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A Multidisciplinary Approach to Agrotechnology Transfer:

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HITAHR • COLLEGE OF TROPICAL AGRICULTURE AND HUMAN RESOURCES • UNIVERSITY OF HAWAII

"Agrotechnology is the taking of an agricultural innovation from one location to another location where the innovation is likely to succeed. To succeed in a new location, the innovation must be technically sound, economically feasible, socially desirable, and environmentally safe."

— G. Uehara

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Relationship of the Benchmark Soils Project to the Farming Systems Approach

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New technology is not always adopted by farmers as quickly as researchers would expect. But there is plenty of evidence to show that farmers will quickly accept new technology that is appropriate and beneficial to them. Consequently, national and international research institutes, donor agencies, and scientists themselves have begun to reevaluate their approaches to agricultural research. These kinds of self-evaluation are useful to provide the rationale to strengthen and increase the efficiency of agricultural research wherever it may be conducted.

Independent and piecemeal research is likely to be a luxury in a developing country. In developed countries, however, there may be sufficient government and private extension efforts, farmer initiative, and economic viability to permit transfer and adoption of fragmentary bits of new technology to meet individual needs. On the other hand, in developing countries, when constraints of limited funds and trained personnel exist, it is appropriate to give more emphasis to systematic and integrated research for specific problems and target areas. The team approach fosters better definition of research objectives, use of existing research information (technology transfer in) and broader implementation of results (technology transfer out).

Farming systems studies of various kinds of teams of agricultural scientists have been a consequence of the concern for development of more appropriate technology. In countries where most of the food consumed comes directly from crop production, there may not be much difference between farming systems and cropping systems research. In cropping systems research, although the emphasis is on crops, all the other related farm activities are also usually considered--from land preparation, which includes animals and family labor, to marketing, which involves transportation and infrastructural development. Consequently, cropping systems research is a coordinated and integrated effort to develop technology that will enable farmers to increase food production in a way that is acceptable to them.

This simple condition "acceptable to them" must not be overlooked today as it often was in the past. It is the reason why many farmers did not or could not accept the new technology.

In order for research programs to be effective in developing countries, the research results or information derived should contribute directly to development needs and government production programs. Trials should be conducted on the farmers' land in order to approximate local farmer conditions and to better understand constraints farmers face. This will increase the relevance of the research to the farmer.

If the agroeconomic environment of the target area is well defined, the transfer of appropriate research technology from area to other similar areas can save time, money, and research effort. These concepts and the methodologies that are being tested in the Benchmark Soils Project can be very useful in describing the biological and physical nature of a target area. It usually takes from three to five years for cropping systems research to reach the implementation stage in a target area. Successful transfer of technology from an original target area to a similar one, using the transfer concept of the Benchmark Soils Project, could save two to three years of research time. Fig. 1 shows the phases and activities required for a cropping system research program and illustrates how more technology can be transferred into a new target area and how much research effort and time may be saved by this approach.

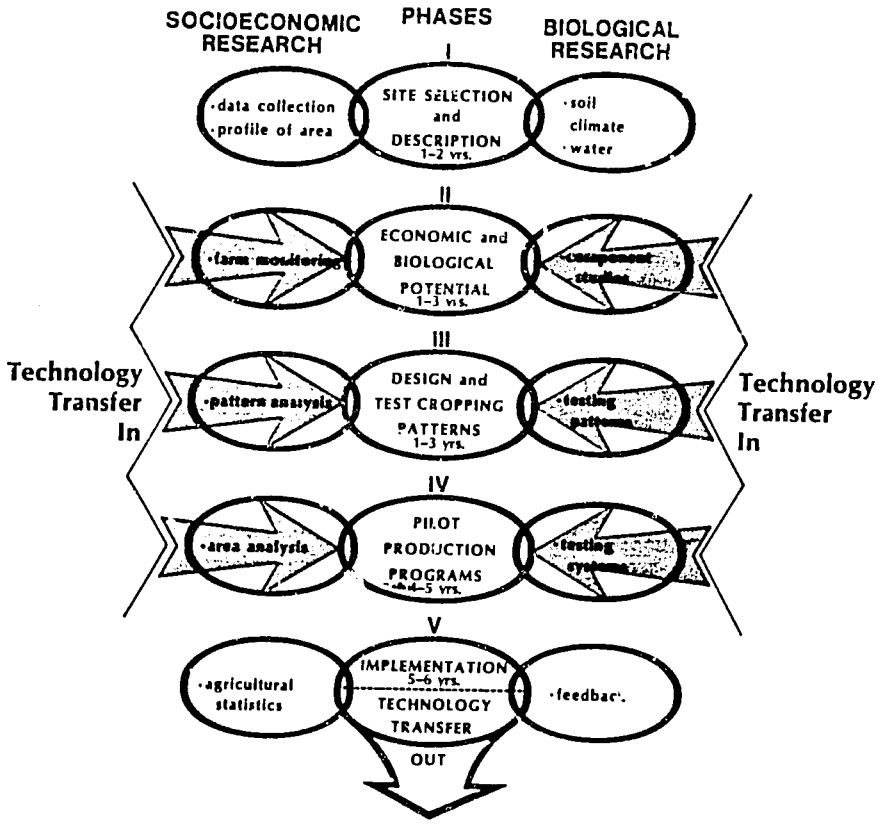

Fig. 1. Phases of a cropping systems research program and illustration of time and effort that may be saved if existing technology is used (transferred in).

Technology 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--this technology can easily be transferred from place to place. The technology of the applied agricultural sciences (such as agronomy, horticulture, and forestry), however, which directly affect the farmers' welfare, usually consists of well-documented studies of some small part of a larger system. Usually the bits of research information obtained cannot be absorbed directly by farmers in developing societies.

One objective of a cropping systems program is to collect and integrate independently existing research information and to test it holistically in a specific environment. This is an example of technology transfer into an area or system. Technology of this kind usually comes from the experiment stations of national and international research institutes and is fragmented according to crop commodities and disciplines. The missing pieces of the research puzzle for a particular target area can be identified and studied by cropping systems research. Further testing and complementary research provide the appropriate technology for use through production programs and technology transfer out.

Descriptive Basis for Transfer

It is theoretically possible to completely describe the ecological and socioeconomic environment of a target area. The agrotechnology developed for the area then should be suited for another area having an identical (or similar) description. The appropriateness of the technology transferred in should be verified by some on-site research. In practice, it is difficult, if not impossible, to find identical areas. Furthermore, researchers usually do not select target areas for research based purely on 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 a cropping systems approach?

In Table 1, descriptive elements of a target area 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.

Example: Case Study of Indramayu, West Java

Technology transfer in

The availability of technology for transfer into Indramayu, West Java, Indonesia, was very limited in 1973 when it was selected as a major target area by the Indonesian Cropping Systems Research Coordinator. It was expected that seeding rice directly and planting earlier maturing varieties were technologies that could be used to intensify cropping patterns in the partially irrigated 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

Table 1. Outline for target area description

Descriptive elements	Data use	Source
I. Integrated Environmental Factors		
• Edaphological classification	• General land use and quality	• Land use maps and soil classification
• Cropping patterns	• Crops and cropping potential	• Group interviews and soil classification
• Farm economy	• Manageability of land	• Group interviews
II. Socioeconomic Determinants		
• Markets	• Vigor of local economy	• Random interviews and local government sources of farm and market prices
• Infrastructure	• Potential and time for development	• Census data and local government
• Farmer responsiveness	• Willingness to assume risk and change	• Random interviews for land tenure, personal property, education, and mobility
• Labor availability	• Distribution and availability of labor	• Random interviews and census data
III. Ecological Determinants		
• Soil-water environment	• Crop production and soil amendments	• Soil classification
• Climate	• Crops and cropping patterns	• Weather data and soil classification
• Rainfall distribution and amount		
• Temperature and solar radiation		
• Cloud cover		
• Wind		
• Water control	• Crops and cropping intensity	• Irrigation and soil classification
• Irrigation		
• Flooding		
• Soil Water		

transmigration areas of southern Sumatra, however, not in West Java. Table 2 shows the initial description of the target area, which was used as a base for selection of the research sites within the target area, for problem identification, and for design of cropping patterns to be tested. Target area descriptions are used later as bases for transfer of relevant technology between or among (transfer out) selected target areas; however, 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 biologic processes.

Markets and availability of inputs (as affected by the infrastructure) are dominating economic factors in vast regions of Indonesia. Water availability from both irrigation and rainfall is the dominant factor in lowland rice production, whereas rainfall alone is the dominant factor for upland crops. Soil, which integrates the long-term effects of its environment, interacts with water availability and plant nutrition to greatly affect crop production, cropping patterns, and agrotechnology transfer. Consequently, the comprehensive nomenclature incorporated in the taxonomic units of Soil Taxonomy provides one

Table 2. Descriptive data for sites in target areas

Descriptive elements	Indramayu site
I. Integrated Environmental Factors	
• Edaphological classification	• Partially-full irrigation for LLR[a]
• Cropping patterns	• LLR-LLR-fallow • LLOR-Palawiji-fallow
• Farm economy	• LLR-fallow • Government-designated food deficit
II. Socioeconomic Determinants	
• Markets	• Good potential
• Infrastructure	• Good
• Farmer responsiveness	• Good
• Labor availability	• Sufficient
III. Ecological Determinants	
• Soil-water environment	• Vertic Tropaquept
• Climate	
• Rainfall distribution	• Dec-Feb > 200 mm Jul-Oct < 100 mm
• Temperature and solar radiation	• 6° 20'S latitude at ± 5 m elevation
• Cloud cover	• Little effect
• Wind	• Significant in dry season
• Water control	
• Irrigation	• Full • Partial--5-7 & 7-9 months
• Flooding	• Rainfed • Hazard in partially irrigated areas
• Soil water	• High water table and good storage soil water

[a]LLR = lowland rice.

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 Soil Taxonomy has been designed to identify soil and climate factors that are important for these purposes. The subgroup may often be adequate if sufficient practical and research experience is available for the soil.

Soil-based management guidelines

The most likely* soil family classification of the Indramayu target area is fine, montmorillonitic, isohyperthermic Vertic Tropaquept. The name provides considerable useful information for soil and crop management purposes.

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 at relatively low elevations and is likely formed from marine deposits. These are fine-textured, montmorillonitic clay soils that are relatively fertile but become very sticky and plastic when wet and develop deep cracks during the dry season. The high content of organic matter in the surface soil somewhat improves the physical condition of the surface. 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 shallow water table moderate the effects of brief dry periods after seeding. Likewise, near the end of the rainy season, sufficient soil water and intermittent rain permit upland crops to grow after harvest of paddy rice, provided surface water can be drained.

Technology development: testing the cropping patterns

Fig. 2 shows the predominating cropping patterns used by farmers in the Indramayu area in 1973. When information on existing farmer practice is combined withlong-term rainfall data and irrigation capabilities, some basis for cropping pattern redesign can be established. Consequently, the basic concern is not identification of problems but of potential alternatives 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 following components of crop production were considered in designing and testing new cropping patterns:

1. Lands were not being fully utilized, and there were food shortages.
2. Labor, markets, agronomic potential, and enough time existed for planting an extra crop per year.
3. Earlier maturing rice varieties (less than 120 days) had been developed.

Fig. 3 shows the 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 3 shows a summary of the results of testing farmers' and introduced

*These soils have not been officially classified according to Soil Taxonomy.

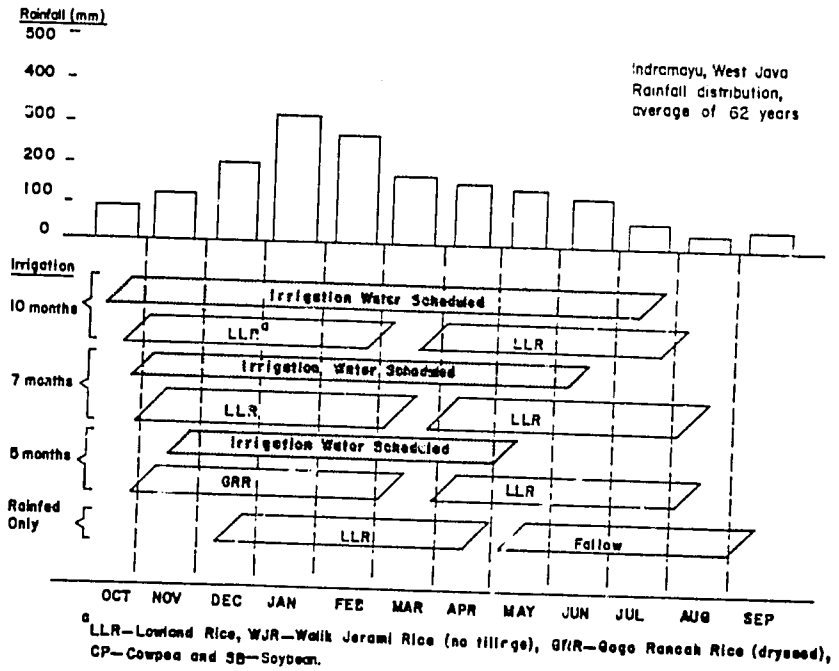

Fig. 2. Working calendar for predomenating cropping patterns of farmers in Indramayu, West Java, 1973.

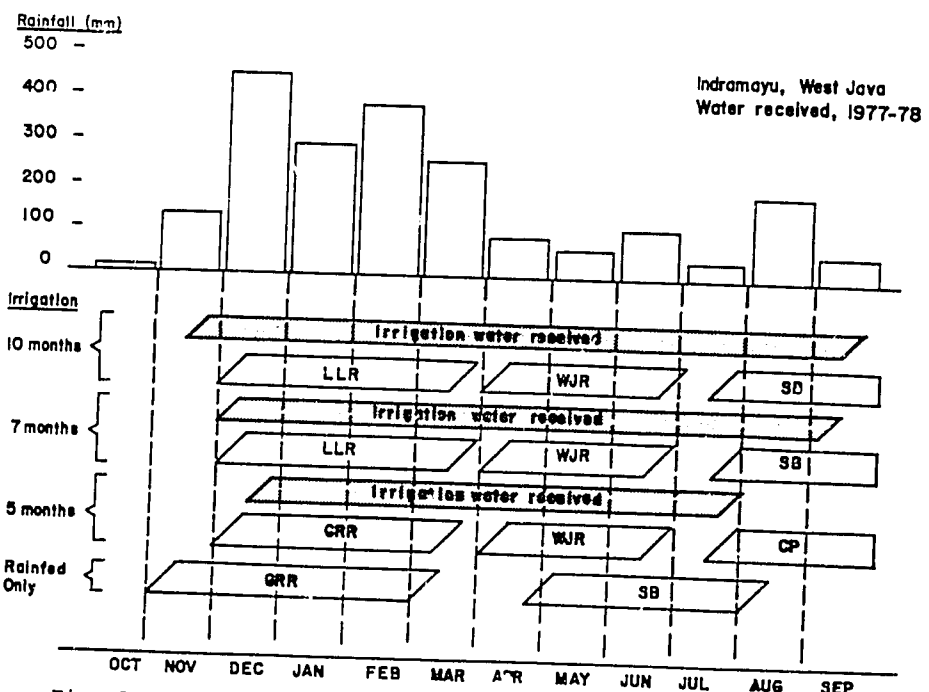

Fig. 3. Working calendar for test of cropping systems pattern, Indramayu, West Java, 1977-78.

Table 3. Comparisons of yields and economic returns from farmers' and introduced cropping patterns, Indramayu, West Java, 1975-78

Cropping patterns	Average yields (kg/ha)[a] by irrigation category		
	10 months	7-9 months	7-5 months
Farmers' cropping pattern[b] (1975-77)			
Lowland rice	5,560	5,334	3,628
Lowland rice	5,820	2,758	2,250
Net returns[c]	Rp381,317	Rp250,599	Rp131,178
Introduced cropping pattern[d] (1975-77)			
Lowland rice	5,314	5,647	4,781 (GRR)
Walik jerami rice	5,032	4,578	4,620
Legume	768	944	541
Net returns[c]	Rp379,591	Rp422,237	Rp222,872
Introduced cropping pattern[e] (1977-78)			
Lowland rice	6,915	7,195	3,451 (G[illegible])
Walik jerami rice	4,910	4,550	2,901
Soybean	462	610	--
Cash surplus for rice	Rp527,923	Rp523,099	Rp205,539

[a]Yields were measured by sampling from 1000 M^2 plots. There were three replications/treatment/year for the 2 years, 1975-77.
[b]Farmers' patterns as shown in Fig. 3.
[c]Net returns is gross returns minus costs for all materials and labor, including farmers' labor; cash surplus is gross returns minus cash costs for materials and labor.
[d]Introduced patterns as shown in Fig. 4. Walik jerami rice (WJR) is rice directly planted after preceding rice crop without plowing the land, and gogo rancah rice (GRR) is rice directly seeded on aerobic soil at the beginning of the rainy season, which is flooded later.
[e]Yields were measured by sampling from contiguous areas of approximately 3 hectares for each irrigation category for pre-production test trials, 1977-78.

cropping patterns for three years. The overall data show that technology to improve rice yields by growing an additional crop per year and to increase net returns under the conditions described is available. The new technology was dependent upon the availability of earlier maturing and adapted varieties of rice, and suitable soil and climatic conditions for gogo rancah (dry-seeded rice) and walik jerami (no-till second rice crop). In addition, the data show dramatically the increased production and economic returns that can be expected by use of the introduced technology.

Implementation and technology transfer out

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, provide varieties, and develop cropping patterns for an appropriate irrigation or agroclimatic complex. Efforts to transfer the technology fully or in part have been successful experimentally in Serang, West Java, and Madura, East Java.

There were general improvements in performance of cropping patterns in the second or succeeding years at a site. This kind of fine tuning is to be expected and probably indicates improvements in management techniques. Not only do the researchers improve their techniques, but, more importantly, the neighboring farmers gradually adopt the low-input practices being tested, such as planting in rows, using improved varieties, and applying small amounts of fertilizer. Furthermore, provincial extension agents may disseminate technology through conversations with farmers even before production programs are initiated.

Summary/Conclusion

Fig. 4 depicts the situation that exists as new technology is developed through cropping systems research in a target area where farmers are financially weak. The gap between farmer's use of technology and that which is available is still too big, even after implementation of production programs. 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. Perhaps with researchers working more closely with farmers, extension workers, 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, economically feasible, and socially acceptable cropping patterns to facilitate farmer adoption. Also by having a better understanding of the capabilities of soils with which we work and by anticipating the minimum or necessary input requirements, we can facilitate the implementation of production programs that are more appropriate for an area. We can reduce the research time required for a specific area. To do this, more emphasis must be placed on obtaining adequate site description, including soil classification, to facilitate the transfer of appropriate technology.

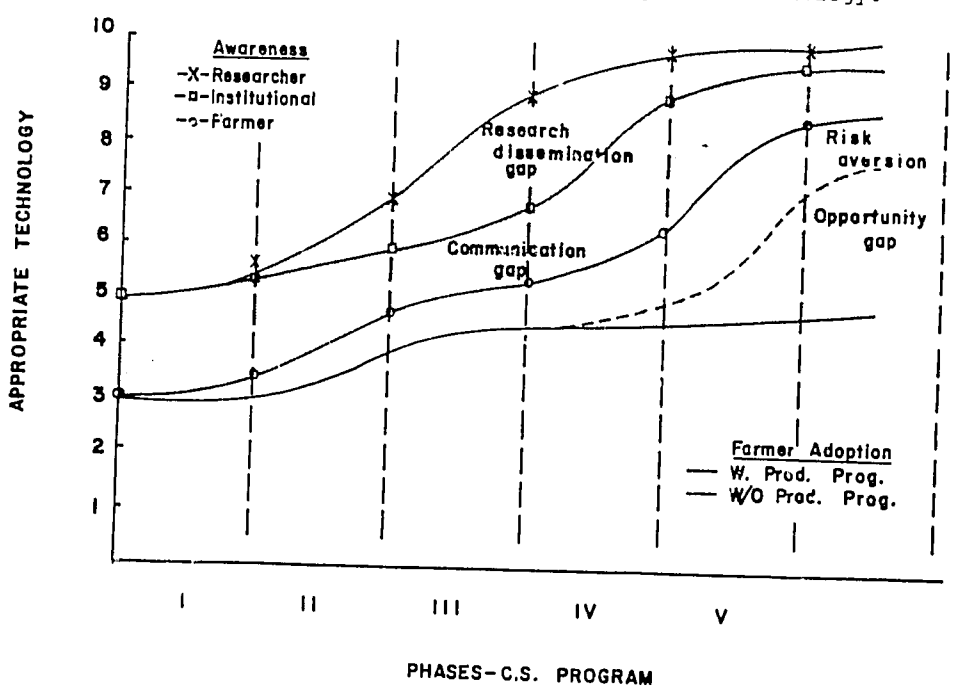

Fig. 4. Research development, dissemenation, and implementation with respect to sequential phases of a cropping systems project in a target area.