JIRCAS Projects for the Development of Technologies for Sustainable Agriculture in Asia

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Abstract

A majority of JIRCAS's on-going projects are being carried out in Asia, accounting for approximately 80 % of the total number. Promotion of agricultural sustainability in harmony with the increase of productivity is the main target of JIRCAS's research collaboration in this region. JIRCAS is carrying out six multidisciplinary research projects in which sustainability of agriculture, forestry and fisheries is a key issue. Among these projects, "Development of sustainable agricultural technology in Northeast Thailand" is a representative program which directly deals with agricultural sustainability in the region. Decrease of soil fertility, soil salinization and lack of animal feed during the dry season are the main problems which are being currently addressed by the researchers of JIRCAS and Thai counterpart institutes. The mechanism of salinization was eventually elucidated based on the analysis of groundwater properties and sugarcane was found to offer a high potential as animal feed during the dry season. Other examples of relevant research projects include "Evaluation and improvement of farming systems combining agriculture, animal husbandry and fisheries in the Mekong Delta" and "Productivity and sustainable utilization of tropical and subtropical brackish water mangrove ecosystems". In the Mekong Delta project, a research team consisting of JIRCAS and Vietnamese counterpart institutions is engaged in studies to improve the traditional farming system referred to as VAC (V : garden, A : pond, C : livestock) which prevails in Vietnam. The brackish water project in Malaysia aims at evaluating the productivity of mangrove ecosystems and identifying the criteria for sustainable utilization, in taking account of the fact that there has been a significant decrease in the area of mangrove forests which display environmental, ecological and socio-economic values.

Introduction

Since TARC was reorganized into JIRCAS in 1993, JIRCAS expanded its targeted areas from the tropics and subtropics to temperate regions such as Central Asia and Eastern Europe. A majority of JIRCAS's on-going projects are, however, being carried out in Southeast Asia, accounting for two-thirds of the total number.

Promotion of agricultural sustainability in harmony with the increase of productivity is the main target of JIRCAS's research collaboration in this region. As of 1996, 13 out of 36 JIRCAS's on-going projects were dealing with agricultural sustainability as the main research subject. Sustainability of agriculture is affected by biological, physical and chemical factors

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such as soil fertility, water availability, cropping systems, and occurrence of diseases and insects, etc. Therefore the implementation of research programs on agricultural sustainability requires a multidisciplinary approach where several researchers in different fields work together. At present, JIRCAS is carrying out six multidisciplinary research projects in which sustainability of agriculture is a key issue (Table 1). Among these projects, three programs implemented in tropical Asia are selected and the current status of the studies and future research needs are described in this paper.

Table 1 Multidisciplinary research projects involved in the sustainability of agriculture, forestry and fisheries implemented by JIRCAS

Title	Site	Year
1 Development of sustainable agricultural technology in Northeast Thailand	Thailand	1995-2002
2 Evaluation and improvement of farming systems combining agriculture, animal husbandry and fisheries in the Mekong Delta	Vietnam	1994-1999
3 Productivity and sustainable utilization of tropical and subtropical brackish water mangrove ecosystems	Malaysia	1995-2000
4 Comprehensive studies on the development of sustainable agro-pastoral systems in the subtropical zone of Brazil	Brazil	1996-2003
5 Development of sustainable production and utilization of major food resources in China	China	1997-2004
6 Comprehensive studies on soybean improvement, production and utilization in South America	MERCOSUR countries	1997-2007

JIRCAS's projects involved in sustainability of agriculture, forestry and fisheries

1 Development of sustainable agricultural technology in Northeast Thailand

1) Background and research subjects

Since the 1960s, a large acreage of forest has been cleared to open up upland fields in Thailand in response to the rapid increase in the population. This is particularly true in the Northeast region, leading to an increased production of upland crops such as kenaf, corn, cassava and sugarcane. Most of these crops have been produced mainly for export, which has largely contributed to the acquisition of foreign currency. The rapid deforestation, however, has led to a reduction of the water-holding capacity and to salt accumulation due to the elevation of the groundwater table. In addition, the deforestation of sloping land has made the land highly vulnerable to soil erosion by wind and rainfall. Recently, flooding and drought have frequently occurred in Northeast Thailand. Soil fertility of the reclaimed fields, which was originally very low, has further deteriorated after several years of cultivation, because of inadequate application of organic materials and fertilizers. Moreover, the dry season lasts for approximately half a year and precipitation is erratic even in the rainy season. These environmental constraints as well as social problems such as outflow of labor force to urban areas have restricted agricultural development in the region.

To address these constraints and problems, JIRCAS initiated in 1995 a 7-year project, "Comprehensive studies on sustainable agricultural technology in Northeast Thailand". This project consists of multidisciplinary studies in the fields of soil, crop and livestock sciences as well as economic and social analyses. Collaborative research activities are currently being carried out at the Agricultural Development Research Center in Northeast Thailand (ADRC) and other Thai research institutes (Kokubun, 1996). Research subjects focused on are as follows:

a) Evaluation of environmental and biological resources in the area and development of more effective uses of these resources,
b) Development of sustainable cropping systems with emphasis placed on soil and water conservation,
c) Improvement of livestock production technologies with locally available feed resources to promote mixed farming systems.

2) Results

Salt-affected soil and groundwater are major constraints on agriculture in Northeast Thailand. The acreage subjected to salinization amounts to 15 % of the whole cultivated area in this region. The salt in the soil and groundwater is considered to be supplied from rock salt strata located at dozens of meters below the soil surface. The mechanism of uplifting of saline groundwater has not been clarified and effective countermeasures to prevent the rise have not been developed. In this project, the relationship between the geological structure and groundwater flow and the physio-chemical characteristics of groundwater were studied on the basis of geophysically prospected and monitored data with use of piezometer nets set up at different depths and at many locations in Khon Kaen Province. The results revealed the existence of several faults in this area and showed that saline groundwater was supplied from some of the faults, and that the flux of upward groundwater increased when the groundwater level decreased below a certain level (Fig. 1), subsequently resulting in the rise of saline groundwater probably through the fault crack.

The role and advantages of alley cropping in sustainable agriculture have been recognized, although quantitative or physiological evidence to support this concept has been very limited (Ong, 1996). This project aims, therefore, at analyzing quantitatively the effects of mixed cultivation of crops and trees on the physiological performance of the crops and on soil fertility and conservation. Based on the preliminary experiments, *Leucaena leucocephala* was selected as an appropriate woody perennial which is expected to prevent soil erosion and enhance soil fertility. *L. leucocephala* is a fast-growing, nitrogen-fixing leguminous tree that can substantially increase soil fertility in 2-3 years (Kang *et al.*, 1990). In this project, several crops including cassava, corn, soybean and mungbean are alley-cropped with *L. leucocephala*, and physiological responses of the crops and nutrient-cycling in this system are currently being evaluated.

The role of animal husbandry is becoming increasingly important due to the strong demand for animal products in Thailand. The northeastern region is a center of meat and milk production in the country. A shortage of available feed in the dry season is a major constraint on the development of animal husbandry in this region. It is necessary to utilize lo-

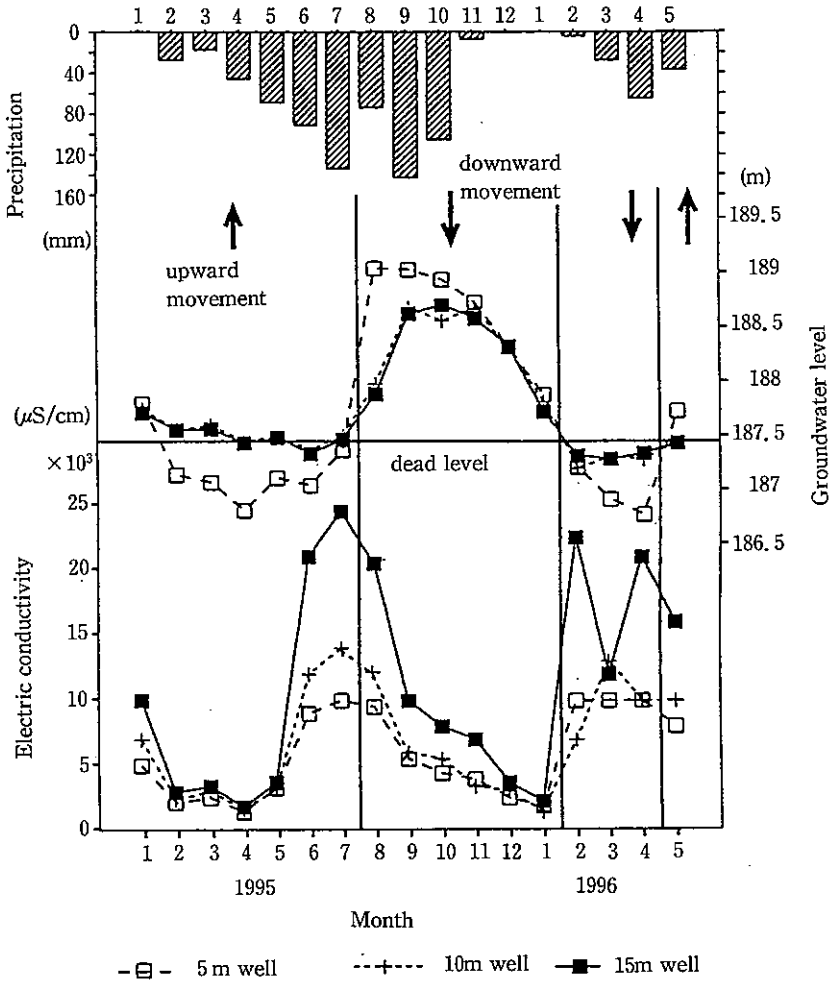

Fig. 1 Fluctuations of monthly precipitation, groundwater level and electric conductivity measured in Khon Kaen Province
Source: M. Imaizumi, unpublished data.

cally available forage resources which have been underexploited as feed. Sugarcane is our targeted feed resource, because it is able to withstand the harsh conditions of the dry season and its potential as feed has been examined in other regions, especially in Caribbean countries. Table 2 presents a comparison of metabolizable energy (ME) and crude protein (CP) content among sugarcane, cassava and ruzi grass per unit area (Kawashima *et al.*, 1996). The data were estimated from the results of experiments on digestibility and the average yield in the statistics in the region. It is clear that sugarcane can produce much more ME than cassava or ruzi grass. When compared with rice straw, which is the major roughage in the region, milk production tended to be higher in the cows which were given sugarcane stalks than those given only rice straw in spite of the lower DM (dry matter) consumption. Currently local farmers are strongly relying on rice straw as a roughage in the dry season. Rice

Table 2 Metabolizable energy and crude protein content of major crops in Northeast Thailand

Crops	Metabolizable energy		Crude protein	
	MJ/kg	MJ/rai	%	kg/rai
Sugarcane	9.1[1)]	27,219[2)]	2.0[1)]	69.4[2)]
Cassava	12.8[3)]	10,886[4)]	3.0[3)]	72.5[4)]
Ruzi grass	8.5	8,500	6.5	65.0

1)Stalk, 2)Stalk + Top, 3)Root, 4)Root + Leaf
Adapted from T. Kawashima (1996).

straw has a low nutritional value and it takes time to collect and carry it from the field. In contrast, sugarcane can be harvested at any time of the dry season and can provide a much higher metabolizable energy than the other kinds of roughages which are locally available. Therefore the use of sugarcane stalk as a feed has a high potential to enhance animal production, especially dairy production in the region.

2 Evaluation and improvement of farming systems combining agriculture, animal husbandry and fisheries in the Mekong Delta (Vietnam)

1) Background and research subjects

The Mekong Delta is an important food-producing area in Vietnam, accounting for approximately 45 % of food and 50 % of rice of the total national production. Recent increase in cereal production in this region has depended on the increase of cropping intensity rather than on the increase of acreage (The Economist Intelligence Unit, 1996). Development of canal networks facilitated irrigation, and enabled to implement rice double cropping. Introduction of high-yielding cultivars and chemical fertilizers has also contributed to the increase of yield.

In this region, a traditional farming system referred to as VAC (V : garden, A : pond, C : livestock) has prevailed. This system is characterized by mutual utilization of resources among components of the system and is considered to be sustainable and environmentally friendly. In order to further develop the farming system, however, many constraints and problems remain to be solved. Salinization, excess or deficit of water, soil acidity and inefficient marketing systems are factors that hinder further development of this farming system. The JIRCAS's project, which is carried out in collaboration with Cuu Long Delta Rice Research Institute (CLRRI) and Can Tho University (CTU), consists of three main subjects (Kobayashi, 1996):

a) Evaluation of ecological and socio-economic aspects of the system,
b) Improvement of component technologies (crop cultivation, pest control, animal husbandry, freshwater aquaculture),
c) Analysis of the conditions under which the system can be applied to other regions.

2) Results

In the Mekong Delta, the differentiation of farmers has developed drastically since the

Table 3 Net income resources of farmers with landholdings of different scale in Trung An Village, Mekong Delta, Vietnam

Income resources	Landless	<1ha	1-2ha	>2ha
		100,000 Dong		
Rice	0	78(65)	120(47)	427(81)
Upland crops	0	12(10)	30(12)	48(9)
Animals	1(100)	22(18)	78(31)	12(2)
Fish	0	8(6)	28(11)	38(7)
Total	1(100)	119(100)	255(100)	524(100)

Average of about 100 farmers. Figures in parentheses indicate % of total.
Adapted from R. Yamazaki, unpublished data.

policy of market-oriented economy was adopted in the late 1980s. A survey conducted by the collaborative team on the socio-economic situation of farmers in the Mekong Delta showed that farmers with small landholdings (less than 2 ha) depend considerably on animal husbandry and/or fisheries while farmers with larger holdings (more than 2 ha) tend to depend further on mono-cropping of rice (Table 3). The profitability in the production of rice was much higher in large-scale mono-cropping than in the combined farming system, which appears to undermine the persistence of the small-scale combined farming system. These findings suggest that the VAC system is losing attraction for big farmers despite the fact that the system has been found to be highly sustainable when properly managed.

Although rice production in Vietnam has increased remarkably due to the development of canal networks and introduction of high-yielding cultivars, there remain several problems threatening the stability and further increase of yield. Particularly, erratic emergence of directly sown seeds and frequent occurrence of lodging during the growth are serious problems which are being addressed in this project. Crossing trial between the local leading cultivars and newly introduced genetic lines with a high emergence ability has produced several promising progenies which display a higher emergence ability than the presently grown cultivars. These bred lines are currently being used in the local breeding programs.

The application of fertilizers is essential to achieve higher yield, but it can cause lodging if the amount and time of application are not appropriate. Determination of the proper time of application and amount of fertilizer during the growth requires a certain expertise. The use of a chlorophyll-meter facilitated the diagnosis of the nitrogen status in the leaf because a high correlation was observed between the values measured by the meter and nitrogen content of leaves (Fig. 2). The yield was significantly correlated with the meter-measured values in the dry season, but not in the wet season. These results and related experiments conducted to determine the appropriate time of fertilizer application indicated that lodging can be minimized by optimizing fertilizer application which can be facilitated by the chlorophyll-meter-assisted diagnosis.

The outbreaks of several insects which had caused serious damage to rice production in the past have become more serious with the increase of the amount of fertilizers applied in this region. At present, many farmers in the Mekong Delta area depend on insecticides to control insects. Excessive or improper use of chemicals is a cause for concern about the

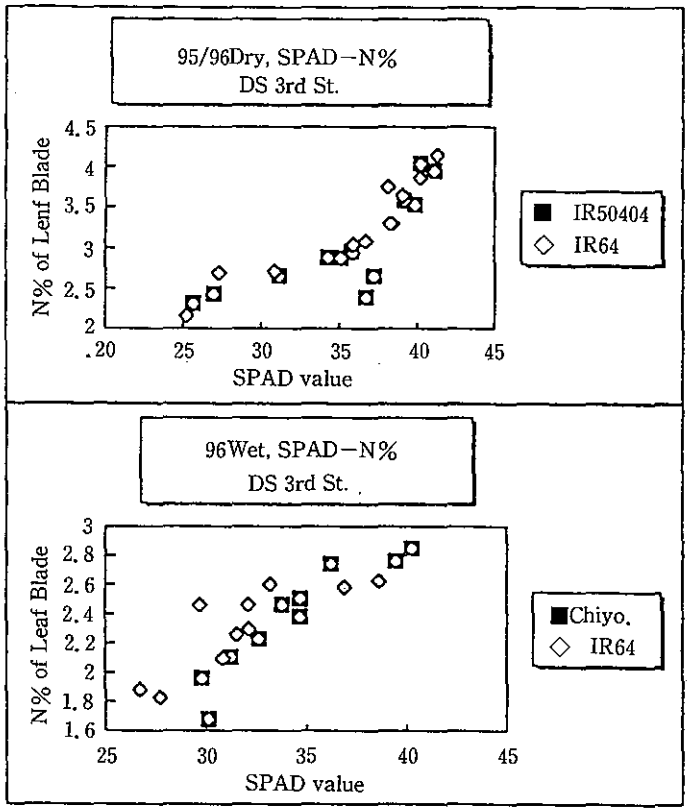

Fig. 2 Relationships between the values measured by chlorophyll meter (SPAD 502) and nitrogen % in the leaves
Source: T. Kon, unpublished data.

adverse effects on human health as well as on the environment. Hence the concept of integrated pest management (IPM) was introduced and efforts to disseminate the concept to farmers are being made as a national project. In this context, the collaborative research team is currently undertaking studies on the identification of germplasm accessions resistant to major insects and diseases, and of natural enemies in the local environment.

In the Mekong Delta, a large number of pigs are raised by farmers. The excreta from the pigs are commonly utilized, directly or after processing by biodigesters, as feed for fish and as nutrients for crops in the farming system. Biodigesters, which are capable of inducing methane fermentation under anaerobic conditions, are being used for fuel production and for sterilization of the excreta. A survey by the research team on the water quality of farmers' ponds revealed that the quality deteriorated when the excreta directly flowed into the ponds, unless the ponds were large enough to process the excreta or the water could be discharged to the connecting paddy fields or river. When the biodigesters were used to process the excreta, the water quality of the ponds improved. Thus biodigesters were found to be indispensable in this VAC system in terms of environmental protection.

3 Productivity and sustainable utilization of tropical and subtropical brackish water mangrove ecosystems (Malaysia)

1) Background and research subjects

Brackish water mangrove forests develop in lagoons and river estuaries of tropical and subtropical regions. The importance of mangroves as habitat, nursery and source of food for both fisheries species and non-commercial fauna is well recognized. However, urbanization, resort development, expansion of farmland and construction of aquaculture ponds have led to the depletion or overexploitation of the mangrove forests and resulted in the loss of the ecological and socio-economic values of the forests. In Malaysia, for example, the area of mangroves decreased by 12 % from 1980 to 1990 (Clough, 1993). It is necessary, therefore, to evaluate the biological productivity and carrying capacity of brackish water mangrove ecosystems, with emphasis placed on sustainable utilization of the mangrove forest. In this context, JIRCAS initiated a collaborative research project in Malaysia in 1995 (Suzuki, 1994). The research subjects of this project include:

1) Evaluation of the biological productivity of mangrove ecosystems,
2) Evaluation of production of aquatic resources in brackish water mangrove areas,
3) Identification of criteria for sustainable utilization of the areas.

The west coast of the Malay Peninsula was selected as the study area due to the presence of different types of mangrove forests. Counterpart organizations include Fisheries Research Institute (FRI), Forest Research Institute Malaysia (FRIM) and University of Malaysia (UM).

2) Results

Wood from mangrove forests has been used traditionally for timber, firewood and charcoal production. The collaborative research team has been carrying out a survey on the vegetation of mangrove forests in Matang, Perak, Malaysia. Several plots were selected and the species growing were identified. In a plot located inside the lagoon, *Avicennia* spp. and *Sonneratia* spp. accounted for more than 90 % of the total number whereas *Bruguiera* spp. and *Rhizophora* spp. were predominant species in another plot set up 180 m apart from the mangrove-fringed river (Table 4). The number and size of the trees also varied with the location. At these locations, litter traps were set up and seasonal changes in the quantity of litter are currently being measured, since leaf litter, fallen branches, dead roots, propagules and organic exudates from mangrove trees provide a rich source of carbon and other nutrients for a wide range of organisms living in mangrove ecosystems (Clough, 1993). In a related survey, the role of macrobenthos in organic decomposition and nutrient regeneration in mangrove ecosystems is being studied. Of particular interest is the role of crabs, especially sesarmid crabs, which appeared to be highly responsible for consumption and cycling of the litter (Kosuge, 1997).

While arguments for the conservation of mangrove forests *versus* fisheries activities are based on the observation that mangroves serve as nursery habitats for fish and other marine invertebrates, it is difficult to quantify the relation between the density of fauna and mangroves. In a preliminary study of this collaborative project, the relation of mangrove forests to the production of aquatic resources was reviewed (Chong, 1996). Significant linear

Table 4 Mangrove species identified in Matang mangrove forest and their number and size

Plot	Species	Number	Height	Diameter
		/0.04ha (%)	m	cm
M32	*Avicennia* spp.	106 (69)	3.8	3.2
	Sonneratia spp.	36 (24)	8.7	11.5
	Rhizophora spp.	11 (7)	4.3	4.6
	Total (Average)	153	5.0	5.3
M46	*Bruguiera* spp.	38 (59)	9.6	9.2
	Rhizophora spp.	26 (41)	19.6	19.3
	Total (Average)	64	13.8	13.3

Source : Ochiai *et al.* (1997).

correlations were derived between offshore prawn catches and the area of mangrove forests in several regions of the world (Fig. 3). Subsequent study on the prawn distribution and production showed that most of the prawn species found in the Matang mangroves had juvenile stages in the mangroves, moving in the offshore direction as they matured (Chong *et al.*, 1997), which suggests the existence of a close relation between prawn and mangroves. In a comparison between a well-managed mangrove area (Matang) and an over-exploited area (Merbok), the catch of *Stolephorus* spp. in the respective brackish water areas was much higher in Matang than in Merbok (Table 5), which also underlines the importance of mangrove forests in fish culture in the brackish water areas. These observations are empirical, however, and scientific data to support the relation are still insufficient. Currently the collaborative research team is investigating the ecological and physiological aspects of the fauna, particularly of commercially important species, in mangrove forests.

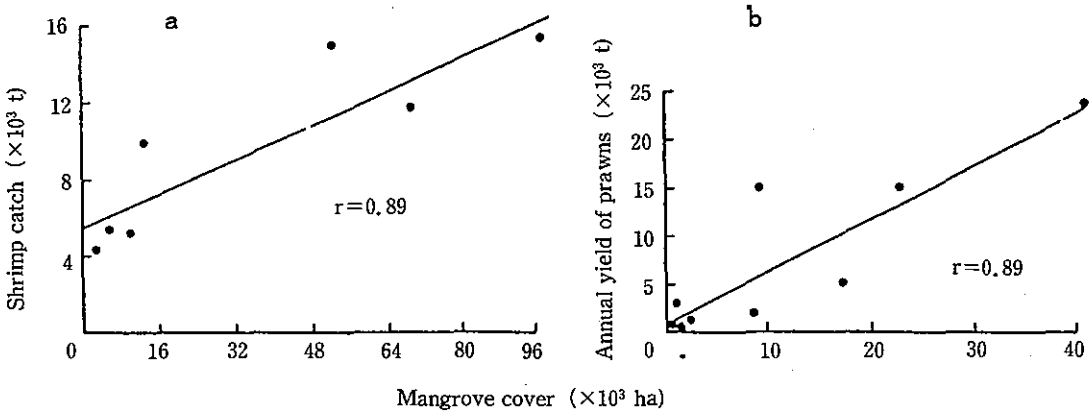

Fig. 3 Relationships between prawn production and mangrove areal extent in two geographical regions; a) Indonesia (from Martosubroto and Naamin, 1997) and b) Peninsular Malaysia (from Sasekumar and Chong, 1987)
Source: V. C. Chong (1996).

Table 5 Estimated daily production of *Stolephorus* spp. in well-managed (Matang) and over-exploited (Merbok) mangrove areas in Malaysia

Site	Density	Biomass	Production
	No./100m^3	mg/100m^3	mg/100m^3
Matang	91	2,688	259
Merbok	60	618	58

Source : Yamashita and Hayase, unpublished data.

Future research needs

Agricultural production has increased in all the major regions of the world over the past few decades, but the growth has been most rapid in Asia. This rapid growth has been derived from both increased acreage of arable land and raised yield per unit area. Land added to agriculture, particularly to crop production has been transformed from forests, marshes and coastal mangroves, as typically seen in Northeast Thailand, Mekong Delta and coastal area of Malaysia, all of which are JIRCAS's research sites. It is anticipated that a similar increase in the acreage will not be duplicated over the next decades for several reasons. Hence, future agricultural growth is expected to originate from yield increase per unit area. Since the 1960 s, by growing improved, high-yielding cultivars and using irrigation, fertilizers and pesticides, crop yields have increased twofold or more. Stabilization and further increases of the yields, however, should be achieved by depending less on these resources due to the need of protecting the environment and limitation of the resources. In this respect, our challenges to breed cultivars with multiple resistance to biotic and abiotic stresses will be more important than ever. To achieve these objectives, biotechnology, as well as conventional methods, will become indispensable tools. In addition, research focused on clarifying the genetic and physiological causes driving the evolution of pests toward adaptation to chemical control and designing strategies for slowing the process should be a high priority. Another priority area is the development of innovative measures to control weeds to reduce the dependence on herbicides, since herbicide increase is significant in rice cultivation where traditional transplanting is giving way to direct sowing and chemical control of weeds.

The implementation of the research programs on agricultural sustainability requires a multidisciplinary approach, since agricultural ecosystems are too complex to be analyzed by a single discipline. In JIRCAS's comprehensive studies, therefore, it is anticipated that the results obtained both at the multidisciplinary and unidisciplinary levels will eventually be integrated. Until now, the main findings in these projects include the clarification of soil salinization mechanism, utilization of sugarcane as animal feed, estimation of ecological and economic roles of mangrove forests, etc. Nevertheless, integration of these individual findings is still incomplete. For integration, socio-economic and cultural aspects of the respective ecosystems should be evaluated along with physical, biochemical and ecological investigations. Only by such multidisciplinary integration, could targeted ecosystems be

understood as a whole and rational management of the ecosystems to ensure ecological and economic sustainability could become possible. Our collaborative research teams are working toward this direction.

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