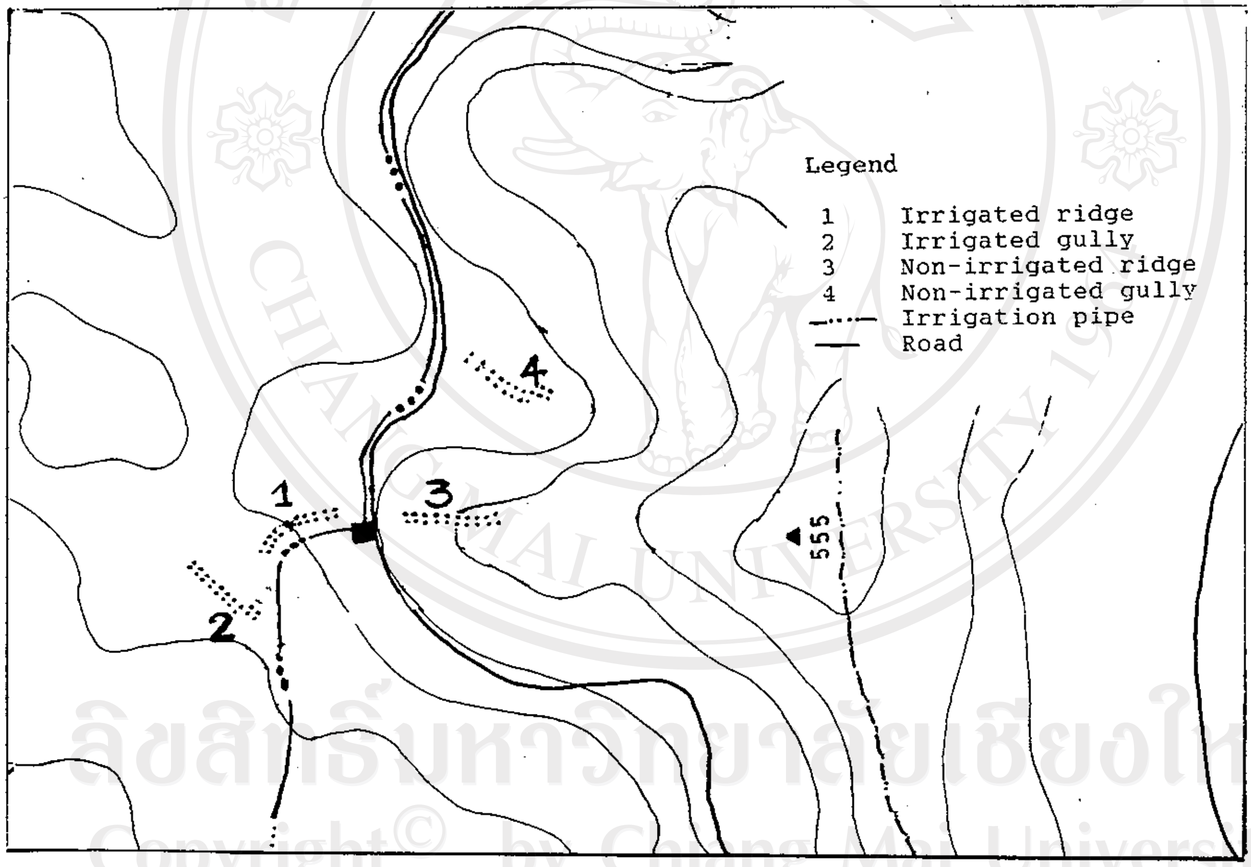

Figure 3. Diagram showing the location of the study site, modified from the topographic map of Huai Hong Khrai Royal Development study center.

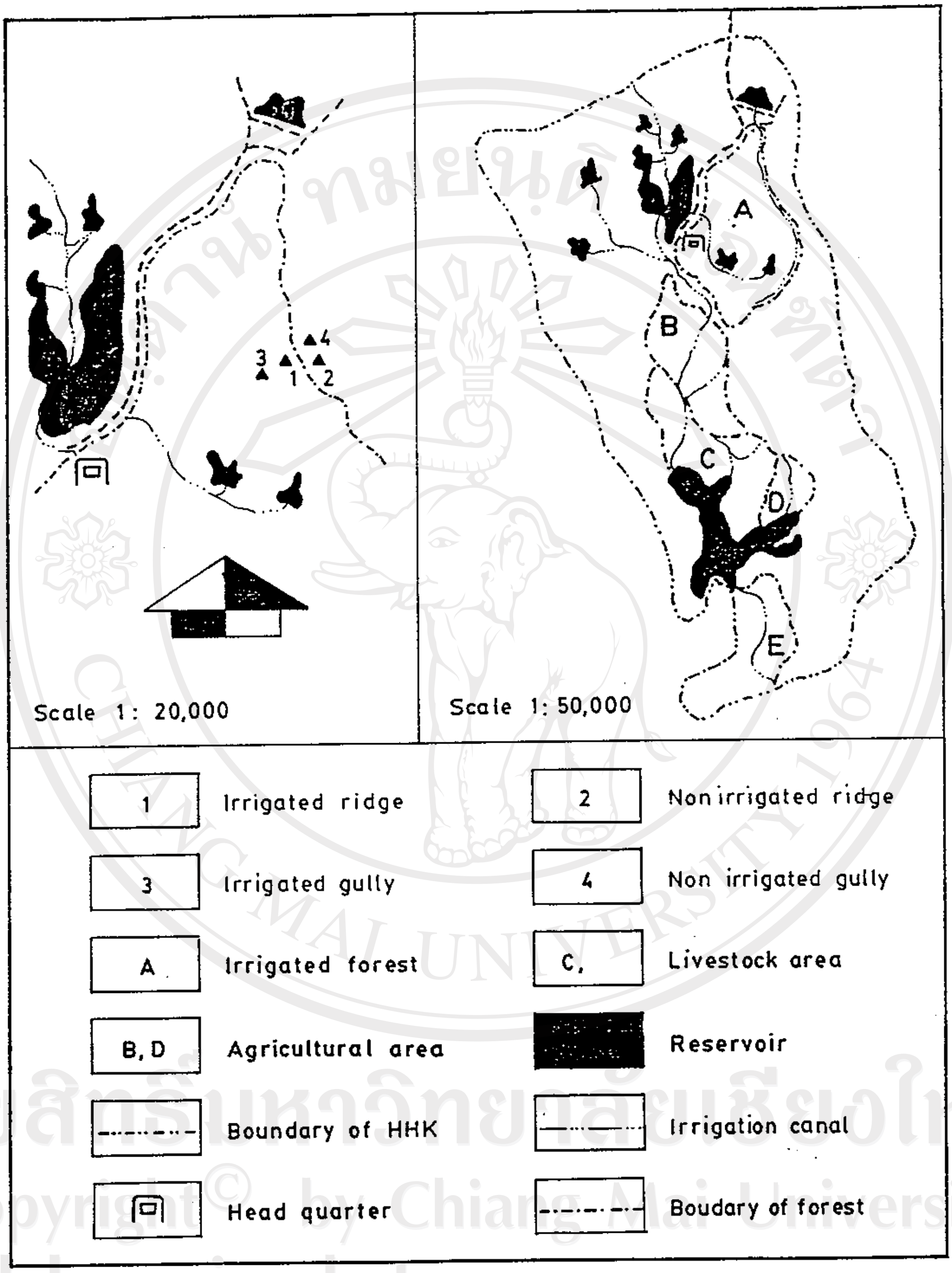

Figure 4. Map of Huai Hong Khrai Royal development study center.

4. MATERIALS AND METHODS

Materials and Equipments Used.

a. Materials

- Plastic bags and elastic bands
- Paper bags
- Data Forms
- Topographic map of Huai Hong Khrai Royal Development Study Center

b. Equipments

- Wire 1 x 1 m^2 quadrats, metal labels and U-shaped wires
- Nylon strings
- Bamboo poles
- Measuring tape (1.5 and 50 meters)
- Strong knife and scissors
- Oven
- Balance
- Compass
- Altimeter
- Plant press

Methods

Study of the Ground Flora Community.

Along the four 50 m transects, 2 permanent quadrats, 1 x 1 m^2, were placed every 5 meters (2 meters apart from each other) (Fig.6). All non-woody plants and young seedlings, not taller than 2 meters, in each quadrat were identified and quantified using the Domin scale and percentage cover, once every three months during the dry season and once every month during the rainy season. All species which flowered or fruited during the observation peroid were collected and reference specimens placed in the Biology herbarium of Chiang Mai University. A species-area curve was plotted. Species richness, diversity and evenness were calculated for each of the 4 sites using the equations below (Ludwig and Reynolds, 1988). Similarity between the IR and NIR, and between the IG and NIG communities was calculated by using Sorensen's index. The Statistical Package for the Social Sciences (SPSS), with "cosine" as an index of difference between quadrats, was used to carry out a cluster analysis of all 80 quadrats (Appendix 4). Analysis was carried out on the Domin score, calculated over the whole study period.

Range of Domin's score:

Class	Domin
+	isolated; cover small
1	scarce; cover small
2	very scattered; cover small
3	scattered; cover small
4	abundant; cover about 5%
5	abundant; cover about 20%
6	cover 25-33%
7	cover 33-50%
8	cover 50-75%
9	cover 75-under 100%
10	cover about 100%

Species Diversity: (Hill's number)

NUMBER 1: $N1 = e^{H'}$

NUMBER 2: $N2 = 1/\lambda$

where H' is Shannon's index

λ is Simpson's index

Shannon's Index

$$H' = -\sum_{i=1}^{S^*} (p_i \ln p_i) \quad , \text{which } pi = \frac{ni}{N}$$

Simpson's Index

$$\lambda = \sum_{i=1}^{s} Pi^2$$

where: H' average uncertainty per species in an infinite community

S^* total number of species in the community

p_i proportional abundance of the i^{th} species

n_i number individuals (abundance) of the i^{th}

N total number of individuals

Species richness:

NO = Total number of species

Evenness: (Modified Hill's Index)

$$E_5 = \frac{(1/\lambda)-1}{e^{H'} - 1}$$

where : $\lambda \quad \sum_{i=1}^{s} p_i^2$

Similarity: (Sorensen's index) of communities in site 1 and 2.

$$S_s = \frac{2a}{b+c+2a}$$

where : a Number of species that occurred in both sites

b Number of species that occurred only in site 1

c Number of species that occurred only in site 2

Determining the Primary Productivity of the Ground Flora.

Fifteen quadrats, 2 x 2 m^2, were laid out on the ridge site of the irrigated and fifteen on the ridge of the non-irrigated area for determination of above-ground primary productivity. Every three months, all above ground standing crop in 1 m^2 was harvested. Living and dead plant parts were separated, weighed, oven dried (at about 80°C) and weighed again to determine fresh and dry weight. A t-test was used to compared the biomass between sites. Primary productivity was determined by calculating the rate of change of biomass.

Figure 5. A permanent quadrat for surveying the ground flora.

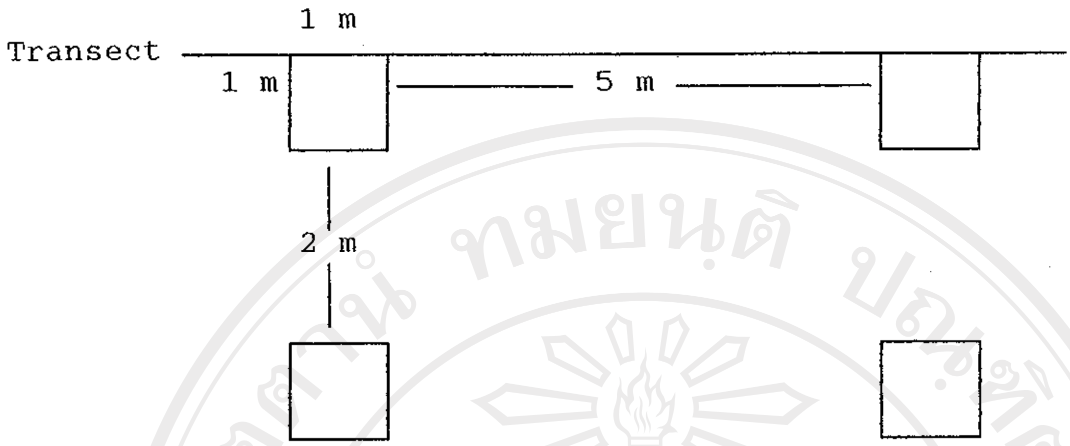

Figure 6. Diagram showing the quadrat positions along the transects.

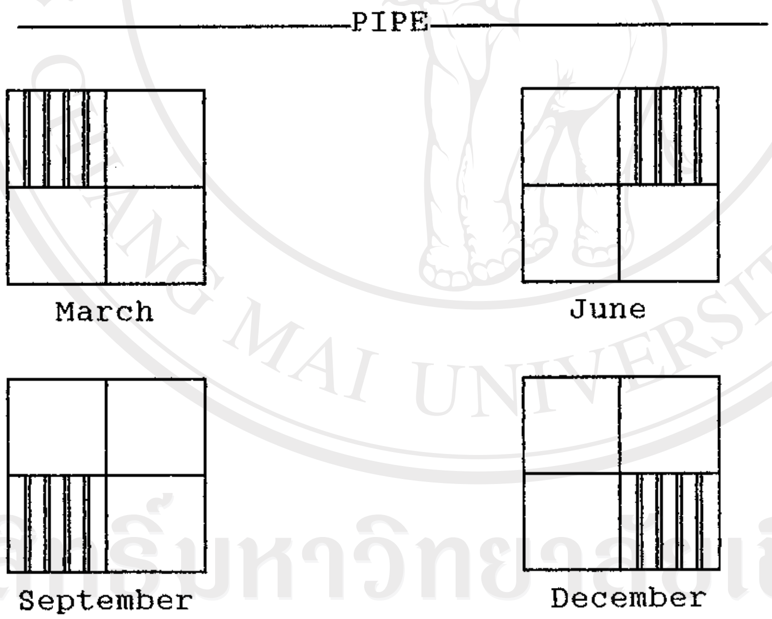

Figure 7. Diagram showing the position of harvested part of the quadrat in at each time during the productivity study. (‖ : the part that harvested.)

Figure 8. Harvesting method (December 1993).

Soil Analysis.

Twelve 1 kg soil samples were collected from each transect at the beginning of the study and analyzed for field capacity, organic matter, pH, nutrients, etc. (using standard methods at the Faculty of Agriculture Central Soil Laboratory). Every month 100 g soil samples were collected (in plastic bags fastened with rubber bands to avoid evaporation) to determine of soil moisture content. Soil samples were dried in an oven at 80°C and the moisture content calculated as percentage of gram water per 100 gram dry soil.

5. RESULTS

Ground Flora Community

Species/Area Curves

Species/area curves were constructed from species frequency data by summing the probabilities of each species occurring in a given number of quadrats (Appendix 4). The curves in Fig. 9 show that non-irrigated gully (NIG) had the highest species richness and non-irrigated ridge (NIR) the lowest. The total number of species in IR (irrigated ridge), NIR, IG (irrigated gully) and NIG was 39, 39, 52 and 63 respectively. The species area curves also show that the number of quadrats used was not enough to contain all species especially in the gully site, both for IG and NIG.

Species Diversity and Evenness

Species diversity indices (both N1 and N2) were higher in the non-irrigated sites, both for the ridge and the gully area. The evenness were also the same (Tab. 1)

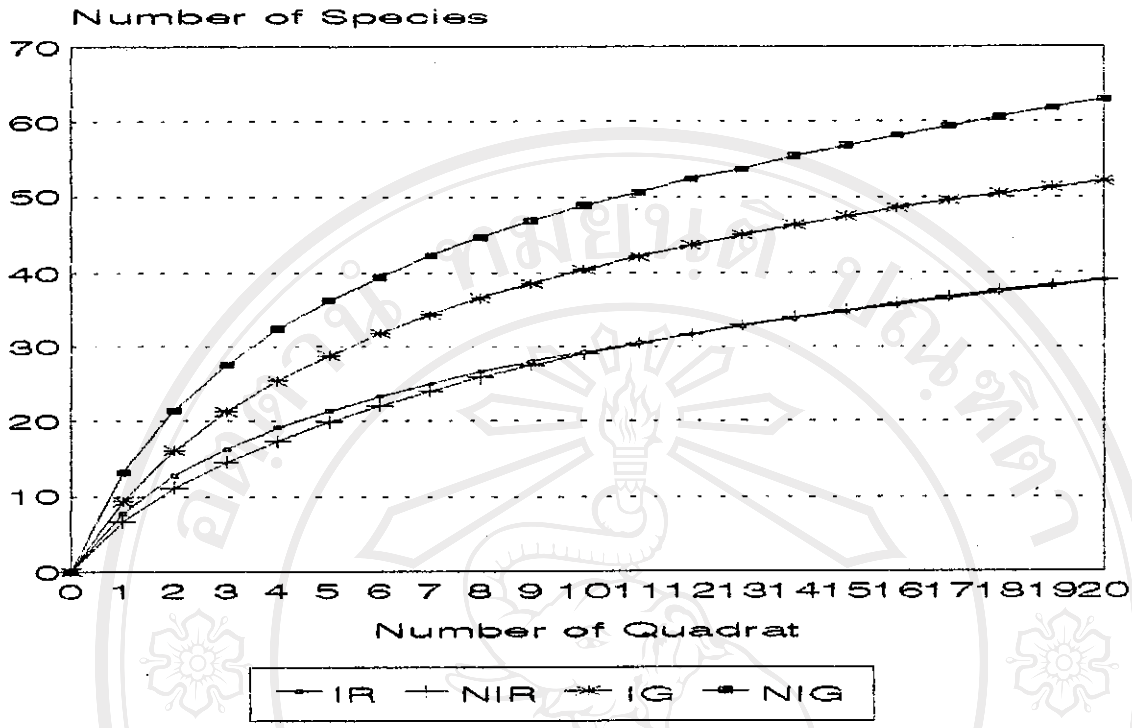

Figure 9. Species/Area curves in four sites.

Annual and Perennial Species Composition

Most members of the ground flora in the 4 sites were perennial. On the ridge site irrigation appeared to reduce the number of perennial species whereas in the gully site it had hardly any effect (Tab. 2). Although the number of perennial species was lower in the irrigated area, their abundance score, compared to the non-irrigated area, was higher. The area that had the highest percentage perennial abundance score was the IG (95.27%) (Tab. 3). The abundance scores for ridge sites were highest in October and lowest in June for the IR but in the NIR, the lowest score was in May. The abundance score for the gully sites peaked earlier in September (Fig. 10).

Table 1. Species diversity (Hill's number) and Evenness (Modified Hill's ratio).

Index	IR	NIR	IG	NIG
Species Diversity				
N1	16.3	19.5	30.6	36.2
N2	11.2	14.6	25.0	31.5
Evenness				
Modified Hill's	0.7	0.7	0.8	0.9

Table 2. Percentage of annual and perennial species in four area.

Study Site	IR	NIR	IG	NIG
Total number of species	39	39	52	64
% Annual species	33.67	23.08	13.46	15.62
% Perennial species	66.67	76.92	86.54	84.38

* The raw data are in appendix 3.

Table 3. Percentage of abundance score occupy by annual and perennial species, % of Domin score.

% of Domin score	IR	NIR	IG	NIG
Annual species	9.84	10.19	4.73	8.34
Perennial species	90.16	89.81	95.27	91.66

* The raw data are in appendix 3.

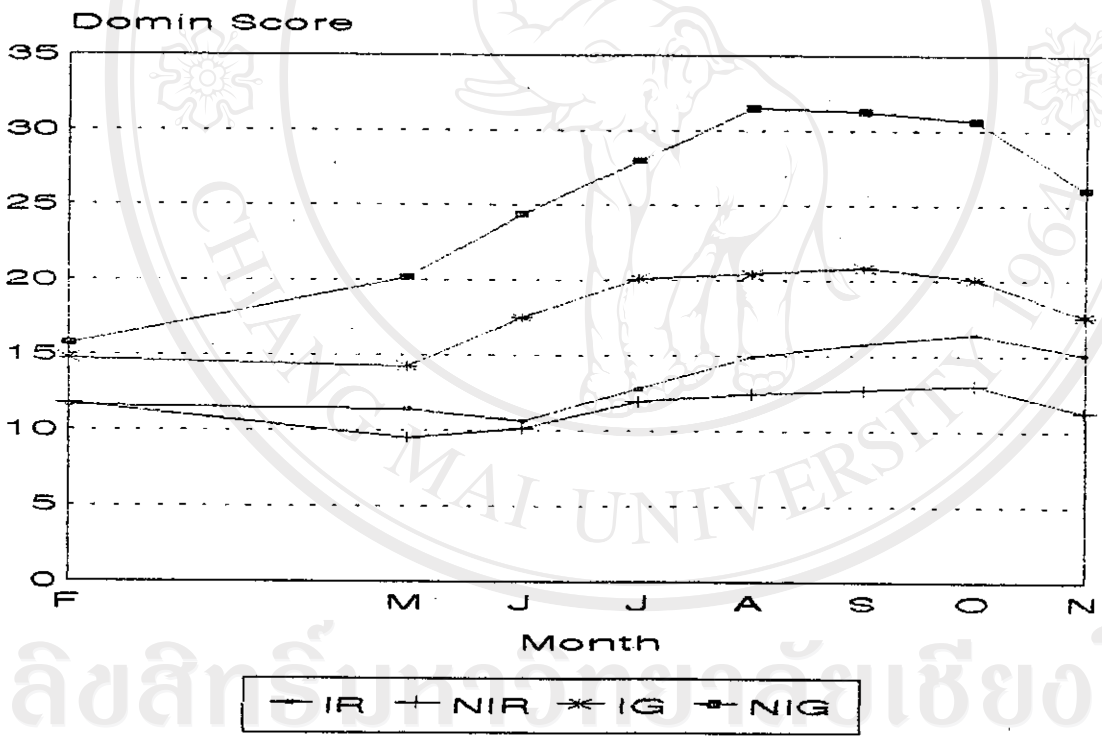

Figure 10.The variation of abundance score (Domin score) of 4 study sites.

Flowering and Fruiting

Most ground flora species in all sites flowered at the end of the rainy season (Fig. 12) and fruited in June to November (Fig. 11). Thirteen species flowered in the IR, 17 in the NIR, 17 in the IG and 22 in the NIG. Some species flowered in more than one site but the timing was different, e.g. *Arundinella setosa* (Gramineae) flowered in August in the IR and in September in the IG but in the NIR and the NIG it began to flower in October. In contrast, *Inula indica* (Compositae) began to flower in the NIR and the NIG before it did so in the irrigated area. Fruiting of the ground flora also occurred mainly at the end of rainy season and the beginning of the dry season but not all species which flowered were observed fruiting (Fig. 12).

Cluster Analysis

Cluster analysis failed to demonstrate clear grouping of the quadrats. Greatest separation was between ridge sites and gully sites. Irrigation did not seem to have caused the development of distinctly different communities (Fig. 13).

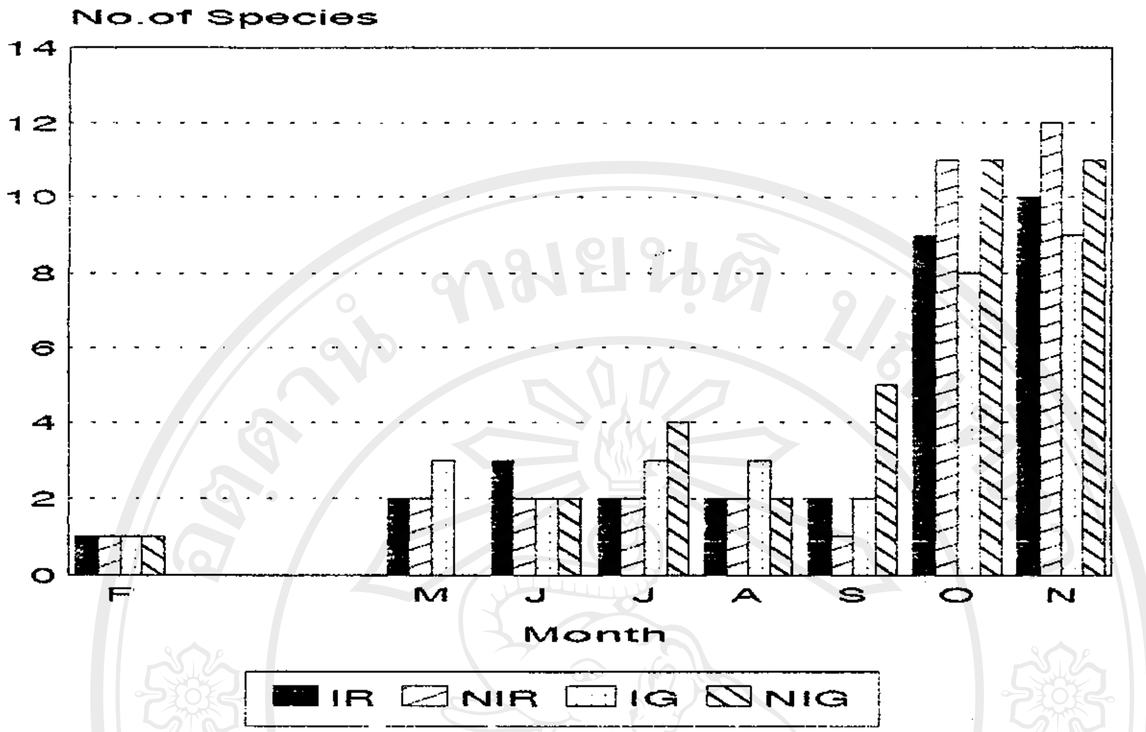

Figure 11. Number of species flowering in four different sites.

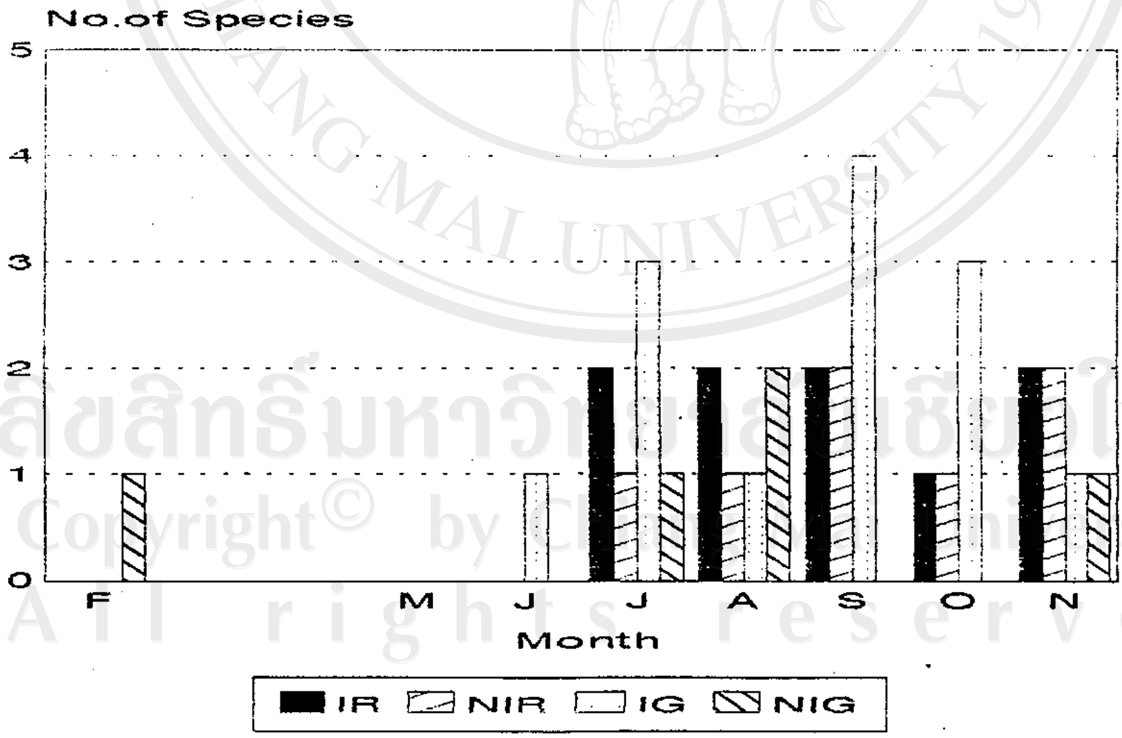

Figure 12. Number of species fruiting in four sites.

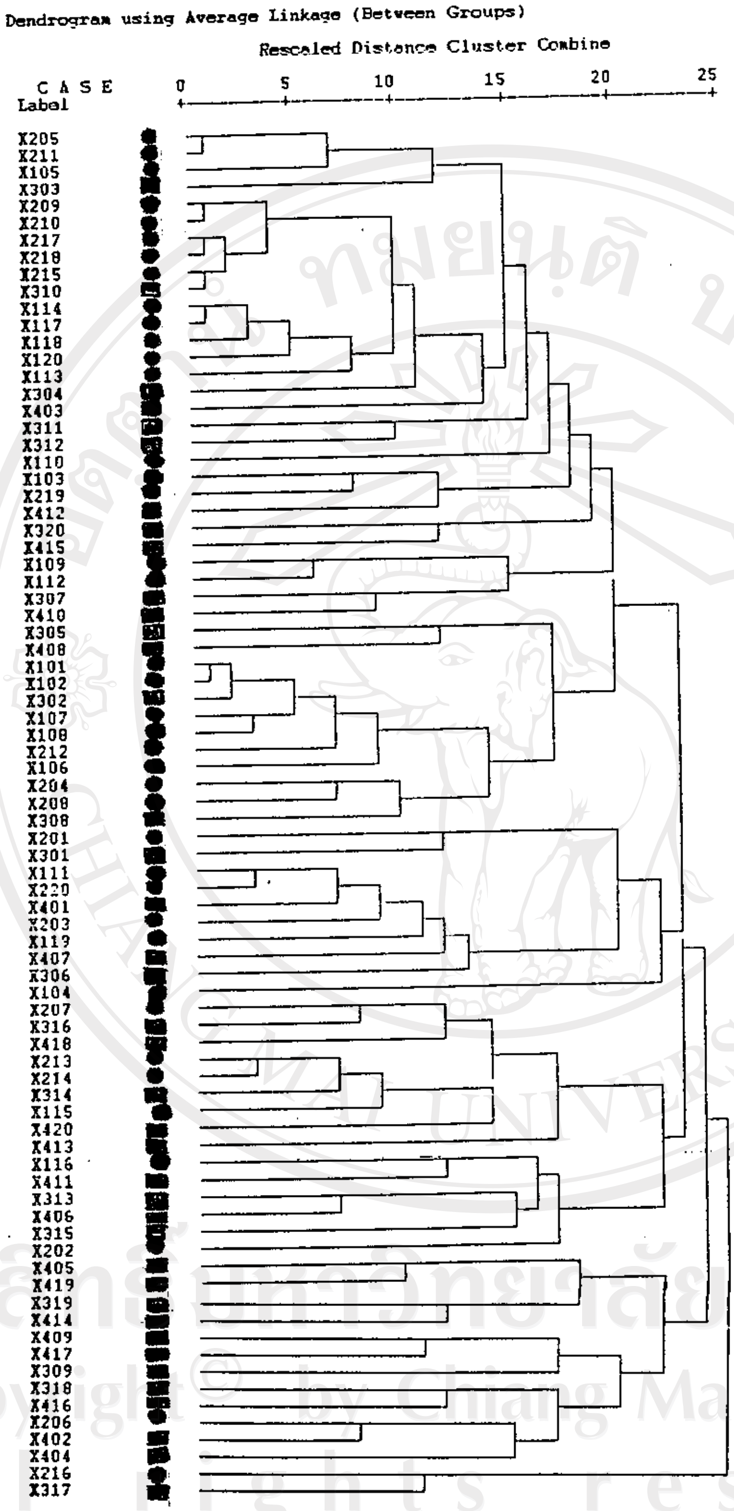

Figure 13. Dendrogram from cluster analysis of four sites.

● : IR, ●: NIR, ■ :IG, ■:NIG

Species that difference between IR and NIR, IG and NIG

On the ridges, 15 species were recorded solely on the IR and another 15 species only in the NIR. In the gully sites, only 8 species were recorded solely in the IG and 21 species solely in the NIG. However, most of these species are typical of deciduous forest. All of the species recorded solely in the irrigated sites were still typical of deciduous dipterocarp forest. So there was no indication that irrigation was causing any major difference in ground flora community. (Appendix 1) The similarity (Sorensen's index) between the ground flora community in IR and NIR was 0.62 while the similarity between IG and NIG was 0.74.

Biomass and Productivity

Biomass

The total above ground biomass (living and dead standing crop) on the IR peaked in February (299.933g/m^2) and September (285.374g/m^2) while on the NIR it peaked in June (222.169g/m^2). The living standing crops of both areas were highest in September, which was the middle of the rainy season, 155.536g/m^2 on the IR and 84.541g/m^2 on the NIR. The total and living standing crops on the IR were always higher than those on the NIR. (Fig.14)

Living/Dead ratio

The living/dead standing crop ratio was higher in the IR plot than in the NIR plot during the first and the third harvesting, but in December the ratios were at the same level. The highest ratio was in September, (1.197 on the IR and 0.938 on the NIR).

Biomass Moisture Content

The moisture content of the living standing crop was higher than that of the dead standing crop in both areas. During the first two harvestings (March and June) the moisture content of the biomass in IR was significantly higher than in NIR.

Productivity

Productivity (the different between B_1 and B_2 of the living standing crop within 3 months) was highest in September in both areas (78.582g/m^2/3 months in IR and 45.628g/m^2/3 months in NIR). The annual net primary productivity (estimated by the formula $P_n = B_{max}$) was 155.536g/m^2 on the IR and 84.541g/m^2 on the NIR.

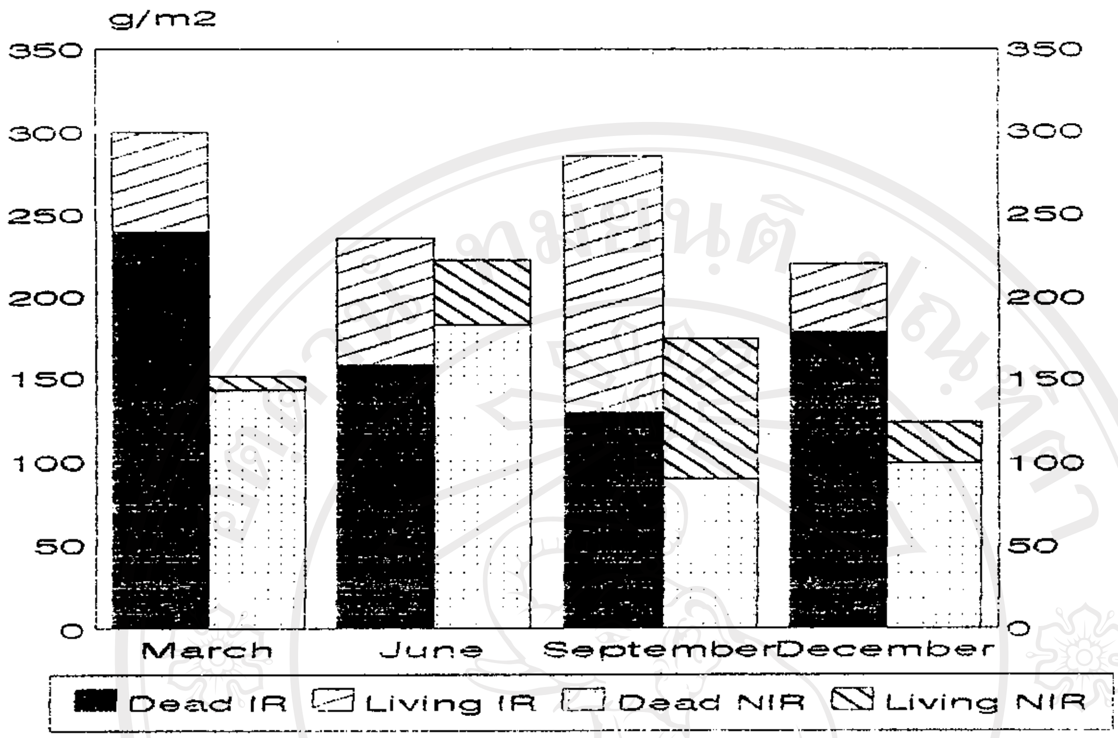

Figure 14. Living and dead biomass (g/m^2).

Soil

Soil Properties

The soil texture at all sites (IR, NIR, IG and NIG) was mainly sandy. There were no significant differences in soil texture between the IR and the NIR. The IG had significantly higher clay content than the NIG. Field capacity was highest in IG and lowest in NIG. Irrigation did not significantly increase organic matter in the gully or on the ridge (Tab. 4).

The pH of the soil was about 6 - 7. There was very little difference in Nitrogen (N) between the sites. Potassium (K) in the gullies was higher than on the ridges, but there was no significant deference within the ridge sites or within the gully sites ($p<0.01$). Only Phosphorus (P) showed a significant difference between the IR and the NIR.

Soil Moisture

Figure 15 shows the variation of soil moisture during the observation period, combined with the monthly rainfall and mean temperature of Huai Hong Khrai. During the irrigation period, February, March and April, the soil moisture content on the IR was higher than that on the NIR, but after the irrigation period, soil moisture in the both areas was very similar only in October and November that the moisture of the NIR exceeded that of the IR. The IG had consistently higher soil moisture than the NIG.

Table 4. Comparison of soil roperties between IR and NIR, IG and NIG

Property	IR		NIR		Level of significant	IG		NIG		Level of significant
	mean	sd	mean	sd		mean	sd	mean	sd	
Soil Texture										
% Sand	50.50	12.00	56.81	7.00	ns	45.75	9.95	59.37	8.61	p<0.01
% Silt	19.33	6.36	18.35	3.39	ns	22.93	8.4	21.4	7.61	ns
% Clay	24.75	4.22	22.17	6.98	ns	30.79	8.47	19.15	11.11	p<0.01
Nutrients										
% Nitrogen	0.20	0.07	0.22	0.55	ns	0.34	0.07	0.29	0.07	ns
Phosphorus (ppm exchangeable)	27.67	15.31	9.25	4.53	p<0.01	19.79	11.57	16.86	7.31	ns
Potassium										ns
(ppm exchangeable)	31.46	20.407	31.88	17.87	ns	71.68	33.06	72.7	28.85	ns
pH	6.32	0.37	6.14	0.32	ns	6.70	0.27	6.59	0.56	ns
% Organic matter	4.16	1.47	4.44	1.10	ns	7.06	1.91	5.86	1.61	ns
%Moisture at Field Capacity	30.10	5.10	32.24	2.96	ns	37.12	3.73	31.61	3.75	p<0.001

The lower the value of p, the more significant is the differece between the means.(ns = difference not significant, $p>0.1$)

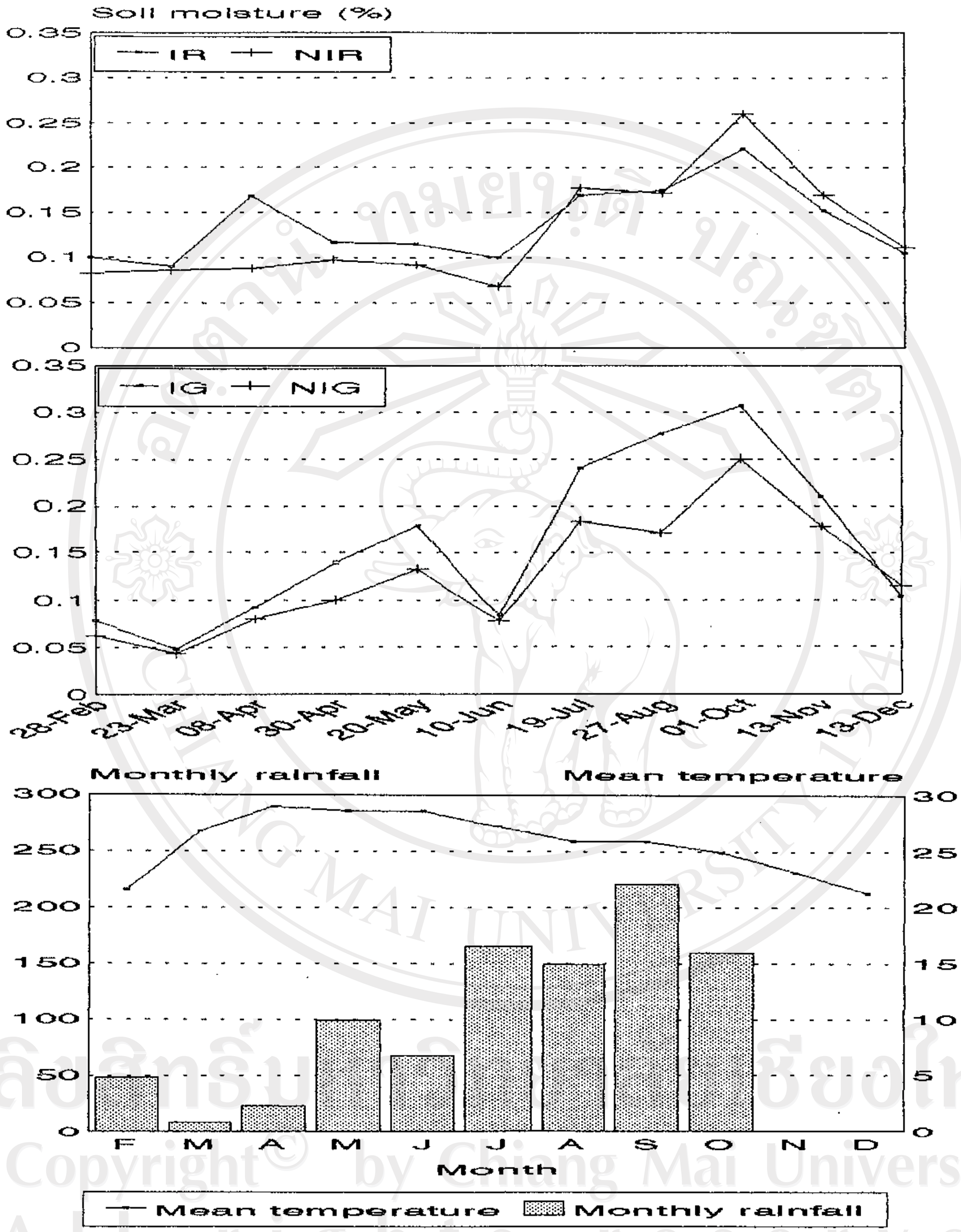

Figure 15. The variation of soil moisture in four study sites with monthly rainfall and mean temperature. (February - December 1993)

6. DISCUSSION

Species-area curves are commonly used to determine the minimum area that can represent a community (Krebs, 1989). The species-area curves from this study showed that the number of quadrats used was not enough to contain all ground flora species for all sites. All curves failed to reach an upper asymptote. However the slopes of the ridge site curves were lower than those for the gully sites and the number of species in non-irrigated gully (NIG) could be expected to be the highest. As in other tropical deciduous forest, the number of species in gullies is normally higher than on ridges, probably due to increased soil moisture content.

Although the number of species on the IR and the NIR were the same, the species composition of these 2 areas differed. The number of perennial species in the non-irrigated area, both for the ridge and the gully, was higher than in the irrigated area. However the Domin score of perennial species in the irrigated areas was slightly higher than in the non-irrigated areas. So perennials in the irrigated sites seem to grow better than in the non-irrigated sites. The abundance scores on the IR were higher than on the NIR. This may be due to a longer period of water availability in the IR site. In the irrigated area, the part which should have demonstrated the greatest effects of irrigation was the upper part (the ridge), but even there the effect was not clear. This may be because of the inefficiency of the irrigation system and the location of the transect. The irrigation system used in this project consisted of pipes and the water just came out from the holes in the pipes. Using this system the water did not spread out eventually over the entire area. Efficiency was low. So only small parts of the site were directly affected by the water. The irrigated ridge (IR) transect in this study was located about 10m from the pipe and very little water actually reached to the quadrats. Therefore the effect of the water was low. However, some effects can be seen on the IR. From February to May, there was very little variation in the abundance scores, while on the non-irrigated ridge (NIR) the abundance score in May had clearly decreased, because in the IR the available water in the soil was high enough to allow vegetation growth but in the NIR a lack of water caused decreased ground cover. In the gully sites the abundance score was highest in the NIG. However, variation in the abundance scores was similar for both areas, so the effects of irrigation were not evident in the gully site.

There were some species that occurred in the gullies and on the IR but not on the NIR, for example, *Pueraria stricta* Kurz (Leguminosae), *Merremia quinata* (R.Br.) Kerr

(Covolvulaceae), *Gutzlaffia pedunculata* Craib (Acanthaceae) and *Cyanotis cristata* (L.) D. Don (Commelinaceae) (out of quadrat). Some species that occurred in the gullies sites were also observed growing near the pipe on the IR such as the ground orchid *Habenaria hosseusii* Schltr (Orchidaceae). This suggests that the environment on the IR, especially near by the pipe, may have more suitable conditions for species that normally grow in the gully sites.

In the study of Elliott (1991) and Pinkowski *et al.* (1985) other systems of irrigation, with higher efficiency, were used. Sprinklers were used at the study site surveyed by Elliott, while in the study of Pinkowski *et al.* feedlot effluent was spread out by means of a gravity-flow system (Appendix 5). In both studies the results showed clear effects of irrigation in a shorter time compared with this study at Huai Hong Khrai. After 1-2 dry season irrigation in degraded deciduous dipterocarp forest in Mae Soi, Chom Tong, Chiang Mai, the ground flora community changed. The number of species in the control site of that project was similar to the number of species in the IR and the NIR (about 26 species in 8 m^2) and the number of the irrigated site in Mae Soi was about 36 species in 8 m^2, about the same as the IG. The study of effect of feedlot runoff by Pinkowski also detected changes after only four years of irrigation. However in this study, besides available water, another factor that affected the community was nutrients. So the effects of this study may be due to one or both of two factors.

Cluster analysis of the 80 quadrat in the 4 study sites could not clearly distinguish the quadrats from the different sites. The community in the irrigated site was expected to be more similar to moist sites.

In this study, control sites were used as baseline data to monitor changes in the community after irrigation. However, no two communities are exactly the same and differences between the control and treatment sites may have existed before irrigation began. The system used in this study was that of a "natural experiment". As in many ecological studies, the experiment began when the project was already in progress (Hairston, 1991) and we cannot sure about the initial conditions of the study sites. However, since no data was collected before the irrigation pipes were laid, this was the only method possible. Also because the irrigated and non-irrigated areas were very close and did not differ in slope and altitude, etc. it is likely that any differences between them were due to irrigation.

In the study of flowering and fruiting times of the ground flora, the period between observations may have been too long. Some species that were recorded as flowering were not recorded in fruit. For some ground flora species their period of fruiting and flowering was shorter than one month and other factors such as predation or lack of pollinator, etc. Therefore their fruiting was not observed. For example, *Globa nuda* K. Lar (Zingiberaceae), *Habenaria hosseusii* Schltr. (Orchidaceae) and *Grewia eriocarpa* Juss. (Tiliaceae).

The results of the study of primary productivity and biomass showed clearer effects of irrigation. This may have been due to the position of the transect for this study, which was laid next to the irrigation pipe. Therefore the vegetation in the quadrats received water from the system directly. Both total and living standing crop on the IR were higher than on the NIG throughout the study. The difference between living standing crops in the two area was highest in March, during the period of irrigation (from February to April). So irrigation allowed the vegetation in the IR to grow during the dry season, which is normally the period of lowest ground cover in deciduous dipterocarp forest.

The dead standing crop in the IR was highest in March with a marked decrease from March to June, while in the NIR it still increased and decreased from June to September. This may be related to soil moisture during the dry season which allows the decomposer organisms in the IR to begin their activity earlier and dead standing crop was changed into soil organic matter. However, in the NIR during dry season the environment was too dry for the decomposers. Therefore, the dead standing crop still accumulated until the rainy season began. The rate of litter decomposition mainly depends on climatic conditions, especially moisture (Hopkin, 1966 and Naik and Mishra, 1976). Therefore, in natural where available water come from rain, liter decomposition in dry area mainly occurred during the rainy season and lowest in the dry season.

The living/dead standing crop ratios from the dry season to the beginning of rainy season on the IR were higher than on the NIR. This showed that plants on the IR can maintain their living parts through the dry season better than those on the NIR.

The NPP/3 months from March to June on the IR was smaller than on the NIR. This may be because the vegetation on the IR had already flushed up in the dry season (March), so the difference of biomass from March to June was low. However, on the NIR, most of the vegetation began to flush up when the rains began. Therefore, the difference in NPP from March to June in the NIR was higher than on the IR. The moisture content of the living standing crop on the IR was significantly higher than on the NIR in March and June, which was during and after the watering period. However, during the rainy season, the moisture contents were at the same levels in both the IR and the NIR, because available water came from rain water only.

The annual above ground productivity (Bmax-Bmin) in this area is compared to other plant communities in Tab.5. The productivity of both the IR and the NIR was lower than that of dry dipterocarp forest and savanna. The productivity of both the IR and NIR were the same as the prairie community only. However, this estimation can be lower estimate, because the harvesting of biomass was done only every 3 month. So the highest and the lowest of living standing crop may occur between 2 observation, therefore the estimated annual productivity will be too low.

Table 5. Annual primary production in different types of vegetation.

Vegatation Type	Annual Primary Productivity (kg/ha)	References
Prairie (USA)		Olson, 1971
Herb layer	920	
Shrub layer	10	
Savanna (USA)		Olson, 1971
Herb layer	1886	
Shrub layer	41	
Arundinaria pusilla in dry dipterocarp forest	3419	Khuldeloke, 1983
IR	1138	
NIR	765	

One interesting observation made during the study was the blooming and high density of the species *Mimosa diplotricha* (L.f.) Bth. (Leguminoseae, Mimosoideae) on the IR, mainly near by the pipe. This plant is an exotic species, from tropical America, introduced into the area. It normally grows in disturbed areas. This species may arrive as seeds in water in the irrigation system. Disturbance during construction of the irrigation system favours this species instead of local species. This may have hindered the ability of native species to regenerate on the IR.

Variation in soil moisture mainly depends on rainfall. However, during the dry season soil moisture on both the IR and the IG was higher than that on the NIR and the NIG, but the differences were very low.

Irrigation seem to have very little effect on soil properties. On the ridge sites only phosphorus on IR was significantly higher than on the NIR, while in the gullies, in the IG, clay content and moisture content at field capacity were significantly higher than in the NIG. Organic matter in all areas was not significantly different. Although primary productivity of the irrigated area was higher than in the non-irrigated ridge, soil organic matter was not increased. This may have been due to higher decomposition activity. For example, it is known that earthworm populations in tallgrass prairie increase with irrigation (James, 1988). Another factor is temperature. Decomposition rate increases with increasing temperature (Tsutsumi, 1971 and Woodmansee and Duncan, 1980). Higher temperatures tend to increase respiratory breakdown of organic matter by decomposer, more than it increases photosynthetic production. Etherington (1982) suggested that if the temperature is higher than 25 °C in a well aerated soil, organic matter cannot accumulate. The mean temperature at Huai Hong Khrai for more than half the year was higher than 25 °C. Therefore accumulation of organic matter is unlikely to occur.

In this study, only one nutrient, phosphorus, was significantly higher on the IR. This may due to the properties of nutrients. Nitrogen is easily lost from the upper part of the soil due to leaching and volatilization. In the NO_3 (nitrate) form, nitrogen is very easily leached down to the lower part of the soil, while in the ammonia form, it is volatilized from the soil. Compared to nitrogen, phosphorus, especially as phosphate, has very low solubility, so, phosphorus can be maintained in the upper part of soil longer (Thompson, 1957 and Gardner, 1965). Another factor that could have caused an increase in phosphorus was quality of the water which put into the area, but from a study of water quality in the reservoir that supplied water for the area by Peerapornpisan (unpublished) all nutrients, including phosphorus, were low. Therefore the increased phosphorus in the area was probably due to the first factor. Anunsiriwat (1986) suggested that phosphorus can be used as a parameter to estimate the amount of biomass. So increasing phosphorus may also have a positive feedback effect on the production of biomass of the area.

The higher clay content in the IG may be due to a higher decomposition rate, increasing the rate of changing organic matter into clay particles. Clay is very fine particle. Therefore it is very easily leached down to the gully site. The lower portion of sand and higher portion of clay content in soil was probably responsible for the increased moisture content at field capacity in the IG, because clay can absorb more water than sand.

7. CONCLUSION

Species area curves showed that not enough quadrats were used in the study especially for the gully sites. The species diversity (Hill's number) and evenness (Modified Hill's ratio) were highest in the NIG and lowest in the IR. The percentage of perennial species on the NIR were higher than on the IR, while in IG and NIG, the percentage of perennial species was almost the same. However, the abundance scores for perennials were higher in the irrigated area for both ridge and gully. Irrigation therefore created a more suitable environment for perennial species to grow and compete with annual species. The similarity (Sorensen's indix) was higher when compare the community of IG with NIG site and lower when compare the community of IR and NIR.

Flowering mostly occurred at the end of rainy season and fruiting occurred between June to November. However, some species had slightly different flowering and fruiting periods in the different sites. Further studies of flowering and fruiting of the ground flora should use a higher frequency of observation, may be every 2 weeks, because the flowering and fruiting periods of some ground flora species is shorter than a month.

The effects of irrigation were more evident in the study of biomass and productivity. The total biomass in the IR was higher than that in the NIR throughout the study. The ground flora in the IR began to flush up earlier after irrigation while the vegetation in the non-irrigated site flushed up only after rain. The decomposition rate of dead standing crop during the dry season in the IR seemed to be higher than that in the NIR (which can be observed from the decreasing dead standing crop from March to June in the IR), due to higher soil moisture and decomposer activity. The annual productivity on the IR was also higher than on the NIR.

Soil texture and properties in all sites were very similar, only phosphorus showed a significant difference between the IR and the NIR. Soil moisture content in the IG was higher than in the NIG and on the IR, soil moisture content during the irrigation period was higher than on the NIR but from the beginning of rainy season that of the NIR, was higher.

Most results showed that the efficiency of the irrigation system was not very high. Only the transect of the biomass study which was laid very near the pipe showed clear effects, while the study of ground flora community, about 10 m from the pipe, showed very low effects. The irrigation system for this project should be improved or changed to another system which has a higher efficiency.

Above all future studies of the effects of irrigation on forests should include data collection before irrigation is started. So that the original condition of the ecosystem is well described and subsequent changes can then be attributed to the irrigation treatment.

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APPENDIX

APPENDIX 1 Species List

1.1 Species list (ordered by name of family).

	a/p	Habit
Acanthaceae		
Barleria cristata L.	p	h
Gutzlaffia pedunculata Craib	p	ds
Anacardiaceae		
Buchanania glabra Wall. ex HK. f.	p	dt
Buchanania latifolia Roxb.	p	dt
Annonaceae		
Ellipeia cherrevensis Pierre ex Fin.& Gagnep.	p	ds
Apocynaceae		
Aganosma marginata (Roxb.) G. Don	p	ev
Araceae		
Amorphophallus sp.	p	dh
Bignoniaceae		
Stereospermum colais (B.H. ex Dillw.) Mabb.	p	dt
Burseraceae		
Protium serratum (Wall. ex Colebr.) Engl.	p	dt
Combretaceae		
Terminalia alata Hey. ex Roth	p	dt
Commelinaceae		
Cyanotis cristata (L.) D. Don	a	h
Murdannia scapiflora (Roxb.) Roy.	p	dh
Compositae		
Blumea lacera (Burm. f.) DC.	a	h
Blumeopsis flava (DC.) Gagnep.	a	h
Eupatoraium odoratum L.	a/p	h
Inula indica (L.) Sw.	a	h

Convolvulaceae		
Merremia quinata (R.) Kerr	a	v
Cyperaceae		
Cyperus leucocephalus Retz.	p	h
Fimbristylis dichotoma (L.) Vahl spp. *dichotoma*	a/p	h
Scleria levis Retz.	p	h
Dipterocarpaceae		
Dipterocarpus tuberculatus Roxb. var. *tuberculatus*	p	dt
Shorea obtusa Wall. ex Bl.	p	dt
Shorea siamensis Miq. var. *siamensis*	p	dt
Euphorbiaceae		
Breynia glauca Craib	p	ds
Bridelia retusa (L.) Spreng.	p	dt
Gramineae		
Arundinella setosa Trin. var. *setosa*	p	dh
Capillipedium parviflorum (R. Br.) Stapf	p	dh
Eulalia birmanica (Hk.f.) A. Camus	p	dh
Eulalia quadrinervis (Hack.) O.K.	p	dh
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	p	dh
Heteropogon triticeus (R. Br.)	p	dh
Hyparrhenia rufa (Nees) Stapf var. *siamensis* Clay.	p	dh
Ophiuros exaltatus (L.f.) O.K.	p	dh
Sehima nervosum (Rottl.) Stapf	p	dh
Sorghum nitidum (Vahl) Pers.	p	dh
Themeda triandra Forssk.	p	dh
Hypoxidaceae		
Hypoxis aurea Lour.	p	dh
Labiatae		
Geniosporum coloratum (D. Don) O.K.	p	dh
Leucas flaccida R. Br.	a	h
Leeaceae		
Leea indica L.	p	s-tl
Leguminosae		
Papiliondeae		
Crotalaria alata D. Don	a	h
Crotalaria albida Hey. ex Roth	a	h
Crotalaria neriifolia Wall. ex Bth.	a	h
Dalbergia fusca Pierre	p	dt
Desmodium laxiflorum DC. spp. *laxiflorum*	a	h
Desmodium pulchellum (L.) Bth.	p	ds

Dunbaria longeracemosa Craib	p	dv
Flemingia chappar Ham. ex Bth.	p	ds
FLemingia grahamiana Wight & Arn.	p	h-s
Pueraria stricta Kurz	p	ds-v
Spatholobus parviflorus (Roxb.) O.K.	p	dwc
Uraria lagopodiodes (L.) Desv. ex DC.	a	h
Caesalpinioideae		
Bauhinia sp.	p	
Mimosoideae		
Albizia odoratissima (L.f.) Bth.	p	dt
Mimosa diplotrica C. Wright ex Sauv. var. *diplotrica*	a	v
Xylia xylocarpa (Roxb.) Taub var. *kerrii* (Craib & Hutch.) Niels.	p	dt
Myrsinaceae		
Embelia subcoriacea Mez	p	ds
Ochnaceae		
Ochna integerrima (Lour.) Merr.	p	dtl-t
Orchidaceae		
Habenaria hosseusii Schltr.	p	dh
Palmae		
Phoenix humilis Roy. var. *humilis*	p	es
Parkerioceae		
Adiantum erylliae C. Chr. & Tard	a	h
Adiantum zollingeri Mett. ex Kuhn	a	h
Rubiaceae		
Borreria brachystema (R. Br. ex Bth.) Valet	a	h
Ceriscoides turgida (Roxb.) DC.	p	dt
Gardenia obtusifolia Roxb. ex Kruz.	p	ds-tl
Knoxia corymbosa Willd.	a	h
Mussaenda parva Wall. ex G. Don	p	esc
Paederia pallida Craib	p	v
Selaginellaceae		
Selaginella ostenfeldii Hier.	a	h
Smilaaceae		
Smilax verticalis Gagnep.	p	dv
Tiliaceae		
Grewia abutilifolia Vent. ex Juss.	p	dt
Grewia eriocarpa Juss.	p	dt

Verbenaceae		
Premna herbacea Roxb.	p	dh
Premna nana Coll.& Hemsl.	p	dh
Vitaceae		
Ampelocissus martini Planch.	p	dv
Zingiberaceae		
Boesenbergia rotunda (L.) Mansf.	p	dh
Curcuma longa L.	p	dh
Curcuma zedoaria (Berg.) Rosc.	p	dh
Globba nuda K. Lar.	p	dh
Kaempferia rotunda L.	p	dh
moss	a/p	h

Note a: annual, p: perennial, h: herb, v: vine, s: shrub, tl: treelet, t: tree, d:deciduous, e: evergreen, wc: woody climber, sc: scandent

1.2 Species list (ordered by species name)

Taxonomic name	Family
Adiantum erylliae C. Chr. & Tard	Parkerioceae
Adiantum zollingeri Mett. ex Kuhn	Parkerioceae
Aganosma marginata (Roxb.) G. Don	Apocynaceae
Albizia odoratissima (L.f.) Bth.	Mimosoideae
Amorphophallus sp.	Araceae
Ampelocissus martini Planch.	Vitaceae
Arundinella setosa Trin. var. *setosa*	*Gramineae
Barleria cristata L.	*Acanthaceae
Bauhinia sp.	Caesalpinioideae
Blumea lacera (Burm. f.) DC.	Compositae
Blumeopsis flava (DC.) Gagnep.	Compositae
Boesenbergia rotunda (L.) Mansf.	Zingiberaceae
Borreria brachystema (R. Br. ex Bth.) Valet	Rubiaceae
Breynia glauca Craib	Euphorbiaceae
Bridelia retusa (L.) Spreng.	Euphorbiaceae
Buchanania glabra Wall. ex HK. f.	Anacardiaceae
Buchanania latifolia Roxb.	Anacardiaceae
Capillipedium parviflorum (R. Br.) Stapf	Gramineae
Ceriscoides turgida (Roxb.) DC.	Rubiaceae
Crotalaria alata D. Don	Papiliondeae
Crotalaria albida Hey. ex Roth	*Papiliondeae
Crotalaria neriifolia Wall. ex Bth.	Papiliondeae
Curcuma longa L.	Zingiberaceae

Curcuma zedoaria (Berg.) Rosc.	*Zingiberaceae
Cyanotis cristata (L.) D. Don	Commelinaceae
Cyperus leucocephalus Retz.	Cyperaceae
Dalbergia fusca Pierre	Papiliondeae
Desmodium laxiflorum DC. spp. *laxiflorum*	Papiliondeae
Desmodium pulchellum (L.) Bth.	Papiliondeae
Dipterocarpus tuberculatus Roxb. var. *tuberculatus*	Dipterocarpaceae
Dunbaria longeracemosa Craib	*Papiliondeae
Ellipeia cherrevensis Pierre ex Fin.& Gagnep.	Annonaceae
Embelia subcoriacea Mez	Myrsinaceae
Eulalia birmanica (Hk.f.) A. Camus	Gramineae
Eulalia quadrinervis (Hack.) O.K.	Gramineae
Eupatoraium odoratum L.	Compositae
Fimbristylis dichotoma (L.) Vahl spp. *dichotoma*	Cyperaceae
Flemingia chappar Ham. ex Bth.	*Papiliondeae
Flemingia grahamiana Wight & Arn.	Papiliondeae
Gardenia obtusifolia Roxb. ex Kruz.	Rubiaceae
Geniosporum coloratum (D. Don) O.K.	Labiatae
Globba nuda K. Lar.	Zingiberaceae
Grewia abutilifolia Vent. ex Juss.	Tiliaceae
Grewia eriocarpa Juss.	Tiliaceae
Gutzlaffia pedunculata Craib	Acanthaceae
Habenaria hosseusii Schltr.	Orchidaceae
Heteropogon contortus (L.) P. Beauv. ex Roem. & Schult.	Gramineae
Heteropogon triticeus (R. Br.)	*Gramineae
Hyparrhenia rufa (Nees) Stapf var. *siamensis* Clay.	Gramineae
Hypoxis aurea Lour.	Hypoxidaceae
Inula indica (L.) Sw.	*Compositae
Kaempferia rotunda L.	Zingiberaceae
Knoxia corymbosa Willd.	Rubiaceae
Leea indica L.	Leeaceae
Leucas flaccida R. Br.	Labiatae
Merremia quinata (R.) Kerr	Convolvulaceae
Mimosa diplotrica C. Wright ex Sauv. var. *diplotrica*	*Mimosoideae
Murdannia scapiflora (Roxb.) Roy.	Commelinaceae
Mussaenda parva Wall. ex G. Don	Rubiaceae
Ochna integerrima (Lour.) Merr.	Ochnaceae
Ophiuros exaltatus (L.f.) O.K.	Gramineae
Paederia pallida Craib	Rubiaceae
Phoenix humilis Roy. var. *humilis*	Palmae
Premna herbacea Roxb.	Verbenaceae
Premna nana Coll.& Hemsl.	Verbenaceae
Protium serratum (Wall. ex Colebr.) Engl.	Burseraceae
Pueraria stricta Kurz	*Papiliondeae
Scleria levis Retz.	Cyperaceae
Sehima nervosum (Rottl.) Stapf	Gramineae

Selaginella ostenfeldii Hier.	Selaginellaceae
Shorea obtusa Wall. ex Bl.	Dipterocarpaceae
Shorea siamensis Miq. var. *siamensis*	Dipterocarpaceae
Smilax verticalis Gagnep.	Smilaaceae
Sorghum nitidum (Vahl) Pers.	Gramineae
Spatholobus parviflorus (Roxb.) O.K.	Papiliondeae
Stereospermum colais (B.H. ex Dillw.) Mabb.	Bignoniaceae
Terminalia alata Hey. ex Roth	Combretaceae
Themeda triandra Forssk.	*Gramineae
Uraria lagopodiodes (L.) Desv. ex DC.	Papiliondeae
Xylia xylocarpa (Roxb.) Taub var. *kerrii* (Craib & Hutch.) Niels.	Mimosoideae

* The photograph of the species were in appendix 2.

Table A1.1 Species that were recorded solely in the IR (compairing with the NIR).

species	Habitat
Blumeopsis flava	df, eg/pine
Borreria brachystema	do
Cyanotis cristata	do
Dalbergia fusca	do, bb/df, eg/df
Dunbaria longeracemosa	do
Flemingia chappar	ddf*
Flemingia grahamiana	ddf*
Globba nuda	do, bb/df, eg/df
Gutzlaffia peduncullata	do
Mimosa diplotricha	da
Merremia quinata	
Mussaenda parva	do, bb/df, eg/df, egf
Smilax verticalis	do
Spatholobus parviflorus	do, bb/df
Uraria lagopodioides	do, bb/df

Data in table A1.1-4 mainly come from Doi Suthep Data base (1994)
*Center for Conservation Biology, MU (1992)

do	Deciduous Dipterocarp/Oak
bb/df	Bamboo/Deciduous forest
do/pine	Pine Dipterocarp
eg/df	Mixed Deciduous/Evergreen
eg	Evergreen Forest
eg/pine	Evergreen with pine
da	Disturbed areas, roadside
sg	Secondary Growth

Table A1.2 Species that were recorded solely in the NIR (compairing with the NIR).

species	Favoured Habitat
Aganosma marginata	do, bb/df, eg/df
Albizia ordoratissima	bb/df, eg/df
Boesenbergia rotunda	bb/df, eg/df
Bauhinia sp.	df
Curcuma zedoaria	do
Cyperus leucocephalus	do
Desmodium laxiflorum	bb/df
Eulalia birmanica	do
Gardenia obtusifolia	do
Grewia abutilifolia	do
Grewia eriocarpa	do, bb/df
Hypoxis aurea	do, bb/df, eg/pine
Kaempferia rotunda	do, bb/df, eg/pine
Premna herbacea	do
Themeda triandra	da, do, bb/df, eg/pine

Table A1.3 Species that were recorded solely in the IG (compairing with the NIR).

species	Favoured Habitat
Amorphophallus sp.	do, bb/df, eg/df, eg
Ampleocissus martini	do, bb/df
Blumea lacera	do, bb/df, eg/df
Crotalaria alata	do, bb/df
Hypoxis aurea	do, bb/df, eg/pine
Terminalia alata	do, bb/df
Themeda triandra	da, do, bb/df, eg/pine
Uraria lagopodioides	do, bb/df

Table A1.4 Species that were recorded solely in the NIG (compairing with the NIR).

Species	Habitat
Albizia ordoratissima	bb/df, eg/df
Bridelia retusa	do, bb/df
Buchanania glbra	do, sg
Buchanania latifolia	do, bb/df, eg/df
Capillipedium parviflorum	do, eg/pine
Crotalaria nerrifolia	do, eg/df
Curcuma longa	bb/df, eg/df, eg/pine
Dalbergia fusca	do, bb/df, eg/df
Desmodium laxiflorum	bb/df
Eulalia birmanica	do
Gardenia obtusifolia	do
Habenaria hosseusii	do
Heteropogon contortus	da, do, bb/df
Leucas flaccida	bb/df, eg/pine
Ochna integerrima	do
Ophiuros exaltatus	da, sg
Premna herbacea	do
Premna nana	do
Protium serratum	eg/df, egf
Stereosperum colais	bb/df, eg/df

2. Photograph of study sites and some ground flora.

The IR and NIR during the rainy season.

The IG and NIG during rainy season.

Variation of the ground cover (February, May and November).

Dunbaria longeracemosa Craib

Pueraria stricta Kurz.

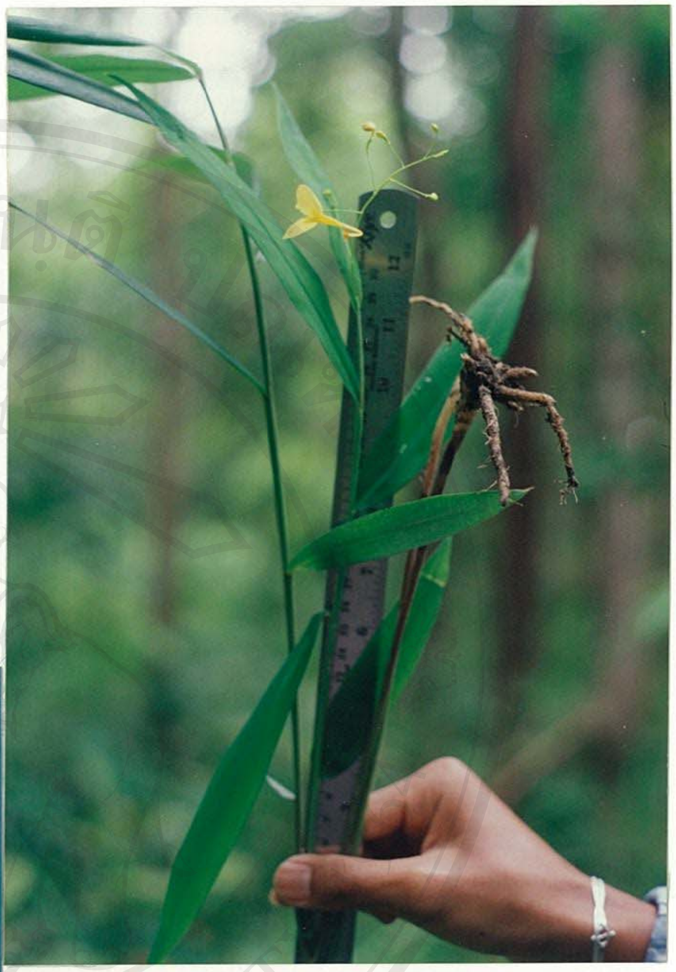
Themeda triandra Forssk.

Arundinella setosa Trin. var. setosa

Crotalaria albida Hey ex Roth.

Inula indica (L.) Sw.

Globba nuda K. Lar.



Curcuma zedoaria (Berg.) Rosc.

Eupatorium odoratum L.

Mimosa diplotricha C. Wright ex Sauv. var. diplotrica

Heteropogon triticeus (R.Br.)

Flemingia chappar Ham. ex Bth.

Appendix 3. Raw data of the results.

Table A3.1 Domin score of IR, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	2.8	6.4	11.4	16.2	19	19	14	3
Arundinella setosa	61.3	61.1	50.2	50	64	64	59	59
Blumeopsis flava	0.2							
Blumea lacerra	6							
Borreria brachystema	0.1							
Ceriscoides turgidata	3	3	3	3	3	3	3	3
Crotalaria alata	0.5	1.1	2	8	7	6	8	8
Crotalaria albida	0.2			1	1	1	2	1
Crotalaria neriifolia				0.1	1	1	1	
Cyanotis cristata				1.1	4	4	2	2
Dalbergia fusca		4	4	4	4	4	4	4
Dunbaria longeracemosa	1							
Eulalia quadrinervis	19	9	14	10	9	9	14	14
Eupatorium ordoratum	0.2		0.1		0.1	0.3	2	
Fimbristylis dichotoma	0.1							
Flemingia chappar	1	5	5	5	5	5	5	6
Flemingia grahamiana	0.2	3						
Globba nuda	.				1	1		
Gutzlaffia pedunculata	17.1	15.1	14.1	17.1	18	18	18	18.1
Heteropogon contortus	0.1			5	6	10	19	19
Heteropogon tritriceus	39.3	28.1	30.1	34	36	40	41	41
Inula indica	0.1							
Knoxia corymbosa				0.2	3	3	3	3
Mimosa diplotricha	8	9	4	5	5	5	6	7
Merremia quinata	5.2	7.1	4.1	9	9	9	10	10
moss	2.1		3.1	4	12.2	20	8	7
Mussaenda parva	0.1							
Paederia pallida					1	1		
Phoenix humilis	5	4	4	4	4	4	4	4
Pueraria stricta				1	1	1	2	2
Scleria levis	7.2	11.1	13.2	19.1	20.1	21.1	21.1	18.1
Sehima nervosum	8.1	12	9	10	12	12	29	25
Selaginella ostenfeldii			0.6	1.6	7	7	5.1	
Shorea obtusa	5.2	10	10	10	11	15	15	15
Shorea siamensis	5	6	5	5	5	5	5	5
Smilax verticalis	0.2		1	6	4			
Sorghum nitidum	28.1	30	15	17	17	17	17	17
Spatholobus parviflorus							1	1
Uraria lagopodioides	7	4	10	10	10	11	11	10
Total Domin Score	233.4	229	212.9	256.4	299.4	316.4	329.2	302.2
X	11.67	11.45	10.64	12.82	14.97	15.82	16.46	15.11

X: Average Domin Score from 20 Quadrat

Table A3.2 Domin score of NIR, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	15.3	16.4	27.2	26.1	28	30	26	11
Aganosma marginata	3	4	4	4	4	4	4	4
Albizia ordoratissima	0.1		0.1	1	1	1	4	4
Arundinella setosa	29	20.2	14	15	19	18	20	18
Blumea lacera	1							
Boesenbergia rotunda		4	6	11	11	13	10.1	
Boahinia sp.		0.2	1	1				
Ceriscoides turgida	0.1							
Crotalaria alata	2					1	1	1
Crotalaria albida	0.1			2	2	2	2	2
Crotalaria neriifolia				2.1	4	3	3	
Curcuma zedoaria			3	5	5	5	2	
Cyperus leucocephalus		8	2	1	1	1	1	1
Desmodium laxiflorum	8	9	9	9	11	11	12	12
Eulalia birmanica	5	4	1	4	5	5	5	5
Eulalia quadrinervis	26	18	15	16	16	17	17	17
Eupatorium ordoratum	10.1	2.2	8.2	10	10	10	14	14
Fimbristylis dichotoma	4							
Gardenia obtusifolia	0.1							
Grewia abutilifolia	5	0.1	5	5	5	5	6	6
Grewia eriocarpa			1	4	4	4	4	4
Heteropogon contortus	7	5	4.1	5	5	5	5	5
Heteropogon triticeus	52	37	36.2	38	41	41	41	41
Hypoxis aurea				0.1	1	1	1	1
Inula indica	0.2				1	1	1	1
Kaempferia rotunda		0.1						
Knoxia corymbosa					1	1	1	
moss	0.1		3	1.1	2	2.1	2	1
Paederia pallida	6	4	4	6	3	3	2	2
Phoenix humilis	14	11	12	12	12	12	13	13
Premna herbacea				1	1	1	1	1
Pueraria stricta	7	5	1	4	4	4	4	4
Scleria levis	8.1	9.3	6.1	10	11	12.1	12.1	13
Sehima nervosum	10		4.2	4.2	4.2	4.1	8.1	8.1
Selaginella ostenfeldii	1.2		1.3	7	3	3	2.1	
Shorea obtusa		5	5	5	5	5	5	5
Shorea siamensis		16	16	16	16	17	17	17
Sorghum miliaceum	5	4	5	5	5	5	5	5
Themeda triandra	16	8	9	9	8	8	9	9
Total Domin Score	235.4	190.5	203.3	239.5	249.2	255.3	260.4	225.1
X	11.77	9.525	10.16	11.97	12.46	12.76	13.02	11.25

X: Average Domin Score from 20 Quadrat

Table A3.3 Domin score of IG, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	19.3	18.2	20.2	22.1	28	28	20	13
Adiantum zollingeri	3.4	7.2	9	10.1	11	11	11	9
Aganosma marginata	5	4	4	4	4	4	4	4
Amorphophallus sp.		0.1	4	4	4	4	4	
Ampleocissus martini	0.1	2.1	6	7	7	7	7	7
Arundinella setosa	27.1	20.1	17	21	21	21	22	22
Barleria cristata	1							
Blumea lacera	1							
Boesenbergia rotunda			1	7	9	12	5	
Breynia glauca	0.1	0.1	4	4	4	4	4	4
Ceriscoides turgida	7.3	9	11	10	11	11	11	12
Crotalaria alata	0.2							1
Crotalaria albida	6.1	0.1		1.1	2.1	5	5	4
Curcuma zedoaria				2	2	2	2	
Desmodium pulchellum	3.1							
Dipterocarpus tubercULartus	16	13	14	16	16	16	16	16
Dunbaria longeracemosa	0.1			4	4	4	4	4
Ellipeia cherrevensis		4	4	4	5	5	4	4
Embelia subcoriacea	0.1	4	5	5	5	5	5	5
Eulalia quadrinervis	20.1	24.1	29	26	25	25	25	25
Eupatorium ordoratum		0.1	1	22	1.1	2	8.1	8.1
Flemingia chappar	10.3	17.1	17	16.1	22.1	22.1	22.1	19
Flemingia grahamiana	0.1							
Geniosporum coloratum		4.1	8	8.1	9.1	9.1	9.1	9.1
Globba nuda		0.3	7	7	10	7	4	
Grewia abutilifolia	10.1	10	11	11	12	12	12	12
Grewia eriocarpa	5.1							
Gutzlaffia pedunculata	5.1	9	8	8	8	8	9	10
Heteropogon triticeus	35.1	40	34	34	35	35	35	35
Hyparrehenia rufa	9	4.1	2	2	2	2	2	2
Hypoxis aurea	0.1	0.1	1	2	1	1	1	1
Inula indica	3							
Knoxia corymbosa				1	3	3	3	3
Leea indica	5	4	4	4	4	4	4	4
Merremia quinata			1			1	1	1
moss	0.1			0.1	1.3	5.1	1.1	
Murdannia scapiflora		1	4	4	4	4	4	
Paederia pallida	3	1	0.1					
Phoenix humilis	5	4	4	4	4	4	4	4
Pueraria stricta	12	9	12	16	17	17	17	17
Scleria levis	11.1	7.1	9	11	12.2	13.3	10.3	12.2
Sehima nervosum	5	4	4	4	4	4	4	

Table A3.3 Domin score of IG, in 8 observations. (Continued)

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Selaginella ostenfeldii	2.9	0.3	6	9.1	10.3	12.1	14.1	
Shorea obtusa	13	13	13	14	15	15	15	15
Shorea siamensis	10	17	20	20	19	19	19	19
Smilax verticalis	0.1	0.1	9	9	9	6	3	1
Sorghum miliaceum	21	18	18	19	18	18	20	20
Spatholobus parviflorus		0.1	8	8	8	8	8	8
Terminalia alata	10	8	8	8	8	8	9	9
Themeda triandra	9	8	8	8	8	8	8	8
Uraria lagopodioides	0.1		1	1	1	1	1	1
Xylia xylocarpa	0.1	0.1	4	4	4	4	4	4
Total Domin Score	295.3	285.5	350.3	401.7	408.2	416.7	400.8	352.4
X	14.76	14.27	17.51	20.08	20.41	20.83	20.04	17.62

X: Average Domin score from 20 Quadrats

Table A3.4 Domin score of NIG, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	4.3	17.7	25.1	29.2	46	45	39	27
Adiantum zollingeri	7.2	2.4	8.1	13.2	17	18	16	10
Aganosma marginata	0.1	4	4	4	4	4	4	4
Albizia ordoratissima		0.1	1	3.2	4.1	6	8	10
Arundinella setosa	8.1	12.1	12	7	12	12	10	10
Barleria cristata		4	4	4	4	4	4	4
Boesenbergia rotunda			5	17	26	28	24	1
Breynia glauca	0.1		3	3	6	7	7	4
Bridelia retusa	4							
Buchanania glbra	7	6	5	5	5	6	6	6
Buchanania latifolia	10	8	8	8	8	8	9	9
Capillipedium paviflorum							4	4
Ceriscoides turgida	21.1	19	16	16	17	17	17	17
Crotalaria albida				1				
Crotalaria nerrifolia					1	1	1	1
Curcuma longa	0.1							
Curcuma zedoaria			5	17	23	23	15	
Dalbergia fusca	0.7	21.3	24.2	20	21	21.1	21.1	22
Desmodium laxiflorum	0.1							
Desmodium pulchellum	0.1							
Dipterocarpus tuberculartus	4	6	6	6	7	7	7	7
Dunbaria longeracemosa				4	4	4	4	4
Ellipeia cherrevensis			4	4	4	4	4	4
Embelia subcoriacea	0.3	12	12	13	13	13	12	8
Eulalia birmanica	5	4	5	5	8	8	8	8
Eulalia quadrinervis	32.1	18.2	16.1	19	20	24	24	24
Eupatorium ordoratum	11.1	10.1	10.1	13.1	15	16	17	17
Flemingia chappar	7.3	14.2	15	15.1	18	19	19	19
Flemingia grahamiana	0.1		1	1	1	1	1	4
Gardenia obtusifolia	6.1							
Geniosporum coloratum		1.1	4	4	4	4	4	2
Globba nuda				2	4	4		
Grewia abutilifolia	1	4	4	4	4	4	4	4
Grewia eriocarpa		4	5	5	5	5	4	5
Gutzlaffia pedunculata	4.1	4.1	9	9	10	11	11	11
Habenaria hosseusii					1	1	1	
Heteropogon contortus	3	4	4	4	4	4	5	5
Heteropogon triticeus	29	25	25	24	21	21	21	21
Hyparrehenia rufa	21.1	21	21	15	18	18	19	19
Inula indica	1.5			1	1	1	1	1
Knoxia corymbosa				5	8	7	7	5
Leea indica		8	8	8	8	8	8	8

Table A3.4 Domin score of NIG, in 8 observations. (Continued)

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Luecas flaccida	3	4	3	3	3	3	3	3
Merremia quinata	4	4	4	5	5	5	4	5
moss	1		4.1	4.2	5.3	7.1		
Ochna integerrima	0.1							
Ophiuros exaltatus								1
Paederia pallida	0.1							
Phoenix humilis	19	14	13	13	14	15	15	15
Premna herbacea			6	9	6	6	5	4
Premna nana			4	5	5	4		
Protium serratum	0.1							
Pueraria stricta	17	16.1	21	29	30	30	27	26
Scleria levis		0.1	1	0.2	2.1	3.3	6.1	5.1
Scutellaria glandulosa	0.1							
Sehima nervosum	11	8.1	9	6	6	6	6	6
Selaginella ostenfeldii	9.6	4.1	11.6	26	30	33	34	10
Shorea obtusa	13.3	31	34	31	31	31	31	31
Shorea siamensis	5	26	25	26	26	26	26	26
Smilax verticalis		12	16	16	16	16	13	9
Sorghum nitidum	24.1	18	17	19	19	19	19	19
Spatholobus parviflorus	17.1	21.2	34	37	38	38	38	38
Stereosperum colais	0.1							
Xylia xylocarpa	2.3	14.3	16	21	21	21	19	18
Total Domin Score	315.5	403.2	488.3	559.3	629.5	625.5	612.2	521.1
X	15.77	20.16	24.41	27.96	31.47	31.27	30.61	26.05

X: Average Domin score from 20 Quadrats

Table A3.5 Percentage cover of IR, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	8	7	16	17	17	17	7	3
Arundinella setosa	284	256	139	138	173	177	166	161
Blumeopsis flava	2							
Blumea lacerra	25							
Borreria brachystema	1							
Ceriscoides turgidata	1	1	1	1	1	1	1	1
Crotalaria alata	4	2	2	9	8	7	18	18
Crotalaria albida	2			2	2	2	2	1
Crotalaria neriifolia				1	1	1	1	
Cyanotis cristata					1	1	1	1
Dalbergia fusca		5	5	5	5	5	5	5
Dunbaria longeracemosa	1							
Eulalia quadrinervis	115	30	50	31	21	21	32	32
Eupatorium ordoratum	2		1		1	2	1	
Fimbristylis dichotoma	1							
Flemingia chappar	1	15	20	20	20	20	25	26
Flemingia grahamiana	2	1						
Globba nuda					1	1		
Gutzlaffia pedunculata	86	51	62	72	77	77	82	87
Heteropogon contortus	16	25	26	26	40	50	65	65
Heteropogon tritriceus	133	61	57	52	47	47	67	72
Inula indica	1							
Knoxia corymbosa				3	4	4	3	3
Mimosa diplotricha	16	35	10	15	20	20	30	31
Merremia quinata	8	7	11	16	16	11	12	11
moss	3		2	5	21	42	22	22
Mussaenda parva	1							
Paederia pallida					1	1		
Phoenix humilis	15	10	5	5	5	5	5	5
Pueraria stricta				1	1	2	2	2
Scleria levis	12	13	9	11	12	12	11	11
Sehima nervosum	6	10	6	6	10	10	26	26
Selaginella ostenfeldii	4		6	7	6	7	6	
Shorea obtusa	22	40	35	35	45	50	50	50
Shorea siamensis	20	25	20	20	20	20	15	15
Smilax verticalis	1		1	5				
Sorghum nitidum	91	100	41	40	40	40	40	40
Spatholobus parviflorus							1	1
Uraria lagopodioides	6	5	12	12	12	13	13	12
Total % cover	890	699	537	555	628	666	709	701
X	44.5	34.95	26.85	27.75	31.4	33.3	35.45	35.05

X: Average percentage cover from 20 quadrats.

<u>Table A3.6</u> Percentage cover of NIR, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	20	12	13	18	22	22	14	10
Aganosma marginata	5	10	10	10	10	10	10	10
Albizia ordoratissima	1		1	1	1	1	5	5
Arundinella setosa	77	27	14	23	28	27	29	28
Blumea lacera	1							
Boesenbergia rotunda		5	7	12	14	14	12	
Boahinia sp.		1	1	1				
Ceriscoides turgida	1							
Crotalaria alata	1					1	1	1
Crotalaria albida	1			2	2	2	2	2
Crotalaria neriifolia				3	4	3	3	
Curcuma zedoaria			2	6	6	6	2	
Cyperus leucocephalus		10	2	1	1	1	1	1
Desmodium laxiflorum	25	25	25	30	40	40	45	45
Eulalia birmanica	15	5	1	5	6	6	11	11
Eulalia quadrinervis	131	45	21	30	35	40	40	40
Eupatorium ordoratum	20	3	14	17	12	22	31	31
Fimbristylis dichotoma	5							
Gardenia obtusifolia	1							
Grewia abutilifolia	15	1	15	15	15	20	25	25
Grewia eriocarpa			1	5	5	5	5	5
Heteropogon contortus	31	6	7	11	11	11	11	11
Heteropogon triticeus	171	85	57	67	66	66	71	76
Hypoxis aurea				1	1	1	1	1
Inula indica	2				1	1	1	1
Kaempferia rotunda		1						
Knoxia corymbosa					1	1	1	
moss	1		1	2	2	3	1	1
Paederia pallida	2	5	5	7	3	3	2	2
Phoenix humilis	85	50	60	60	60	60	65	65
Premna herbacea				1	1	1	1	1
Pueraria stricta	16	6	1	5	5	5	10	10
Scleria levis	11	14	4	6	6	8	8	8
Sehima nervosum	30		1	1	1	1	6	6
Selaginella ostenfeldii	3		3	7	3	3	3	
Shorea obtusa		20	15	15	15	15	15	15
Shorea siamensis		75	65	70	75	85	80	80
Sorghum nitidum	15	5	6	6	6	6	6	6
Themeda triandra	46	10	10	11	10	10	16	11
Total % cover	732	421	362	449	468	500	534	508
X	36.6	21.05	18.1	22.45	23.4	25	26.7	25.4

X: Average percentage cover from 20 quadrats

Table A3.7 Percentage cover of IG, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	27	17	28	22	35	36	18	10
Adiantum zollingeri	6	12	7	13	12	12	13	8
Aganosma marginata	15	5	5	5	5	5	5	5
Amorphophallus sp.		1	5	5	5	5	5	
Ampleocissus martini	1	1	6	8	8	8	8	8
Arundinella setosa	61	26	21	31	31	31	32	32
Barleria cristata	1							
Blumea lacera	1							
Boesenbergia rotunda			1	7	9	9	5	
Breynia glauca	1	1	5	5	5	5	5	5
Ceriscoides turgida	29	27	31	26	31	36	36	46
Crotalaria alata	2							1
Crotalaria albida	3	2		2	3	5	5	4
Curcuma zedoaria				2	2	2	2	
Desmodium pulchellum	2							
Dipterocarpus tuberculartus	55	35	50	60	65	65	65	65
Dunbaria longeracemosa	1			5	5	5	10	10
Ellipeia cherrevensis		5	5	5	6	6	5	5
Embelia subcoriacea	1	5	15	15	15	20	20	20
Eulalia quadrinervis	42	36	41	37	36	36	36	41
Eupatorium ordoratum		1	1	4	2	2	12	12
Flemingia chappar	24	41	31	31	46	51	51	46
Flemingia grahamiana	1							
Geniosporum coloratum		11	15	16	21	21	21	21
Globba nuda		2	3	8	12	8	5	
Grewia abutilifolia	31	30	50	50	70	70	70	10
Grewia eriocarpa	16							
Gutzlaffia pedunculata	16	20	10	10	10	10	25	30
Heteropogon triticeus	121	80	70	70	80	80	90	85
Hyparrehenia rufa	25	11	2	2	2	2	2	2
Hypoxis aurea	1	1	1	2	1	1	1	1
Inula indica	2							
Knoxia corymbosa				1	2	2	2	2
Leea indica	15	10	10	10	10	5	5	5
Merremia quinata			1			1	1	1
moss	1			1	4	7	2	
Murdannia scapiflora		1	5	5	5	5	5	
Paederia pallida	1	1	1					
Phoenix humilis	15	10	10	5	5	5	5	10
Pueraria stricta	25	11	25	30	35	35	40	40
Scleria levis	13	8	9	13	17	18	14	14
Sehima nervosum	15	10	10	5	5	5	5	

Table A3.7 Percentage cover of IG, in 8 observations.

(Continued)

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Selaginella ostenfeldii	10	4	4	11	13	13	17	
Shorea obtusa	25	30	30	40	55	60	60	60
Shorea siamensis	21	40	61	71	75	80	80	80
Smilax verticalis	1	1	10	11	11	7	3	1
Sorghum nitidum	91	41	36	46	41	41	56	56
Spatholobus parviflorus		1	15	15	15	15	15	10
Terminalia alata	30	15	20	20	20	20	30	35
Themeda triandra	20	10	10	10	10	10	10	10
Uraria lagopodioides	1		1	1	1	1	1	1
Xylia xylocarpa	1	1	5	5	5	5	5	5
Total % cover	770	564	666	741	846	866	903	797
X	38.5	28.2	33.3	37.05	42.3	43.3	45.15	39.85

X: Average percentage cover from 20 quadrats

Table A3.8 Percentage cover of NIG, in 8 observations.

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Adiantum erylliae	13	18	27	38	53	53	49	28
Adiantum zollingeri	6	6	12	13	13	15	15	8
Aganosma marginata	1	5	5	5	5	5	5	5
Albizia ordoratissima		1	1	4	4	4	8	12
Arundinella setosa	12	21	17	9	38	43	18	18
Barleria cristata		5	5	5	5	5	5	5
Boesenbergia rotunda			5	17	21	25	18	1
Breynia glauca	1		3	3	2	3	8	4
Bridelia retusa	5							
Buchanania glbra	50	25	20	20	20	25	30	30
Buchanania latifolia	35	20	20	20	20	20	25	25
Capillidium parviflorum							5	5
Ceriscoides turgida	91	100	70	65	65	65	65	65
Crotalaria albida				1				
Crotalaria nerrifolia					1	1	1	1
Curcuma longa	1							
Curcuma zedoaria			6	23	36	31	21	
Dalbergia fusca	7	53	73	47	57	58	53	53
Desmodium laxiflorum	1							
Desmodium pulchellum	1							
Dipterocarpus tuberculartus	10	25	25	30	40	50	50	50
Dunbaria longeracemosa				10	10	10	10	10
Ellipeia cherrevensis			5	5	5	5	5	5
Embelia subcoriacea	3	15	20	21	21	21	20	25
Eulalia birmanica	15	5	11	11	10	10	10	10
Eulalia quadrinervis	111	47	43	42	47	47	47	47
Eupatorium ordoratum	32	31	31	39	41	42	42	42
Flemingia chappar	29	47	37	38	41	37	37	37
Flemingia grahamiana	1		1	1	1	1	1	5
Gardenia obtusifolia	26							
Geniosporum coloratum	1	2	2	2	2	2	2	2
Globba nuda			2	3	3	2		
Grewia abutilifolia	1	5	5	5	5	5	5	5
Grewia eriocarpa		10	15	15	11	11	10	20
Gutzlaffia pedunculata	6	6	25	30	35	40	40	40
Habenaria hosseusii					1	1	1	
Heteropogon contortus	5	5	5	5	5	5	6	6
Heteropogon triticeus	85	55	55	45	46	46	46	46
Hyparrehenia rufa	96	60	40	35	40	40	51	51
Inula indica	6			1	1	1	1	1
Knoxia corymbosa			1	6	8	7	7	4
Leea indica		15	15	15	15	15	15	2

Table A3.8 Percentage cover of NIG, in 8 observations.

(Continued)

species	Feb	May	Jun	Jul	Aug	Sep	Oct	Nov
Luecas flaccida	1	5	1	1	1	1	1	1
Merremia quinata	5	5	5	6	11	11	10	6
moss	1		6	7	8	8		
Ochna integerrima	1							
Ophiuros exaltatus								1
Paederia pallida	1							
Phoenix humilis	65	55	40	40	50	51	51	56
Premna herbacea			7	11	7	7	6	5
Premna nana			10	15	15	10		
Protium serratum	1							
Pueraria stricta	45	31	36	46	51	46	37	36
Scleria levis		1	1	1	3	4	6	5
Sehima nervosum	30	11	6	6	6	6	6	6
Selaginella ostenfeldii	19	12	17	27	32	31	31	12
Shorea obtusa	83	125	165	120	135	125	130	130
Shorea siamensis	11	90	85	90	90	100	100	100
Smilax verticalis		15	20	20	20	20	16	6
Sorghum nitidum	66	41	40	46	46	46	46	46
Spatholobus parviflorus	36	33	56	55	65	65	65	65
Stereosperum colais	1							
Xylia xylocarpa	4	38	38	57	72	72	32	22
Total % cover	1021	1044	1135	1177	1340	1354	1269	1165
X	51.05	52.2	56.75	58.85	67	67.7	63.45	58.25

X: Average percentage from 20 quadrats

Table A3.9 Expected number of species in 20 quadrats.

No. of Quadrat	Number of species			
	IR	NIR	IG	NIG
0	0	0	0	0
1	7.80	6.65	9.35	13.20
2	12.76	11.12	16.12	21.45
3	16.32	14.54	21.28	27.55
4	19.10	17.30	25.40	32.30
5	21.39	19.87	28.82	36.21
6	23.35	22.08	31.73	39.45
7	25.06	24.06	34.28	42.23
8	26.60	25.86	36.54	44.66
9	27.99	27.51	38.57	46.84
10	29.28	29.01	40.40	48.82
11	30.48	30.39	42.07	50.63
12	31.61	31.66	43.60	52.31
13	32.68	32.84	45.00	53.89
14	33.69	33.92	46.28	55.37
15	34.67	34.93	47.45	56.78
16	35.60	35.86	48.53	58.13
17	36.50	36.73	49.52	59.42
18	37.36	37.54	50.42	60.65
19	38.20	38.30	51.25	61.85
20	39.00	39.00	52.00	63.00

Table A3.10 The mean Domin score in 4 different sites.

Month	Average Domin Score			
	IR	NIR	IG	NIG
February	11.67	11.77	14.76	15.77
May	11.45	9.525	14.27	20.16
June	10.64	10.16	17.51	24.41
July	12.82	11.97	20.08	27.96
August	14.97	12.46	20.41	31.47
September	15.82	12.76	20.83	31.27
October	16.46	13.02	20.04	30.61
November	15.11	11.25	17.62	26.05

Table A3.11 Hierachical cluster analysis, using Cosine index.

Agglomeration Schedule using Average Linkage (Between Groups)

Stage	Clusters Combined		Coefficient	Stage Cluster 1st Appears		Next
Stage	Cluster 1	Cluster 2	Coefficient	Cluster 1	Cluster 2	Stage
1	25	31	967949	0	0	18
2	37	38	.961278	0	0	7
3	35	50	.953104	0	0	7
4	1	2	.953039	0	0	8
5	14	17	.940706	0	0	11
6	29	30	.936406	0	0	13
7	35	37	.906612	3	2	13
8	1	42	.902353	4	0	15
9	7	8	.886731	0	0	15
10	11	40	.873422	0	0	20
11	14	18	.871105	5	0	14
12	33	34	.858554	0	0	22
13	29	35	839821	6	7	31
14	14	20	.815134	11	0	25
15	1	7	.811627	8	9	19
16	9	12	761791	0	0	57
17	24	28	.745479	0	0	34
18	5	25	.743054	0	1	41
19	1	32	.741148	15	0	28
20	11	61	.726474	10	0	29
21	53	66	.720614	0	0	54
22	33	54	.718255	12	0	30
23	3	39	.709563	0	0	43
24	27	56	.704611	0	0	44
25	13	14	703754	0	14	31
26	26	62	.677976	0	0	56
27	47	70	671879	0	0	57
28	1	6	662844	19	0	51
29	11	23	.645850	20	0	35
30	15	33	.645396	0	22	50
31	13	29	.633766	25	13	37
32	51	52	.624425	0	0	59
33	65	79	.612353	0	0	66
34	24	48	.610785	17	0	51
35	11	19	.592550	29	0	46
36	36	57	.577880	0	0	79
37	13	44	.574455	31	0	52
38	69	77	.574179	0	0	60
39	16	71	.565560	0	0	58
40	21	41	.562116	0	0	71
41	5	43	.554541	18	0	55
42	45	68	.553855	0	0	64
43	3	72	.548577	23	0	67
44	27	78	.547741	24	0	53
45	60	75	.542925	0	0	68
46	11	67	.537557	35	0	49
47	58	76	.535962	0	0	65
48	59	74	.532030	0	0	66
49	11	46	.495406	46	0	71
50	15	80	.478972	30	0	53
51	1	24	.474813	28	34	64
52	13	63	.468827	37	0	55
53	15	27	.459041	50	44	61
54	53	55	.440199	21	0	56
55	5	13	.439099	41	52	59

Table A3.11 Hierachical cluster analysis, using Cosine index.

(Continued)

56	26	64	.427400	26	0	65
57	9	47	.424036	16	27	69
58	16	53	.408555	39	54	62
59	5	51	.388302	55	32	63
60	49	69	.376870	0	38	70
61	15	73	375919	53	0	75
62	16	22	.367167	58	0	75
63	5	10	.364844	59	0	67
64	1	45	.349468	51	42	72
65	26	58	.348912	56	47	70
66	59	65	.340064	48	33	73
67	3	5	.332889	43	63	68
68	3	60	309479	67	45	69
69	3	9	.255836	68	57	72
70	26	49	.245195	65	60	73
71	11	21	.243530	49	40	74
72	1	3	.240939	64	69	76
73	26	59	.193790	70	66	78
74	4	11	.175922	0	71	76
75	15	16	.168423	61	62	77
76	1	4	.146124	72	74	77
77	1	15	.144021	76	75	78
78	1	26	.096823	77	73	79
79	1	36	.053613	78	36	0

Table A3.12 Number of species flowering in each observation.

Month	Number of Species Flowering			
	IR	NIR	IG	NIG
Feb	1	1	1	1
May	2	2	3	0
June	3	2	2	2
July	2	2	3	4
August	2	2	3	2
September	2	1	2	5
October	9	11	8	11
November	10	12	9	11

Table A3.13 Productivity in IR and NIR (g/m^2/3 months)

Time	IR	NIR
March–June	16.731	30.671
June–Sept	78.582	45.628
Sept–Dec	−113.789	−59.731

Table A3.14 Number of annual and perennial species in four study sites. (The total number from February - November 1993)

Number of Species	IR	NIR	IG	NIG
Annuals	12	9	7	10
Perennials	27	30	45	54
Total	39	39	52	64

Table A3.15 Domin score of the annual and perennial species in 4 sites. (Mean of Total domin score from 20 quadrat, from February - November 1993).

Domin Score	IR	NIR	IG	NIG
Annuals	0.89	1.18	0.84	2.15
Perennial	12.47	10.43	16.95	23.66
Total	13.36	11.62	17.79	25.81

4. Species/area curves and Cluster analysis.

Species/Area Curves

In normal species/area curve number of species typically rises with quadrat size (or quadrat number) but then the plateaus at a quadrat size that determines the minimal area of a community. Therefore the species/area curves was used in plant ecology to define a suitable quadrat size (Goldsmith and Harrison, 1976). The commonly abundance score that used in species area curve are number of individual. In this study the score used to construct this curve was Domin score and percentage cover which cannot used to calculate the normal species/area curve. So that the formula used in this study was modify to use the frequency of occurrence of each species in quadrat.

when : Q = Number of total quadrat

n = Number of quadrat contain species S

S = Summary of the probability of all species absence

PAqX = Probability of species A in X quadrat

PBqX = Probability of species B in X quadrat

The probability to have species A in X quadrat can be calculated by

$$PAq1 = 1 - \frac{Q - n - 0}{Q - 0}$$

$$PAq2 = 1 - \{ \frac{Q - n - 0}{Q - 0} \times \frac{Q - n - 1}{Q - 1} \}$$

$$PAqm = 1 - \{ \frac{Q-n-0}{Q-0} \times \frac{Q-n-1}{Q-1} \times \ldots \times \frac{Q-n-(m-1)}{Q-(m-1)}$$

Sum(probability of absence) = PAqX + PBq +...+ PZ

The expected number of species in n quadrat (N)

$$N = S - \text{Sum(probability of absence)}$$

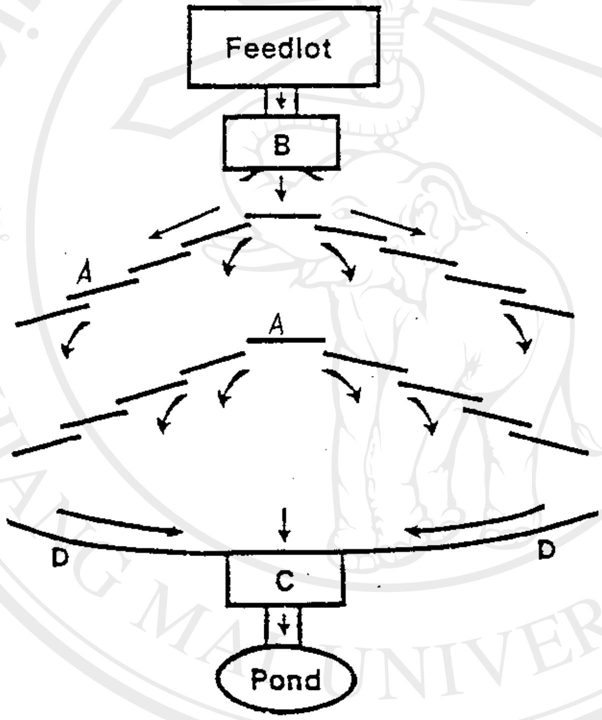
Cluster Analysis

Cluster analysis is a classification technique for placing similar entities or object into groups or "cluster". The objects will be grouped together in cluster analysis by using either distance or similarity between two cases (Norusis, 1990). There are many methods that can be used for this purpose. In this study the index that used was cosine of vectors of variables. The subunits will be projected onto a circle of unit radius through the use of direction cosine. The index can bee calculated with the formula below:

$$\text{Cosine} = \frac{\sum_{i=1}^{s} (X_i Y_i)}{\sum_{i=1}^{s} X_i^2 \sum Y_i^2}$$

After the first calculation the most similar subunits will be grouped together and form the artificial subunit. After that the similar between all subunits will be calculate again and the most similar will be put together, this cycle will be done until all subunits will be grouped together.

5. Irrigation system used by Pinkowski *et. al* (1985).



A) Baffle system for even distribution of runoff

B) Water sampling station 1: samples feedlot runoff

C) Water sampling station 2: samples flow from watershed

D) Catch baffle for surface and subsurface flow

CURRICULUM VITAE

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