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INDONESIAN FARMING SYSTEMS RESEARCH AND DEVELOPMENT

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Forward

The research strategy and data presented are intended to be descriptive rather than comprehensive. Hopefully though, enough detail is included to give a clear picture of cropping systems research, its role in the development of farming systems and its inter-relationship with other research that is discipline and commodity oriented.

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Farming Systems - Issues and Some Answers

Indonesian Farming Systems Research and Development

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Introduction

The problems that farmers face are always interrelated. Attempts to solve a specific problem may create new problems. This fact creates a dilemma for agricultural researchers. By training and temperament scientist like to simplify. A common technique is to study one aspect of a system while holding other factors constant. This technique is a powerful tool. Agricultural research in developed countries is usually directed toward disciplines or kind of crop or animal. This specialization permits in depth study of the components of a farming system. When carried to an extreme this approach becomes counter productive and produces a kind of research irrelevence. But fortunately extension and farmers are able to incorporate certain useful aspects of the research into the existing situation. However, even in developed countries there is a trend at present for scientists to devote more time and effort to systems research that addresses the immediate problems farmers face. This is similar to the approach that was used in the early days of agricultural research and is appropriate in many situations in developing countries today.

Unfortunately, the interdisciplinary, integrated and holistic approach to farm research sounds complicated. It does not fit the usual scientific approach that is commonly taught in colleges and universities. It costs a lot of money and takes considerable time and commitment.

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[1]Cropping Systems Agronomist and Cropping Systems Coordinator. Cooperative CRIFC/IRRI Program and Central Research Institute for Food Crops, respectively. Agency for Agriculture Research and Development, Bogor, Indonesia. September 4, 1981.

It is difficult to mobilize and maintain the interest of scientists because of the difficulty to establish ones identity, either personally or scientifically, in this kind of research. But for those who empathize with farmers and their problems this kind of research is highly rewarding. The reward is not monetary nor necessarily in quantity or even quality of scientific papers but in the realization that one is identifying problems and directly meeting the needs of people. There is a reward in working with colleagues from other disciplines. There is also fascination in understanding how farmers cope with problems and situations that we as scientists tend to shy away from.

In addition to relevant problem focused research, agricultural scientists should provide the technology and ideas for future agricultural development activities. It would be expedient for these scientists to do the research before they are requested to provide answers. The stimulus for agricultural development should come from researchers rather than the stimulus for research coming from development. In this way agricultural scientists will be able to serve the country better, bring credit to themselves and gain support to their research organization.

A comprehensive national farming systems program by definition should address the many situations that exist horizontally across the country and vertically within any system. This is not possible to do at any one time. Some logical rationale must be established

for priority, scope and depth of research. If we look at some of the specific situations that exist in Indonesian agriculture and achievements that have been made in a systematic fashion the prospects for success are much greater.

Achievements

I. Indonesian cropping systems scientists have developed a strong and comprehensive research and development program over the last 10 years. It has evolved into a farming system research program.

II. In Collaboration with Colleagues in the Asian Cropping Systems Network, methodology for effective interdisciplinary cropping systems research has been developed. Indonesia has been a leader in this development and has demonstrated the effectiveness of the methodology for intensifying cropping systems on irrigated and rainfed lowland rice lands of Java and on the fragile and infertile upland soils of Sumatra, Kalimantan and Sulawesi. Except for the original research sites in Indramayu, West Java and Bandarjaya, Central Lampung, most site selection for research has been in response to requests from various Indonesian development projects.

III. A team of interdisciplinary scientists has been trained and initiated through formal training courses outside and within Indonesia and through experience in the field. These activities have provided a cadre of personnel that are now ready and capable of conducting comprehensive and phased research that can effectively identify

and remove constraints that farmers face for increased crop production and economic well being.

IV. Farming systems research in transmigration areas and upper watershed projects has begun. A precedent for successful interdisciplinary research among all research centers in the Agency for Agricultural Research and Development has been established.

Statement of present situation

Although the emphasis is on crops, cropping systems research in Indonesia considers all farm related activities; from land preparation, which includes animals and family labor, to marketing, which includes transportation and infrastructural development. In the strategy, initial research concentrates on food crops production for the farmer's subsistence. Concurrent with the objective, constraints to increased production or landuse are identified. For example, in upland areas family labor with hand tools can cultivate only about 0.6 hectare of land per year. There is shortage of power to make use of the remaining land resources. Animal power may be the solution. If so, the farmer will need animal drawn farm machinery and forage for feed. Consequently, the farmer may be able to cultivate more land because of the additional power and make use of even more by using some land for forage crops. Use of animal manure and excess forage for green manure will improve the soil fertility. Additional land may be used profitably for production of perennial crops for spices,

food, fiber and fuel. Furthermore, structures developed for water control and soil conservation can be used to impound water for family use, fish and animals. Systematically, cropping systems research evolves into farming systems but on a limited and systematic basis that can be managed.

The terminology "food crops based farming systems research" accurately describes this kind of research that has been conducted in Indonesia. The research is carried out by a coordinated group of scientists from various disciplines. It is interdisciplinary and integrated with other government agencies and activities (extension local government, irrigation and national production programs). It is focused upon specific target areas and limited in scope to make more efficient use of research staff and funds. Indonesia has developed methodology and staff sufficiently strong to continue this research. But, renewed efforts are needed to stabilize the gains that have been made through longer term research projects. Although production of food crops sufficient for subsistence has been and will continue to be the first step in the development of farming systems for small Indonesian farm operations, greater effort will be made to study and improve all production aspects of the operation.

Research Approach

Inventory of resources

In addition to the traditional commodity and discipline oriented research activities we need to develop a systematic way of arriving

at priorities for adaptive agricultural research for all disciplines within AARD. The subsequent research should precede development projects and even provide the initiative for such projects. The first priority is an inventory of natural resources and the present agricultural situation. The final stage in this process is usually the development of a "land use capability map". Such maps have been developed for Indonesia. They are useful. But for researchers the logical sequence of information that is needed for development of such maps may be more valuable to the scientist than the final product. A series of maps presented in a sequence from the edaphological classification of land, through the physical determinants and finally to the individual food crops and farming systems would be more useful. It helps us see where we are and what research might have more relevance in all disciplines.

Edaphological classification of land. In this classification we attempt to delineate distinct land areas that differ based on the chemical and physical characteristics of the soil and water environment without reference to climate and other overlapping factors such as slope or land form. As a first approximation, based on experience and data available, the fol[illegible]ng classifications are used for Indonesia. In each case t[illegible]ount of land area for each classification should be included, if possible, on an island by island basis.

A. Upland areas (not mountainous)

B. Lowland rice areas (padi sawah)

1. Irrigated - The following subgroups may be put together for a national map.

a. Fully (>10 months)

b. Partially (7-9 months)

c. Partially (5-7 months)

2. Rainfed lowland

C. Swampy areas (lebak)

D. Tidal areas (pasang surut)

E. Mangrove areas.

Environmental determinants. In this section some of the most important environmental factors which determine the suitability of land for crop production are given. The effects of environmental factors on land use capability vary depending upon the edaphological character of the land. These environmental factors may be looked upon as modifiers when used in combination with the edaphological map.

A. Soils map

On a national scale only the major soil groups can be effectively shown. Soils delineated should be those whose characteristics necessitate different land management practices. For example, differences in inherent nutrient status would not be a reason for delineating between two soils unless one soil required unusual amounts of fertilizer for corrective treatment.

B. Rainfall map

On a national scale the classification based on numbers of wet and dry months are sufficient. At the working level (Kabupaten) the bargraphs which show monthly rainfall distribution are more useful.

C. Elevation map

A biological classification in which altitudes between 500 M and 1000 M are delineated would be sufficient for a national map. These would correspond to the elevation above which cold tolerant rice varieties are needed (> 500 M) and the altitude above which wheat grows well (> 1000 M). At altitudes higher than 1500 M (another elevation may be more valid) the use of the land for food crops production is limited.

D. Slope map

An average slope above which agricultural activity is limited is difficult to define. A slope of 15% has been considered the cut-off point for food crops production. Obviously, many times land with more than 15% slope has been used for crop production without any extreme problems with erosion. On Java and Bali where terracing is widely practiced for lowland rice much steeper slopes are modified for use. The slope factor becomes almost irrelevant. This is an example of farmers modifying or removing physical constraints to crop production.

Present land use map. In development of land or research objectives within an area, the most significant data available are the present land use and information obtained from farmers. What exists cannot be disregarded. On a national scale the following land use classifications may be useful:

A. Upland food crops

B. Lowland rice (including gogorancah and swamp and pasang surut rice)

C. Mixed alang-alang and brush land

D. Forest (primary and secondary)

E. Perennial estate crops

F. Pasture

The land use information delineated can be valuable in two ways. First of all it is useful to relate land use, by distinctly different crops or vegetation which have different ecological needs, to a physical setting that can be characterized. Further break down by crops or species of plants provide the "standards" for evaluating land capability. They give some bases for modification of present land use or extrapolation of a particular kind of land use into new areas having similar agro-climatic conditions. Secondly, production figures for different food crop commodities from different areas of the country provide a basis of comparison. If production in areas with similar agro-climatic conditions differ greatly, we are provided with an ideal problem for applied and basic research projects that have relevance. We have rational bases for developing research priorities.

Use of resources maps.

Survey maps. The combination of all the factors that affect crop production into one land use capability map in a useful fashion is difficult. The Center for Soils Research has made these kinds of maps. They are available and are useful for many purposes. For an over view the inventory maps described (Scale of 1:2,500,000)

are adequate. It may be useful to have more detailed maps of each major island group at a Scale of 1:1,000,000.

Working maps. These maps at a Scale of 1:50,000 are needed for provinces or groups of provinces that may be treated as a unit. This would translate to 1 cm of map for each one half kilometer of land. This would provide sufficient detail for most agricultural purposes. Unfortunately data in this detail are not available for much of Indonesia. However, enough data are available in detail to provide thorough agro-climatic descriptions of parts of many of the major agricultural areas. Further, many surveys funded by the Directorage General of Transmigration and Ministry of Public Works are detailed descriptions of forested and grass covered lands not yet investigated by agricultural researchers. These reports have been prepared by some of the best consulting firms available anywhere. The data in these reports along with the research and experience of AARD staff are valuable resources. In combination with the survey maps enough data is available to provide the bases for interpretation and horizontal transfer of technology needed for establishing national research priorities.

The usefulness of the large scale survey maps and working maps may be enhanced by considering just the relevant combinations. For example, if we consider the categories in the Edaphological Classification of land and the modifier maps the following combinations would be useful:

A. Upland areas - in combination with:

1. Soil map

2. Rainfall map

3. Elevation map

4. Slope map

If we can identify certain upland crops, perennial crops or farming systems used in one location we might expect [illegible] (or plan to grow) the crop or system in another location with similar agro-climatic conditions. The upland areas farming systems are the most complex.

B. Lowland rice areas

1. Irrigated areas - in combination with

   a. Soils map

   b. Rainfall map (not so important for irrigated areas)

   c. Elevation map

2. Rainfed lowland areas - in combination with

   a. Soils map

   b. Rainfall map

   c. Elevation map

The combination of variables are less and the effects of soil and rainfall are minimized by the system, particularly in the irrigated areas. These areas are well known to AARD Scientists and extrapolation of recommendations for varieties, cropping patterns and farming systems are relatively easy.

C. Lebak areas - in combination with:

1. Nature of peat (peat domes)

2. Depth of water

3. Acid sulphate

D. Pasang surut areas - in combination with:

1. Acid sulphate
2. Depth of water
3. Direct or indirect tides

For the lebak and pasang-surut areas more detail is needed than we have indicated in the survey maps for Indonesia. In many instances the delineation of factors such as depth and nature of peat and acid sulphate are not clear. Transfer of technology from one area to another is risky until we have more detailed information. However, our work has been made easier by farmers who have pioneered the development of some of these areas. We should work with the pioneers first and then push into the unsettled areas as we gain more information and experience.

Selection of target area.

Farming systems research is a coordinated and integrated effort to develop technology that will enable farmers to increase production. The technology must be acceptable to the farmers who will use it. In some cases it may be desirable to identify and remove constraints to the farmers through government programs. The increased production may result from better management of present farming systems, introduction of an extra crop(s) or form of husbandry per year (intensification), or expansion of agricultural activities into newly opened or under-used land areas (extensification).

The research is carried out by a coordinated group of scientists from various disciplines. It is focused upon specific target areas to make more efficient use of research staff and funds. The selection of target areas for farming systems research is very crucial. The Indonesian program emphasizes the following criteria for selection of target areas:

1. Critical areas in terms of food shortages and governmental designation.
2. Large areas having similar soils and climate.
3. Feasibility of intensifying cropping patterns and farming systems based on prior evidence.
4. Availability of markets and infrastructure.

A diagram for the farming systems research in Indonesia (Figure 1) shows five distinct phases, associated research activities and approximate time frame that follow after selection of the target area.

Edaphic target areas. Target areas for farming systems research may fall within one agro-climatic region or a distinct edaphological land area. For farming systems in which crop production is dominant, we attempt to delineate distinct land areas that differ based on the chemical and physical characteristics of the soil and water environment. For example, land for lowland rice is different from land for upland rice even though the soil, climate and other overlapping factors such as slope or land form may be the same. This approach is very useful for developing cropping systems technology across political boundaries.

CROPPING SYSTEMS RESEARCH PROGRAM FOR SELECTED TARGET AREAS

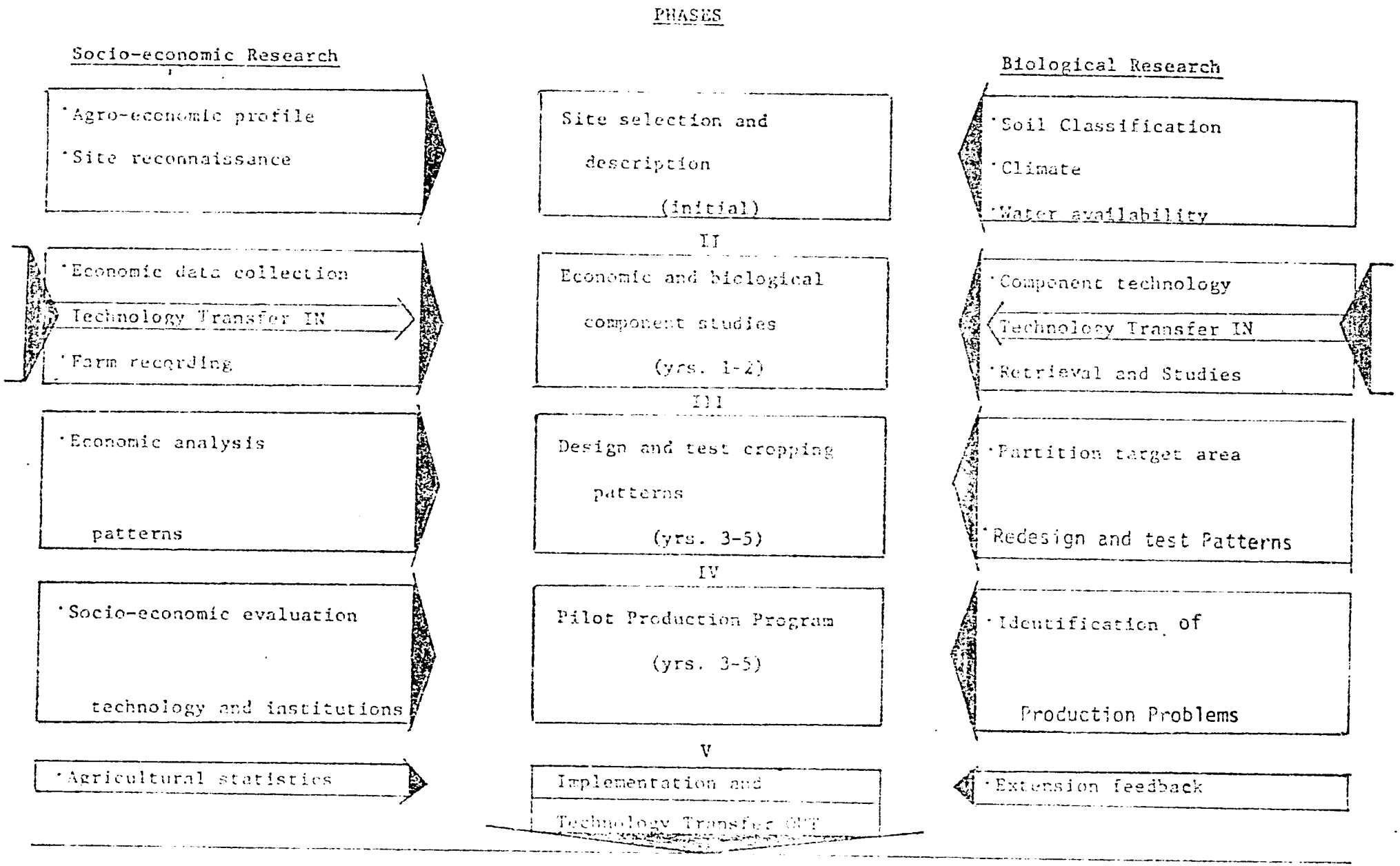


Fig. 1. Parallel biological and socio-economic activities required for the five distinct research and implementation phases of a cropping systems program with little inflow of technology

This is the basis for specifying the characteristics of national production programs such as BIMAS for upland crops, irrigated lowland rice and rainfed lowland rice. Consequently, for food crop based farming systems research, the identification and delineation of the following edaphological conditions is useful. Figure 2 shows how these delineated areas relate to each other in a natural setting.

A. Upland (not mountainous)

B. Lowland rice

1. Irrigated

2. Partially irrigated

3. Rainfed

C. Swampy (lebak)

D. Tidal (pasang-surut)

E. Mangrove (no crops)

Developmental target areas. But in many instances the target areas will be in less developed regions and consist of many different ecological conditions. This is true for many new transmigration, watershed, and rural development projects delineated by policy decisions. Rather than addressing a specific or limited number of edaphological conditions, the target area may represent a geographical region and may cut across many isograms. Land use and farming systems must be developed for each. Usually, elevation and interrelating climate and soil are dominating factors that must be considered. Because we are dealing with farming systems, as a first priority, land not suitable or not designated for settlement and use by small

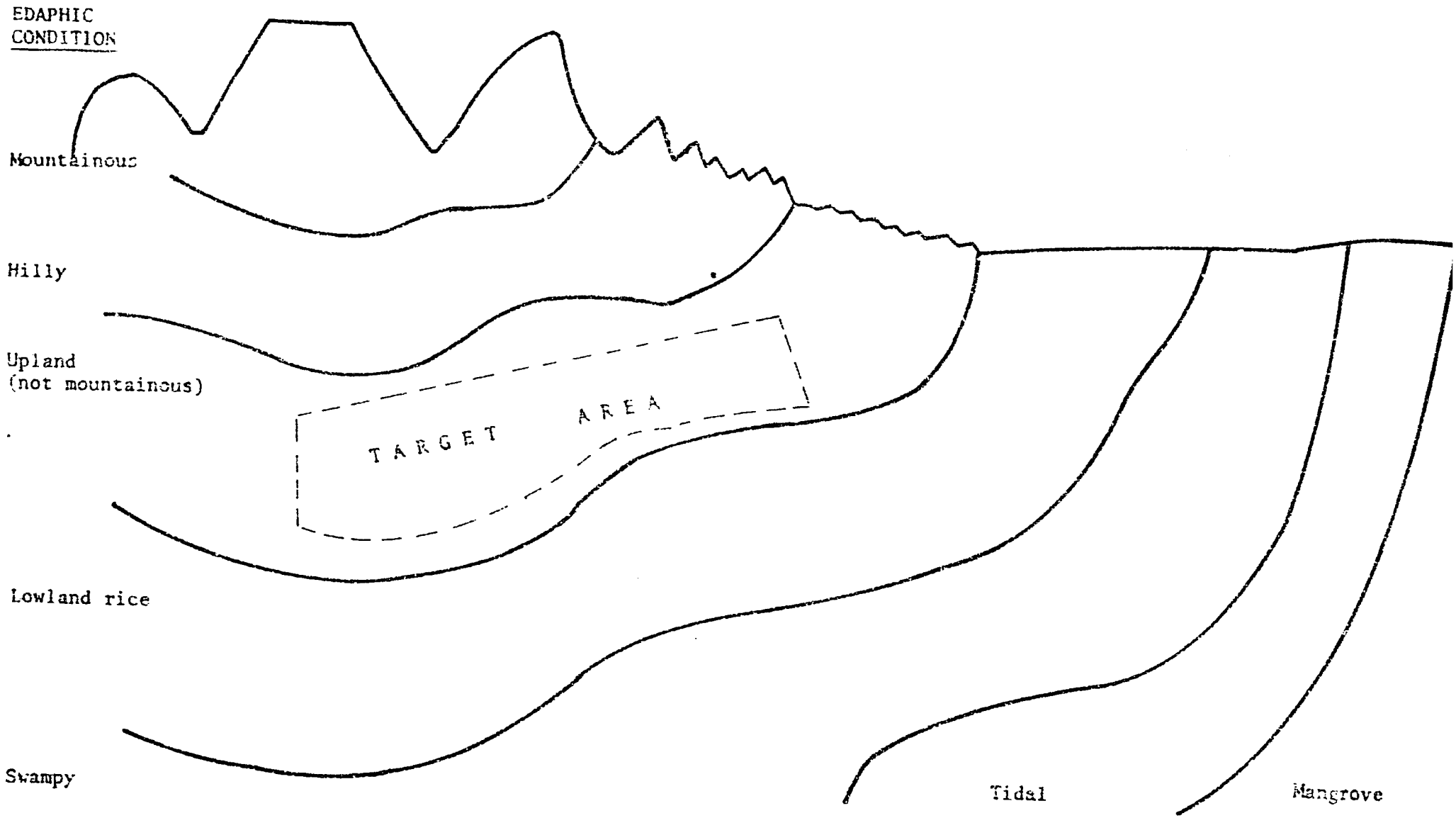


Figure 2. Identification of a target area within a specific edaphological zone simplifies farming systems research and development.

farmers should be delineated. The delineation of conditions might be as follows:

A. Forest and wildlife preserves

B. Forest concessions

C. Range lands for animal production

D. Perennial crops estates

E. Farming systems

1. Mixed farming

2. Food crops based

Figure 3 shows some of the different land uses and how they relate to each other. Usually the administration of a development project for such an area would be at a level that would permit coordination of efforts. But at the operational level, the Ministry or Agency responsible for each kind of land use would carry out its own activity.

For example, forest and wildlife preserves would be the responsibility of the Ministry of Natural Resources. Lands for production and harvest of forest products would be under the Directorate General of Forestry. Range lands for animal production usually are government enterprises or privately owned but are closely associated with the Directorate General of Animal Husbandry. Each of these kinds of land use activity require few people. Usually enough land exists for workers who are associated with the management of such activities to grow some food for their own use. Furthermore, they have employment and some expectation for help in times of emergencies.

To a certain extent these conditions apply for estate crop enterprises also. But usually more labor is required for estate crops and,

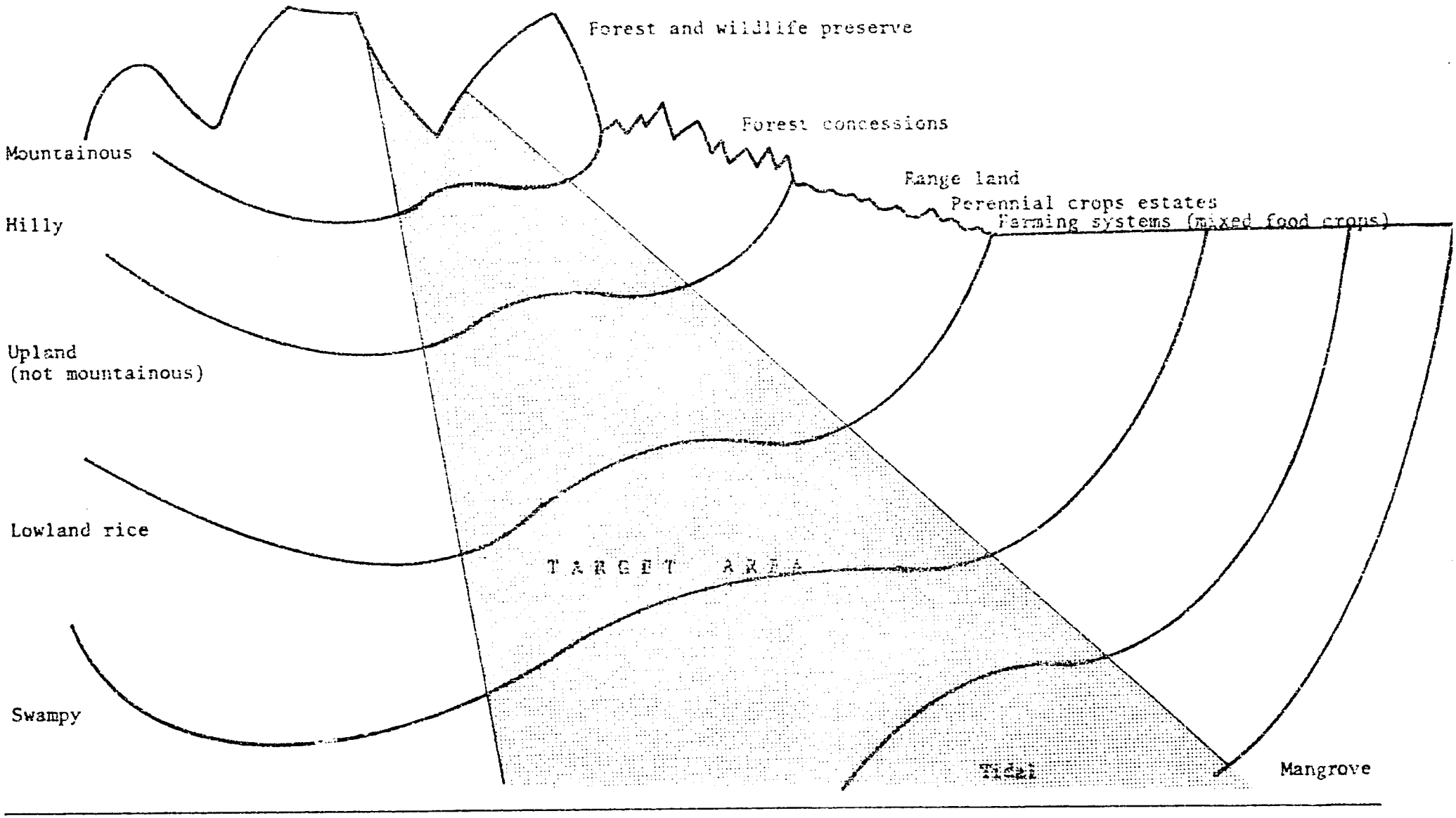


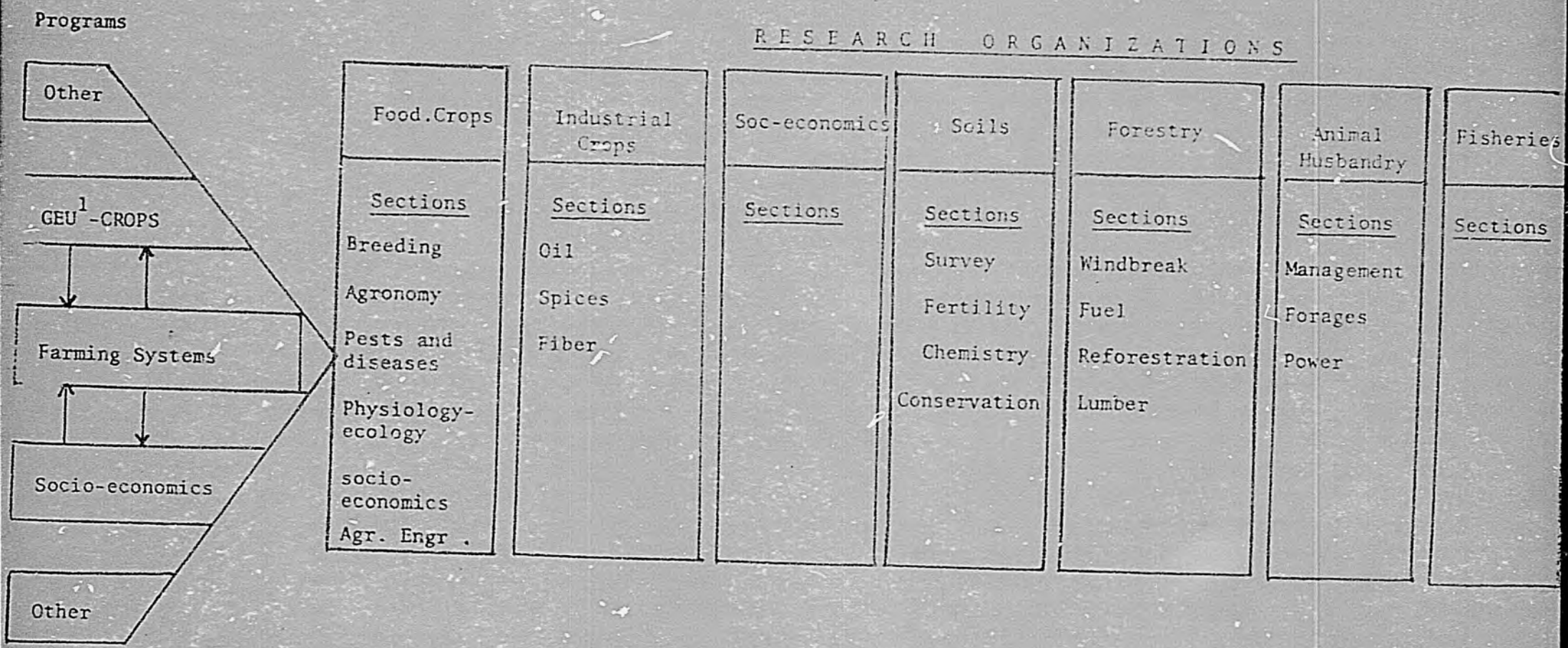
Figure 3. Identification of a "developmental target area" and examples of landuse that may exist due to edaphic conditions and soil, slope and elevation.

consequently, more people are involved. The management and ownership may be centralized and the laborers dependent upon daily or contract wages. When either production or prices are low the laborers may not have enough money to buy food. Furthermore, if food is scarce, even if the workers have money, food may not be available for them to buy. Two approaches have been suggested and in some instances tried to solve these problems. The easiest solution is to provide land, either solely for food crops production or in intercrop combination with estate crops. The other approach has been to develop nucleus estates in which farmers own the land -- some for their homesite and food production and some cooperatively in a contiguous unit for production of an estate crop such as rubber, oil palm or perhaps rice. Consequently, a situation for mixed farming research exists. Other areas with land suitable for cultivation will be used solely by small farmers for their farm enterprises. These are the areas where farming systems research is most needed and will be covered in greater detail in this paper.

Site selection and description.

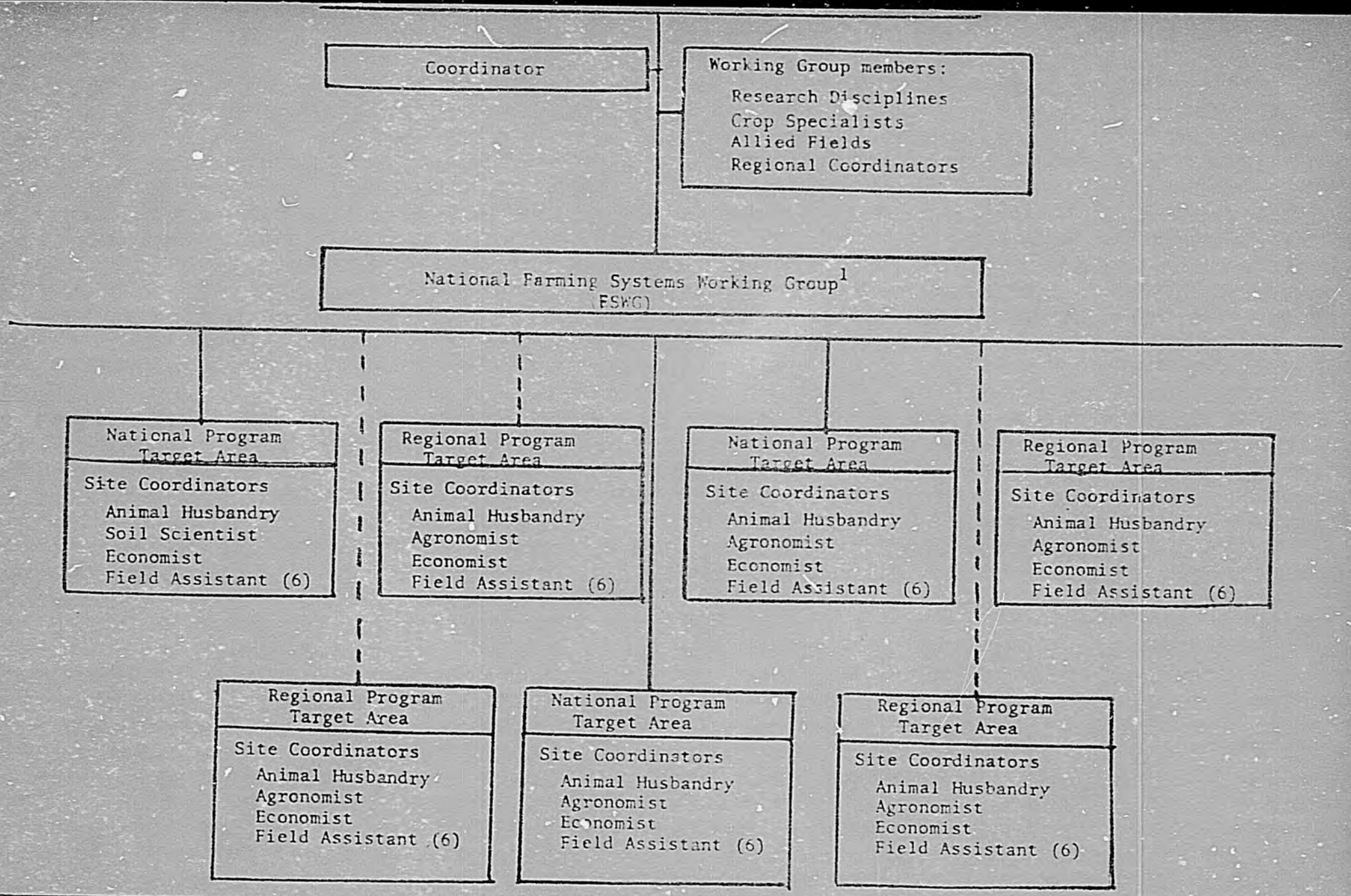
These activities are carried out as soon as possible after a target area for farming systems research has been selected (Figure 1). The survey and data collection teams consist of interdisciplinary groups of scientists and extension workers who will be involved in later stages of the program. Figure 4 illustrates how a farming systems program interacts with other system programs and commodity- and discipline-oriented activities. Staff and expertise would come from the various research organizations to form a Farming Systems Working Group (FSWG) of scientists (Figure 5).

Framework for integrated farming systems research for small farms



[1]GEU--Genetic Evaluation and Utilization refers to systematic varietal improvement studies for food crops such as: rice, corn, legumes, etc.

Fig. 4. This diagram illustrates how research in a farming systems program (FSP) interacts with other systems, programs and traditional commodity and discipline-oriented research activities.



[1] Regional Programs would be the administrative responsibility of the Regional Research Institute, but hopefully in collaboration with the National Program. There would likely be more than one site within a Target area, and different technical expertise may be needed for different areas.

Fig. 5. Possible organizational chart and staffing requirements for a Farming Systems Program.

Site selection. At this point the FSWG will have formulated general objectives for the research and designated a coordinator. All problems and conditions existing in the target area cannot be tackled at once. A preliminary survey of the land and water resources and collection of secondary data from government offices and group interviews usually provide enough data to permit the development of an agroeconomic profile of the area for use in site selection.

Site description. Generally data collection from government offices and inspection of the prospective area are sufficient for site selection. A better data source is needed for (1) designing and conducting in-depth research and (2) transfer of technology to other areas having similar conditions. Table 1 gives an outline for site description that has been useful for most conditions.

A. Agroeconomic reconnaisance surveys. The data collected should comprehensively describe the site, including the institutional, social, economic, and relevant aspects of the physical environments. There should be sufficient scope to permit identification of some of the constraints to higher production that might preclude alternative farming systems strategies that may be considered for the target area. The data collection must be completed in a minimum of time (2-3 days per site) and the report written in a concise manner within two weeks after returning from the field. Many times, unfortunately, too much irrelevent data are collected and months pass before the final report is finished. By this time, the most appropriate planting dates, for example, may have passed and cooperating scientists are discouraged.

Table 1. Outline for Site Description

DESCRIPTIVE ELEMENTS	DATA USE	SOURCE
I. INTEGRATED ENVIRONMENT FACTORS		
Edaphological classification -	• General landuse and quality	• Landuse maps and soil classification
Cropping patterns and farming systems	• Crops and cropping potential	• Group interviews and soil classification
Farm economy -	• Manageability of land and options	• Group interviews
II. SOCIO-ECONOMIC DETERMINANTS		
Markets -	• Vigor of local economy	• Random interviews and local govt. sources of farm and market prices
Infrastructure -	• Potential and time for development	• Census data and local govt.
Farmer responsiveness -	• Willingness to assume risk and change	• Random interviews for land tenure, personal property, education, and mobility
Labor pool -	• Distribution and availability of labor	• Random interviews and census data
III. ECOLOGICAL DETERMINANTS		
Soil-water environment -	• Crop production and soil amendments	• Soil classification
Climate: Rainfall dis't. and am't. - Temp. & solar rad. - Cloud cover -	• Crops, cropping patterns and farming systems	• Weather data and soil classification
Water control	• Crops and cropping intensity	• Irrigation and soil classification

Finally, the report should follow a general framework. This permits rapid data collection and reporting from new sites and allows cross-site comparisons for transfer of technology.

B. Physical description. Much of the information needed for this activity can be obtained from secondary sources. Some information may not appear necessary for the research phase of the farming systems project, but it may be very important for the transfer of research technology to other places.

1. Soil classification. Soil classification along with the commonly used chemical analyses for soil fertility should adequately describe the soil properties associated with plant growth and crop production. The special value of classification by Soil Taxonomy and related methods will be described later.

2. Rainfall distribution. Monthly rainfall data collected over many years are available for many locations. Usually there is a need to collect new data for specific sites. The long-term data should not only be used for the average rainfall distribution but also be analyzed for possible changes in the patterns and probabilities for starting and ending of the rainy season.

3. Irrigation. We must know the length of time water is available and when it starts and ends.

D. Other climatic data. Solar radiation and temperature data should be collected if not readily available from sources nearby.

E. Location and elevation.

Economic and biological component studies.

These activities should be started as soon as possible after selection of the target area and research sites and then continued as long as needed. In newly developed land areas, this phase may precede the farming systems design and testing. In older developed areas the two phases may proceed simultaneously. Usually the research sites within a target area are under one coordinator, and the research team in each site consists of a team leader (agronomist), an assistant team leader, and six field assistants. The assistant team leader should be selected on the basis of need for particular expertise in the particular site. If this is not possible, back-up expertise can be made available from headquarters. The field assistants should be evenly divided according to biologic and economic research activities. Initial research usually centers on food crop production and self sufficiency. Later research explores options the farmer may employ to increase stability and economic return.

The economic information needed may be collected from routine government sources but should be determined mostly from continuous recording of the farmers' activities. Most of the agronomic studies can be conducted in small plots (3 x 5 m^2) by the team leader and his assistants in the farmers' fields.

Economic data collection and farm recording. Monitoring of the farmer cooperators and surrounding farm families must be started as early as possible. The data collection must be specific and the

analysis quick, and the information should be used in designing and testing of farm operations.

A. Income. The amount and distribution of the farmers' income determines his attitude toward the acceptance of new technology. Farming systems may be designed which require different levels of economic input. The farmers may first accept new technology with low inputs and then with time and success be willing to accept technology with higher inputs.

B. Labor. The amount and distribution of labor required for different systems must be determined. Surveys of labor supply and demand in the surrounding areas will be needed.

C. Market prices. The selling and buying price at the farmers' market level is needed on a weekly basis.

Problem-focused surveys. Rather than try to collect all the data thought needed in one large survey, it is better to focus on specific issues as they arise. Broad-based surveys tend to be inefficient and difficult to conduct and analyze, particularly in situations where the staff has had little experience in dealing with them.

Component technology studies. These studies may involve all disciplines in the biological sciences. Mostly these would consist of studies of components of the system made at the time of the year and in the sequence they would fit into the cropping patterns or farming systems to be tested.

A. Variety trials. Many times adapted plant materials are not available for new target areas. The cropping systems program should not become a breeding program, but some testing of new and introduced plant materials is appropriate.

B. Fertilizer responses. Response curves for the macronutrient elements are needed to determine the agronomic and economic thresholds. Depending upon conditions, these trials may be conducted with and without addition of lime and trace elements. These should be carried out as uniformly as possible so that soil and climatic factors across the country (or region) may be better understood in relation to crop production. Care should be taken to locate the trials on soils representative of the area so the results can have wide application.

C. Crop combinations. Different mixed crop and intercrop combinations may be evaluated just as for variety trials. These field studies usually show the need for more detailed research concerning light, competition for nutrients, spacing, and economics. The latter studies can usually be conducted more efficiently in the experiment stations. This is a useful way to involve more disciplines and research colleagues in basic research studies that can directly contribute to development.

D. Mixed farming. Evaluation of farm forestry, animal husbandry and fishery options for inclusion into farming systems.

E. Other biological sciences. Guidelines for pest and disease management must be developed. Field studies can usually be carried out by superimposing treatments over cropping patterns being tested without undue interference.

Designing and testing of farming systems.

Generally in this approach simply looking at the existing farming system is the first step in the research phase. Together with preliminary survey data, enough information will be available to begin the design process. The first priority is for food self sufficiency. Once this requirement is assured by production or other means, the research may be broaden to study other components of the farming system.

Partition of the target area. There are so. economic and natural and man-made environmental factors that have a dominating influence on the appropriateness of cropping patterns and farming systems within a site area. The main idea is to partition the area into management units that reflect these conditions. Sometimes for practical reasons land areas with different soils and climates may be managed alike. On the other hand, land areas with similar soils and climates may require different farming systems because of economic and marketing reasons. The examples that follow from the Indonesian program illustrate the procedures for partitioning of a site within an edaphological classification.

A. All sites. Market accessibility must be considered as a dominating factor influencing cropping pattern design and proportions of individual crops in the patterns and ultimately the farming systems. For example, in remote areas far from roads and markets, food crops are grown mostly for subsistence. This is especially true for crops such as cassava which are difficult to store and transport. On the other hand, if the fields are near starch factories and good roads, cassava would likely be the most profitable crop. The proportion of cassava for cropping patterns in remote areas would likely be much less than near markets even within a cropping systems target area. If food crops are not extensively grown in remote areas, strategies which include perennial crops, animal husbandry, fisheries and forestry must be included along with food crops for subsistence in mixed farming systems. The examples which follow emphasize strategies for development of stable cropping systems. As the systems are developed constraints to production and options for alternatives — including other kinds of crops and animals are examined.

B. Upland sites. A generalized systematic approach for partitioning of a site within such a target area would be useful. So far we have relied mostly upon the judgment and experience of our staff. The following example illustrates how expertise has developed to deal with a major upland area (edaphic target area) in Indonesia. Although specific objectives may differ, this same general approach may be used for mixed farming systems research.

The target area selected was for transmigration settlements on upland red-yellow podzolic soils of southern Sumatra. An old transmigration scheme in Central Lampung, Sumatra was picked as a site for cropping systems studies.

The government program for movement of people from highly populated areas of Java to less populated areas in the outer islands (transmigration) had been carried out in this location about 20 years earlier. The area had been given a high priority for further development by the government. The soil in the site area was classified under the old system as red-yellow podzolic (Orthoxic Tropudults) and was similar to the soil of about 46 million hectares or slightly less than one-fourth of the land area of Indonesia. Furthermore the rainfall, which exceeds 200 mm for six months and falls below 100 mm for only three months, was sufficient for year-round crop production, provided crops such as cassava and cowpea were grown during the driest time of the year. Unfortunately, the soil was low in inherent fertility which was held largely in the organic component and was soon lost after cultivation. Fertilizer inputs were not available. As a result, this large agroclimatic zone was underdeveloped for agriculture.

It was estimated there were about 20 million hectares of this soil suitable mostly for upland agriculture which were not effectively used. Traditionally, farmers had used shifting cultivation and an extensive type of agriculture to avoid the soil fertility problems. The transmigration schemes, however, were committed to a sedentary agriculture. Farmers in older transmigration settlements had difficulties in producing enough food to sustain their families. Our job was to develop cropping patterns and soil management practices that would enable the farmers to produce enough food for their families and have some surplus to sell. The original bases for partition of the area into categories were dependent upon present and past land use:

Upland (food crops)

Category I	Area set aside for lowland rice
Category II	Land opened for many years (more than 3 years)
Category III	Land newly opened from Imperata and brush

Even though this target area was for upland agriculture, farmers tried to grow lowland rice wherever possible. Furthermore, within the area, an irrigation scheme was being developed which would provide water enough for only one rice crop. Upland crops, on the other hand, could be grown throughout the year. The cropping systems program was flexible enough to include lowland rice areas into the research.

The research in Central Lampung has reached the implementation phase. The most recent research is being conducted in new transmigration projects on newly opened land from forests or Imperata. Even though most of the land could be used for food crop production there is some land within this "developmental target area" that may be used only for pasture or forests. This land has rolling to hilly topography and should not be used intensively for food crop production unless soil conservation practices are used. Based on these conditions and our past experiences, we are now using the following criteria for partitioning the target areas for farming systems research:

Upland (mixed farming)

Category I	Relatively level land on hill tops
Category II	Sloping land that must be terraced
Category III	Land newly opened from forests (compared to land opened from Imperata)
Category IV	Not suited for cultivation

Figure 6 shows how these research categories may related to each other in a developmental target area.

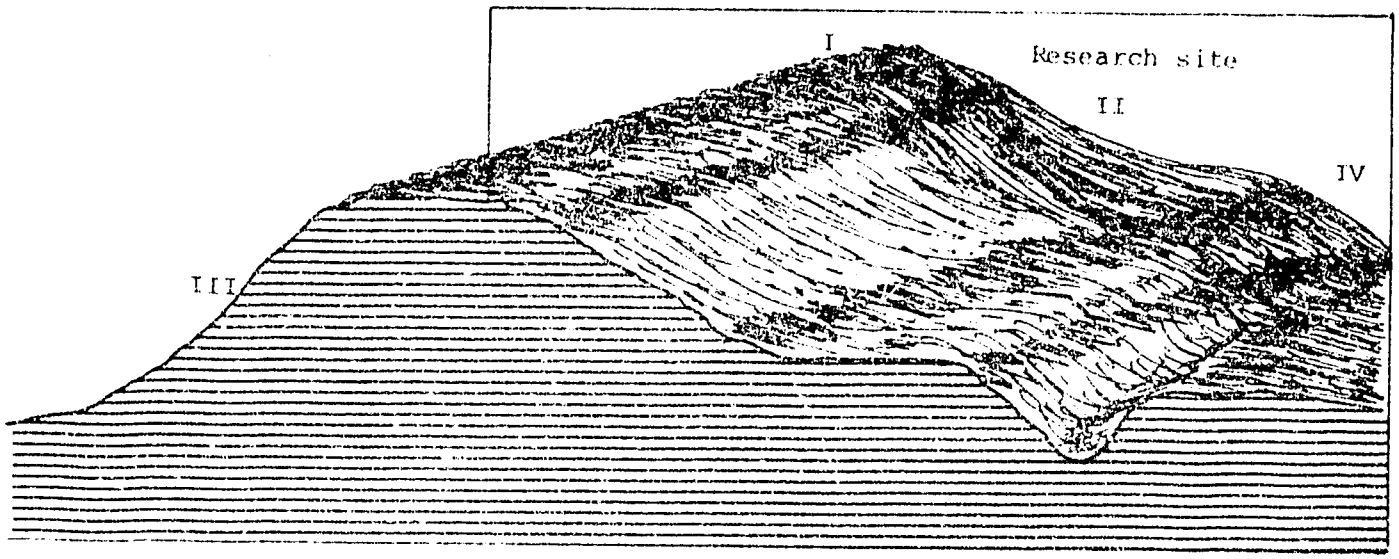


Figure 6. Partitioning of a site into Categories for Farming Systems Research in an upland area:

A farmer may have land in more than one of these delineated categories, particularly, if the land is hilly and has short slopes. We would develop appropriate technology for each category in early phases of the research and then combine the developed technology into relevant farming systems. Figure 6 accurately describes the situation in Transmigration projects in upland area. The distance from Category I to IV in Figure 6 may be no greater than 150 meters. The use of the land in each category would vary according to the farmers preferences. But usually certain patterns or land uses tend to be common in an area.

The differences usually are more due to intensity of land use.

Category I. Home lot (pekarangan) and food crops.

Category II. Terraced land with rotation of food crops and pasture. Leguminous trees would be planted on terrace bunds. Perennial cash crops such as clove, coffee and fruit trees would be planted on the steeper land.

Category III. Same as II, but some management adjustments would have to be made to accommodate the method used for land clearing.

Category IV. Small ponds may be built to hold water for family, fish and livestocks use.

C. Lowland rice areas. These areas are dependent upon the reliability of irrigation water and rainfall in sufficient quantities to permit flooding and puddling of the soil and maturity of a rice crop. Water availability determines the length of time the soil can be flooded and when and how many rice crops can be planted in one year.

1. Irrigated lowland rice areas. The classifications such as technical, semitechnical, and simple irrigation provide little help to cropping systems research. For example, one target area in Indonesia is located in Indramayu, West Java. The area is characterized by relatively level topography, alluvial clay soils, 3 to 4 wet months with rainfall greater than 200 mm and a long dry season (Typic Tropaquepts).

There are problems with water control — flooding during the rainy season and partial irrigation during the dry season. The area was partitioned (Fig. 7) into four categories based on present conditions that are mostly dependent on water. These dominating conditions determine cropping intensities and patterns:

Irrigated lowland area

Category I	Area with 10 months irrigation
Category II	Area with 7 months irrigation
Category III	Area with 5 months irrigation

2. Rainfed lowland rice areas. Vast areas of nonirrigated land in Southeast Asia are used for rice production. The crop is dependent upon rainfall and some movement of water (surface and subsurface) by gravity from paddy to paddy. The paddies are usually leveled and the soil puddled before planting rice. The land surface may vary from almost level to very steep. The basis for rainfed rice production within an agroclimatic area is mostly dependent upon the ease of flooding and maintaining the water level. The position of the paddy on the slope, internal and surface drainage and depth of water table are dominant determinants for the following partitions of the target area (Fig. 8).

Rainfed lowland area

Category I	Poorly drained
Category II	Easily flooded but well drained
Category III	Difficult to flood and excessively drained

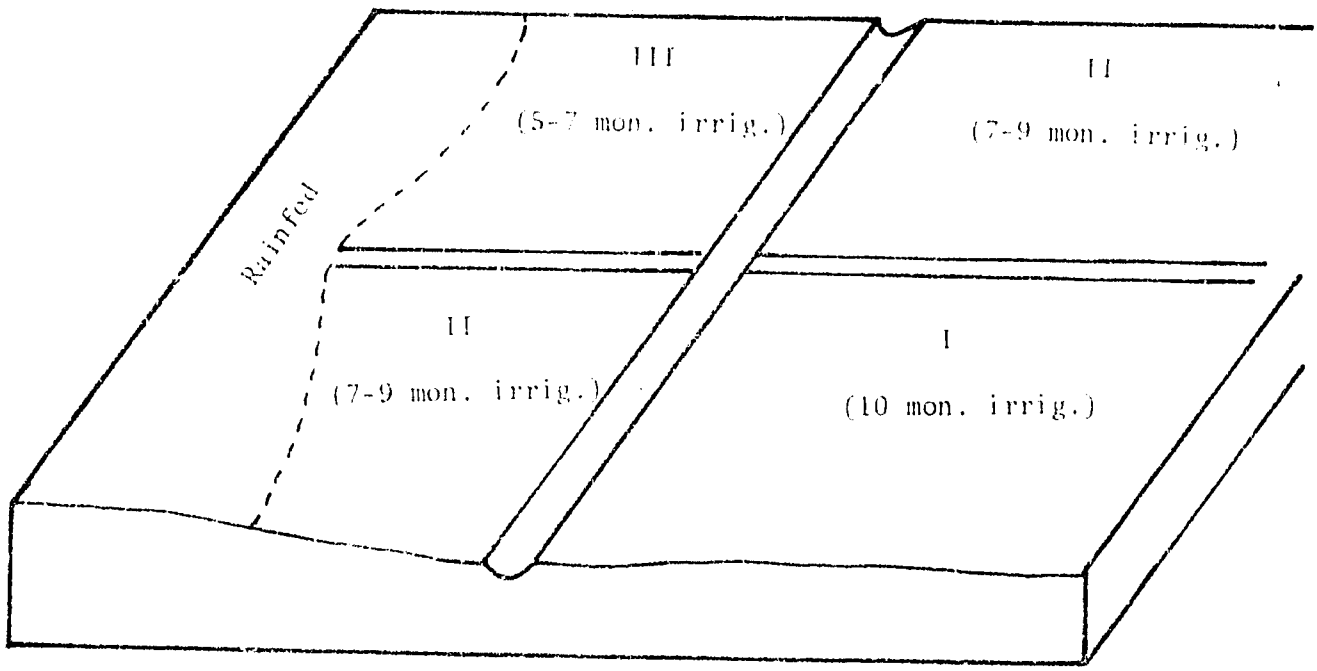


Figure 7. Partitioning of a site into categories for Farming Systems Research in an irrigated lowland rice area.

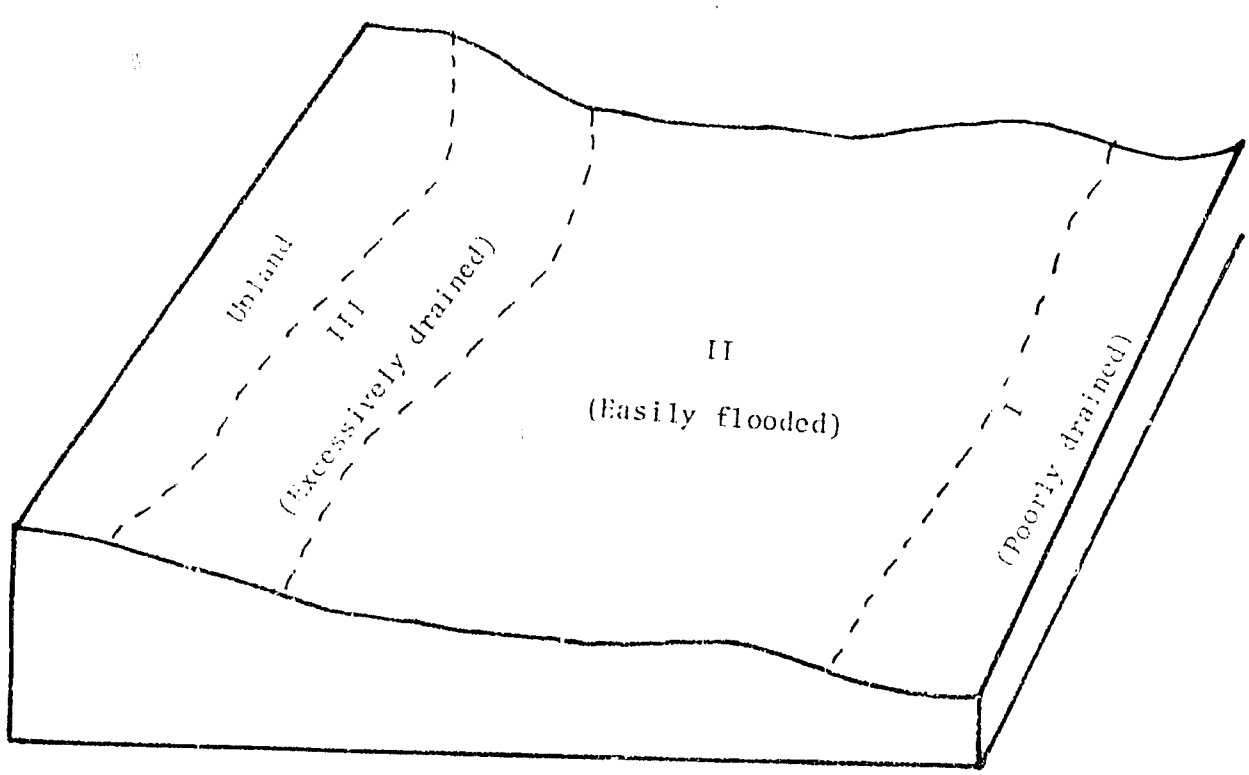


Figure 8. Partitioning of a site into categories for Farming Systems Research in a rainfed lowland rice area.

Concepts for cropping pattern design in farming system. In some instances, cropping systems research is simply the testing of many cropping sequences in the farmers' fields under different environmental conditions. The aproach used in Indonesia has emphasized the testing of patterns designed on the basis of concepts. The actual crop sequences used for each conceptual pattern depend upon the level of technology sought or available.

Three conceptual cropping patterns were tested in each category for each target area when the Indonesian program started in 1975. Each trial was replicated three times but by different farmers (or across farms). The cropping sequences for a pattern tested in each category were not necessarily the same, but were selected on the basis of the same criterion. The criteria for selection of the sequence of crops and management practices for each pattern and the rationale for each criterion were as follows:

1. Criterion A. Farmer's present cropping pattern

   Rationale: To establish a base-line check for comparison

2. Criterion B. Farmer's choice of cropping pattern if input and market constraints were removed

   Rationale: To evaluate the farmer's level of competence and managerial skill and perhaps uncover hidden socioeconomic constraints

3. Criterion C. Our introduced cropping pattern with input and market constraints removed and technical assistance provided

   Rationale: To determine production and economic potential and our ability to remove constraints

The use of these criteria for design of cropping patterns has been successful. It has allowed us to be objective. We do not get bogged down in evaluating small differences in results from using different species of legumes or varieties of rice in testing many different cropping sequences. These refinements are necessary but are the kinds of component studies that are never finished. In our studies, however, we have been made aware of the severe economic stress faced by many Indonesian farmers. They simply do not have money they can use for material inputs. If they do, they are afraid to take the risk. This is particularly true for farmers who have seldom worked with the extension service. We feel we must develop low input patterns for new adopters. If the technology is good and shows evidence of being profitable, they will soon learn how to use more inputs. We now recommend the following criteria for design of cropping patterns:

1. Criterion A. Farmer's present cropping patterns (monitor only)

   Rationale: To establish a base-line check for comparison

2. Criterion B. Farmer's cropping pattern with inputs and optimum management.

   Rationale: To evaluate the farmer's pattern without input and managerial constraints

3. Criterion C. Our introduced pattern with low inputs

   Rationale: To induce the farmer to gradually try new technology

4. Criterion D. Our introduced pattern with input and market constraints removed and technical assistance provided

   Rationale: To determine production and economic potential

Strategies for design of introduced patterns in a farming systems. The impression that evolved from accumulated survey, soil classification, climate, and market data and from observation of farmers' patterns is the best guide for cropping pattern design. If nothing appears obvious to the Cropping Systems Working Group after this exercise it would probably be better to work somewhere else. Among the techniques used by cropping systems scientists to intensify cropping and increase production there is a thread of commonality. The techniques used for the lowland rice-producing areas of Asia are shown in Table 2.

These specific examples are useful in understanding how the role of intensification can be tackled. More generalized guidelines for pattern design may be useful for situations where less is know.

A. Selection of crops to be grown. New or exotic crops are likely to be unsuccessful when first introduced. Initial phases of a cropping systems program will be dependent upon the use and improvement in production of familiar and marketable crops. Gradual introduction of new crops can be one of the most important strategies for cropping systems research.

1. Agronomic adaptation. This is an important consideration for selection of crops to be included in new cropping patterns. The crop must fit the rainfall and its distribution (or irrigation) during the time of the year the crop is to be grown. Usually food crops receive the haighest priority for government support in developing countries. Of these crops, rice is the most valued in Asia and, consequently, is grown if possible. Corn is usually the next highest valued crop and could be grown under drier conditions than rice. Sorghum and millet are usually more drought tolerant than corn and rice but many times are not as adapted to acid soil conditions. The versatility of upland rice, in this respect, has not been fully exploited. The

Table 2. Common strategy for crop intensification in lowland rice areas

Fully irrigated. Go from 2 to 3 crops per year.

1. Plant earlier in crop year.
2. Use earlier maturing varieties.
3. Reduce turn-around-time between two consecutive crops.
4. Tailor inputs to soil, climate, and crops.

Partially irrigated and rainfed. Synchronize plantings to permit an extra crop per year.

1. Plant earlier in crop year by direct seeding and use of minimum tillage.
2. Reduce turn-around-time between two consecutive crops.
3. Plant earlier maturing varieties of rice and other crops.
4. Plant upland crops other than rice during dry season after harvest of lowland rice.
5. Plant early maturing upland crops at beginning of rainy season before there is enough water for lowland rice.
6. Use year-round crop production and soil management practices. This will reduce labor needed for tillage and weeding and ultimately contribute to crop intensification.

root crops, sweet potatoes and cassava, can fit into most patterns for upland areas. These are usually high-valued, fresh-market crops near cities and subsistence food crops in remote areas. Cassava is an especially stable crop in drier regions and times of the year. Legumes usually grow well at the beginning of the rainy season when disease and insect problems are less. Many of the legumes are photoperiod sensitive and this must be taken into

consideration. In irrigated areas, legumes usually are catch crops to utilize residual soil moisture after lowland rice. Seeds produced at the beginning of the rainy season in adjacent upland areas may be used as seed sources for the lowland areas. Seed viability is a problem particularly for soybeans. Their value as a protein source must be given high priority, particularly in remote upland areas where sweet potatoes, cassava, and other starchy food crops make up a major portion of the diet.

2. Market and market potential. Farmers grow food crops to feed their families and to sell. The first priority is for food. The incentive to grow extra crops for marketing purposes depends upon the profit the farmer can make. In most developing countries there are government policies to keep food prices low. These policies benefit the large number of consumers in the cities and towns but hinder efforts to increase agricultural production. These problems have been recognized by most governments and attempts are being made to establish and maintain minimum market prices.

Since rice is the preferred crop in Southeast Asia, it is usually the most profitable crop to grow. Other crops (unfortunately referred to as secondary crops) may be much less profitable especially if they cannot be easily processed within country or exported. Corn, cassava, soybeans, mungbeans, and peanuts usually offer the widest range of market potential.

B. Management of cropping sequences. The prevailing farmers' cropping patterns usually give the best clues to the opportunities and constraints faced by farmers. Good surveys can help pinpoint and clarify many socio-economic as well as agronomic conditions that affect the farmers' decisions.

1. Minimize risk. This concept is especially important in remote or newly opened areas where the farmer must be self-sufficient and can expect little help from government agencies. These are the conditions under which farmers many times use complex mixed cropping combinations and little material inputs. In partially irrigated areas farmers are reluctant to grow a second crop of rice and if they do they usually reduce fertilizer and labor inputs. These evidences of the farmer's understanding of risk must not be ignored. We design and test improved patterns which require low levels of material inputs. At the same time similar patterns are designed and tested with what we expect to be agroeconomic optimum levels of inputs. In this way we can develop technology with a broader base and gradually introduce it at a level farmers can more readily accept.

2. Minimize and distribute labor. Power for land preparation is a major constraint to increased crop production through intensification in upland areas. A farm family can prepare only about 0.5 to 0.6 hectare of land by hand labor at the beginning of the rainy season. Labor is also a constraint in partially rainfed areas where time is a factor in getting the land prepared for planting rice at the beginning of the rainy season. Design of cropping patterns to utilize available water can be an effective technique to save labor. The introduction of extra crops usually induces more land cultivation and competition for weeds. The farmer benefits by the reduction in labor requirement for land preparation and weeding per crop and the opportunity for gainful labor during times of the year the family would be idle.

3. Distribute cash flow. New cropping patterns must take into account the farmer's economic situation. In newly opened upland areas farmers usually have less money available for purchase of inputs than farmers in the lowland rice-producing areas. In either case there is generally financial stress. Recommendations for larger inputs are not likely to be adopted unless the new technology is gradually introduced and arrangements are made for credit. Farmers who have never had much cash are not usually willing to make use of credit when it is first offered. Gradual introduction of technology represents one strategy to overcome this reluctance. Consequently, in addition to "optimum patterns," cropping patterns should be designed for developing low and intermediate levels of technology. If the lower levels of technology are adopted by farmers and found beneficial they will likely be willing to assume the responsibility for more credit and inputs.

Cropping patterns which involve more crops and harvests usually provide for better labor distribution and even out the cash flow for production costs and income from sale of marketable produce. The farmer may have less money for short periods of time but some money over a longer period. He is more likely to have some money for food and for production inputs when needed.

Testing cropping patterns in a farming system

The cropping systems approach to research has developed for several reasons. But some of the original work was done to study two basic questions in tropical agriculture--how to utilize more efficiently the tremendous energy,

land, water, and labor resources available and how to get farmers to adopt the technology developed.

Rationale for systems research. The physiological, agronomic, and technical aspects relating to the first question may be studied in the laboratories and research stations. The potential for total production is evident from this kind of research even if many times the technology is inappropriate for adoption by small farmers of the less-developed countries (LDCs) of the tropics. The contrasting situations between the developed and less-developed areas of the world must be recognized even if there is a problem of oversimplification. In developed countries where farmers are likely to be better educated and economically stronger, published and disseminated research information may be sufficient to meet the farmer's need. The farmers are able to apply the technology, assume the risk and evaluate the technology within their context. In developing countries, however, farmers may be undereducated, financially weak, and afraid to assume the financial risk and peer pressures associated with change. The technology must be developed and tested systematically and extended to the farmers in a simplified farm.

Production programs have been developed and financed to solve some of these problems. Technological packages were made available to farmers with credit facilities through such programs as MASAGANA 99 in the Philippines and BIMAS in Indonesia. Production was increased for individual crop commodities. These steps forward were very successful even though many farmers did not greatly benefit from the efforts and many did not continue to participate. The basic problems of development and adoption of appropriate technology by farmers were not solved by the production programs.

Before these programs for crop commedities and cropping systems reach the stage of implementation, they should be preceded by research conducted under conditions approximating that of the farmers. The research and implementation must be target-area specific. The first step, as has been described in this paper, is to conduct preliminary research in the farmer's field under the researcher's management to get some idea of crop performances and production potential within a target area. If this looks promising, the cropping patterns that have been designed should be further tested in farmers' fields as much as possible under the prevailing conditions that exist.

Methodology used. Using this approach, the Indonesian cropping systems program has been effective in West Java, Lampung, South Kalimantan, and Southeast Sulawesi in developing and implementing research.

A team composed of a coordinator, agronomist, and economist was stationed in each target area. A team leader and field work and data collection for input-output within each site in the target area (Fig. 5). A system for collecting daily farm records for all farm buying and selling activities was implemented in cooperation with farmers (about 30) in each target area to get a larger base for socioeconomic evaluation.

The organization of the research and research team should be as simple and self-contained as possible. The coordinator should have flexibility in implementing the research once the general guidelines for trials, patterns, organization, and staffing are decided upon. He should have mobility so

that he can visit the sites and research plots frequently, talk with the farmer cooperators, and develop cooperation with the extension service and local government officials. He should assume the responsibility for summarizing and preparing a draft report of the research results. Most of all, he should, in consultation with his staff, critique the research in progress and prepare a tentative project proposal for the following year. The involvement of those close to the field research activities is the key to successful and relevant research and staff development.

The Indonesian program has usually replicated the field trials across farmers' fields. This has been successful primarily because the target area had been stratified by partitioning the area into categories. For each cropping pattern tested, three farmers within a category were randomly selected as cooperators after screening based on criteria relating to land tenure, size of farm, cropping system, location, and desire to cooperate. Each farmer agreed to permit 0.1 hectare of land to be used for the research. He provided the labor, and the project provided the necessary inputs. The farmer was compensated for any losses and extra labor caused by the project. All data concerning labor and costs of inputs were collected. The cash flow of the agronomic farmer cooperators and the other farmer cooperators for economics were monitored. The data were reported in terms of yields, gross returns, labor costs, material costs, and net returns for each pattern in each category. The data from economic farmer cooperators were summarized in the same way to establish more precisely the economics of the farmers' cropping patterns and to understand their farm operations.

Pilot production projects.

In many countries pilot production projects are an integral part of the technology delivery process. Sometimes it is considered a research function and sometimes exclusively extension. In Indonesia, as Fig. 4, phase IV indicates, this activity has a legitimate research component, particularly, for new research target areas. But it is recognized that in most instances it is largely an extension activity.

Pre-production testing. We would normally expect that the technology developed and tested by a research organization would be adopted by farmers with only dissemination of the information by extension workers and by development of production programs. The latter step is usually not necessary in developed countries where the agricultural economy may be strong. Even in less well developed countries, technology for new varieties and management practices for crop commodities may be directly and easily introduced. But for cropping systems research implementation, there will likely be a need for an additional research phase. This phase may be described as pre-production testing. The research is more complex than indicated by this terminology. It is an evaluation not only of the appropriateness of the technology but also of the infrastructure. The weak links in the infrastructural chain should be identified and strengthened to absorb the new technology. This can be best illustrated by an example from the Indonesian program.

A. Methodology used. Research was begun in both Indramayu, West Java, and Central Lampung, Lampung, in 1973. Results from the first two years in Indramayu showed the feasibility of increasing crop production by introduction of high-yielding and early-maturing varieties and inclusion of an extra crop either before or after the main crop season. In Lampung, the results showed the potential for crop production and stable agriculture on the red-yellow

podzolic soils of Lampung under rainfed-upland conditions. The research in these two areas was expanded in 1975 to include on-farm testing of farmers' and introduced cropping patterns in the three main irrigation categories of Indramayu (10 months, 7-9 months, and 5 months of water availability) and for partially irrigated (5-6 months water availability) and "newly opened" and "old opened" areas in Central Lampung. This research was conducted in close cooperation with the extension service and local government officials in hopes that the research results could be smoothly and quickly adopted by the farmers. During the third year (1977-78), the trials were not replicated but were consolidated into one contiguous area for each irrigation or land use classification (an embryonic Phase IV of Fig. 1). The idea was to test the introduced patterns in plots large enough to cover several farms and minor differences in soil and water availability and to gain visibility among farmers and extension workers.

B. Constraints identified. The data and experiences from the 1977-78 research verified previous findings. We felt there was sufficient evidence to support the development of Production (BIMAS) programs in these two target areas for cropping patterns rather than for individual crops as has been done in the past. The BIMAS program would help remove the credit, input and perhaps market constraints faced by farmers. But in order to be successful, all components of the production system would have to be synchronized. This would include synchronization of varieties, insecticides, planting and harvesting dates, time of arrival and termination of irrigation water, and local government activities. These infrastructural considerations are not so important when new varieties, insecticides, and other single-faceted technologies are introduced. But for cropping pattern changes the constraints that have prevented the farmer from modifying his systems in the past must be identified and removed. Furthermore, the new problems that arise from implementation of the new cropping patterns must be anticipated and removed. For example, increased

production will cause marketing problems and overloading of the existing agri-business community. We feel that an expanded Phase IV is needed in the sequence of site selection, agroeconomic potential, designing and testing and implementing new cropping systems technology for a target area (Fig. 9). But we also recognize that this activity must be an integrated endeavor with other government agencies.

C. Institutional constraints. The pre-production or pilot production phase (Phase IV) should cover one or more of the smallest governmental units (Desa in Indonesia) within the target area. The planning could be coordinated by the Ministry of Agriculture in cooperation with the provincial planning agency (BAPPEDA in Indonesia) so that all relevant governmental agencies would be involved. In this way, the institutional constraints that might arise from introduction of the new technology could be identified (and removed) before wide-scale implementation was attempted. The coordination of research, extension, irrigation, and local governmental agencies is vital if the pre- and post- production constraints are to be removed. This idealized kind of on-farm research would have been useful as a follow-up to the embryonic efforts we made in Indramayu and Lampung to solve these problems. These two target areas differ greatly in their stages of development and kinds of agriculture. However, if the site descriptions are accurate and sufficiently detailed, research results could be applied (transferred) to other areas with similar agroclimatic conditions.

Test farms. The research approach used for test farms does not necessarily differ from that described in this paper. The land tenure arrangement represents the major difference. The land is under control of the researchers and consequently, the researchers are more sheltered from the public and will likely conduct research more in line with tradition. But the security offered by a test farm arrangement permits development of research facilities, quarters and longer term experiments. Technology generated should finally be tested directly in the farmers' fields.

Research-Extension interface over different phases of a cropping systems program

Target Area Selection	RESEARCH & IMPLEMENTATION PHASES					Technology transfer
	I Site description	II Econ & Biol. Pot'l	III Design & Test	IV Pilot Prod. Prog.	V Implementation	
CSWG[1]	CSWG	CSWG	CSWG	CSWG	CSWG	CSWG
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] CSWG--abbreviation for cropping systems working group which is the multi-disciplinary research group that coordinates and carries out the research plans of cropping systems programs in a target area.

Fig. 9. This is a schematic representation of the research-extension workload distribution and interaction with farmers and other government agencies in different phases of cropping systems research and implementation.

Implementation through production programs

The experiences with government-sponsored production programs in general have been good. An acknowledgement of the need for support to small farmers for development of appropriate technology, credit, production inputs, technical services, and markets has been made. These are steps in the right direction for developing countries. The prospects for this kind of governmental activity affects the research processes and the technology developed. If the farmers in a developing country are economically weak (and they likely will be) and the government is indisposed to support production programs, the agricultural research effort should be mostly directed toward low-input technology. This places a great constraint upon research options. Not much can be done to increase total agricultural production, but some techniques can be developed to conserve the soil and stabilize production. Hopefully, under the most austere circumstances some support can be obtained to remove the most severe constraints to production. Research should be directed to identify these constraints and develop technology that is within the economic grasp of the individual farmer. The methodology that has been described can be used for these different situations.

The experiences with production programs in the Philippines and Indonesia have been described in several publications. The important question is how to make them more effective from a technical point of view. It is recognized that initially production increased each year after implementation of the programs. Then production began to level off. It is at this stage that cropping systems research can be most useful. The technology developed for

CROPPING SYSTEMS RESEARCH PROGRAM FOR SELECTED TARGET AREAS

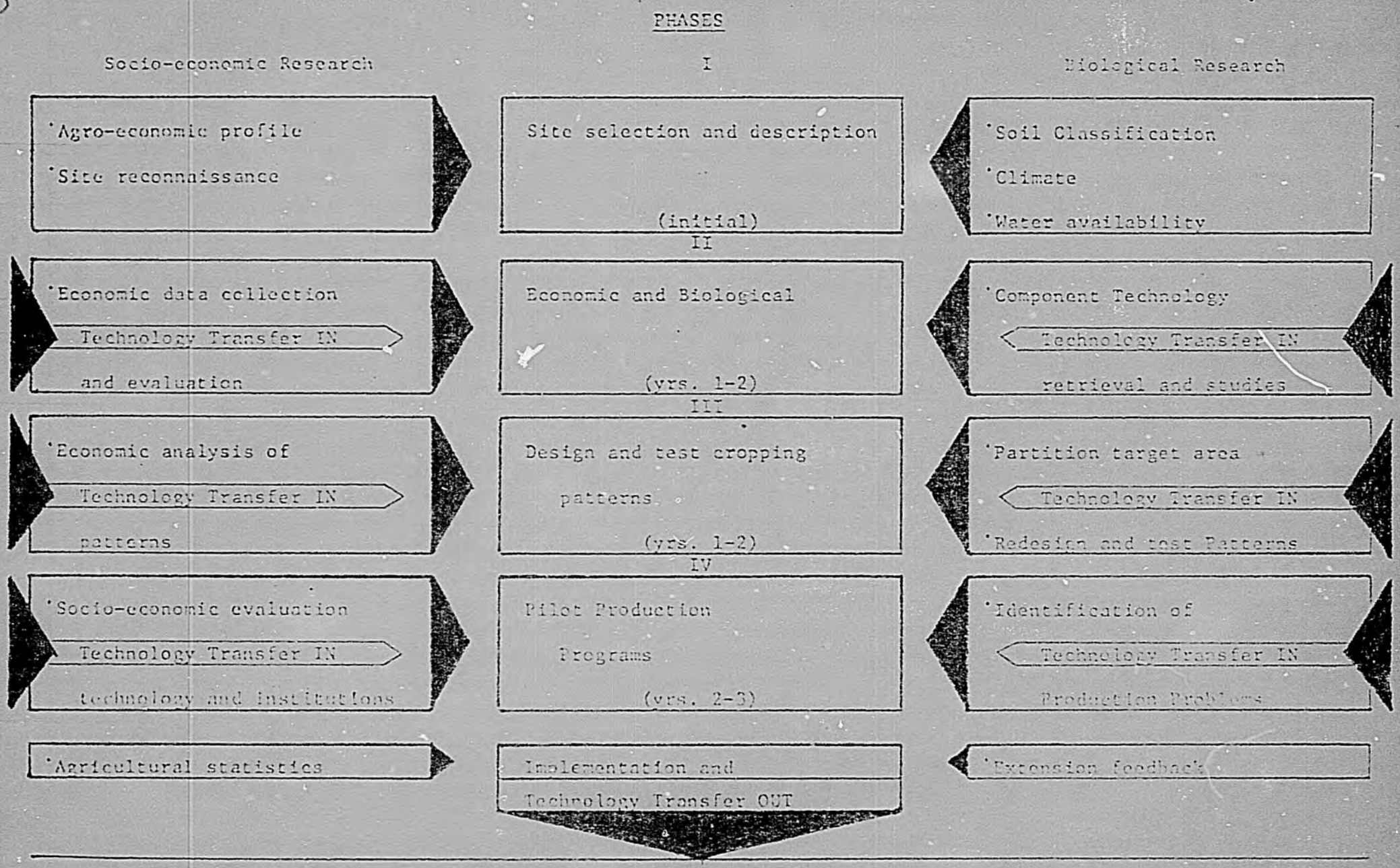


Fig. 10 Time frame for research and implementation phases of a cropping systems program with significant inflow of technology from research in areas with similar site descriptions. This technology transfer may reduce the research time in a target area by two or more years.

specific target areas permits more specific recommendations and higher production possibilities for these areas. This technology then becomes more acceptable and allows for transfer of technology to similar agro-climatic and economic regions. The transfer of appropriate technology may reduce the research time required in new target areas by 2 or 3 years (Fig. 10). Production packages can be tailored to better meet the requirements for increased production and farmers' needs.

Technology Transfer

Technology flow.

Vertical flow. One objective of a farming systems program is to use existing information by bringing it together and testing it in a specific environment. Technology of this kind usually comes from the experiment stations of national and international institutes and is fragmented according to crop commodities and disciplines. The technology is then transferred to the government bureaucracy and finally to the extension service. This is a kind of vertical transfer of technology. The information is diseminated by the extension service in a "trickle-down" fashion.

Horizontal flow. Improving the flow of technology (transfer of technology) is simply a way of using research funds, personnel, and time more efficiently. The concept is useful in that it provokes scientists to consider application and integration of new technology as a legitimate part of a research effort. This approach has not been fully exploited in most agricultural research and development activities that apply directly to farmers. Basic studies in soil science, biochemistry, plant physiology, and related fields usually are well described and documented.

The technology developed can be transferred from place to place (horizontally) as well as vertically. The technology of the applied agricultural sciences (such as agronomy, horticulture, and foresty), which directly affect the farmers' welfare, usually consist of well-documented studies of some small part of a larger system. The bits of research information can be absorbed directly by farmers in developed and developing societies. But many times farmers in less-developed countries cannot make use of this technology. The missing pieces of the research puzzle for a partic target area can be identified and studied by cropping systems research. Further testing and complementary research provides the appropriate technology for use through production programs and horizontal transfer of technology. Comparisons of Fig. 1 and Fig. 10 illustrate how research time and effort can be saved by transfer of appropriate technology from one target area, horizontally, to another.

Descriptive basis for horizontal transfer.

It is theoretically possible to completely describe the ecological and socio-economic environment of a target area. The agrotechnology developed for the area would be suited for an area with an identical (or similar) description. Then some on-site research could be conducted to further verify the appropriateness of the technology transferred in. In practice, it is difficult -- if not impossible -- to find identical areas. Furthermore, researchers usually do not select target areas for research based on purely technical reasons.

The question then is how or to what extent can agrotechnology be transferred from one area to another when there are differences as well as

similarities between the two areas. What are manageable levels of diversity among the socioeconomic and biological determinants that describe a target area for cropping systems?

In Table 1, descriptive elements of a target area (summarized from the text of this paper) are listed along with a statement of intended use and expected sources of information. These are given to provide a basis for further discussion and are not intended to be comprehensive. The purpose is to illustrate how data can be collected and used to characterize a target area.

Descriptions of target areas. Two major target areas were selected in 1973 by the Indonesian Cropping Systems Research Coordinator. One area was in Indramayu, West Java, and the other in Bandarjaya, Central Lampung. These two areas met the criteria for selection that were being developed by the Cropping Systems Working Group (listed on page 13). The availability of technology for transfer in was very limited. We expected that seeding rice directly and planting earlier maturing varieties were technologies that could be used to intensify cropping patterns in the partially irrigated Indramay area. Using fertilizers and crop residues to improve soil fertility and more systematically arranging farmers' cropping patterns were technologies that could be used to improve production and stabilize agriculture in the upland transmigration areas of souther Sumatra. Cropping systems studies were begun in 1973. The target area descriptions are summarized in Table 3.

Table 3. Descriptive data for sites in target areas

DESCRIPTIVE ELEMENTS	INDRAMAYU	BANDARJAYA
I. INTEGRATED ENVIRONMENTAL FACTORS		
Edaphological Classification -	• Partially-full irrig. for LLR	• Upland crops & Imperata cylindrica • Partially irrig. for LLR
Cropping patterns -	• LLR - LLR - fallow • LLR - Palawiji - fallow • LLR - fallow	• C + ULR + Cv • LLR - fallow
Farm economy -	• Gov't designated minus area, land idle	• Gov't designated minus area, low production
II. SOCIO-ECONOMIC DETERMINANTS		
Markets -	• Good potential	• Good potential
Infrastructure -	• Good	• Good
Farmer responsiveness -	• Good	• Good among transmigrants
Labor availability -	• Sufficient	• Seasonal
III. ECOLOGICAL DETERMINANTS		
Soil-water environment -	• Vertic Tropaquepts	• Orthoxic Tropudults
Climate:		
Rainfall dis't. & am't. -	• Dec - Feb > 200 mm • Jul - Oct < 100 mm	• Nov - Apr > 200 mm • Aug - Sep < 100 mm
Temp. & solar rad. -	• 6° 20'S latitude at ± 5 m ele.	• 4° 40'S latitude at ± 40 m ele.
Cloud cover -	• Little effect	• Significant effect on disease problems
Wind -	• Significant in dry season	• Not significant
Water control:		
Irrigation -	• Full • Partial - 5-7 & 7-9 months • Rainfed	• 5 month intermittant irrig. in limited area • Predominantly rainfed upland
Flooding -	• Hazard in partially irrig. areas	• No hazard
Soil water -	• High water table and good storage soil water	• High water table in irrig. area but poor storage soil water in upland

The descriptions are used basically for two purposes. Initially, the data are used to provide bases for selection of the research sites within the target area, for problem identification, and for design of cropping patterns to be tested. Later, the descriptions are used as bases for transfer of relevant technology between or among (transfer out) selected target areas. There is no attempt to precisely match descriptions as a basis for technology transfer. The real task is to identify and match the dominant factors in each environment that control the socioeconomic and biological processes.

Markets and availability of inputs (as affected by the infrastructure) are dominating economic factors in vast regions of Indonesia. Water availability from irrigation and rainfall (and its reliability) dominates lowland rice production. Rainfall is the dominant factor for upland crops. Soil, as it exists and as a consequence of its formation, interacts with water availability and plant nutrition in both instances to greatly affect crop production, cropping patterns and agrotechnology transfer. Consequently, the comprehensive nomenclature incorporated in the taxonomic units embodied in Soil Taxonomy provides one source of information needed to characterize the biological and environmental aspects of a site or target area for appropriate soil and crop management. The family category of that system of soil classification has been hypothesized to be appropriate for these purposes. Many times the subgroup is adequate (Table 3) if there is sufficient practical and research experience within the area. Information that can be derived from the soil family name useful for crop and soil management purposes can be illustrated by using the dominant soils found in our two target areas.

A. Indramayu example. The most likely classification for the soil in sites of the Indramayu target area would be clayer, montmorillonitic, isohyperthermic Vertic

Tropaquept. These are immature soils that have no horizons of accumulation of clay and aluminum. The natural drainage is poor and groundwater stands close to the surface during some part of the year. The soil is found in tropical regions of relatively low elevations and is likely formed from marine deposits. These are relatively fertile clay soils that are dry enough in most years to crack deeply. But the surface soil has considerable organic matter that ameliorates the effects of the clay and provides favorable conditions for cultivation. The effects of the dry period reduce weed growth, loosen the surface soil, and permit shallow cultivation and preparation of a seed bed for direct-seeded rice at the beginning of the rainy season. The relatively high water-holding capacity and water table moderate the effects of brief dry periods after seeding. Likewise, near the end of the rainy season sufficient soil water and intermittant rain permit upland crops to grow after harvest of paddy rich provided surface water is drained away.

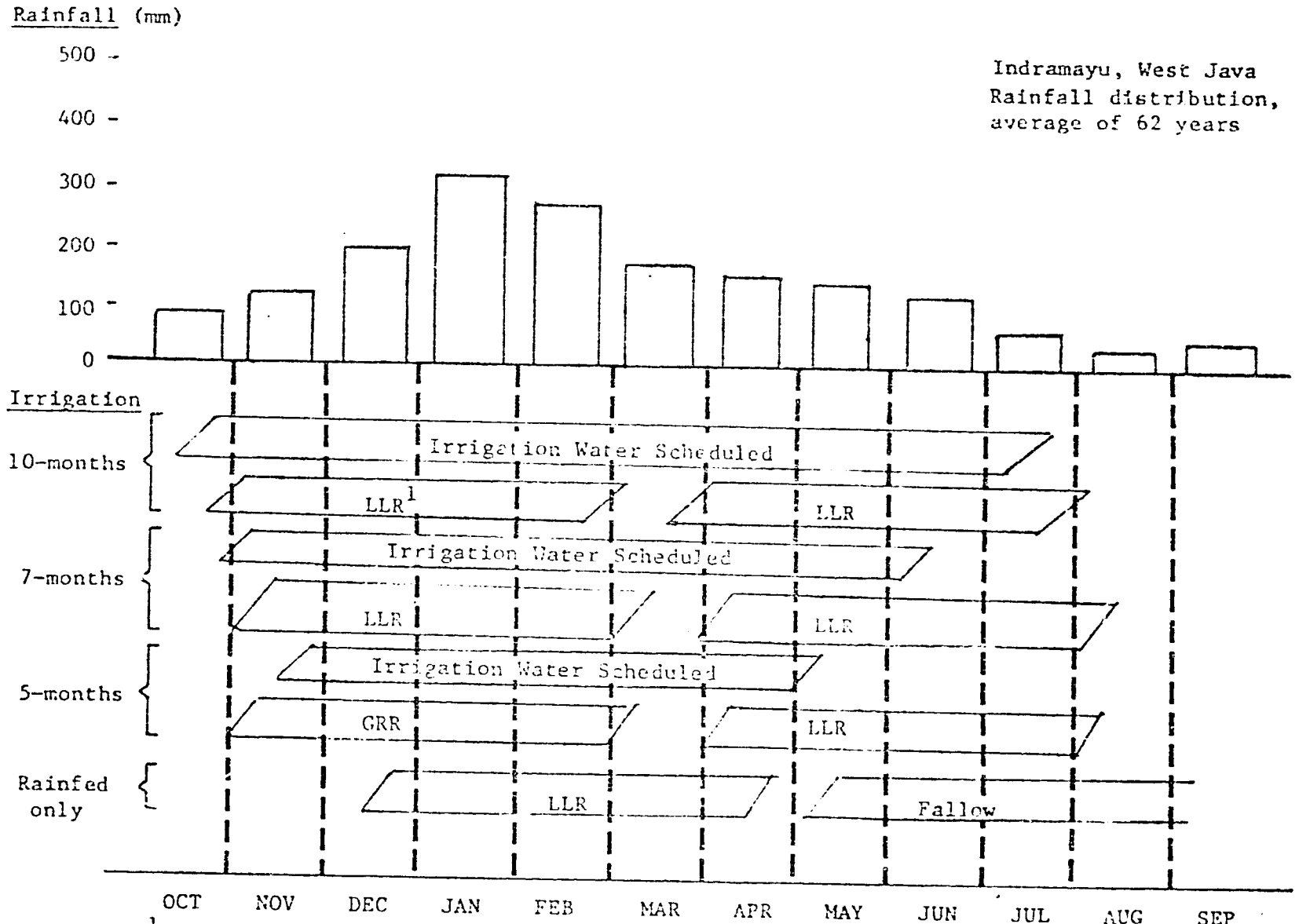
B. Central Lampung - The most likely classification for soil in sites of the Central Lampung target area would be fine loamy, kaolinitic, isohyperthermic Plinthic Tropudult. The name indicates this is a highly weathered tropical soil with some plinthite in or below the argillic horizon. It is low in inherent fertility and likely has a perched water table at sometime during the year. The udic moisture regime permits year round crop production provided drought tolerant crops are grown during the dryer times of the year and soil management practices for fertilizer and crop residue recycling are used. This soil must be managed carefully to prevent erosion and rapid loss of soil organic matter. On the other hand, this soil tends to be very responsive to small increments of phosphate fertilizer application and is easily cultivated. The surface horizon is well drained and the clay particles aggregated so that the soil can be cultivated soon after a rain. This soil is responsive to intensive management and is well

suited for farming systems that include animal components as well as food, forage, and perennial crops. It is best suited for management in small units by family farm type operations.

Technology developed and transferred

Indramayu. Fig. 11 shows the predominating cropping patterns used by farmers in the Indramayu area at the time research was begun in 1973. When existing farmer practice is combined with the long-term rainfall data and irrigation capabilities, some basis for cropping pattern redesign can be seen. Consequently, the following observations are not looked upon as problem identification but as potential for increased crop production and improved farm economy.

The second rice crops in the partially irrigated areas were not receiving water long enough to adequately meet their requirements. Practically no food crops other than rice (palawija crops) were grown. Direct seeding of rice by broadcasting or dibbling seed on aerobic soils (gogo rancah) was practiced on a limited scale by farmers in partially irrigated areas and even less in rainfed areas. The components of crop production were considered in designing and testing new cropping patterns as outlined in this paper: (1) lands were not being fully utilized and there were food shortages, (2) labor, markets, agronomic potential, and time existed to permit increased crop production, and (3) earlier maturing rice varieties (less than 120 days) had been developed. Fig.12 shows patterns that were tested in 1977-78 along with the rainfall distribution and irrigation water available for that crop year. These patterns were tested as introduced patterns in the two previous crop years. Table 4 shows a summary of the results of testing farmers' and introduced cropping patterns for 3 years. The pre-production test plots



[1] LLR--Lowland Rice, WJR--Walik Jerami Rice (no tillage), GRR--Gogo Rancah Rice (dryseed), CP--Cowpea and SB--Soybean.

Fig. 11. Working calendar of Farmers' Cropping Patterns. Indramayu, West Java. 1973.

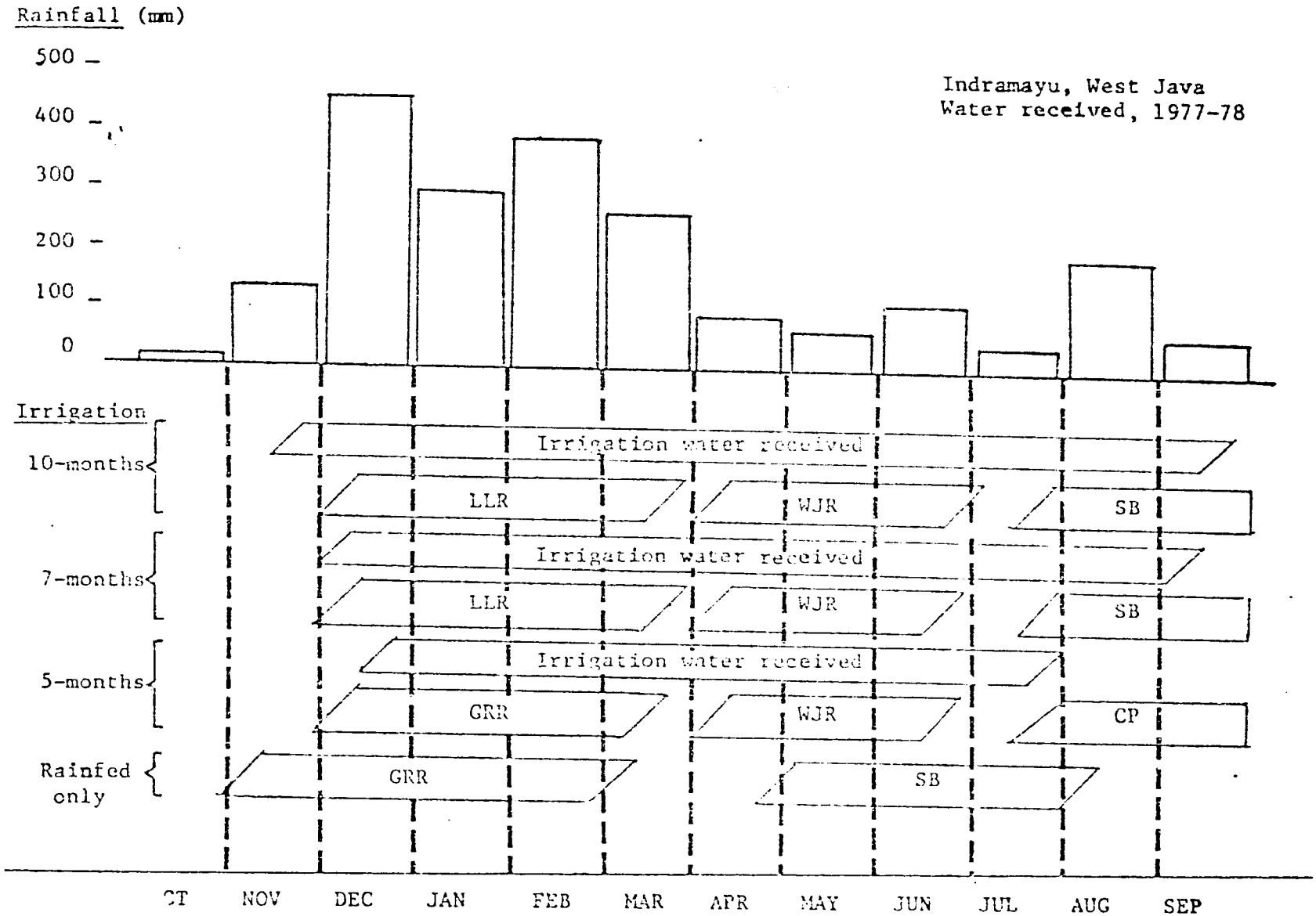


Fig. -. Working calendar of Pre-production Cropping Patterns. Indramayu, West Java, 1977-78.

Table 4. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns. CRIA C. S. Proj., Indramayu, West Java. 1975-78.

Cropping Patterns	Irrigation Category		
	10 months	7-9 months	5-8 months
	Ave. yield - kg/ha[3]		
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' Patterns as shown in Fig.11

[2] Introduced Patterns as shown in Fig.12 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 replication/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.

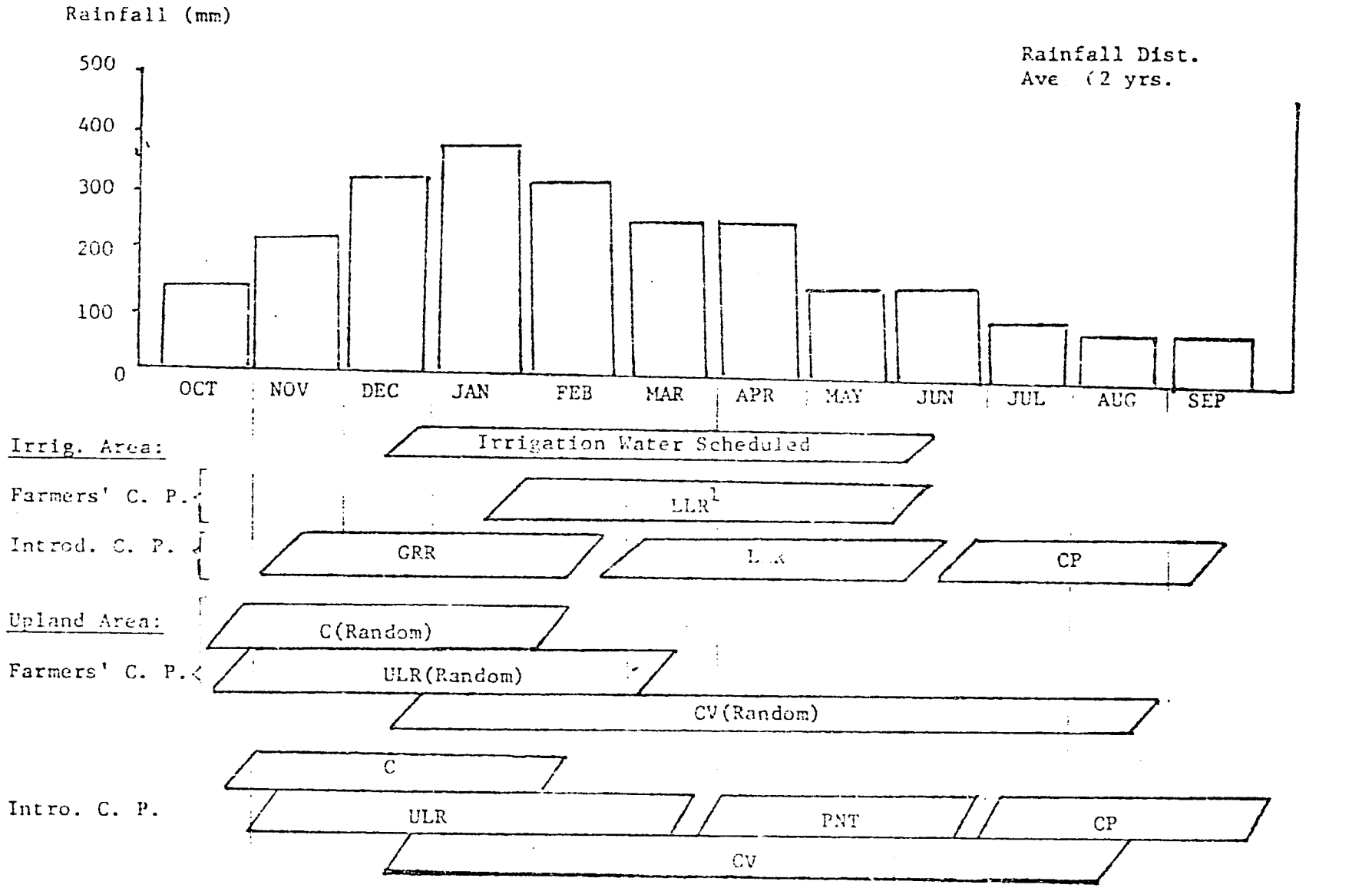
[5] Cash surplus is Gross Returns minus cash costs for Materials and Labor, while net returns is Gross Returns minus costs for all Materials and Labor, including Farmers' Labor.

(1977-78) were subjected to extreme weather conditions in that year. The rains were unusually late and began abruptly with high intensity in December. Flooding was severe in the rainfed and partially irrigated areas. Unusually heavy rainfall continued through the dry season of 1978 so that it was more difficult to grow palawija crops during this period. Nevertheless, crops in the introduced cropping patterns performed well, particularly in the partially irrigated areas when compared to the average results of the farmers' patterns tested the previous two years. The yield of the second rice crop in the 5 to 7 months irrigation area was reduced during 1977-78 in comparison to the first because of stem borer and unusual weather conditions. Nevertheless, the overall data showed that technology to improve rice yields, grow an extra crop per year and increase net returns for these areas under these conditions is available. The new technology was dependent upon availability of earlier maturing and adapted varieties of rice, suitable soil and climatic conditions for gogo rancah (dry seeded rice) and walik jerami (no till second rice crop).

Implementation over an extended area is considered to be dependent upon the synchronized activities of government agencies (research, extension, irrigation, and local government) to regulate the use of water, varieties and cropping patterns in an appropriate irrigation or agroclimatic complex. Efforts to transfer the technology, fully or in part, have been successful experimentally in Serang, West Java; Madura, East Java, and most notably in Mambah Dadi, Central Lampung (see Fig.14). The latter example will be discussed in the next section of this paper.

Central Lampung. Fig.13 shows the predominating cropping patterns used by farmers in the partially irrigated lowland areas in Nambah Dadi village and the upland areas of Central Lampung. The farmers had become dependent upon the irrigation water in Nambah Dadi and grew only one rice crop per year in their irrigated fields but grew crops throughout the year in their upland fields. This is an unfortunate example of overdependence upon irrigation. Although it had not been our intention to work in an irrigated area, because of our experiences in Indramayu and observations that the land was underutilized, we established one site in Nambah Dadi.

A. Partially irrigated area. Our first attempts to improve the cropping patterns in this area consisted of introducing earlier maturing rice varieties, reducing turn-around time between planting of rice crops in the wet season and growing secondary crops during the dry season. We found that the supply of irrigation water was less dependable than anticipated and that we could not save enough time to get two lowland rice crops per season. But there appeared to be potential for growing legume crops during the dry season after the rice crops. We had tried gogo rancah (direct seeding of rice on aerobic soil that will be flooded later) in some small plots and found that even though the rats and birds ate the rice because it was out of phase with the surrounding crops, the vigor of the crop of rice (gogo rancah) appeared good. The soil was considerably different from the alluvial clay soils of Indramayu (see Table 3), but other factors made the area suitable for this method of rice culture. First of all, the rainfall



[1] LLR--Lowland Rice, WJR--Walik Jerami Rice (no tillage), GRR--Gogo Rancah Rice (dry seed), CP--Cowpea, SB--Soybean, C--Corn, CV--Cassava, ULR--Upland Rice, PNT--Peanut, RB--Ricebean and F--Fallow

Fig. 13. Working Calendar of Farmers' and Pre production (Introd. C. P.) Cropping Patterns. Central Lampung, Lampung. 1977-78.

gradually increases over time (more than two months) to reach a peak suitable for flooding and rainfed lowland rice culture. This may be seen by comparing rainfall distribution data in Figs. 11 and 13. There was sufficient rainfall to permit establishment of an upland crop. However, if the rainfall is high, aerobic conditions to permit continued cultivation of upland crops is possible only if aerobic conditions are provided by extensive drainage facilities. The gogo rancah rice, on the other hand, can be directly seeded on aerobic soil and then flooded. The usual benefits of flooding for control of weeds and improved nutrient availability result. Generally, in well drained soils, such as that existing in Nambah Dadi, excess drainage hinders gogo rancah rice production. Furthermore, since the soil is not puddled when this cultural method is used, downward percolation of water and leaching of plant nutrients are excessive. Fortunately, because of the level topography of the partially-irrigated rice fields and the gradual raising of the water table with irrigation water and rainfall within the system, this problem did not occur. Table 5 shows the yields and economic returns from farmers' and introduced cropping patterns in this partially-irrigated area when the gogo rancah technology was used in the improved pattern. The plots were about 3 hectares in size and included fields of several farmers. This pre-production trial was sufficient evidence to many farmers to spontaneously adopt this technology. Thus, the technology was transferred from Java successfully and within the Nambah Dadi area. Considerable research effort and time were saved.

Table 5. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns in Pre-production Trials in partially irrigated area with 3 hectare plots. CRIA C. S. Proj., Nambah Dadi, Central Lampung. 1977-78.

Cropping Patterns[1]	Yields and Cash Surplus[2]				
	Yield kg/ha	Gross Returns	Material Costs	Hired Labor Cost	Cash Surplus
		RP/ha			
Farmers' C. P.:					
Lowland Rice -	3,743	190,434	24,670	73,537	92,227
Fallow	--	--	--	--	--
				Total	Rp 92,227
Introd. C. P.:					
Gogo Rancah Rice -	3,562	382,387	44,450	128,177	209,760
Walik Jerami Rice -	2,873	146,523	35,300	61,405	49,818
Cowpea	679	74,690	7,300	6,000	61,390
				Total	Rp 320,968

Farmers' and Introduced Patterns are diagramed in Fig. 13. Gogo Rancah Rice is rice directly seeded on aerobic soil at beginning of rainy season. Later it is flooded.

Yields were measured by sampling from farmers' fields and from within the 3 hectares of contiguous plot area. Cash surplus means Gross Returns minus cash costs of Materials and Labor only.

B. Upland areas. The other two sites were located in upland fields that were being newly opened (Komering Putih) and that had been opened several years before but allowed to revert to Imperata (Bandar Agung). Fig. 13 shows the predominating cropping pattern used by the farmers. The farmers' patterns appeared to be well adapted to the existing soil, climatic, and market conditions. But the probability of increasing production by use of fertilizer, improved management practices (planting in rows) and introduction of more legumes into the systems appeared to be good (Fig. 13). Research had begun in 1973 to evaluate these ideas. Tables 6 and 7 illustrate some of the dramatic results that were obtained. Yield and net return data show the advantage of planting in rows compared to random planting as practiced by the farmers. This was especially important for crops other than cassava when fertilizers were used. The data also show that the practice of farmers to grow combinations of crops was more productive and profitable than growing crops separately in sequence. Most of all these data show the importance of improving soil fertility through use of fertilizer. This is further illustrated in Table 7 where the yield data for the intercropping pattern are expressed in terms of calories, protein, and paddy rice (gabah equivalent). Thus, if properly managed, the total production per hectare on these nonirrigated and underutilized uplands can exceed that of the irrigated and fertile lowland areas of Java. Extensive and systematic cropping systems studies were started to test this technology in farmers' fields under different conditions within the target area. In 1975, sites

Table 6. Average yield of crops and approximate net returns for check and full treatment plots. CRIA C. S. Proj., Bandarjaya, Central Lampung, 1973-74.[1]

Fertility Treatment	Corn	Upland rice	Peanut	Rice bean	Cassava	Approximate net return
	----------Dry grain-kg/ha----------				Fresh root (ton/ha)	Rp/ha[2]
			Mixed Cropping			
Check	467	690	161	55	12.7	65,000
Full + mulch	1,165	1,358	356	248	28.3	132,000
			Intercropping			
Check	455	769	222	93	14.6	91,000
Full + mulch	1,350	2,724	567	627	23.2	265,000
			Sequential Planning			
Check	606	850	-	153	-	(-6,000)
Full + mulch	2,935	3,536	-	723	-	74,000

[1]Yields subsequently have varied due to pests and management but have remained basically the same.

[2]One (1) U.S. dollar equivalent to Rp. 415 until November 1977; thereafter, approximately Rp. 620 per dollar.

Table 7. Calories and protein produced per hectare from year-round cropping patterns with no and full fertilizer treatments. CRIA C. S. Proj., Bandarjaya, Central Lampung. 1973-74.

Cropping Pattern	No Treatment			Full Treatment		
	Yield	Calories	Protein	Yield	Calories	Protein
	kg/ha	K cal/ha	kg/ha	kg/ha	K cal/ha	kg/ha
Corn +	455	1,615	42	1,350	4,792	124
Rice +	769	1,840	52	2,724	6,521	185
Cassava +	14,600	17,520	102	23,200	27,840	162
Peanut -	222	1,003	51	567	2,563	145
Rice bean	93	308	23	627	2,075	157
Total		22,286	276		43,791	773
Gabah[1] equivalent kg/ha/year		9,325	4,060		18,323	11,371

[1]Gabah x .665 = milled rice and average value of 6.8% protein used for conversion from protein to gabah.

were established in Bandar Agung and Komering Putih, Central Lampung. In succeeding years, sites were established in Way Abung, North Lampung; Batu Raja, South Sumatra; and Tajau Pecah, South Kalimantan (Fig.14). These sites were similar in many respects to the description given for Bandarjaya in Table 3.

Yield and economic data are shown in Tables 8, 9, and 10. Tables 8 and 9 show the data from the first and second years, respectively, for the sites mentioned above. Basically, the same cropping patterns and management practices that were used in Bandarjaya were transferred intact to these sites. The data show dramatically the increased production and economic returns that could be expected by use of the introduced technology. But the data also show that usually there were general improvements in cropping pattern performances the second or succeeding years in a site. This kind of fine tuning is to be expected and probably indicates improvement in management techniques. Not only do the researchers improve their techniques but, more importantly, the neighboring farmers gradually adopt low-input practices such as planting in rows using improved varieties and small amounts of fertilizer. An example of this took place in Komering Putih in 1976-77 (Table 9) where farmers' crop yields and economic returns increased. Furthermore, provincial extension agents began to disseminate technology through conversations with farmers before production programs were initiated. With the fragile local economy and given the economic status of the farmers, technologies that require considerable money for inputs, such as fertilizer, insecticides, and legume seeds are not readily adopted.

Figure 14.

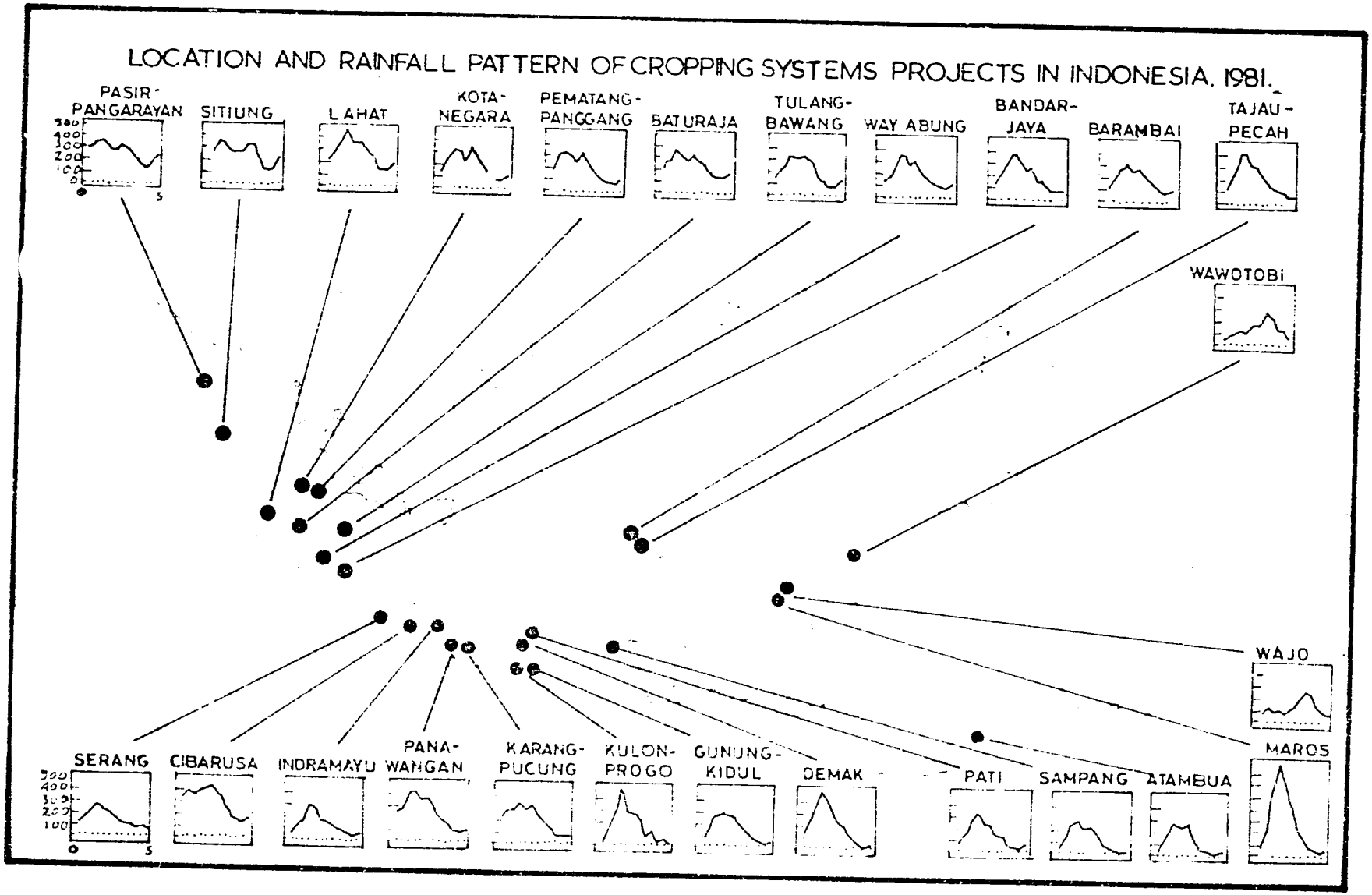

LOCATION AND RAINFALL PATTERN OF CROPPING SYSTEMS PROJECTS IN INDONESIA, 1981.
PASIR-PANGARAYAN
SITIUNG
LAHAT
KOTA-NEGARA
PEMATANG-PANGGANG
BATURAJA
TULANG-BAWANG
WAY ABUNG
BANDAR-JAYA
BARAMBAI
TAJAU-PECAH
WAWOTOBI
WAJO
MAROS
ATAMBUA
SAMPANG
PATI
DEMAK
GUNUNG-KIDUL
KULON-PROGO
KARANG-PUCUNG
PANA-WANGAN
INDRAMAYU
CIBARUSA
SERANG

Table 8. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns for first years' results from different locations. CRIA C. S. Proj., Lampung, South Sumatra and Kalimantan. 1975-79.

Cropping Patterns	Yields and Net Returns/Location				
	Bandar Agung 1975-76	Komering Putih 1975-76	Way Abung 1976-77	Batu Raja 1976-77	Tajau Pecah 1978-79
	kg/ha				
Farmers' C.P.:					
Corn +	235	287	569	332	3,000 ears
Upland Rice +	722	461	1,930	1,043	1,030
Cassava +		7,975	9,767	5,880	
Peanut	(C) 793	--	--	329	(C) 8,270 ears
Net Returns	Rp 23,446	Rp 33,410	Rp 119,062	- (Rp 77,900)	Rp 50,954
Gabah Rice Equiv: (T/ha/yr)	2.24	4,87	7.66	5.94	--
Introd. C.P.:					
Corn +	1,798	2,140	1,169	1,877	698
Upland Rice +	1,094	1,231	1,858	746	1,665
Cassava +	11,151	9,933	22,200	16,649	7,200
Peanut -	(PNT) --	--	567	499	(CP) 632
Ricebean	--	--	228	531	
Net Returns	Rp 76,523	Rp 61,343	Rp 148,107	Rp 114,527	Rp 223,708
Gabah Rice Equiv: (T/ha/yr)	9.33	9.36	16.07	13.52	6.86

Table 9. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns for second years' results from different locations. CRIA C. S. Proj., Lampung and South Sumatra. 1976-79.

Cropping Patterns		Yields and Net Returns/Location				
		Bandar Agung	Komering Putih	Way Abung	Batu Raja	Lahat bing 1
		1976-77	1976-77	1977-78	1977-78	1977
		kg/ha				
Farmers' C. P.:						
Corn +		759	337	924	402	Non
Upland Rice +		2,018	1,562	1,905	1,877	"
Cassava +		--	18,333	9,788		"
Peanut	(C)	806	--	--	525	"
Net Returns		Rp 110,859	Rp 159,237	Rp 125,763	Rp 132,500	
Gabah Rice Equiv: (T/ha/yr)		4.33	11.23	8.16	3.46	
Introd. C. P.:						
Corn +		1,977	2,080	2,553	1,626	2,4
Upland Rice +		1,689	1,022	3,688	1,076	2,8
Cassava +		21,125	26,110	19,888	14,710	14,8
Peanut -	(C)	1,739	385	580	573	5
Ricebean	(CB)	328	--	280	544	2
Net Returns		Rp 216,594	Rp 201,878	Rp 409,743	Rp 176,540	Rp 377,8
Gabah Rice Equiv: (T/ha/yr)		18.22	17.88	18.89	12.67	15.2

Table 10. Comparisons of yields and economic returns from Farmers' and Introduced Cropping Patterns in Pre-production Trials in upland area with 3 hectare plots. CRIA C. S. Proj., Bandar Agung, Central Lampung. 1977-78.

Cropping Patterns[1]	Yields and Cash Surplus				
	Yield kg/ha	Gross Returns	Material Costs	Hired Labor Cost	Cash Surplus
		RP/ha			
Farmers' C. P.:					
Corn +	396	27,720	20,740	34,344	115,854
Upland Rice	1,418	143,218			
Gabah Rice Equiv: (T/ha/yr)	2.0			Total	Rp 115,854
Introd. C. P.:					
Corn +	1,105	77,350			
Upland Rice ≠	2,965	299,465			
Cassava ≠	29,331	87,993	105,550	75,193	382,880
Corn -	2,553	89,355			
Cowpea	86	9,460			
Gabah Rice Equiv: (T/ha/yr)	23.16			Total	Rp 382,880

Farmers' and Introduced Patterns are variants from Fig. 8. Farmers in this area have jobs with nearby plantations. They have developed a reasonably good market for corn and are just beginning to see the value of cassava.

Summary

Fig. 15 depicts the situation that exists as new technology is developed through cropping systems research in a target area. The gap between farmers' use of technology and that which is available is still too big even after implementation of production programs. Perhaps with researchers working more closely with farmers, extension, and local government officials, we will become more sensitive to the farmers' needs. We cannot eliminate the need for inputs, but we can devise low input cropping patterns to facilitate farmer adoption. Also by understanding the capabilities of soils we work with better and by anticipating the input requirements, we can facilitate the implementation of production programs that are more appropriate for an area. We can shorten the time required for research in an area and thereby increase the number of other sites that can be studied. In order to do this, more emphasis must be placed on site description and technology transfer.

As we work within a target area and develop the technology for improved cropping patterns, other opportunities and constraints faced by farmers are identified. This is the time for the research to develop into a holistic farming systems program. This is the proper sequence. The initial surveys can be holistic in scope. But the experimentation that is implicit in this kind of research must be focussed at early stages on the needs that have the highest priority. Usually that priority is for food crops. When that need is satisfied, either on the farm or by other means, then new priorities can be tackled.

Farming Systems - Issues and Some Answers

Jerry L. McIntosh and Surjatna Effendi

Good research raises more questions than it answers. But also good research is specific enough to address the objectives for which it was designed and provides solutions to problems. The research approach described shows how crop intensification could be used to increase food production and income of small land holders in irrigated and partially irrigated areas on Java. Furthermore, the research shows the feasibility of using upland areas in Sumatra and Kalimantan for food crop production and establishment of a profitable and stable agricultural economy. In the process many interesting questions have been raised that have not been addressed specifically in the paper. Many questions concern the research approach itself and some are of general interest only. Some suggest a broadening of the research to a holistic or farming systems approach.

Intensification versus extensification

Many countries have no choice but to intensify crop production. They have no more land to bring into production. In some cases all the land is intensively used and the only option remaining to increase food production is to increase yields per crop.

One task of agricultural research is to analyze the opportunities to increase crop production in line with government policy and decide where research should be conducted. For example, contrary to belief of many people there is ample opportunity to intensify crop production on Java. The research data in this paper show how this could be accomplished. Then why open new lands in the outer islands? In this case, area development is an immediate objective. Increased food production and population

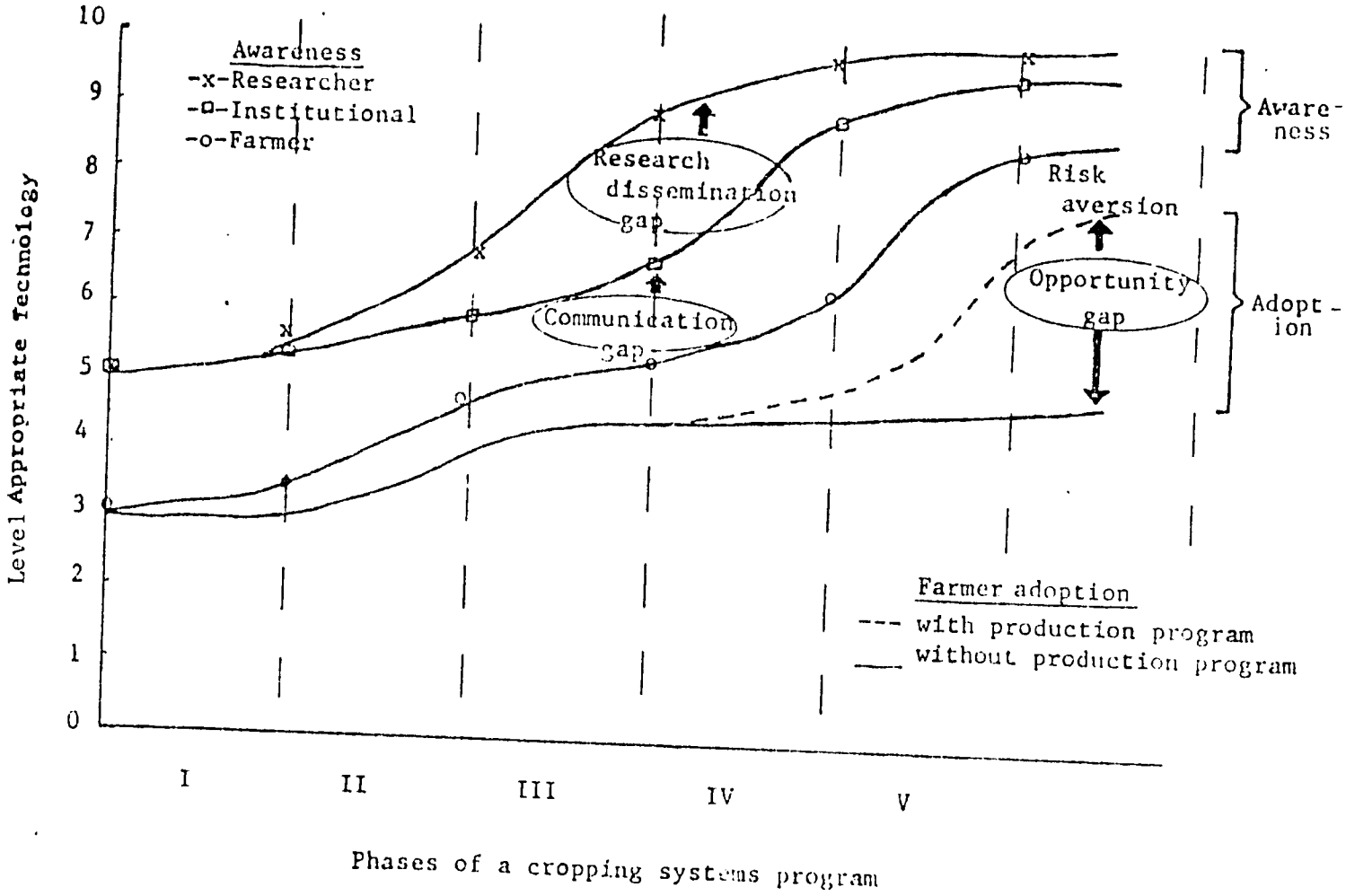


Fig. 15. Research development, dissemination, and implementation with respect to sequential phases of a Cropping Systems Project in an underdeveloped target area.

Table 11. Implications of cropping systems research

Self Sufficiency in Rice on Present Irrigated Lands

1. Total irrigated land area		3.94 M. hectare (land area)
2. Should be able to double crop about 2.66 M hectare out of 3.94 M hectare		6.6 M hectare (crop area
3. Should be able to average		4 t/hectare/crop
4. Production per year :	Gabah	26.4 M t/year
	Beras	17.5 M t/year
5. Sufficient rice (120 kg per capita)		146 M people

pressure relief are also objectives but longterm. Infrastructural development is a prerequisite for these objectives. Consequently, for the time being the greatest opportunity to increase food production would be to concentrate on the fully and partially irrigated lands on Java or the outer islands. Table 11 shows how Indonesia could be self sufficient in rice by just increasing the average yield per hectare to 4 tons of gabah rice for the irrigated rice lands. The average yield of gabah for BIMAS was 3.54 ton per hectare in 1978. Data from this paper shows that 4 tons is a reasonable yield for these irrigated and fertile rice lands. It is estimated that about two thirds of the 4 million hectares of irrigated land could be double cropped to give a total crop area of 6.6 million hectares of irrigated rice per year. This area should produce ample rice for self sufficiency. Furthermore, since these lands have reasonably good drainage and some irrigation during the dry season palawija crops like soybean, cowpea and sunflower could be grown after the two (in some cases one) rice crops.

Food crops versus perennial crops

Strategies for increasing food production depend upon the situation. The options are greater in newly opened areas compared to settled areas. Irrigated rice lands are not likely to be converted into dry lands for perennial crops. But upland areas that are newly opened could have several uses. The stability and marketability of perennial crop products like timber, rubber, coffee, coconut, pepper and clove tend to polarize development plans and promote specialization. However, this tendency may be due more to the specialists than to the peculiarities of the crops.

In industrialized societies and in societies where there are food surpluses, movement and availability of food is taken for granted. But in newly developed areas in societies where food shortages are common, proximity to food production sources takes on more urgency. People living the fartherest from production areas or ports will likely suffer the most when food shortages occur. Consequently, in newly opened lands in developing societies food production must receive a high priority. The first phase in agricultural development must meet this need so that a reasonable degree of food self sufficiency can be assured.

This line of reasoning is logical and no one seriously disagrees. But many times in the planning process, the estate concept for efficient and profitable production of marketable perennial crops is looked upon with favor. The vastness, uniformity and production efficiency of these estates clouds the picture; while, the vulnerability of the employees to food shortages and market fluctuations is not clearly seen. The nucleus estate concept is an attempt to allow the plantation workers to share in profits and hold title to land. The vulnerability to food shortages still exist and the pros and cons can be argued. But if it is impractical for the employees of the estates to produce their own food, a reasonable alternative is to insure that there is food self sufficiency in the regions. The definition of a region in this case will depend upon the infrastructure for production, movement and marketing of food products. For example, a transmigration project area could be a major producer of rubber or palm oil but either within the project area or adjacent to it enough food should be produced to meet the mutual needs.

Small farms versus estates for food crops.

Success with production of estate and perennial crops on large plantations has created an interest in trying to duplicate this achievement with food crops. Furthermore, proponents give examples of large corporations and collective farms in temperate regions that are efficient and productive. Consequently, in contrast to small farm production it is assumed that estate type operations would be more efficient and productive in the tropics. The net result would be the production of a surplus of quality food crops for sale or storage in government warehouses.

Unfortunately the performances of the estates have not been up to expectations. This may be an over simplification. But there are many problems associated with large scale operations that small farmers never face under tropical conditions.

First of all most of the good land suitable for upland agricultural was put into production long ago. The land available for agricultural development now usually is infertile, erodible, hilly and isolated. The other major area usually considered as a candidate for development is the tidal swamps. Here the logistic and agronomic problems are even greater.

The problems begin with land preparation and continue throughout the crop cycle. The size of the estates and the magnitude of the operations usually absorb all the labor available in the area. Mechanization of land preparation, planting, weeding, cultivating, harvesting and post harvest handling appears to be the break-through needed to make the operation efficient and timely. Unfortunately, about the only

operation that can be successfully mechanized is the land preparation at the beginning of each crop season. Ironically, this operation in the longrun is one of the major pitfalls in upland estates. Planting in straight furrows across large fields creates the conditions conducive for erosion and gully formation. Since most of the inherent soil fertility is contained in the organic fraction of the surface horizon much is lost the first two or three years after opening the land due to sheet erosion and percolation. Even though soil conservation practices are planned they usually cannot be implemented before serious soil losses occur.

Some of the planting operations can be carried out by mechanization. Usually cultivation for weed control and mechanical harvesting are not satisfactory. Excessive moisture, mechanical failures and problems with spare parts create delays. These delays in cultivation, harvesting and drying cause losses in yields and quality of production. Simple activities like drying cassava chips for small farmers become logistic nightmares for large estates. The general practice is to revert to hired day laborers to manually carry out these operations.

About the only advantage to the food crop estate is their ability to more efficiently market a larger volume of produce when compared to small farm operations. This is an important aspect that should not be under emphasized. One possible aternative, however, is to develop a cooperative market arrangement among small farmers in a contiguous area. These are issues that need further consideration and study in a farming systems research program.

Cropping Systems versus research systems research

The objectives and benefits of cropping systems research have been sufficiently described in earlier sections of this paper. But there are ancillary activities and benefits which occur that sometimes are overlooked It is ironic that some of the greatest efforts to systematize agricultural research and make it more relevant have occurred among the so called developing nations. Usually these have been collaborative efforts with international or bilateral development research programs. Nevertheless the ingenuity and sophistication of the research in national programs should not be overlooked. The accomodation of new ideas and research approaches to fixed organizational structures in order to move forward with systems programs is exemplary. Systems research usually exist for the various research areas. Consequently, up to this point in many developing countries, cropping system research has not emanated from the research administration. It has been sanctioned and encouraged but not conceived by the usual chain of command. Rather, the researchers were motivated by conviction to develop programs that would lead them to interact with other scientists in other disciplines and plan research for areas broader than their own individual expertise. Since limited personnel and money encouraged targeted research under farmers' conditions, many junior scientists come face to face for the first time with simple as well as complex problems farmers face every day. These interactions have been invaluable for research staff development and problem identification. The research and the formal and informal training conducted have developed a cadre of scientists who are capable and aware of research needs.

In the final analysis an effective cropping systems program has a tendency to lead to its own demise. Because all the elements of an effective research program usually are in place, cropping systems plays the role of a catalyst to activate the existing components to do their jobs. Cropping systems research is not a competing discipline but a contemporary program. Consequently, the flush of cropping systems research activities may self destruct but a catalyzing nucleus should remain to serve a similar purpose in the future.

Mixed cropping versus sequential planting

One objective of a cropping systems programs is to make maximum use of land, water, sunshine and time. Strategies have been described how to accomplish these objectives for different agroclimatic conditions. In retrospect approaches described appear straight forward if not simplistic. They have focused on either adding an extra crop to the existing cropping pattern or improving the production per component. Radical redesign of patterns was not considered to be a viable alternative. Even in the case of mixed cropping patterns, which are viewed by some scientists as examples of "under developed" agriculture, redesign consisted only of decreasing the number of crops growing at any one time and systematically growing the crops in rows. This approach has provoked critical comments and questions about the merits of cropping patterns that have mixed cropping components particularly when research programs were first begun. One reason for this apprehension was because the research was called multiple cropping. This term evokes different images to different people but usually creates conditions for long discourses

on definition. In order to avoid this problem the term "cropping systems" has been widely adopted as an umbrella under which cultural practices like intercropping, interplanting, relay planting and sequential planting are components. These components are obviously various kinds of multiple cropping. The first three may be described as different kinds of mixed cropping. There may still be questions as to their usefulness in modern agriculture.

The answer depends upon the situation. Three crops of paddy rice growing in a sequence per year on irrigated land is probably one of the most efficient and stable cropping systems. On the other hand a mixed cropping system of rice, corn, cassava and legumes may be best for some upland crop areas. In the latter case the argument can be made that it would be better to grow all these crops but grow them separately in the proper sequence so that the management per crop could be more specific. The diversity of production and the concomitant effects on food, market and economic stability would be about the same as far mixed cropping. The productivity and management aspects become very fascinating research questions.

Rich soil versus poor soil

It is commonly said that agriculture in the United States is so productive because the farm land is so fertile. This is only partly true. Some soils of the upper midwest have considerable inherent fertility and adequate rainfall during the growing season. They are naturally productive. Other soils are fertile but have inadequate rainfall during the growing season. They require irrigation in order

to be productive. Other soils like many of ultisols receive adequate rainfall but are not inherently fertile. They must receive fertilizer and good management to be productive. Even the best soils are not inexhaustible sources of plant nutrients and fertility. Farmers in Illinois usually use higher rates of fertilizer for corn than farmers anywhere else. There has been a tendency to substitute fertilizer for labor. The rainfall is usually good, and the soil deep. There is little risk involved in applying large amounts of fertilizer.

Initially in the opening of new areas the inherent soil fertility is an important factor in the management and productivity of the land. For almost 100 years little fertilizer was used on the Udolls of northern Illinois and Iowa. Management practices involving crop rotations and wates such as manure and stover helped maintain the high levels of inherent soil fertility. But for the last 30 years increasingly higher rates of fertilizer are being used. Consequently, the managements of soils that were inherently quite different may be the same. Constraints to production such as adverse topography, physical properties and climate constitute much more severe obstacles than soil fertility to crop production and farm management.

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