REVIEW
CROPPING/FARMING SYSTEMS RESEARCH AND DEVELOPMENT IN INDONESIA

A. Syarifuddin K., Inu G. Ismail and J.L. McIntosh*)

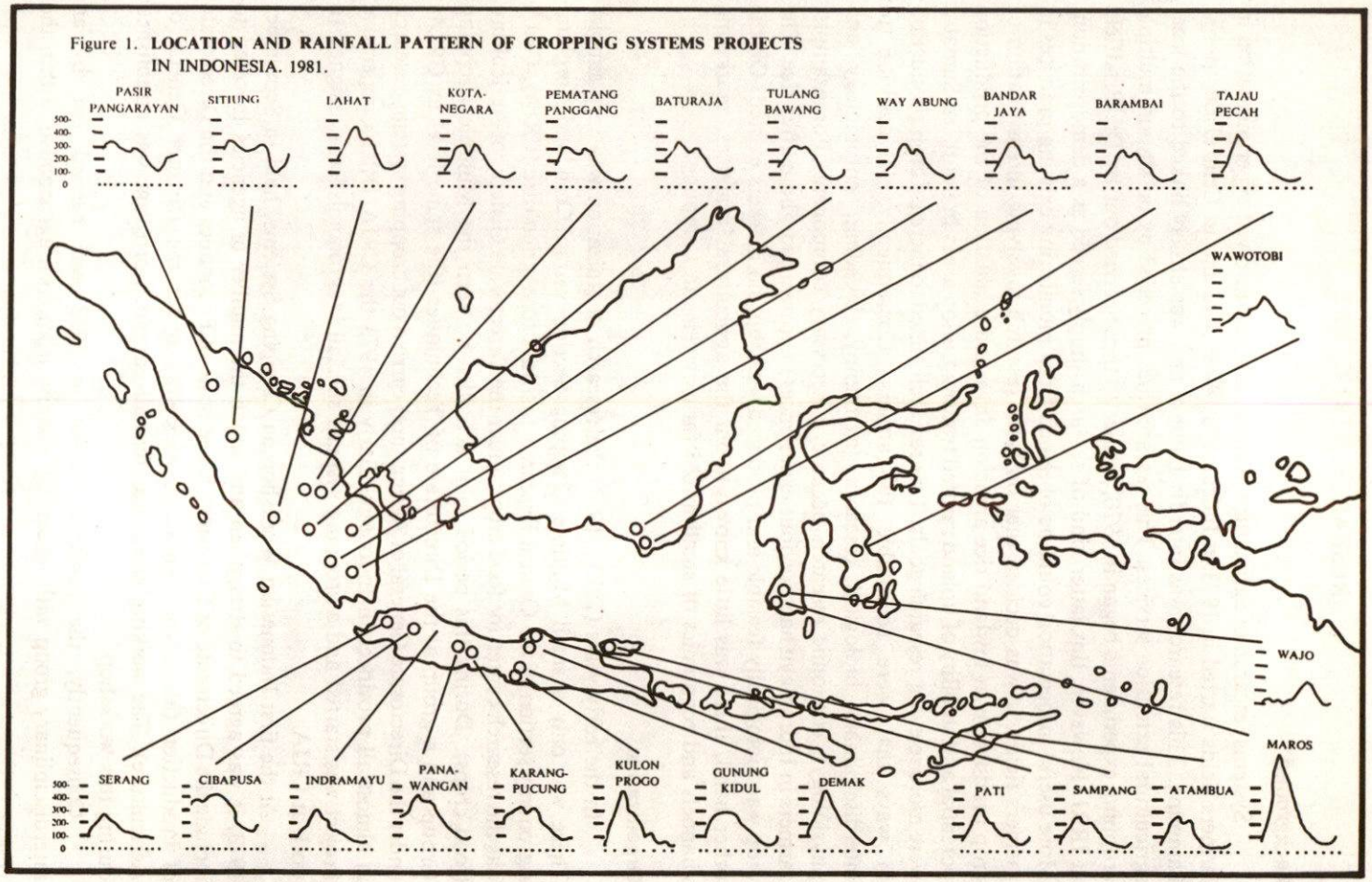
INTRODUCTION

The gradual development of farming systems research in Indonesia has been reported at several meetings and workshops. In brief, the evolutionary process started with some multiple cropping experiments initiated during the 1970 rainy season, at the Central Research Institute for Agriculture (CRIA), Bogor. In the following years, more research was conducted in several locations in cooperation with extension (Directorate General of Food Crops) central and provincial offices. Based on this interest and research IRRI and USAID developed a cooperative project with Indonesia to provide technical assistance for training, equipment, supplies and expatriate technical support. In 1975 IDRC provided additional support for cropping systems research through IRRI to CRIA. In 1976 the Directorate General of Transmigration became interested in our research and provided funds for cropping systems research in several new transmigration sites. Latter, these activities increased further through support of other cooperating agencies and sites were established in Provincial Development Project (PDP) areas in Central Java and Nusa Tenggara Timur (NTT), in the Citanduy Upper River Watershed Project in West Java and in rural development projects in Yogyakarta and Central Java. There have been or presently exist at least 40 cropping/farming systems research sites, just within the Food Crops and Soils Research Center (Figure 1). The research programs vary from one site to the other depending on the respective site characteristics and needs. Within each site, the research program changes with time as research progress changes the needs.

The cropping systems research program has developed several alternative cropping patterns for different agroclimatical and edaphological conditions. Since farmers deal with many components in their farming systems, the interaction of the cropping systems with components of farming systems must receive more research emphasis if we are to really help the farmers. Therefore, this research has become pragmatic and oriented more toward farming systems. It is **focused** research. Only the most important combinations of components of the farm systems are studied at one time. Consequently, though animal and perennial crops are studied as parts of the farming systems, some further research to develop stable food crops production for food subsistence is still a necessity for many small farms.

*) Director, SARIF; Cropping Systems Agronomist, BORIF; and Cropping Systems Agronomist, AARD/IRRI Collaborative Program, Agency for Agricultural Research and Development, Jalan Merdeka 99, Bogor, Indonesia.

Figure 1. **LOCATION AND RAINFALL PATTERN OF CROPPING SYSTEMS PROJECTS IN INDONESIA. 1981.**



RESEARCH STRUCTURE

Background

Systems research in agriculture in Indonesia that involved experimentation in farmers fields started in 1973 in Indramayu, West Java and in Central Lampung, Lampung. This research was interdisciplinary and was closely linked to the local agricultural extension services. This research was preceded by on station multiple cropping experiments began in 1970, similar to those carried out by Dr. Bradfield at IRRI. However, this latter kind of research simply served as a demonstration. More useful information could be obtained from monitoring existing practices in farmers fields. It was decided that on farm research involving intensification of crop production in lowland rice areas on Java and evaluation of the production potential and stability of upland rainfed transmigration areas in Southern Sumatra were more relevant research goals. This research aimed to increase crop production in ways that were acceptable to farmers. Consequently, in addition to interdisciplinary biological research (agronomy, breeding, entomology and physiology), economic research because a necessary component. For example, farmers in Indramayu had previous experiences in growing sorghum after rice. The crop was biologically feasible and produced well, but no markets existed. On the other hand, there was little known about the agricultural practices, marketing channels and economics of small mixed farm systems in Lampung.

Organization

In the early years (1970 - 1973) the research organization was very simple. There was only a small Multiple Cropping Section within Corn and Sorghum Agronomy section of the Central Research Institute for Agriculture (CRIA). CRIA was the research center for food crops under the Directorate General of Agriculture (food crops). During this period joint activities between the Multiple Cropping Group and a group at the Directorate of Techniques (the same level as CRIA, under the Directorate General of Agriculture) carried out cropping systems research in almost all provinces in Indonesia. Early in 1973 the CRIA/IRRI Cooperative Project was started and a cropping systems specialist/agronomist was assigned to work at CRIA.

At the first Indonesian Workshop on Cropping Systems, held in September 1973, it was agreed to strengthen and widen the number of agencies involved to include the Directorate of Extension, Directorate of Economics and the Directorate of Production (all at the same level as CRIA, under the Director General of Agriculture). The working group was formalized and a program was established during this workshop.

Consequently, the research started in 1973 was carried out by an interdisciplinary group with leadership coming from corn agronomists within the

CRIA. This research expanded considerably in 1975 when technical assistance was received from IDRC through a CRIA/IRRI Cooperative Project. The research was further expanded in 1976 when funding was received from the World Bank through a CRIA/Transmigration project. By 1978 there were 25 research sites in Java, Sumatra, Kalimantan and Sulawesi, all within the CRIA research system.

Even though no national coordination was formally established to organize the cropping systems program, the cropping systems working group informally organized annual meetings and provided the forum for coordination. During these workshops the previous research, development and extension activities on cropping systems were evaluated and new programs were discussed. The actual activities were conducted by different institutions and agencies.

Over the next few years, the research organization changed considerably in line with reorganizations. By 1978 the Agency for Agricultural Research and Development (AARD) had become operational and the research needs, particularly in transmigration areas more diversified. All research in the Ministry of Agriculture came under the administrative direction of the AARD. In 1980, CRIA changed to CRIFC (Central Research Institute for Food Crops) and six semi autonomous Research Institutes were organized under its framework. Each Institute was given specific research mandates (Table 1). Within each Institute, cropping systems research exists as a sub project of the research and development programs. This kind of decentralization was carried out for all of the Research Centers in AARD. On the other hand research administration was centralized and the time was right to begin Farming Systems Research that involved all of the research disciplines and agricultural commodities.

Within the past 5 years, other research institutes working with other agricultural commodities have taken part in the working group - in the workshop and in the field work. The organization changed from A Cropping Systems to A Farming Systems Working Group. Although universities and other ministries are not members of the Working Group, they usually participate.

Table 1. Research Institutes and their mandates, within the Central Research Institute for Food Crops.

Banjarmasin	— Tidal Swamp Areas
Bogor	— Pioneer Research
Malang	— Palawija Crops Areas
Maros	— Upland Rainfed, Drought Prone Areas
Sukarami	— Upland Rainfed, Humid Areas
Sukamandi	— Lowland Rice Areas

Figure 2 illustrates the organization of the Ministry of Agriculture and shows the agencies responsible for research (AARD), extension (AETE) and action programs (Directorate General). Figure 3 shows the organizational framework of AARD. In effect each Center may carry out systems research through its research institutes. The components of the farming systems may be studied and developed as need and opportunity exist. These component activities (of the farming systems) may be studied separately, in combinations or all together (holistic) in projects that are administered by the AARD. The administration and organization of a farming systems project may be as illustrated in Figure 4.

In summary systems research in Indonesian agriculture has different levels of complexity. Each Institute may carry out systems research relevant to its research mandate. These components may be studied together in the context of a project at the center level or holistically at the AARD level as need and judgment indicate.

PAST CROPPING/FARMING SYSTEMS RESEARCH

The Cropping Systems research program that started in 1973 has developed an on farm research capability and stable and sustainable cropping patterns that are acceptable to farmers in the most areas of Indonesia. This interdisciplinary research has been integrated with other government agencies through on site research, workshops and training activities. Farmer adoption of research findings has increased year by year. However, technology implementation in the 1982 - 1983 crop year through BIMAS, INSUS and OPSUS programs represents a major breakthrough in the wide scale adoption and transfer of the new technology. (Table 2).

Research on crops and directly related agricultural enterprises has developed simultaneously with research on livestock, perennial and industrial crops, forestry and fishery components of the farming systems within the other Research Centers. Consequently, within the AARD the stage is set for coordinated and holistic farming systems research and development. This approach will ensure continued effective and efficient research support for small, mixed farm systems that make up a large part of Indonesian agriculture.

The principal objectives of cropping systems research have been to develop technologies that permit use of marginal or under utilized lands and more intensive cropping patterns for existing and productive agricultural areas. These technologies must be economical and acceptable to farmers. Methodology for the research includes assessing the existing socio-economic situation and potential for agricultural production within selected target areas, designing and testing of improved cropping patterns, evaluating and monitoring of on farm trials and transferring of technology to appropriate government agencies for multi locational trials and pilot production programs.

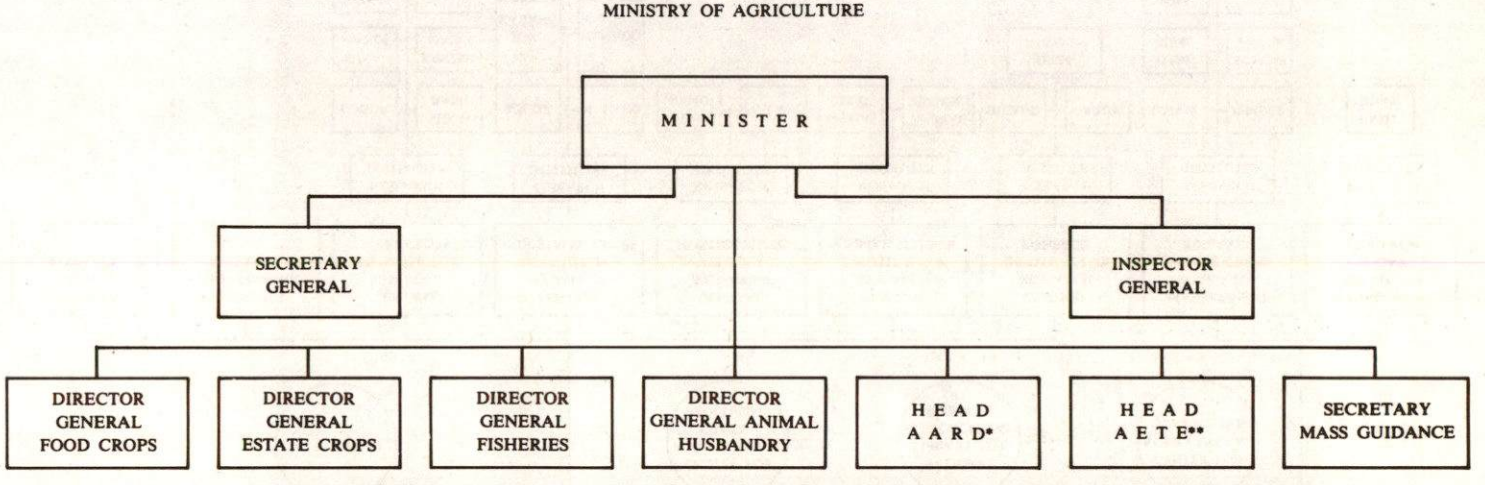


Figure 2. Organizational arrangement of the Ministry of Agriculture.

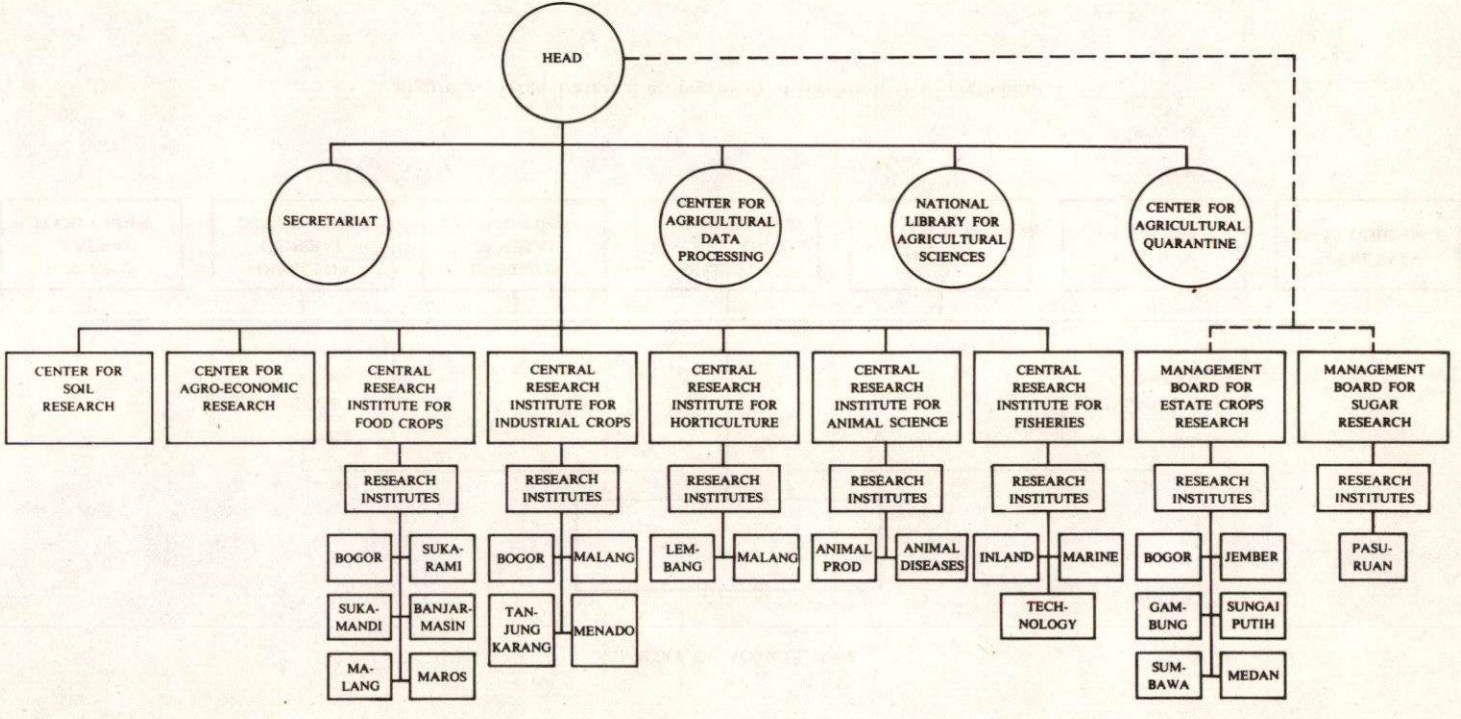


Figure 3. Organizational structure of AARD.

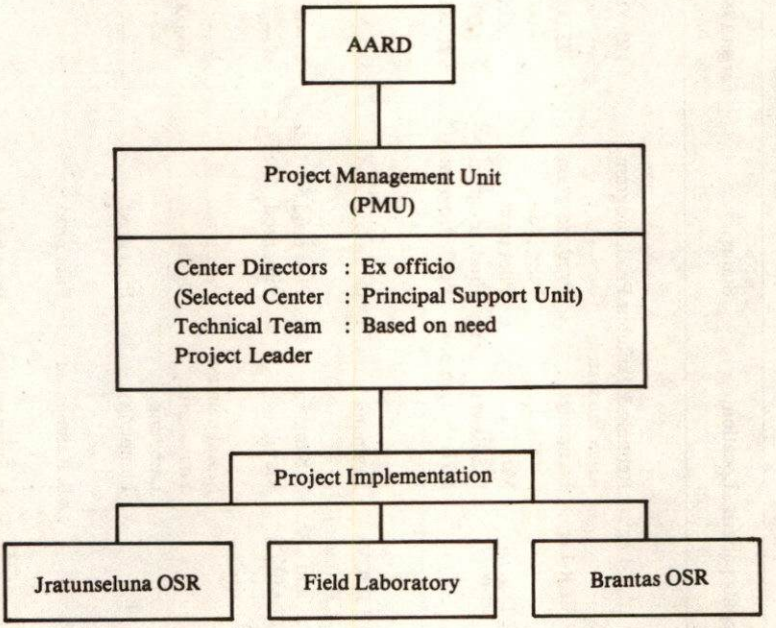


Figure 4. Organizational framework for Farming Systems Research in the Upland Agriculture and Conservation Project.

Table 2. Land areas, research and implementation phases, present impact and potential for cropping systems development in Indonesia.

Land areas	Research			Implementation			
	Sites	Phase	Cropping pattern	Location	Status	Target 1982-83 ha	Potential Area ha
I. **Lowland**							
Irrigated	Indramayu	Implementation	LLR-LLR-Leg[1]	Rentang & Jatiluhur irrigation system	Prod. program	150,000	1,070,779
Partially irrigated & Rainfed	Indramayu	"	GRR-LLR-Leg or GRR-Leg	Lampung	Prod. program	72,000	2,900,000 (partially irrigated) 1,800,000 (rainfed)
	Serang	"		Serang	Pilot prod.	5,000	
	Cibarusa	"		Madura	Pilot prod.	5,000	
	Madura	"	"	S. Sulawesi	Prod. program	75,000	
	Bontoa	"	"	NTB (S. Lombok)	Prod. program	26,000	
II. **Rainfed upland**							
Humid areas	*Sumatra*						
	Sitiung	Testing	C + ULR/CV/ PNT-CP[2](main) and C + SB-MB-CP (aux)	Lampung	Opsus	—	6,000,000 (1/3 x total)
	Pasir Pangaraian	Testing		S. Sumatra	Pilot prod.	—	
	Pematang Pang-gang	Pre-prod.		Riau	Pilot prod.	—	
	Baturaja	Pre-prod.	"	S. Kalimantan	Pilot prod.	—	
	Tulang Bawang	Pre-prod.	"	Yogyakarta	Opsus	30,000	
	Way Abung	Pre-prod.	"	Lampung		—	
	Bandarjaya	Implementation	"	Lampung	Pilot prod.	—	
	Kalimantan						
	Tajau Pecah	Implementation	"	S. Kalimantan	Pilot prod.	—	
	Sulawesi						
	Luwu	Implementation	"	S. Sulawesi	Pilot prod.	—	
	Puriala	Testing	"	S.E. Sulawesi	—	—	
	Java						
	Madura	Implementation	C + ULR/CV-PNT		Pilot prod.	—	

Table 2. (Continued).

Land areas	Research			Implementation			
	Sites	Phase	Cropping pattern	Location	Status	Target 1982-83 ha	Potential Area ha
Drought prone	Atambua	Testing	C + ULR/CV-CP or C + PNT/CV-CP	NTT			
Upper river	Panawangan	Preproduction	C + ULR/CV-PNT-CP	West Java	Pilot prod.		
Watersheds	Solo	Preproduction		C. Java	Pilot prod.		
III. **Deep water**	Kayu Agung	Site selection		S. Sumatra			
IV. **Tidal swamp**	Barambai	Implementation	Surjan system	S. Kalimantan	Pilot prod.	1,000	2,000,000
	Karang Agung	Design	Raised bed: C + PNT or SB/CV-CP Lower part: LLR-LLR	S. Sumatra			

[1] Indicates the pattern: Lowland Rice followed by Lowland Rice followed by Legume.

[2] Indicates the pattern: Cassava interplanted into an intercrop combination of Corn plus Upland Rice (the latter two crops planted about the same time). After harvest of Corn plus Rice, Peanut is interplanted in the Cassava and followed by Cowpea.

CROPPING SYSTEMS RESEARCH

Lowland rice areas. The greatest potential for immediate increases in food crops production exists in these lowland areas which usually have enough infrastructural development to support intensified agricultural production efforts. Cropping Systems Research has been able to develop technologies to further intensify crop production. Even in areas, where considerable irrigation and drainage efforts have been made. The strategies used have included introduction of early maturing and improved crop varieties, direct seeding of rice, reduction in turn around time between successive crops and improved crop management techniques. To facilitate research in the field and direct research to more specific research issues these land areas were usually partitioned according to water availability into the following categories:

- Irrigated lowland
  - Full — 10 months or more
  - Partial — 7-9 months or
    5-7 months
- Rainfed lowland
  - Humid areas
  - Drought prone

Research was carried out in six sites in West Java, Lampung, East Java (Madura) and South Sulawesi. The initial and most comprehensive research was in the Rentang and Jatiluhur irrigation systems in Indramayu. Inspection of the area indicated that usually only two rice crops were grown in the 7 - 9 months and fully irrigated areas. Usually only one rice crop was successfully grown in the areas with less irrigation. If a second crop was planted water shortages drastically reduced yields. However, the extension service was developing the practice of direct seeding of rice on aerobic soil and then allowing the land to flood as the rains increased (gogo rancah) on rainfed areas in Indramayu. This practice permitted some intensification even without irrigation. (Tables 3 and 4).

Cropping systems research successfully showed how these systems could be further intensified through use of earlier maturing crop varieties, use of gogo rancah in partially irrigated and rainfed areas, and a reduction in turn around time. Component research developed more appropriate fertilizer rates and methods of application, insect control measures and weed management.

The patterns of "lowland rice - lowland rice - legume" were successfully and profitably grown in the fully and 7 - 9 months irrigation categories. A combination of gogo rancah rice and lowland rice in the pattern "gogo rancah - lowland rice - cowpea" permitted the production of three crops annually where previously only one crop was grown in the other categories which received only 5 months or no irrigation.

The adoption of this technology from 1973-1977 was slow. The longer maturing Pelita varieties, which were vigorous and high yielding varieties of good

Table 3. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns. CRIA C.S. Project, Indramayu, West Java. 1975-78.

Cropping Patterns	Irrigation category		
	10 months	7-9 months Ave. yield - kg/ha[3]	5-8 months
Farmers' C.P.[1] (1975-77)			
Lowland Rice -	5,560	5,334	3,628
Lowland Rice -	5,820	2,758	2,250
Net Returns	Rp. 381,317	Rp. 250,599	Rp. 131,178
Introd. C.P.[2] (1975-77)			
Lowland Rice -	5,314	5,647	4,781 (GRR)
Walik Jerami Rice -	5,032	4,578	4,630
Legume -	768	944	541
Net Returns	Rp. 379,591	Rp. 422,237	Rp. 222,872
Introd. C.P.[4] (1977-78)			
Lowland Rice -	6,915	7,195	3,451 (GRR)
Walik Jerami Rice -	4,910	4,550	2,901
Soybean -	462	610	---
Cash Surplus[5] to rice	Rp. 527,923	Rp. 523,099	Rp. 205,539

[1] Farmers' cropping pattern.

[2] Introduced cropping pattern. Walik jerami rice is rice directly planted after preceding rice crop w/o plowing the land and Gogo Rancah Rice (GRR) is rice directly seeded on aerobic soil at beginning of rainy season. It is flooded later.

[3] Yields were measured by sampling from 1000 M^2 plots. There were 3 replications/treatment/year for the 2 years, 1975-77.

[4] Yields were measured by sampling from contiguous areas of approximately 3 hectares for each irrigation category for pre-production test trials, 1977-78.

[5] Cash surplus is gross returns minus cash costs for materials and labor, while net returns is gross returns minus costs for all materials and labor, including farmers' labor. One US dollar equal to 425 rupiah at time of research.

Source: Annual Reports, Cropping Systems Research in Indonesia.

Table 4. Adoption of gogorancah in Lampung, 1976-83.

Year	Nambahdadi	Way Seputih	Lampung
	hectares		
1976-77	0,1	—	—
1977-78	4,0	—	—
1978-79	30,0	—	—
1979-80	212,5	—	—
1980-81	262,0	—	—
1981-82*	640,0	5,517	7,000
1982-83**		8,000	72,000

* Program Insus

** Target

Source: Tim Studi Dampak.

quality, were widely accepted by farmers. But because of the longer maturity period only one good crop could be grown per year in the partially irrigated and rainfed areas. Farmers were reluctant to change to earlier maturing varieties until they were forced to change during the brown plant hopper epidemic in 1977. The introduction and use of IR 36, which has a field duration of only 90 days when transplanted, removed much of the risk for intensifying cropping patterns. Consequently, after adoption of earlier maturing varieties, the rice production has drastically increased because two crops can be grown with little risk in irrigated and partially irrigated areas. One good crop can be grown in the rainfed areas. Programs for production of legume crops after rice are being implemented. These include soybeans in the irrigated areas, mungbean in partially irrigated areas and cowpeas in the rainfed areas. The major constraint to widespread and rapid adoption is availability of sufficient quantities of viable and vigorous seed of adapted varieties.

Upland rainfed areas. The second major target area for cropping systems research was the rainfed uplands that were being used for transmigration project development in Sumatra, Kalimantan and Sulawesi. Generally these areas receive enough adequately distributed rainfall, for year around crop production but management constraints have prevented stable and sustainable food crops production. There have been soil management, pest and disease, and socio-economic problems that transmigrant farmers could not easily overcome by themselves.

The initial research showed that the existing cropping patterns could be simplified and made more productive by growing crops in rows, use of moderate rates of fertilizers, and returning crop residues to the soil directly or as manure. The technology developed in Central Lampung has been found to be applicable with

some modifications for the humid areas of Western Indonesia where the rainfall is greater than 2000 mm per year and where there is no distinct dry season. The basic pattern of corn plus upland rice interplanted with cassava (corn + upland rice / cassava), however, is applicable and can be used throughout Indonesia. In the more humid areas the cassava is planted in rows placed two to four meters apart (depending on the market for cassava). One or two legume crops (such as peanut or peanut followed by cowpea) may be planted between the rows of cassava after the harvest of the rice. In the drought prone areas of Eastern Indonesia where there is a prolonged dry season, the cassava may be planted at random and interplanted with a drought tolerant crop such as cowpea.

This technology has been widely accepted by farmers and is now incorporated within the BIMAS production programs. Justification for expansion of transmigration programs in the rainfed upland areas was based to a large extent upon the initial data from cropping systems research in Central Lampung and the successful transfer of technology through on site cropping systems research to other areas of South Sumatra, South Kalimantan and Southeast Sulawesi. (Tables 5 and 6).

Tidal swamp areas. Barambai, South Kalimantan was selected as the initial target area for cropping systems research in the tidal swamps. The tidal swamp ecology varies considerably from place to place. The degree of infrastructural development also varies. Barambai was chosen because some stability has been imposed by drainage, land clearing and settlement activities through the transmigration program. It was felt that new technology could be directly transferred to other land areas with similar descriptions and which were being used for transmigration.

Initially it was observed that indigenous farmers grew rice and other food crops, but that they invariably built raised beds and introduced perennial crops such as coconut, clove, coffee and citrus. The rice varieties used were often photo period sensitive, required several transplantings and took 7 - 9 months to mature. Introduction of earlier maturing rice varieties, improved fertilizer practices and acid tolerant secondary crops permitted more intensive and productive crop production in the lower bed. Longer termed studies are needed to demonstrate techniques for production of perennial crops and development of the raised beds. But from field observations and theory it was concluded that gradual development of the raised beds by adding soil to the sides of the beds each year would not only reduce the labor constraints faced by farmers but would also permit gradual leaching of the sulfurous compound from the soil added to the beds. This research technology has been included in pilot production programs jointly carried out by the food crops research and extension agencies in South Kalimantan. The prospects for transfer and widescale use of this technology are very good. (Figure 5).

Table 5. Yield performance of crops in the introduced cropping pattern tested in ten different rainfed upland areas.

Location	No. years of testing	Yield of crops (t/ha) *				
		Corn +	upland rice /	cassava /	peanut /	ricebean
1. Bandarjaya	5	2.1	2.4	25.6	0.6	0.5
2. Way Abung	5	1.4	2.3	14.7	0.5	0.3
3. Batumarta	5	1.6	1.8	14.8	0.7	0.5
4. Tulang Bawang	2	1.1	2.4	17.7	0.9	0.5 (cowpea)
5. Pematang Panggang	2	0.9	1.3	6.1	0.9	0.4 (cowpea)
6. Kotanegara	2	1.2	0.7	9.8	0.5	0.3 (cowpea)
7. Tajau Pecah	2	0.7	0.7	9.7	0.6	0.3 (cowpea)
8. Pasir Pangaraian	2	1.5	1.2	8.0	1.0	0.4 (mungbean)
9. Puriala	2	1.0	2.1	11.2	0.4	0.3
10. Lahat - Tebing Tinggi	1	2.4	2.8	14.9	0.6	0.3

* Dry grain for corn, rice and legume and wet root for cassava.

Table 6. Production and economic comparison of the farmers' existing cropping pattern with the introduced cropping pattern in two different rainfed upland areas. Southern Sumatra, 1976-82.

	Way Abung		Batumarta	
	FCP	ICP	FCP	ICP
Yield of crops (t/ha)				
Corn +	0.6	1.4	0.6	1.6
Upland rice /	1.5	2.3	1.2	1.8
Cassava /	7.8	14.7	4.2	14.8
Peanut -		0.5		
Rice bean or Cowpea		0.3		
Total calories (Kcal/ha/year)	15,081	31,732	9,972	32,326
Rice (gabah) equivalent (t/ha/year)	6.3	13.2	4.1	13.5
Total labor (man-days/ha/year)	285	605	245	517
Total cost of production (Rp/ha/year)	164,300	444,920	193,250	504,045
Gross return (Rp/ha/year)	348,000	1,004,500	297,750	1,097,523
Net return (Rp/ha/year)	183,700	559,580	104,500	593,478

Note: FCP = Farmers' cropping pattern
ICP = Introduced cropping pattern
1 US$ = Rp. 970.-

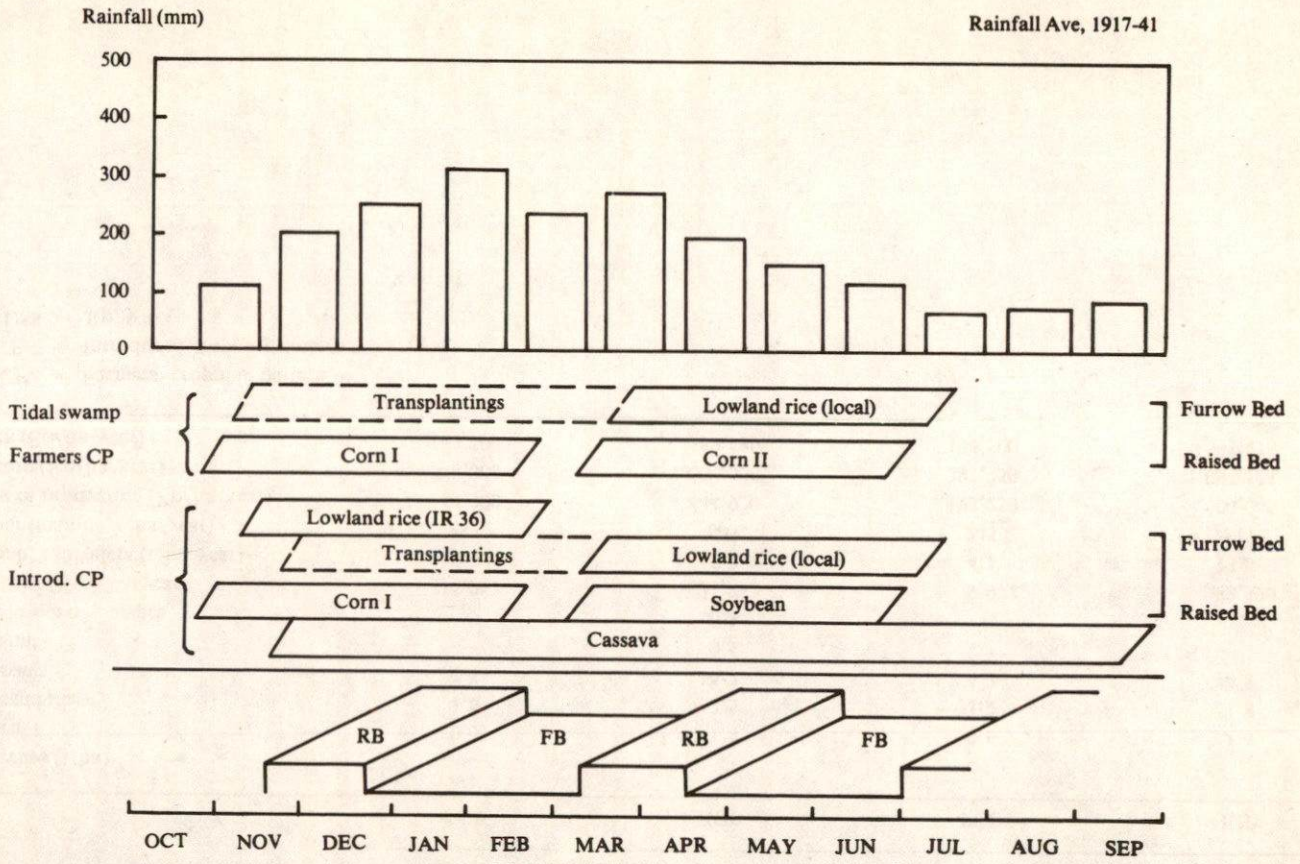


Figure 5. Rainfall distribution, cropping patterns tested and bedding arrangements for cropping system research in drained tidal swamp, Barambai, South Kalimantan. 1979-81.

Source: Annual Report, Banjarmasin Research Institute for Food Crops, 1982.

PRESENT FARMING SYSTEMS RESEARCH

The cropping systems research program developed methodology and a core of personnel that can design and carry out on farm research. The linkages with other commodity research groups and government agencies have also been developed. Gradually farming systems research capability that is holistic has evolved. But in order to conduct research efficiently and effectivelly, it is still appropriate to identify and conduct research on specific research issues that involve only two or three commodity groups or research components. For example, in the upland rainfed areas, food crops agriculture is necessary but usually limited to only a part of the land area owned by a farmer. The farmer finds difficulty to use more than 0.75 hectare of land for food crops production if only family labor is available. Extra power is needed if more land is to be cultivated for these crops. But usually production of food crops in excess of family consumption needs is not the most suitable use of the land. Labor shortages, risk from drought, pests and diseases, erosion and marketing problems limit the attractiveness of food crops production. Yet most farmers own more than two hectares of land. How should this land be used? These are valid research issues, especially since the basic cropping systems for subsistence have been developed.

Crop/livestock research. Much technology has been developed for perennial crops. Present farming systems research strategy encourages the introduction of perennial crops into the farm systems gradually as planting materials become available and farmers identify locations on their land where these crops fit. The major research thrust, however, involves the crop/livestock combination. Suitable on farm research will be carried out to develop more stable and nutritious animal feed supplies. Animal health problems will be studied and controlled. Some research has been carried out in Lampung and South Sumatra in Transmigration areas. However, longer term research is being planned that requires longer duration than can be carried out in the farmer's field.

Upper river watersheds. Throughout Indonesia settlements have flourished in the intra mountain regions. The climates within these areas are moderated by higher elevations and proximity to the high mountains. These settlements have been stable and have flourished. Populations have increased and settlements have gradually moved into lands that are too steep for stable and sustainable agriculture. Many of the lands are suitable only for forests and sources of water for rivers. Losses of the forests have exacerbated problems with flooding, erosion, and siltation during the rainy season and drought during the dry season.

AARD has collaborated with watershed projects in the Citanduy and Solo river systems and in Yogyakarta. These farming systems studies have been directly useful within the project areas but have also provided methodology and experiences for more comprehensive research. In particular research with cropping systems, bench terraces and forage management has provided the technological base for

expansion programs for soil and water conservation. These initial and limited efforts also provide the background needed for further research.

Basically, the traditional cropping patterns in both areas are similar and consist of a mixed cropping of corn, upland rice and cassava. However, in Gunung Kidul the farmers also plant peanuts after rice harvest. The productivity of these traditional cropping patterns may be increased with better management and use of improved varieties. Better management includes the use of soil and water conservation practices by terracing and planting of forage grasses on the terrace risers. Brachiaria at Citanduy and setaria in Yogyakarta grow well on the risers even during the dry season. Further studies are needed to determine the most effective management practices for use of the forage grasses either for large or small ruminants.

Pests and diseases were found to be the major limiting factor for growth and yield of crops in the upper watershed areas studied. Crop varieties may also react differently to varying degrees of slope and elevation. Consequently, further studies are needed to develop crop yield stability in these upper river areas.

DIRECTION AND STRATEGY FOR FUTURE RESEARCH

Cropping Systems Research

The main thrust for cropping systems research in Indonesia has been made. Methodology has been developed, staff have been trained (approximately 150 research and extension workers have been sent to IRRI and other places for training, workshops and monitoring tours in cropping systems alone over the past 10 years) and systems research carried out in all the major ecological areas of Indonesia. These efforts have been well executed and have received wide acclaim. However, this research has identified many specific component studies that need attention and there are problems for maintaining supprot and coordination as administrative and personnel changes take place.

Coordination. Cropping systems research is basically the responsibility of the Research Institutes for Food Crops. These six regional institutes have their own research mandates and develop their own research programs.

Consequently, with time each Institute will develop its own cropping systems program designed to meet the individual research mandates.

For the most part these mandates are based on an edaphological breakdown of land areas in Indonesia and each Institute can and should develop cropping systems research suitable to their area and mandate. There is no need to use such terms as "rice based" or "palawija crop based" cropping systems research but to simply carry out relevant cropping systems research. If the research is done well, the focus will be right also. To make this research as efficient and effective as possible, it would be useful to strengthen the National Cropping Systems Working Group that has functioned over the last 10 years and formalize the periodic

Working Group Meetings. The intent is to provide a technical advisory group to give direction to the coordinated research the organizational structure could be as shown in Figure 6.

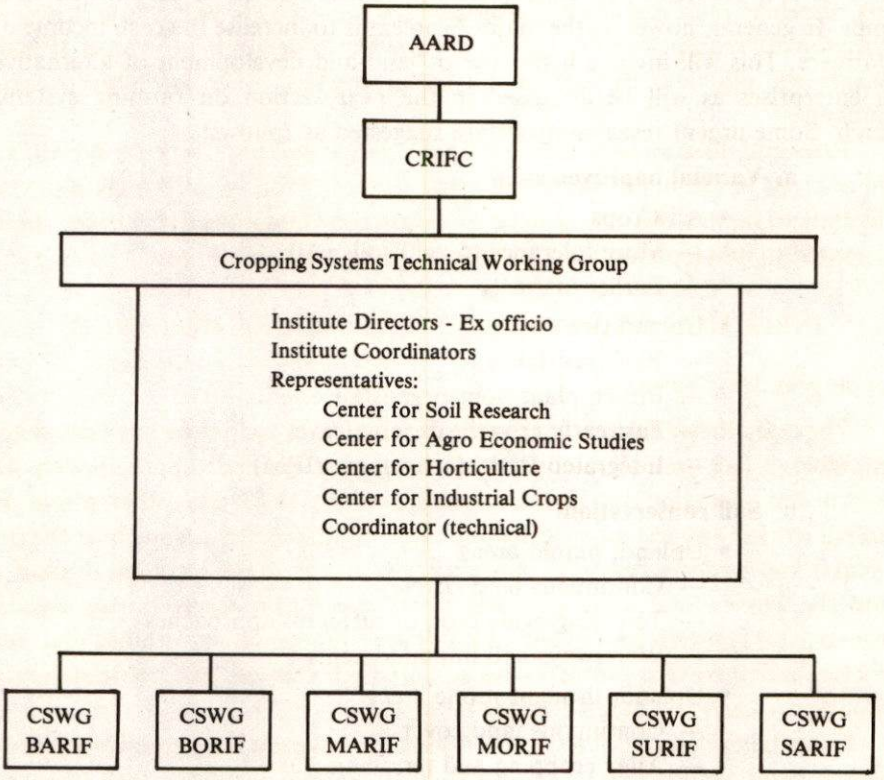


Figure 6. A possible administrative structure for technical coordination of cropping systems research.

Specific Component Studies. As has been pointed out the basic cropping systems research has been completed for the major edaphological land areas in Indonesia. The objective of the research has been limited to food self sufficiency. Unless there is a major production break through or change in the economics of food crops production and marketing this objective will not likely change. But even with this limited objective there are constraints. There are problems with yield stability from one crop season to the next and sustainability of production over time. This is a problem, particularly for the upland rainfed areas and the tidal swamps. In general, however, the major problem is to increase the cash income of the farmers. This will involve better use of land and development of alternative farm enterprises as will be discussed in the next section on farming systems research. Some urgent research needs are suggested as follows:

a. **Varietal improvement**
   - All Crops
     - — More tolerance to acid soils (Al)
     - — Earlier maturity
   - Upland rice
     - — Blast resistance
     - — Brown plant hopper resistance
     - — Fast early growth, droopy leaves
     - — Integrated Pest Management (IPM)

b. **Soil conservation**
   - Upland, humid areas
     - — Continuous land cover
     - — Terracing-evaluation of different approaches
     - — Waterways and impoundments
   - Upland, drought prone areas
     - — Continuous land cover
     - — Alley cropping and terracing

c. **Soil fertility and management-long term**
   - All upland areas
     - — Soil characteristics related to crop performances
     - — Lime x phosphorus studies
     - — Organic matter management
   - Tidal swamp areas
     - — Soil characteristics related to crop performances
     - — Evaluate systematically the raised bed-furrow bed system

d. **Pest management**
   - All areas
     - — Weeds, broodleaf (boreria)

— Pod borers
— Integrated pest management for blast and hoppers

e. **Farm implements**

- All upland areas
  — Seeders
  — Cultivators
  — Weeders

Uniform Systems Trials. We do not know the long term effects of intensive cropping nor the relationship between soil analyses and crop responses particularly on soils in upland areas. We need to establish a transect of sites across Indonesia in the upland red-yellow podzolic soil areas to evaluate over a five to ten year period the effects of intensive cropping and soil fertility and management practices. This fund of research has begun through the fertilizer efficiency working Group within the Centers for Soil and Food Crops Research.

a. **Lime x phosphorus studies on intact and scraped (remove top organic layer ± 10 cm) soils.**

- Minimum input
- Medium input
- High input

b. **Residue management studies**

- Remove
- Return all
- Supplement

c. **High management plots - Demonstration and yield potentials.**

- High soil fertility
- Fully terraced
- Intensively cropped

d. **Complete soil and plant analyses as required.**

- Develop rationale-common methods
- Correlation

Transfer of technology. Even though there has been more than ten years of cropping systems research and development there is still much confusion concerning data, publications, guidelines and/or recommendations. There are many reasons for this. That is one of the primary objectives of this paper. We must plan the research and disseminate the results better so that it is more convincing to ourselves, colleagues and clients. Site description and abstracts shown in Appendix I need to be further developed and stored. References of all reports, seminar papers and Published documents need to be compiled and computerized to permit quick retrieval, Appendix II.

a. **Improve quality of research**

- Coordination as has been stated
- Improve precision of experiments
- Improve data collection and characterization

b. **Workshops**

- Discussion and consensus among working group members
- Planning and policy
- Where have been and where to go
- Analyze and discuss results of research

c. **Research publications**

- Complete
- Readable
- Authorized

Farming Systems Research

The usual farming systems in Indonesia are composed of several components. These components are sometimes referred to as sub-systems. On the other hand, the study of the whole farm would be called holistic farming systems research.

The initial work in Indonesia was pragmatic and largely directed by policy and circumstances. But gradually the research that started with intensification of lowland rice and long term soil fertility and management studies in Central Lampung has evolved into a broad based farming systems research program. Considerable experience has been gained and approaches developed to carry out effective research in the various land areas of Indonesia. But there is a continual need for more effective coordination and planning.

Coordination. Farming systems research is basically the responsibility of the Agency for Agricultural Research and Development (AARD) just as cropping systems is a responsibility of the Research Institute for Food Crops. In a similar fashion we may consider cropping systems to be one component of the farming systems. The same relationship holds for the systems research from the other Centers which represent commodities. Forestry, which is now a separate ministry, must also be a part of the farming systems research consortium together with its soil conservation unit (P3DAS) and must be considered along with the other research groups. It is likely and even necessary that each Center or research Institute carries out its own systems research as it develops the technology to meet its mandate. But at some point it is useful and very important that all the relevant Centers, Agencies and Universities work together in one project or geographical area. How can this work be administered and technically coodinated effectively?

Figure 4 showed an example of an organizational framework for a Farming Systems Research Project. This is a large long term project that will require a full

time project leader and several senior staff from the various Research Centers. In many instances this kind of administrative and technical organization is necessary for area development projects. But on the other hand for Transmigration Areas it might be better to develop smaller research projects that are more narrowly focused. Broad based and holistic farming systems research can be very difficult to manage and may be inefficient. It may be better to build on past cropping systems research (including staff as well as expertise) and add complexity one step at a time. In general the objectives or goals given in Table 7 are relative for research in new

Table 7. Research goals for farming systems research and the degree to which these goals have been attained in upland Transmigration Areas.

Goals for Systems Research	Status
I. Initial subsistence (cropping systems)	
• Appropriate food crops systems	— OK
• Productivity (subsistence)	— OK
• Economical (break even)	— OK
• Acceptable level of risk	— Still too high
• Stability (Short term)	— Need economic stability
• Family labor use	— Not adequately used on farm (off farm labor sought)
• Land resource use	— Still land not used
II. Long term (farming systems research)	
• Subsistence + Cash income	— Need more cash income
• Full use of family labor	— Opportunity for more on farm labor needed
• Full use of land resource	— Options for use follow land
• Low risk	— Need for technology for alternative agricultural interprises
• Stability	
Production	a. Subsistence needs met with food crops
Economic	b. Alternative interprises, for example, animal and perennial crops needed.
• Sustainability	
Production	Perennial crops needed to make better use of land and provide production and economic stability and sustainability.
Economic	

Transmigration Areas. The degree to which we have accomplished the initial goals for subsistence determines what we do next. If these goals can be easily attained and the farmers desire more income and are not fully using their land and labor resources, another production component (agricultural enterprise) may be added to the system. There are several factors that farmers must consider when adding to a subsistence (cropping) system. Usually in upland transmigration areas the

decision to add depends on the following situations:

- Little opportunity for off farm labor
- Family labor is not fully and efficiently utilized
- Land available is not fully utilized.

The actual farm enterprise added usually involves livestock or perennial crops or a combination of both. A research proposal for crop/livestock research has been developed to address some of the research issues involved for the Batumarta Transmigration Area. This proposal represents the "limited farming systems approach" that appears to be most efficient for most situations in Indonesia (Figure 7). We usually consider that the farmers will, on their own, develop a home garden and gradually add perennial crops to the system. But this process can be greatly simplified and assisted by research and development of relevant technology. Government assistance through production programs can provide the quantity of production that is necessary many times to overcome processing and marketing constraints. Consequently, coordination is not only a prerequisite for effective research but also for technology transfer and implementation.

Target areas and research issues for FSR. The division of assignments among the various Research Institutes of the Central Research Institute for Food Crops according to edaphological land areas (Table 1) is an effective way of providing for research coverage and efficiency. These target areas may be partitioned further as needed. For example, the tidal affected land areas may be divided into direct, indirect and drained tidal swamps. Each has characteristics that require special attention. For more general farming systems research the same target area divisions may be used but with additions as needed. One addition presently under consideration is the upper river watersheds.

It must be understood that each Center is responsible for component and systems studies that relate to its speciality. For example, the Cropping Systems Research and organization that has been described in this paper is or may be one example of kinds of research each should be doing. In an integrated farming systems project all or some of these components must work together. There is no need for one national farming systems project that covers all areas and conditions. There may be a need for national coordination as mentioned in the previous section but research in each specific target area or division there of may have its own project management unit and project leader. Specific administrative and technical responsibility must exist if a project is to be effective. It is assumed that systems research in each Center will provide much relevant component technology for Target Area Research. However, this will not preclude further research on site.

Generally the target Areas for integrated farming systems research in Indonesia are as follows:

- Tidal Swamp Areas
- Palawija Crops Areas
- Upland Rainfed - Drought Prone Areas
- Upland Rainfed - Humid Areas
- Lowland Rice Areas
- Upper River Watershed Areas

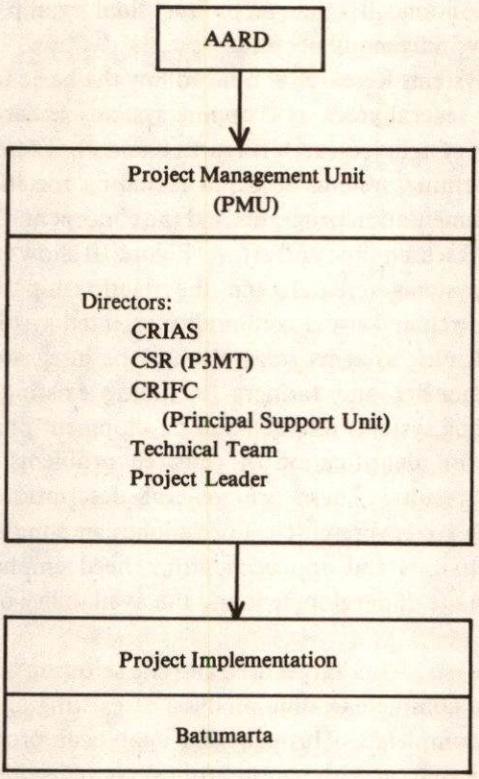


Figure 7. Organizational framework for the crop/livestock project in Batumarta, South Sumatra.

Research approach. The first five broad target areas given in the previous section coincide with the research mandates of five of the Research Institutes for Food Crops. The upper river watershed areas fall within each of these five target areas but it is logical that the major research thrust be carried out by one Institute. The Upland Agriculture and Conservation Project that is being developed, however, will play a major role in addressing the research needs of the areas and will likely be administered by a Project Management Unit directly responsible to AARD (Figure 4). Each of these target areas may be further partitioned into areas that require special attention or needs for example a drained tidal swamp area settled with transmigrants is vastly different (econologically, biologically, sociologically and economically) than an indirect tidal swamp that has been settled for many decades by indigenous people.

The Farming Systems Research should follow the basic format that has been successfully used for several years by cropping systems research in Indonesia and modified for farming systems research (Figures 8 and 9). These diagrams show the basic strategy for farming systems research including the interfacing with pilot production and implementation programs and the concept and value of technology transfer in saving of research time and effort. Figure 10 shows the interdisciplinary nature of farming systems research and the relationship of integrated mixed farming systems research and usual commodity oriented systems research. Figure 11 illustrates how farming systems research must be integrated (linked) with the other government agencies and farmers (including existing private enterprise) through all the farming systems research and development phases. These linkages are vital especially for identification of research problems and for subsequent implementation of results. These are general descriptions of activities and intentions of farming systems research. For Indonesian conditions there are some specific research activities and approaches that need emphasis because of the natural conditions, stage of development and the availability of technology for the specific target areas.

a. **Ex ante analysis.** After target area and site selection and as part of the site description process a complete **ex ante** analysis of existing and predicted farming systems should be completed. Through this analytical process many unviable systems may be rejected and the more robust systems identified for further evaluation. To do this considerable background information and data are needed. Collecting these data is a logical function of the agro-economic studies team involved in site description. There is a need for the National Farming Systems Working Group to collect these data and reach a consensus among relevant scientists for the accuracy of the data. This background information is needed for the different agricultural enterprises such as food, vegetable and perennial crops and for fish, poultry and animal husbandry. The data should include the following which specifically relate to food crops but may be easily adapted to include perennial crops and livestock (including fish and poultry).

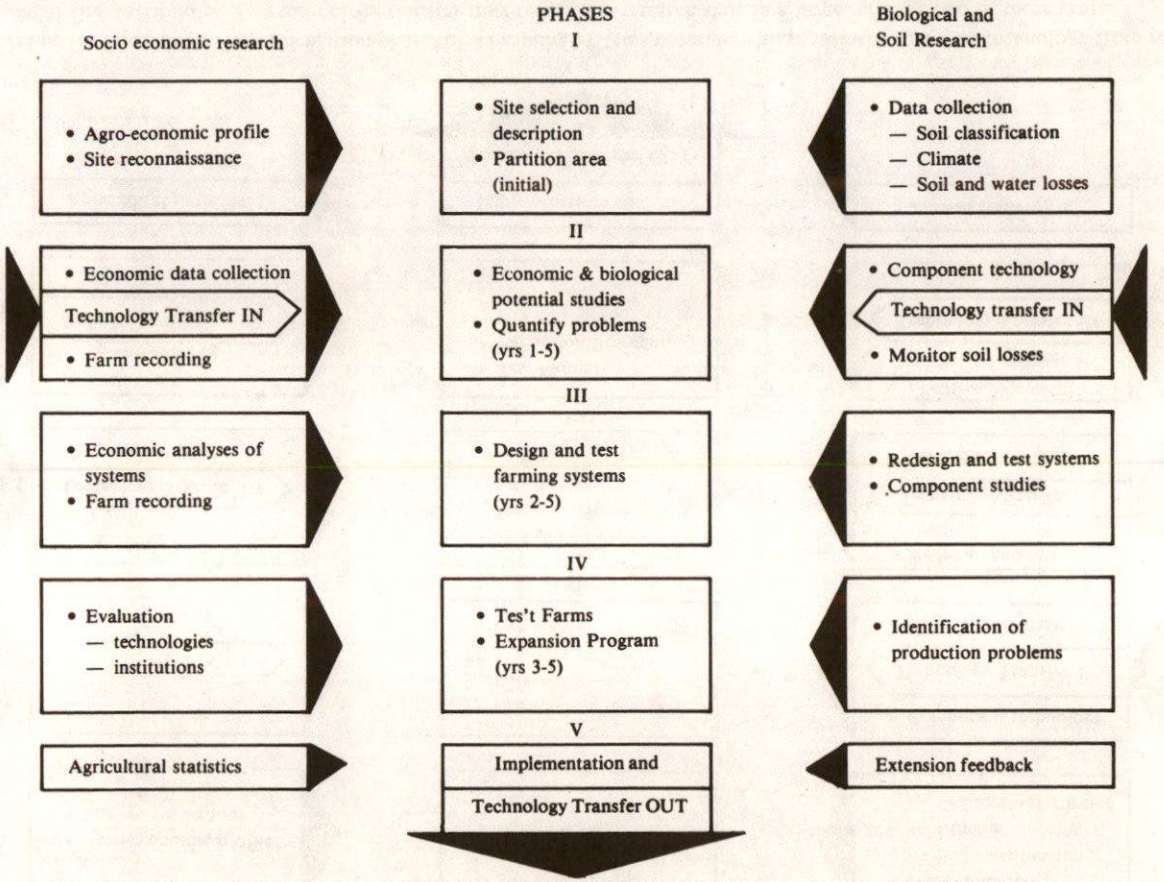


Figure 8. Parallel biological and socio-economic activities required for the five distinct research and implementation phases of a Farming Systems program with little inflow of technology.

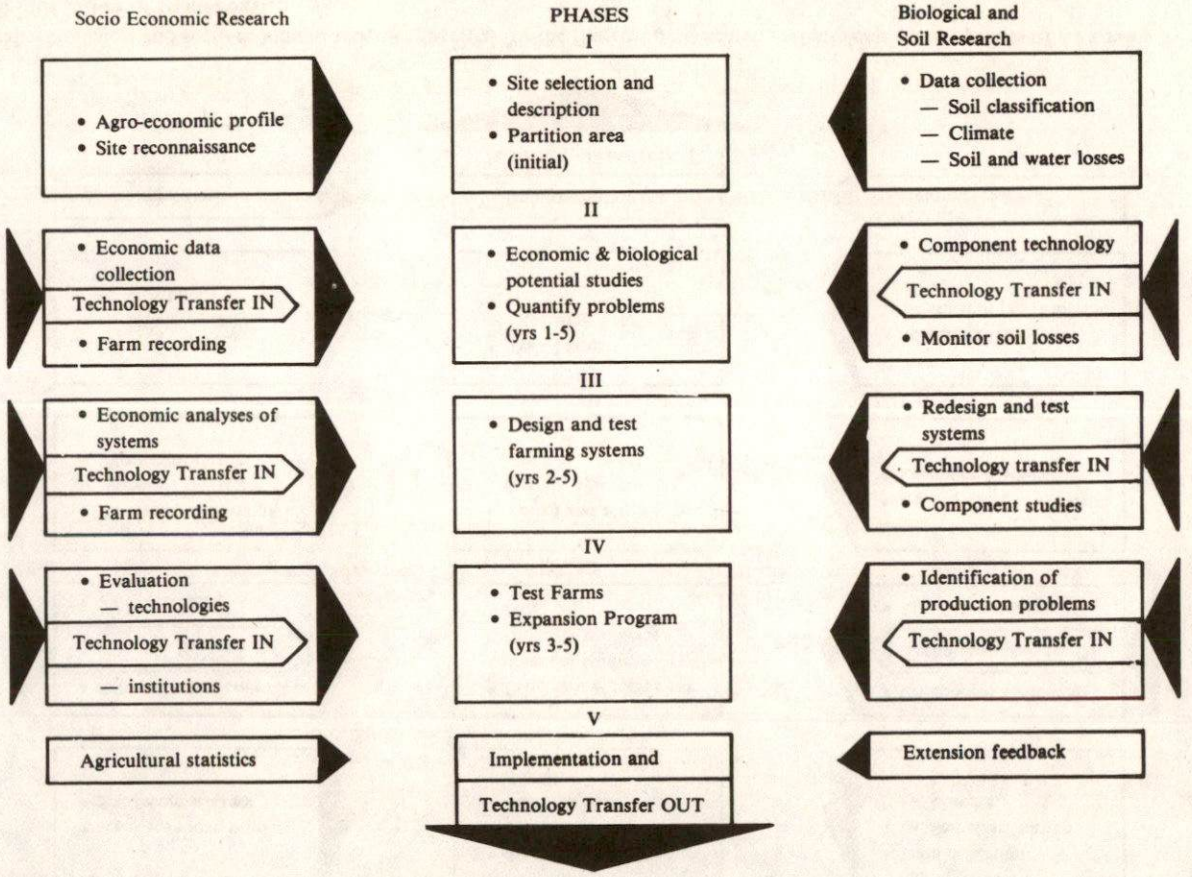
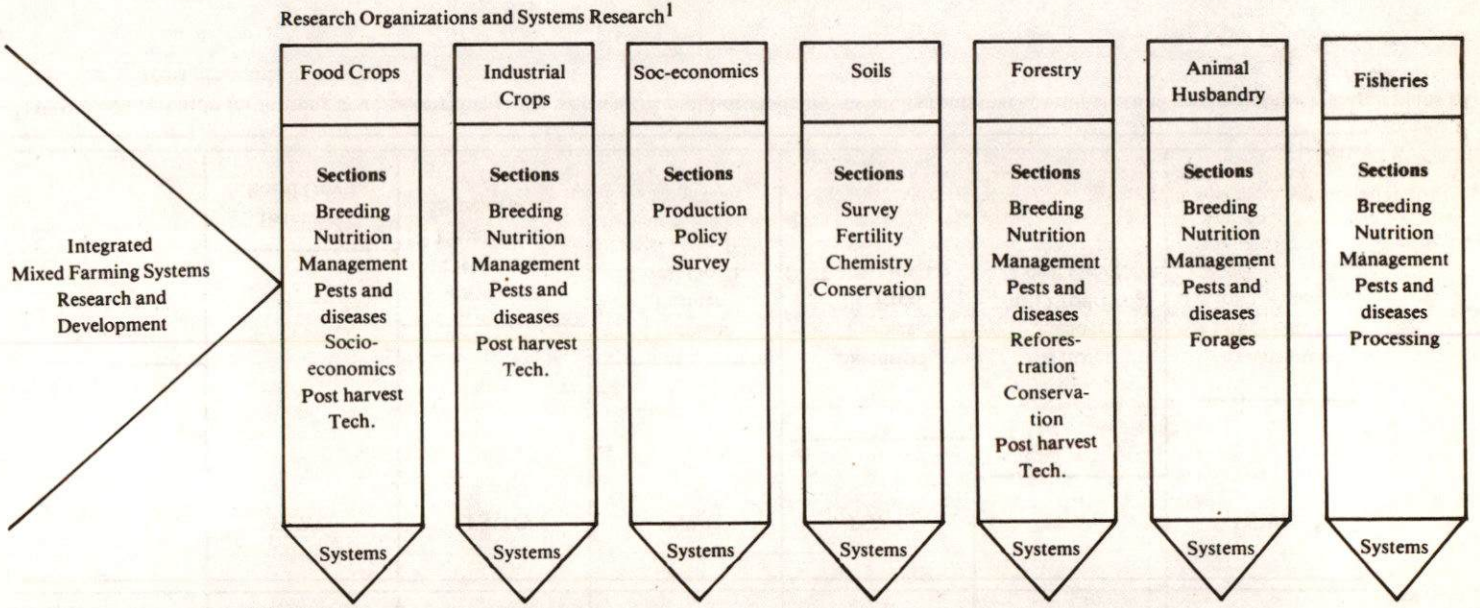


Figure 9. Time frame for research and implementation phases of a Farming Systems program with significant inflow of technology from research in areas with similar site discriptions. This technology transfer may reduce the research time in a target area by two or more years.



[1] This diagram illustrates how research in a farming systems program (FSP) interacts with other systems, programs and traditional commodity and discipline-oriented research activities.

Figure 10. Framework for integrated mixed farming systems research for small farms.

	RESEARCH & IMPLEMENTATION PHASES					
Target Area Selection	I Site Description	II Econ & Biol.Pot'l	III Design & Test	IV Pilot Prod.Prog.	V Implementation	Technology Transfer
FSWG[1]	FSWG	FSWG	FSWG	FSWG	FSWG	FSWG
Extension Local Gov't. Nat'l Gov't.	Extension Local Gov't.	Extension Farmer Local Gov't. Bureau Stat.	Extension Farmer Local Gov't.	Extension Farmer Dir. Prod. Local Gov't.	Extension Farmer Nat'l Prod.Prog. Local Gov't.	Extension Other Nat'l Gov't, Agen.

[1] FSWG-abbreviation for farming systems working group which is the multi-disciplinary research group that coordinates and carries out the research plans of farming systems programs in a target area.

Figure 11. Research interface with other government agencies and farmers through different phases of a farming systems program.

Suggestions: Data to be collected and verified for general use are:

- Management practices and labor requirements
  - — Land preparation (plowing, terracing and cultivation)
  - — Planting (spacing, seeding rates and varieties)
  - — Fertilizer practices (rates, placement and timing)
  - — Pest and disease management
  - — Harvesting
  - — Post harvest (drying, storage and transport)
- Costs of production
  - — Labor (from above)
  - — Inputs (from above)
  - — Credit
- Expected yields
  - — Individual crops (time as well as yields)
  - — In combination (monoculture and intercrop)
- Expected sale prices
- Expected profit or loss from year to year until stable system is developed
  - — Crop or agricultural enterprise
  - — Whole system

b. **Field Laboratory.** Much of the information needed for the **ex ante** analysis is available from the routine activities and publications of the various Research Centers of AARD and the Directorate's General of the Ministry of Agriculture. It should be reiterated that Farming Systems Research and Development does not replace nor supercede the routine research and development activities of the Ministry of Agriculture. In order to develop more appropriate technology for farm systems for the different edaphological areas of Indonesia, more direct effort and interaction of researchers with farmers and their circumstances in needed. This has been done through on-site research that is a routine part of cropping systems research. Within Indonesia where so many different conditions exist (edaphological, sociological and institutional) the gap between routine commodity and disciplinary research in research centers and on-site research in farming systems is very wide. For cropping systems research (a part of the farming systems) this has not been a problem.

On-site research for farming systems is not likely to be effective if there is insufficient technical and staff support from the research centers. Unfortunately, frequently the support that is available is fragmented according to discipline and commodities.

There is a need to provide a research environment for technology development that closely resembles the farming systems in which the technology will be used, but which permits more experimentation over a longer period of time under the researcher's control than can be managed through on farm research. The

relationship among Research Centers, On Site Research and Farming Systems Field Laboratories is shown in Figure 12.

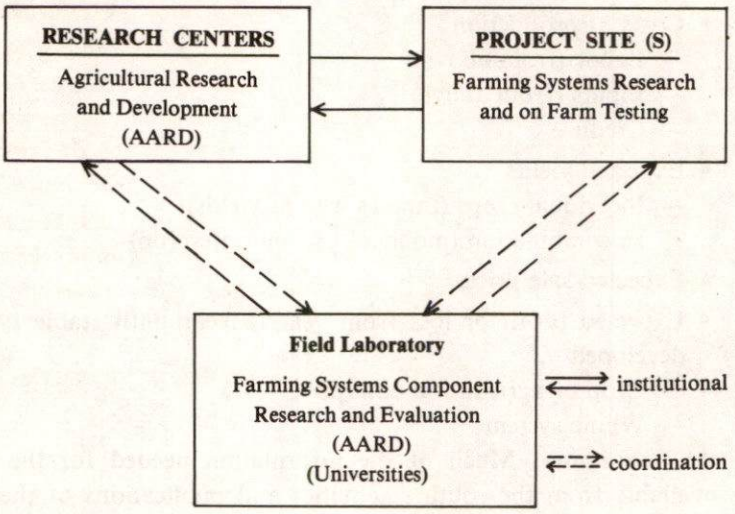


Figure 12. Development, evaluation, testing and flow of technology for Farming Systems Research and Development.

Suggestions:

Support the development of Farming Systems Field Laboratories in which relevant component and systems technology may be developed and evaluated on an interdisciplinary, comprehensive and longer termed basis for the major edaphological areas of Indonesia where existing facilities are not adequate or appropriate. The objectives would be:

- to provide a central location for more efficient collection, evaluation and transfer of appropriate component technology,
- to provide an opportunity to conduct long term experiments on topics, such as, land clearing, perennial crops, soil conservation,

water control, fertilizer efficiency, crop residue management, crop/livestock and stability and sustainability of different farming systems and land management,

- to provide an environment for conducting interdisciplinary farming systems research before technology is transferred to farmers.

c. **On-Site Farming Systems Research.** This kind of research must be on-farm and not as long term and comprehensive as that in the Field Laboratory. Since the methodology for cropping systems research and basic technology for cropping patterns and management have been developed for many agricultural areas, new studies will, in most areas, concentrate on the development of stable and sustainable mixed farming systems. The research will focus on the components which appear most relevant with the intent of making better use of farmer labor, reducing risk and improving soil and water conservation practices. Since past research on cropping systems has developed much relevant technology for that component new projects will in most cases emphasize animal, pasture and perennial crops research. The order depends on field conditions on site.

Suggestions:

Except for special circumstances the farming systems research follows the sequence outlined below.

- Develop subsistence from food crops
  - — Develop appropriate cropping systems
  - — Produce calories needed
  - — Determine minimum labor and land requirements

  Rationale:

  Except for lowland rice, food crops tend to have high risks for production and marketing and tend to have high labor peaks and seasonal demand for inputs.
- Develop cash income and minimize risk through diversification
  - — Off farm labor
  - — Crop/livestock
  - — Crop/livestock/perennial crops
  - — Speciality crops

  Rationale:

  Diversification permits better use of land and labor resources and provides more market opportunities. Sequence of agricultural enterprises to study and eventually include in a farming systems depends on the situation. Neither researchers nor farmers are able to cope with adjustments in all components at one time. Most likely sequence would be as shown above.

4. **Technology transfer.** Field Laboratories and On-Site Research activities are expensive in terms of personnel, funds and time. It is not feasible nor necessary

to carry out detailed farming systems research within all the various land areas in Indonesia.

There are two effective ways to improve efficiency for the development and use of technology.

a. **Research coordination.** This term has been used many times in this paper and will be used again to emphasize the importance of providing a format by which researchers have some feeling of research priorities but not constrained by boundaries. Coordination can provide the framework that encourages collaboration but does not prohibit some competition. It discourages repetition of preliminary and shallow research and provides a mechanism for transfer of technology among scientists.

b. **Site description and transfer of technology.** Systematic socio-economic and soil and biological descriptions of research sites provide the bases for technology transfer to target areas with similar conditions. Figures 8 and 9 illustrate the mechanism for this kind of technology transfer. It is not necessary to repeat all the research phases of a farming systems project in each target area. It is especially important in a developing country to make efficient use of research funds.

Suggestions:

- Organize a National Farming Systems Working Group similar to that for Cropping Systems (Figure 4) and provide for periodic group meeting and publication of data.
- Develop a systematic procedure for site description and format for presentation of data so that all members of the Working Group understand each other's work.
- Develop linkages for informal technologic transfer.

REFERENCES

1. Anonymous. 1977. The third workshop on cropping system, August 1-13, 1977. CRIA, Jalan Merdeka 99, Bogor.
2. Anonymous. 1978. The final result on cropping systems research in transmigration areas, Southern Sumatra 1976-1977. Cooperation Work between Directorate General of Transmigration and CRIA, Bogor.
3. Anonymous. 1982. Hasil penelitian pola usahatani orientasi pangan di daerah transmigrasi lahan kering Tulang Bawang dan Pasir Pangaraian 1981/1982. Badan Litbang Pertanian, P3MT, Bogor.
4. Anonymous. 1983. Lokakarya Teknologi dan Dampak Penelitian Pola Tanam. Badan Penelitian dan Pengembangan Tanaman Pangan. Bogor, 20-21 Juni 1983.
5. McIntosh, J.L., Surjatna Effendi and A. Syarifuddin. 1976. Proceedings of IRRI Symposium on "Cropping Systems Research and Development for the Asian Rice Farmer". September 21-24, 1976. IRRI, Los Banos, Philippines.
6. McIntosh, J.L. and Surjatna Effendi. 1978. Soil Fertility Implications of Cropping Patterns and Practices for Cassava. In: Proceedings, International Workshop for Intercropping with Cassava held at Trivandrum, India, Nov. 27-Dec.1, 1978. IDRC-142e. Pp 77-86.

7. McIntosh, J.L., Surjatna Effendi and Inu Gandana Ismail. 1980. Productivity of tropical upland soils can be maintained and improved. Indonesian Agricultural Research and Development Journal. Vol.2, No.1, 1980. Pp 13-16.
8. McIntosh, J.L., 1981. Indonesia Cropping Systems Program. In: Readings in Farming Systems Research and Development. Ed. by: W.W. Shaner, P.F. Philipp and W.R. Schmehl for USAID Contract No. AID/PSAN-C-0054.
9. McIntosh, J.L., Inu Gandana Ismail, Surjatna Effendi and M. Sudjadi. 1981. Cropping Systems to preserve fertility of red-yellow podzolic soils in Indonesia. In: Proceedings, International Symposium on Distribution. Characteristics and Utilization of Problem Soils. TARC, Tsukuba, Japan, October 16-26, 1981. 11p.
10. McIntosh, J,L., Zainuddin Harahap and B.H. Siwi. 1982. Cropping Systems and Upland Rice - Asia. In: Proceedings, Upland Rice Workshop. October 4-8. 1982. Bouake, Ivory Coast. 17 p.
11. McIntosh, J.L. 1983. Cropping Systems Research for Agrotechnology development and transfer. In: Agrotechnology transfer in Indonesia and the Philippines. B.G. Cagauan, Jr., G.Y. Tsuiji and L.W. Peterson, Editors. BSP Tech. Rep. 9 HITAHR Res. Ext. Series 027. College of Tropical Agriculture and Human Resources, Univ. of Hawai at Manoa. Pp 105-113.
12. McIntosh, J.L., Surjatna Effendi, R.H. Bernsten, A. Syarifuddin Karama, Inu G. Ismail, Imtiaz Basa, Asep Saefuddin and Soeharsono. 1983. Indonesian Farming Systems Research and Development. Agency for Agricultural Research and Development, Central Research Institute for Food Crops, Bogor, Indonesia, Publisher.
13. Pandang, M.S., J. Tandiabang, and J.R. Hoopper. 1980. The final result of cropping systems research in Makaleo, Southeast Sulawesi (1978-1979). Lembaga Penelitian Pertanian Maros.
14. Pasaribu, Djuber and J.L. McIntosh. 1983. Increasing Soybean Production through Improved Cropping Systems and Management in the Tropics. In: Proceedings. The First International Symposium on Soybean in Tropical and Subtropical Cropping Systems, TARC, Tsukuba, Japan. September 22 - October 1, 1983. 28 P.
15. Surjatna E.S., J.L. McIntosh, Soetjipto Partohardjono, and Haeruddin Taslim.1979. Cropping Patterns for Rainfed Lowland Rice Areas in Indonesia. In: Rainfed Lowland Rice. Selected papers from the 1978 International Rice Research Conference. Los Banos, Philippines. Pp 285-296.
16. Surjatna E.S., and J.L. McIntosh. 1980. Food Crops Production and Control on **Imperata Cylindrica** (L.) Beauv. on Small Farms In: Proceedings of Biotrop Workshop on Alang-alang. Bogor, Indonesia, July 27-29, 1976. Biotrop Special Publication No.5 Pp. 135-147.
17. Surjatna E.S., I.G. Ismail, Hidayat N. and I. Basa. 1982. Hasil penelitian pola usahatani menunjang program transmigrasi. Departement Pertanian, Badan Litbang Pertanian. P3MT. Bogor.
18. Surjatna E.S., I.G. Ismail, and J.L. McIntosh. 1982. Cropping systems research in Indonesia. Report of a Workshop on Cropping Systems Research in Asia. IRRI, Los Banos, Philippines.
19. Syarifuddin A., Surjatna Effendi, Inu G. Ismail, and J.L. McIntosh. 1974. Performance of corn, peanut, mungbean and soybean in monoculture and intercrop combinations of corn and legumes in dry season 1973. Contribution No.12. Central Research Institute for Agriculture, Bogor, Indonesia.
20. Syarifuddin A., Soeharsono and J.L. McIntosh, 1975. Multiple Cropping in Indonesia, Proceedings of Workshop for South and Southeast Asia Cropping Systems Network. IRRI, Los Banos, Philippines. March 18-20, 1975.
21. Syarifuddin A., and J.L. McIntosh. 1975. Cropping Systems for Transmigration Areas in Lampung on Upland red-yellow podzolic soils. A preliminary report. In: Proceedings of Symposium "Pencegahan dan Pemulihan Tanah-tanah Kritis". Jakarta, Indonesia.
22. Syarifuddin, A.K., I Madi, Adlis G. 1983. Palawija sesudah padi sawah tadah hujan di Aceh Utara. Pemberitaan Penelitian Sukarami No.1, April 1983, Balittan Sukarami.