Workshop on

RESEARCH PRIORITIES IN TIDAL SWAMP RICE

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FOREWORD

The Workshop on Research Priorities in Tidal Swamp Rice, held 22-25 June 1981 in Banjarmasin, South Kalimantan, marked a departure from the international rice research community's usual approach to tidal swamp rice culture. In previous conferences on submergence-prone rice, tidal swamp rice sessions were ancillary to the broader approach to deepwater rice. But increasingly scientists have begun to recognize the tidal swamps as a unique environment, and to consider the rice culture practiced in those areas as important enough to merit a workshop exclusively on tidal swamp rice. The workshop was unique in another way as well. It was the first international scientific conference to be held in South Kalimantan.

The best rice growing areas are, of course, those in which water can be efficiently and economically controlled. And those land resources Lave received the greatest priority in research efforts over the last few decades. But only one of four rice farmers are fortunate enough to live in such favored environments. The other 75% must make do in a diversity of adverse environments.

Farmers in the tidal swamps of Bangladesh, India, Indonesia, Sri Lanka, Thailand, and Vietnam face problems different from those encountered by farmers in more favored environments, among them uncontrolled water regimes, soil acidity, and mineral deficiency. By identifying the problems unique to the tidal swamp areas, the workshop attempted to identify new technologies that, by a concerted research effort, could be generated for the fragile environment of those tidal swamps.

Land is a shrinking resource for agriculture and we must learn to produce more food from lands now considered marginal in production potential. The demands of an ever increasing population make it necessary to increase our capability to produce rice and other food crops on lands such as tidal swamps. The workshop enabled us to review our knowledge of tidal swamp rice, to identify research priorities, and to formulate collaborative programs.

The Agency for Agricultural Research and Development (AARD) of the Government of Indonesia, with whom IRRI cosponsored the workshop, deserves special recognition for undertaking the workshop in an area where logistics were difficult, but the rewards were great.

The workshop organizing committee consisted of B. S. Vergara, chairman, S. K. De Datta, and D. V. Seshu, all of IRRI headquarters; J. R. Cowan, IRRI liaison scientist for Indonesia and Malaysia; B. R. Jackson, IRRI representative for Thailand; and B. H. Siwi, H. Anwarhan, and H. Noorsyamsi, AARD. The workshop papers were edited by W. H. Smith, editor, with the assistance of Gloria S. Argosino, assistant editor.

M. S. Swaminathan
Director General

REPORT OF THE ORGANIZING COMMITTEE

H. NOORSYAMSI

On behalf of the Organizing Committee of the International Workshop on Research Priorities in Tidal Swamp rice, I would like to present a brief report on the Committee's activities. This workshop is cosponsored by the Government of Indonesia Department of Agriculture, and the International Rice Research Institute. On the Indonesian side we have established two committees, 1) the Central Organizing Committee (B. H. Siwi, chairman), and 2) the Local (Banjarmasin) Organizing Committee (H. Noorsyamsi, chairman). On the IRRI side, Dr. B. S. Vergara is the chairman.

The workshop has 91 participants consisting of delegates from 13 countries: the Philippines, Bangladesh, Thailand, India, Sri Lanka, Vietnam, Japan, Ecuador, Netherlands, Germany, England, United States, and Indonesia. From Indonesia there are participants from various Indonesian universities such as IPB, Unpad, Gama, Ulam, Unmul, and Unsri; and from various ministries such as Public Works, Transmigration, Agriculture, and Foreign Affairs. Representative of local governments and of Patra Tani (Palembang Rice Estate) are also here. And there are participants from international institutions such as IRRI and Transmigration Areal Development.

The agenda of the workshop is as follows:

- The opening session takes place at Gedung Dharma Wanita.
- Presentation and discussion of papers will take place at the Maramin Hotel.
- We have scheduled field trips to the tidal swamp areas at Tamban (old transmigration area); field stations of Banjarmasin Research Institute for Food Crops at Belandean, Banjarmasin, and Handilmanarap; and Haji Idak's Farm in Sungai Tabuk.
- Research priorities will be discussed after the technical sessions and field trips. These discussions will result in written recommendations on research priorities in tidal swamp rice — the reason for our meeting in Banjarmasin.

Outside the formal sessions, workshop participants will be dinner guests of the Governor of South Kalimantan; the Agency for Agricultural Research and Development, including the South Kalimantan representative of the Ministry of Agriculture; and the Mayor of Banjarmasin.

We, the members of the Organizing Committee, wish to express our sincere appreciation to all those who have contributed to make this workshop successful.

Chairman, Banjarmasin Organizing Committee, and agronomist, Banjarmasin Research Institute for Food Crops, Banjarmasin, South Kalimantan, Indonesia.

WELCOME ADDRESS

M. TJOKROKUSUMO

Today I am very pleased to be here with you, scientists from various rice producing countries, to participate in this first International Workshop on Research Priorities in Tidal Swamp Rice. On behalf of the South Kalimantan and Indonesian Government, permit me to welcome you to Banjarmasin. It is an honor for us that you have selected Banjarmasin to be the place of this international workshop. We have tried our best to provide you with facilities in which you can discuss all problems on tidal swamp rice.

I am very happy to meet you, scientists who come to this country to share experiences and information, and to exchange ideas on research in tidal swamp rice. It seems that tidal swamp areas are a problem not only for Indonesia but for your countries as well. The problems of tidal swamp areas are universal and should be solved immediately.

Various problems faced by farmers in tidal swamp areas include uncontrolled water regimes, soil acidity, and other factors that constrain farming systems. Solving these problems to increase the productivity of tidal swamp areas will, in Indonesia, support the transmigration program in those areas. Such problems are not found in areas with good irrigation systems. I am convinced that, by identifying problems in tidal areas, this workshop will also identify new technology that can be generated through research.

New research findings and the exchange of that information among scientists from different countries will help farmers in tidal areas. Nowadays, millions of people in Asia, Africa, and Latin America use tidal areas to produce their food. In Indonesia, tidal swamp areas cover about 10 million ha in Kalimantan, Sumatra, and Irian Jaya. In South Kalimantan, 800,000 ha of swampy lands have agricultural potential. Two hundred thousand hectares are suitable for growing tidal swamp rice. These areas have been used traditionally since 1936. At present, around 1 10,000 ha are cropped with rice once a year. Therefore, farmers in South Kalimantan have the experience to manage tidal swamp rice in particular, and swampy land in general. That is one of the reasons why the Indonesian Government proposed Banjarmasin as the site of this international workshop. The hope is that we can learn, compare, and exchange information on tidal areas through discussions and field trips.

Through the discussions and field trips we hope that you scientists can help the

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Governor, South Kalimantan Province, Republic of Indonesia.

farmers, whose knowledge and resources are limited, solve their problems. I wish to take this opportunity to ask scientists and researchers to improve collaborative studies, and exchange knowledge and information on new technology in agriculture. Moreover, I ask the government officials and communities to give their support to ensure the success of this workshop.

We thank the International Rice Research Institute far cosponsoring this workshop with the Government of Indonesia. Once again, we welcome all participants to Bhumi Lambung Mangkurat and wish you good luck. We hope that this workshop will be fruitful for all of us.

Thank you for your attention. I now declare this International Workshop on Research Priorities in Tidal Swamp Rice officially open.

KEYNOTE ADDRESS

S. HADISAPOETRO

It is a privilege for me to welcome you to my country. I was pleased to learn that there are representatives here from many rice-growing countries around the world, including South America. It is reassuring to know that there is an interest in more efficient use of the tidal swamp natural resource by so many different countries. This workshop provides us all with an opportunity to share our experiences. It is practically an impossible task to physically control the water in tidal swamps. The cost of constructing dams, leveling land, and building drainage channels in these flooded areas is beyond the scope of practical implementation. We must be realistic. We must seek ways to grow rice and other food crops under the existing conditions with practical and economical modifications.

It appears only appropriate at this stage for me to express my thanks and appreciation to the Governor of this Province of South Kalimantan and his staff. They have rendered valuable assistance in the preparation and organization of this important workshop. The arrangements made by the Indonesian Organizing Committee and the IRRI Program Committee will contribute greatly to the smoothness of the workshop's deliberations in the next four days.

We believe the way to progress is through cooperation, not only among our scientists but within the international community as well. In my judgment, this meeting is a good example of such an activity. I trust good results will be forthcoming. We have millions of hectares of swampy lands in Indonesia. One only needs to look at a topographical map to be impressed by the high percentage of this country's landmass that is swampy. We have, however, reclaimed almost 500,000 ha of tidal swamplands for agricultural purposes. Before 1970, less than 150,000 ha were under cultivation.

Environmentalists and ecologists would strongly recommend that such a fragile environment not be disturbed. Of course, if such a philosophy were pursued to its limit, we would have little or no agriculture today. There are areas in Asia and Europe that have been successfully farmed for thousands of years. We can manage our agricultural land resources. They can be maintained and continue to be productive for thousands of years more. They do require wise management. The nature of tidal marshes is such that careful attention must be given to their reclamation and development. Your workshop here will enable us to focus greater attention on the potential that this natural resource offers – and the constraints

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Minister of Agriculture, Republic of Indonesia.

that must be considered so that it is retained as a food production natural resource for generations to come.

There is water management, with all of its complexities. There is soil fertility with minor elements, deficiencies, and toxicities to be considered. Then there is economics and all that makes up development technology. We could become so confused and negative that we might raise the ecologist's question about the swampy environment. Should we even disturb it? Now, I think — at least I sincerely hope — we recognize that we must not lose our perspective of the real world. In Indonesia, as in most of the countries from which you come, rice is a staple food. For centuries — quite likely back to prehistoric times — rice has been grown along the river banks on lands that today we classify as tidal swamps. You know better than I that those regions in which water can be efficiently and economically controlled are the best rice growing areas. Hence, we have given such land resources the greatest priority in our research and development programs in the last few decades. Now we find it paramount to rapidly increase our capability to produce rice and other food crops on land areas such as the tidal swamps.

Thanks to favorable weather, increased use of fertilizer, relatively low incidence of pests and diseases, the expanded application of a new method of intensification (INSUS) and, of course, sound research, Indonesian rice production in 1980 was more than 10% higher than in 1979. Total 1980 production was some 20 million tons of milled rice. We are also increasing our production of other food crops: maize, cassava, and sweet potato. Despite these encouraging results, which over the last 15 years have given us a steady increase in production, we must plan for continually expanded production to meet future needs.

It is difficult to get an exact inventory of the total area of tidal swamp we have. During your deliberations here, Indonesian scientists among you can give you more precise information on the nature of our swampy lands than I can. I would, however, like to reflect in general on the immensity of this particular problem as we look at it in Indonesia. There are people who need food. There are possibilities for producing food in our tidal marshes. Here in South Kalimantan, pioneers who settled in these tidal marshes have been very successful. There are many transmigration projects, and you will have an opportunity to visit some of them. They demonstrate that through wise and careful husbandry, food crop production from this natural resource can be quite remarkable. Thus, there are areas that *can be developed and used economically.* There are areas of the tidal marshes that *should be left undisturbed.* We can learn much from those farmers who have been successful. Well planned research, however, will be the cornerstone of our success in utilizing the tidal swamps. It will take careful planning and wise execution. This, I know, is the reason for which you have come. I must not dwell further on this particular aspect. But I do challenge you to develop some significant recommendations. Crop extensification and the role of cropping systems in the development of this land resource are basic. I trust it will be the fabric of your discussions.

I wish to thank the International Rice Research Institute for joining with us in sponsoring this meeting. We have enjoyed cooperating with IRRI for many years. We are pleased and honored that our Head of the Agency for Agricultural

Research and Development, Mr. Sadikin, is currently a member of IRRI’s Board of Trustees. Before him, two more of our leading agricultural scientists and administrators were IRRI trustees.

Now in conclusion, if I may, I would like to acknowledge and express my appreciation to our CRIFC scientists here in Banjarmasin for undertaking the tremendous task of being your hosts. Sponsoring an international workshop is a major undertaking at best. In Jakarta it can be quite easily done. Here in Banjarmasin there are many logistics which I am sure have taxed the ingenuity of my colleagues. Regardless of that fact, I know you will be well looked after during the coming week. I wish you well in your deliberations.

RESPONSE

N. C. BRADY

The opportunity to say a few words at the opening session of this workshop is sincerely appreciated. The tidal swamp rice area is substantial; moreover, a significant number of people have only this type of rice culture to depend upon. Thus the workshop was organized to "review the knowledge on tidal swamp rice to identify research priorities and to formulate the collaborative actions necessary to facilitate development in these areas." We are very thankful to the Ministry of Agriculture, Government of Indonesia, through the Agency for Agricultural Research and Development, for readily accepting cosponsorship of the workshop on tidal swamp rice and for agreeing to have it held in Indonesia, more specifically in South Kalimantan. It is my understanding that the tidal swamp type of rice culture (sawah pasang surut) is the most extensive culture used in Kalimantan.

In terms ofresource allocation the improvement of rice in the tidal swamp areas has been receiving relatively little attention, although national programs such as those in Bangladesh, India, Indonesia, Sri Lanka, Thailand, and Vietnam devote part of their efforts for the improvement of yields to this type of rice area.

The kinds of production problems encountered in tidal swamp rice areas are admittedly more complicated than those faced by rice farmers in the more favorable rice-growing regions. This is all the more reason tidal swamp rice should receive the attention and the team effort of rice scientists of different disciplines. I am confident that the accumulated knowledge and the experiences of the eminent scientists gathered here will provide us with an updated picture of the situation in tidal swamp rice — the gains thus far made, the numerous problems waiting to be solved, and, more important in many respects, the collaborative research that must be planned together and then carried out to produce the technology toward the betterment of the farmers in the tidal swamp areas. I do want to make a special appeal to all of you to actively participate in the development of plans for collaborative research and its implementation. We are certain that results derived from these collaborative efforts will have far-reaching effects and will shorten the time it will take to offer viable solutions to the production problems of tidal swamp rice. The workshop proceedings will certainly be of great use to scientists and administrators alike.

It is my misfortune that I cannot be with you to listen to and participate in your

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Director general, International Rice Research Institute, P. O. Box 933, Manila, Philippines (presented by S. K. De Datta, agronomist, on behalf of N. C. Brady).

deliberations. However, I assure you that IRRI is giving full support to this workshop, and will actively play its role in the implementation of the mutually agreed upon collaborative research.

We are fully cognizant of the time and the effort required to plan, organize, and run a workshop such as you are having now. While the IRRI staff in Los Baños did put in their share of time and talent, I do want to give special recognition to the individuals in the battlefront: Dr. Bernard Siwi, Dr. Hans Anwarhan, Dr. Hadji Noorsyamsi, and Dr. Ritchie Cowan.

I wish you success in your workshop, and may you have a pleasant and worthwhile stay in Kalimantan.

TIDAL SWAMPS: AN OVERVIEW OF THE PROBLEM

B. H. SIWI and H. M. BEACHELL

This international tidal swamp rice workshop is the first to specifically address food crop production research for tidal swampland development. At previous deepwater rice workshops, it became evident that tidal swamps, because of their complex soil, water, and plant relations, could be the focus of a workshop in themselves. The papers to be presented show that this judgment was correct. Many problems confront us as we attempt to utilize tidal swamps for agricultural production. But through integrated international research, we are certain that significant gains can be made. Fifteen representatives from eight countries will present papers concerning various aspects of tidal swamp soils, hydrology, crop management, varietal development, and socioeconomics.

Millions of hectares of coastal areas in many countries are classed as tidal swamplands. In Indonesia alone there are at least 10 million ha located mainly in Sumatra and Kalimantan. The Government of Indonesia has designated 5-7 million ha for agricultural development. The balance has been set aside for forests and fish. Indonesia has reclaimed some 250,000 ha of tidal lands for agricultural use. Development in other countries would no doubt be on a similar scale. An important reason for the slow development of tidal areas is the lack of knowledge of how to economically manage the highly complex soils and hydrology.

Additional land for food crop production will be required to produce food for the ever-increasing world population. In Indonesia, and perhaps elsewhere, the tidal lands are an important land resource. They are marginal in the sense that reclamation costs are high, crop yields are low, and soil and water management are difficult and not well understood.

In Indonesia, tidal lands have been cropped to rice for many years by enterprising settlers who reclaimed land to produce crops for their subsistence. They carried out these operations with little technical knowledge of the soils and hydrology of the swamps. Yet these pioneering farmers had a keen sense of how to select soil types based on the natural vegetation that was supported. They provided us with a reservoir of practical knowledge that can be utilized today.

Some tidal lands have been under cultivation for many years. Rice and a range of upland food crops as well as coconut, coffee, citrus, and clove are grown. Because

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Director, Sukamandi Research Institute for Food Crops (SURIF), and coordinator, National Rice Research Program, Sukamandi, West Java, Indonesia; and plant breeder, CRIFC-IRRI Program, Bogor, Indonesia.

most of the tidal lands are still to be developed, we can profit from the successes and failures of the early settlers. We will see on our field tour that in some areas the tidal swamp soils are being successfully managed in integrated farming systems. The sorjan system of growing upland crops on raised beds and rice in the furrows is successfully leaching toxic substances from the soil.

We will see areas where integrated farming systems are not economically feasible because farm labor is in short supply and crop yields are low.

The system of two rice crops per year in areas where only one rice crop had formerly been grown is being tried. Can legumes or other dryland crops be fitted into rotation systems where early-maturing, photoperiod-insensitive rice varieties are being grown? We think they can.

Crop management offers many challenges. For example, what can be done in rice production with early-maturing, problem soil-tolerant varieties with high yield potential? How can we utilize late transplanting (40- to 60-day-old seedlings) of early-maturing rice varieties to reduce field time so that another rice crop — or even an upland crop — can be grown after rice?

The complex hydrology of the tidal swamps requires further research for economically feasible water control systems that provide improved water quality and adequate drainage and flooding. Soil, water, and crop management studies must be highly integrated. General soil and hydrology surveys are essential before reclamation is started. This has been done in Indonesia. Site-specific soil hydrology and socioeconomic information will be required before we can project the types of farming systems for different sites. Our tropical tidal swamp environments are fragile and highly complex. They will require precise management so that the soils can be utilized through the years.

The soils present many problems, but evidence from lands now in production shows that many of these problem soils can be made productive. There is much information on management of peat soils in temperate regions, but not all of it will apply to the more complex problems existing under tropical environments.

The peat and acid sulfate soils that cover much of the tidal areas are difficult to manage. They require well-organized research programs to improve soil management and crop response.

The rice varieties grown in the tidal swamps are for the most part traditional photoperiod-sensitive varieties requiring more than 200 days from seeding to maturity. The high yielding, wetland irrigated varieties are not adapted to the soils and hydrology of the tidal swamps. One of the important questions before us today is whether site-specific improved plant varieties can be developed to substantially increase per hectare per year returns.

A technology package that takes into account land pieparation, soil amendments, water, cropping systems, and socioeconomic factors must be considered.

A realistic approach to the many problems must be maintained. It can be accomplished only when all phases of research are coordinated to the highest degree.

The purpose of this workshop is to review current research and set priorities for research required on soils, hydrology, agronomy, pest and disease control, varietal improvement, and socioeconomics. Many countries working on common problems will automatically provide more varied testing conditions that will bring solutions to light more rapidly. On-farm research is essential. Satellite stations on farms with a wide range of soil and water regimes that international collaboration would provide are important. In many instances it is impossible to simulate the necessary range of field conditions in the laboratory, or under the limiting land conditions of experiment stations. International collaboration should play an important role in the advance of tidal swamp research.

We must keep in mind that well-organize. and managed research must continue to be the main role of research scientists. If we are to solve farm problems, dynamic research programs must be developed. But we must resist the temptation to engage in extension trials to bring about faster results for farmers who need production information. That course will only delay the ultimate solution to most problems. Close cooperation between research and extension, however, will provide the correct balance.

The tidal swamp farmer has benefited little from modern agricultural research. He grows traditional varieties of rice and other crops in traditional ways. His main concern will be increasing the productivity of his land. The increments of improvement will be small — and difficult to achieve. But through research we can assure that even small increments will be forthcoming, and the farmer will reap the benefits of tidal swamp research.

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1. The Tidal Swamp Workshop was officially opened by the Hon. M. Tjokrokusomo, Governor of South Kalimantan (right). Here he visits with Rusli Hakim (left) and J. Ritchie Cowan.

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2. The Hon. S. Hadisapoetro, Minister of Agriculture, Government of Indonesia, greets workshop participants after presenting the keynote address.

3. H. Noorsyamsi (extreme right), Chairman of the Local Organizing Committee, greet workshop participants at the Miramin Hotel in Banjarmasin. From left are Subiyanto, Loy Crowder, Greta Watson, S. Sumantri, Hank Beachell, and Noorsyamsi.

4. Loyd Johnson, Ben S. Vergara, and Derk HilleRis-Lambers visit with Ahlam B. Razif, Minister of Foreign Affairs, Government of Indonesia, during a break between technical sessions.

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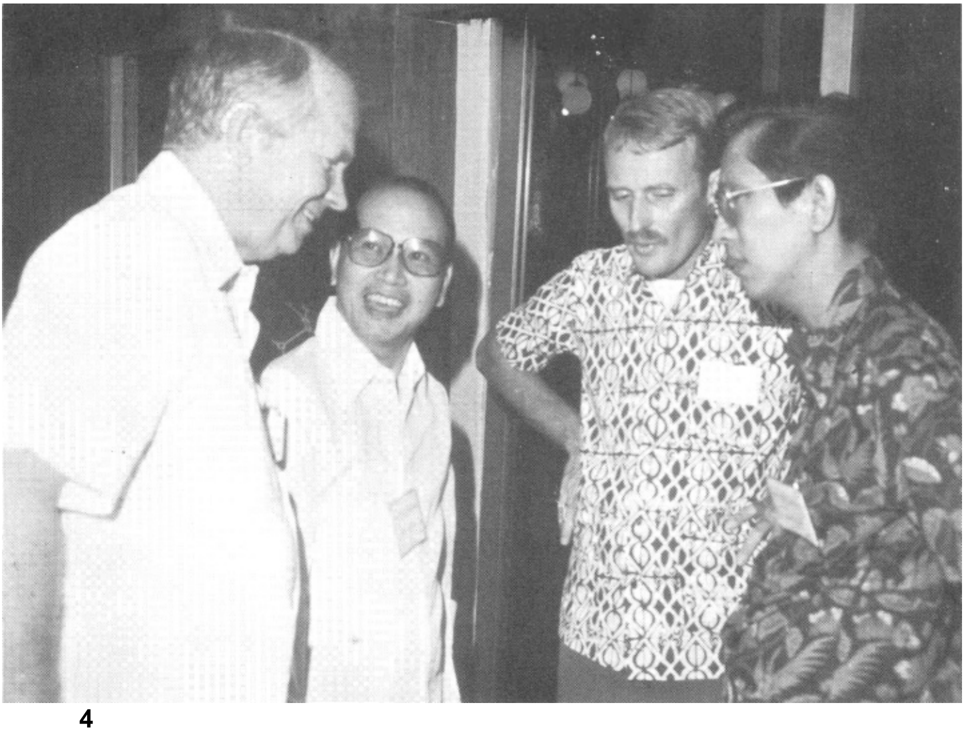

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5. Discussion group on the agronomy of tidal swamps, one of the concurrent planning sessions that made recommendations for future action.

6. Participants observe the effects of macroelements and microelements on the growth of rice in minus-1 pot experiments at Banjarmasin Experimental Farm.

7. At the Belandean Experimental Farm, participants were shown experiments on varietal improvement and soil amendments.

8

8. Hadji Odak (extreme left), a prominent Kalimantan farmer, was host to workshop participants, who viewed advanced yield trials of promising lines and varieties for tidal swamps.

9. Soil properties on the Handilmanarap Experimental Farm absorb the attention of P. Driessen, Robert Brinkman, and Somsri Arunin.

10. Hans Anwarhan, Chief, Banjarmasin Experimental Farm, takes to the field with workshop participants. From left are S. K. De Datta, Brian Carew, Anwarhan, Derk HilleRisLambers, and B. H. Siwi.

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11. At Handilmanarap, varietal improvement and cultural practices were the main focus of experiments. From left are H. Noorsyamsi, H. Ikehashi, Suryatna Effendi.

Tidal Swamp Rice Culture

RICE CULTIVATION IN THE TIDAL SWAMPS OF KALIMANTAN

H. NOORSYAMSI, H. ANWARHAN, S. SOELAIMAN,
and H. M. BEACHELL

Indonesia has about 10 m ha of tidal swamp land with agricultural potential but only 250,000 ha are under cultivation (1 35,000 ha to rice). Tidal lands include swampy areas directly and indirectly influenced by sea tide, low-lying freshwater swamps, and highland rainfed swamps unaffected by sea tides. Soils include fluvial deposits, marine sediments, organic and aeolian soils, acid sulfate and acid sulfate potential soils overlain by 0.5 to more than 1 m peat widespread. Temperatures are moderate throughout the year and the climate is tropical with 7-9 months of more than 100 mm rainfall (1600-2900 mm annually). Rice production constraints are low yields, stem borers and rats, severe labor shortages, and inadequate transport. Farmers grow one rice crop a year using photoperiod-sensitive varieties of 9-10 month duration. They also grow fruit trees, industrial crops, vegetables, Palawija (food crops) and fish. Management practices under study involve monoculture, intercropping, minimum tillage, the sorjan system, and early maturing rice varieties.

Self-sufficiency in food production is a main target of the Government of Indonesia (GOI). It is vital to the economic stability of the nation, which is faced with a population increase of 2.3% annually.

Indonesia is fortunate to have vast arable lands, especially outside of Java, that can be developed for food crop production. Vast areas of tidal swamps have tremendous potential for agriculture. Of the estimated 10 million hectares of tidal swampland in Indonesia suitable for agriculture, more than 2 million hectares are in Kalimantan. No more than 250,000 ha are presently under cultivation and not all are under stable farming systems (Collier 1980). Rice is grown on about 135,000 ha of tidal swamps in South Kalimantan.

The average yields are about 1.0 t rough rice/ha on newly reclaimed land, and up to 2.5 t/ha on long-established lands. The annual rough rice production of the cultivated area is roughly 500,000 t.

The water depths in the tidal swamps are influenced by the tide and rainfall. The water levels of areas near the rivers are under strong and direct tidal influence.

Agronomists and assistant plant breeder, Banjarmasin Research Institute for Food Crops (BARIF) Banjarmasin, Indonesia; and plant breeder, CRIFC-IRRI Cooperative Program, Bogor, Indonesia.

The areas under direct influence may extend up to 7 km from the rivers. Day-to-day tidal fluctuations at given sites depend on where they are located along the river and on the amount of rainfall. Maximum and minimum daily tide levels in the rivers may vary as much as 2.5 m during the spring.

By adapting cultivation schemes to existing hydrological conditions, local farmers grow one rice crop a year using photoperiod-sensitive varieties known as Bayar varieties (9-10 months). These varieties are well adapted to swampy conditions, produce numerous tillers, tolerate a rather high water level, and have good eating quality. They are sown in October or November (the start of wet season) and transplanted up to 3 times at intervals of 40 to 50 days. Final transplanting is in April, harvest is in August-September (dry season).

CLIMATE

Rainfall

The rainy season starts in October. Water levels rise as the rainy season progresses, reaching maximum depths in January-February. They decline somewhat in March-April, remain static until June, and then decline again in July, August, and September (dry season). The swamps have a wet tropical climate with 7-9 months of more than 100 mm rainfall/month. The annual rainfall is between 1,600 and 2,900 mm, with 83-160 rainy days (Table 1). The swamps are generally flooded during the wet season.

Temperature

The tropical climate of Kalimantan is characterized by rather uniform air temperatures throughout the year. Seasonal variations are never great enough to restrict plant growth. At Syamsuddinnoor Airport (close to Banjarmasin), the average annual temperature is 26.8°C, the average annual maximum is 32°C, and the average annual minimum 23.3°C. Temperatures (31°C) in February begin to rise and reach a maximum (33°C) in September. Minimum temperatures (22.1°C) occur in September coinciding with the driest month (Table 2).

CLASSIFICATION OF TIDAL SWAMPS

The tidal swamps are divided into four types based on the prevailing water levels in fields from tidal influence and from rainfall:

- Type A swamps are directly affected by sea tides and floods during both the spring and neap tides. Water depths fluctuate as much as 2.5 m within 24 hours near the rivers during the spring tide.
- Type B swamps are directly influenced by the sea tides, but flooded only during the spring tide.
- Type C swamps are not directly influenced by the sea tide and not flooded by either the spring or neap tides. Tides indirectly affect them by water infiltration through the soil. Water levels are affected more by rainfall than by tide.
- Type D is highland areas in the tidal swamps that are unaffected by sea tides.

Table 1. Mean monthly rainfall distribution and rain days at 6 sites in South Kalimantan, Indonesia.[a]

Observation period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
						Marabahan							
1967·72	1) 186.0	266.2	164.5	179.2	117.2	72.6	51.2	101.3	93.2	117.8	78.4	192.0	1,619.6
	2) 9.2	10.0	8.0	8.0	8.0	5.2	4.0	8.3	5.5	6.6	4.4	9.3	83.1
						Negara							
1960-69	1) 318.1	319.1	296.7	223.1	169.1	90.7	79.4	51.4	61.7	129.8	114.5	288.8	2,142.4
	2) 13.8	13.0	13.0	10.8	9.6	6.5	5.4	4.9	4.3	7.0	7.8	12.6	108.7
						Kuala Kapuas							
1960-64	1) 336.8	356.2	316.4	225.8	226.2	117.2	54.2	175.8	140.2	90.0	233.8	294.4	2,567.0
	2) 12.4	13.8	11.6	9.6	8.6	6.0	4.7	3.2	5.0	4.6	11.4	10.2	101.1
						Purwosari							
1960-69	1) 409.8	327.7	255.0	233.3	217.0	91.2	82.2	44.9	43.7	74.4	218.7	293.1	2,291.0
	2) 11.1	9.4	11.3	9.2	6.9	4.5	4.0	3.1	2.3	3.9	8.4	10.9	85.2
						Syamsuddinnoor Airport							
1960-69	1) 391.5	322.8	297.5	191.7	175.9	123.5	197.5	65.5	83.7	113.5	245.9	298.0	2,508.0
	2) 20.4	18.5	20.0	13.9	13.7	10.8	9.3	7.6	6.8	10.9	17.3	19.8	169.0
						Banjarmasin							
1960-64	1) 31 1.5	621.0	413.0	139.0	230.6	128.0	168.0	93.5	98.0	128.0	335.5	274.0	2,940.1
	2) 18.5	17.5	16.3	10.6	12.0	7.0	12.0	8.5	9.6	9.5	20.5	18.0	160.0

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[a] 1) = precipitation (mm); 2) = rain days (no.).

Table 2. Maximum, minimum, and mean monthly temperature at Syamsuddinnoor Airport, South Kalimantan, Indonesia, 1956-69.[a]

Month	Temperature (°C)			Month	Temperature (°C)		
	Maximum	Minimum	Mean		Maximum	Minimum	Mean
Jan	30.6	23.6	26.3	Jul	32.3	22.5	26.6
Feb	30.9	23.9	26.3	Aug	32.8	22.1	26.7
Mar	31.0	23.5	26.4	Sep	33.5	22.1	27.1
Apr	32.5	24.2	27.3	Oct	32.8	23.4	27.1
May	32.6	24.1	27.3	Nov	31.9	24.0	26.9
Jun	31.9	26.7	26.6	Dec	30.8	23.8	26.6

[a] Mean annual maximum: 32.0°C. Mean annual minimum: 23.3°C. Annual mean: 26.8°C.

There is no water infiltration through the soil.

Type A and B swamps are called direct tidal swamps; Type C, indirect tidal swamps; and Type D, rainfed tidal swamps.

SOILS

The tidal swamps of Kalimantan are a marine plain (a geosynclinal coastal bay partly filled with sediments from the hinterland). There are four major soil groups: 1) soils on fluvial deposits, 2) soils developed on marine sediments, 3) organic soils, and 4) aeolian soils (Soils Research Institute 1972).

Fluvial deposits

Barito and Kapuas soils on fluvial deposits are found along the levees of the rivers. The profiles are generally deep and greyish or brownish. They are clayey with pH around 5.5, are covered with a peat layer, have grey to dark grey surface soil and dark grey subsoil. The organic matter content is high, P_2O_5 ranges from very low to moderately high, K_2O is low and sulfate content is extremely high. The pyrites range from 0 to 12% and the mineral reserve is low.

Soils developed on marine sediment

Potential acid sulfate soils. Soils near rivers where tidal movement is still significant and natural drainage is fair are potential acid sulfate soils. Soil aeration proceeds gradually, resulting in slow oxidation of the pyrites. They have a clayey texture with pH ranging from 4.5 to 5.5, are peat covered, and have a black to greyish brown surface layer, and dark grey (5 Y 5/1) to greyish brown (2.5 Y 5/2) subsoil. The organic matter content and P_2O_5 are high to very high in the surface layer. Phosphate content is low in the subsoil, K_2O is moderate, and the sulfate content is extremely high. The pyrite content ranges from 0 to 12% and the mineral reserve is low.

Acid sulfate soils. Acid sulfate soils are in the rain-dependent areas where tidal movement is no longer noticeable. Stagnant and very acid marshes occur. The acid formed is not entirely carried off during the wet season because of poor natural drainage. These soils have a clayey texture, a very dark grey (10 YR 3/1) surface layer and dark grey (5 Y 5/1) (10 YR 4/1) to dark greyish brown (10 YR 4/2) anaerobic subsoil. The organic matter content is high, P_2O_5 is low to moderately high in the surface layer and low to very low in the subsoil, K_2O is low to very low, and the sulfate content is extremely high. The pyrite content ranges from 0 to 12%. Exchangeable Ca in the surface layer is very low; more than 70% of the total exchangeable cations consist of magnesium and sodium. Mineral reserves are low.

Organic soils

Freshwater marshes in the lowest part of the tidal region are entirely rain dependent. Primary marsh forests occur on thick layers of mesotrophic, hemic, and sapric peat. The peat layer is from 0.5 to more than 1.0 m thick.

FARMING SYSTEMS AND CULTURAL PRACTICES

Farming methods

Farmers usually grow rice in the tidal swamp areas, but they can also grow fruit trees, industrial crops, vegetables, palawija (secondary food crops), and fish. Crops best suited to different soil types are being studied. The management practices under study for each crop include monoculture, intercropping or relay-cropping with emphasis on minimum tillage, and sorjan system. In cropping systems experiments using the sorjan system, two crops of rice are grown in the furrows and maize - cassava - coconut or maize - cassava - coffee are grown as intercrops on the ridges. Clove may be substituted for coconut or coffee.

With early-maturing rice varieties, two rice crops per year can be grown. The first crop may be an early-maturing variety, the second a traditional variety, or both crops may be early-maturing varieties. The method is not widely used because of labor shortages, lack of suitable early-maturing varieties, and insufficient knowledge of land management practices.

Methods of raising seedlings

Dry bed nursery. Rice culture in the tidal swamp starts with dry-seeded seedbed nurseries at the beginning of the rainy season (October-November). This dry-bed method, called taradakan, is the most widely used method ofraising seedlings. The steps are different from those for ordinary seedbed preparation. After the soil is cleaned and pulverized, 50 pregerminated seeds are placed in holes 15 cm apart and a few centimeters below the soil surface with a dibble stick. Five kilograms of seed is sufficient to plant a 150-m^2 seedbed that, after 2 transplantings, will plant 1 ha.

Raft nursery. If the taradakan fails because of heavy rains or rat damage and time does not permit reseeding, a Kalimantan version of the dapog nursery used in the Philippines is practiced. Rafts made of banana trunks are covered with mud 5 to 10 cm thick and placed on structures or floated in the river. A thick layer of pregerminated seeds is sown on the mud (1 kg seeds/2 m^2) and lightly covered.

Five kilograms of seed sown on a 10-m^2 seedbed usually provides enough seedlings, after 2 transplantings, for 1 ha of land. Seedlings in the raft nursery (palaian) grow faster, but are generally weaker than the taradakan seedlings. Raft nurseries are emergency nurseries.

First transplanting. Taradakan seedlings are kept on the seedbed for 40 days, palaian seedlings for 15 days. Seedlings are then transplanted in the lowest parts of the field that have been inundated. Seedlings transplanted for the first time are called ampakan. The first transplanting strengthens the seedlings and promotes tillering.

Second transplanting. Ampakan seedlings remain in the field for about 40 days. During this period land is prepared for the second transplanting. Rainfall is at its heaviest and the land where they will be transplanted the second time is fully inundated. The only land preparation for the second transplanting is to cut the vegetation, which is allowed to decompose in the water. Later it is applied to the land as green manure. One third of the total land area to be planted is prepared in strips. The ampakan seedlings are usually transplanted the second time in January. Seedlings transplanted for the second time are called lacakan. They are spaced 50 cm apart, 3-4 seedlings/hill. The lacakan seedlings cannot be planted until they develop vigorous tillers and have developed to where they can grow satisfactorily in the water level in the main field. The number of days the lacakan seedlings remain in the field depends on the number required for final transplanting and the water depth in the main field. Lacakan seedlings should be 55 to 60 days old for best performance (Noorsyamsi and Hidayat 1969a).

Land preparation for final transplanting

About a month after the lacakan seedlings have been planted, the remaining land is prepared for the final planting. This work is usually done in February, following the same practices as for the previous transplanting. The vegetation is cut or peeled in strips with a tajak (a scythe-like tool with short handle). The cut vegetation is allowed to remain in the water for 10 to 15 days. The partly decomposed organic mass is then gathered into little heaps or puntalans that are periodically turned to speed decomposition. The well-decomposed organic mass is applied to the land as green manure before planting. The land is neither plowed nor harrowed. This traditional land preparation method is the only one considered feasible under existing conditions. Kuilman and Van der Meulen (1941) stressed the significance of green manuring, stating that the success of tidal swamp rice culture under existing conditions was determined entirely by the vegetation that was the source of plant nutrients. Van Wijk (1951) recommended growing legume species adapted to swamp conditions to improve the quality of the organic matter.

Planting the main fields

By March-April the water level in the fields is low enough for the final planting. The lacakan seedlings, which by now have produced abundant tillers, are dug and planted after their tops and roots are pruned. No definite plant spacing is required. The planting method is known as sedepa lima. Five hills are planted to one depa (1.70 m^{2}) with 2 or 3 seedlings/hill depending on the variety. Noorsyamsi and Hidayat (1969b) reported the optimum plant spacing for Bayar varieties to be 35 ´ 35 cm, with 3 seedlings/hill. Except for green manure, no other fertilizer is applied. The water level is relatively high during the vegetative growth of the rice crop and the shading effect of traditional varieties is high. Therefore weed populations are relatively low and no weeding is practiced.

Water management

Water channels between the rivers and the fields must function freely and be kept in good condition. Where the channels are deep, wide, free from vegetation, and properly maintained, water flows easily into and out of the fields. The free flow of water is essential to reduce water depth and improve water quality.

Harvesting

Crops are usually harvested in August-September by cutting the panicles at their bases with an ani-ani knife. The sickle is not commonly used in this region. The paddy is then collected and threshed by foot. Cleaning is by gumbaan, a hand-operated winnowing machine. The paddy is sun-dried before it is stored in small bins (kindai).

VARIETIES

Potentials and limitations

Most local varieties (Bayar Kuning, Bayar Putih, etc.) are strongly photoperiod sensitive. Photoperiod sensitivity makes it possible for the farmers to delay planting until April if water levels in March are too high. Even though the rice crops are transplanted at different times they flower and mature at the same time; flowering is triggered by the shortest days of the year (June-July). Therefore pest infestations (especially rats and birds) are distributed more or less evenly over the area. In addition, the flowering time, which coincides with the dry months (June-July), provides some advantages from higher light intensity and ease of postharvest activity. Because the photoperiod-sensitive varieties can be planted in March and April without affecting harvest date or yield, the system tends to overcome labor shortages during the planting period. The disadvantage is that all of the crop mature at the same time and this creates labor shortages during harvest.

The local varieties Siyam Halus and Karang Dukuh are characterized by their good eating quality. Although their yield potential is low, consumer preference for them compensates the farmer by the higher price he receives for them.

Several traditional varieties including Lemo and Pandak appear to have some resistance to pests and diseases. Because most of the traditional varieties are well adapted to the environment of the tidal swamps, farmers use them even though their yield potential is low and they tend to lodge early. They are not responsive to fertilizer applications, which increase their tendency to lodge. Their long stems and droopy leaves that result in mutual shading contribute to lodging. Yields are only 1.5 to 2.5 t/ha.

Breeding objectives

Single-cropping of rice using traditional varieties provides relatively stable but low yields. Double-cropping is not widely adopted because of: 1) severe labor shortages for weeding the direct-seeded first crop, and 2) the unavailability of suitable improved varieties for either the first or second crop. Labor shortages are also acute at harvest of the first crop and transplanting of the second crop.

For the first crop, farmers use PB5 or C4-63 direct-seeded in October-November and harvested in February-March. Lemo, a relatively early-maturing improved traditional variety, is used for the second crop that is transplanted in the same fields in April-May. This crop is harvested in July-August. The seedlings for the second crop are transplanted three times as described earlier. Availability of adequate seedlings for transplanting the second crop is a problem. More labor for seedling preparation and for the final transplanting is also necessary.

The breeding objectives focus on the development ofvarieties suited for the first and second rice crops. The required characters for the first crop are

- high yield potential;
- plant type of PB5 and Pelita;
- early maturity, 110-120 days;
- resistance to major pests and diseases;
- drought tolerance; and
- good eating quality.

Desirable traits for the second crop are

- high yield potential;
- plant type somewhat taller and more vigorous that PB5 and Pelita;
- moderate photoperiod sensitivity;
- resistance to major pests and diseases;
- submergence tolerance; and
- good eating quality.

If suitable varieties for double-cropping can be developed, farmers may be induced to support more full-time laborers, improving social conditions and increasing food production.

PESTS AND DISEASES

The incidence of diseases is generally not serious under the existing cropping pattern of a single rice crop. The most important diseases observed in farmers' fields are brown spot, Cercospora leaf spot, bacterial leaf blight, bacterial leaf streak, sheath blight, stem rot, and blast. Normally these diseases do not cause significant yield losses under the low level of crop intensification practiced.

Tungro virus occasionally causes moderate damage at a few sites. Grassy stunt and ragged stunt viruses are less common than tungro under single rice cropping, but are potentially serious under a more intensive two-rice crop production system.

Insects that are usually found in farmers' fields include the mole cricket, rice bug, stem borer, armyworm, caseworm, green leafhopper (GLH), and brown planthopper (BPH). Rats are a serious pest in some areas.

Some farmers use insecticides, but intensive control is seldom required even when the insect population is high. Under intensive cultivation, an integrated pest management program will be required.

ECONOMIC ASPECTS

The total area of tidal swampland opened for agriculture in South Kalimantan is about 250,000 ha, including 135,000 ha used for rice production. This constitutes about 45% of the total rice production in South Kalimantan. Assuming the average yield of tidal swamp rice to be 2.0 t/ha, the area would produce about 270,000 t rough rice or 160,000 t milled rice. Most of this rice is produced on lands that were opened a number of years ago by farmers who use the land only for rice production.

There are several constraints to increasing production of rice and other food crops in the tidal swamps. Adequate transport for inputs, produce, and labor is generally not available; some areas are inaccessible. That leads to increased production costs.

Labor shortages have become serious, particularly during harvest. Because harvest labor is largely recruited from surrounding urban areas, labor costs increase and returns to the farmer are reduced. As farming becomes more intensive and diversified, year-round work opportunities should lead to a larger and more dependable work force.

Average farm size in the newly opened transmigration areas ranges from 1 to 1.5 ha. Cash availability is low, labor is in short supply, and income from food crop production low. Consequently, many farmers operate at subsistence level, producing only enough rice for their own consumption and high value cash crops (coconut, coffee, clove) for income. If rice yields can be improved, in some areas rice could serve as a temporary cash crop until the high value crops become established.

The livelihood of people living in the tidal swamps can be bettered through research leading to higher crop yields and more diversification and intensification. A rice-based farming system using high value cash crops intercropped with rice, maize, cassava, and other crops is the goal.

CURRENT RESEARCH

Cropping systems

Cropping systems research was started in 1978 in the populated type C tidal swamps in the Transmigration Project at Barambai. In most instances, the alluvial areas near the rivers are settled by indigenous, reasonably prosperous people who are engaged in farming and business.

The deep peat areas (peat domes) far from the rivers are not well suited to agriculture. Consequently, the Barambai area, which has a soil with a shallow peat layer over a clay-loam subsoil, was considered suitable as a target area for cropping systems research. Water was controlled by using a furrow-bed system similar to the sorjan system on Java. We have shown that early-maturing varieties such as IR36 grow well, and improved management practices are profitable (Table 3).

Our experience shows the need to partition the area according to the depth of the water table at high tide. In patterns for the high water table area (<20 cm deep) a wetland rice-based cropping system seems most appropriate. For areas with more drainage and a lower water table, upland or perennial crop-based-cropping patterns are indicated. In either instance, perennial crops are an important component of the cropping patterns. Perennial crops provide economic stability and distribution of labor. We propose to develop long-term plots to evaluate the

Table 3. Average yields, cost of inputs, and returns of 3 cropping patterns, Barambai, South Kalimantan, 1978-79.

Cropping pattern	Crops	Yield (t/ha)	Gross returns (US$/ha)	Costs (US$/ha)		Net returns above cash costs (US$/ha)
				Hired labor	Material input	
Pattern A (farmer pattern)	*Furrow bed*					
	Wetland rice (local variety)	1.9	380			
	Raised bed[a]					
	Maize	6000[b]	58			
	Maize	7504	72			
	Total		510	52	28	
Pattern B (introduced pattern with medium input)	*Furrow bed*					
	IR36 –	2.0	397			
	local variety (Lemo)	1.5	297			
	Raised bed[a]					
	Dryland rice +	04	89			
	maize ⌿	432[b]	70			
	cassava	3.8	155			
	Total		1008	122	53	833
Pattern C (introduced pattern with high input)	*Furrow bed*					
	IR36 –	1.8	362			
	local variety (Lemo)	1.9	390			
	Raised bed[a]					
	Dryland rice +	0.4	92			
	maize ⌿	428[b]	69			
	cassava	3.9	158			
	Total		1071		87	830

[a] Effective area only 30%. – = followed by, + = planted at about the same time, ⌿ = intercropped (about 1 month later). [b] Number of marketable ears.

productivity of the perennial crops and the stability of the cropping patterns.

At Handilmanarap, a double-cropping experiment started in November 1980 with transplanted IR38 resulted in a yield of 3.5 t/ha harvested in April 1981. The second crop was Lemo, an improved local variety, and several high-yielding wetland varieties.

Tillage

Traditionally, farmers use minimum tillage for land preparation. We are studying the effects of tillage on rice yields.

Fertilizer and micronutrients

Different fertilizer treatments have been tried, but so far no yield increases have been obtained.

Because many of the fields are usually flooded, it is difficult to apply nitrogen fertilizer without high loss. An International Network on Soil Fertility and Fertilizer Evaluation for Rice experiment to study ordinary urea, sulfate-coated urea, and supergranules applied in standing water was begun in 1981.

The knowledge of micronutrient deficiencies in tidal swamp soils is quite limited. The effects of trace elements on yields are being studied in the greenhouse using specific soil types from different sites. In a minus-one experiment, molybdenum, copper, and manganese were limiting on different soil types.

Varietal improvement

Siyam Halus and Siyam Kuning have good eating quality and are well adapted to tidal swamp conditions. They were sent to IRRI for mutation breeding. The mutant selections have more erect leaves than the parent varieties. At IRRI they showed lower plant height and earlier maturity.

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LARGE-SCALE FARMING BORDERING THE MUSI RIVER TIDAL SWAMPS: THE P.T. PATRA TANI PROJECT

B. P. CAREW

P. T. Patra Tani (PATA) is a national development project sponsored by Pertamina, the Indonesian national oil company. *Patra tani* means farm from oil, and was adopted in 1980 to reflect Pertamina's sponsorship. The project began as the Palembang Rice Estate in 1974.

PATA has several goals:

- to contribute to the development of South Sumatra by reclaiming marginally productive swamp lands;
- to produce seed for agricultural extension, and
- to turn developed lands over to smallholders and encourage resettlement from Java.

Production can be both capital and labor intensive. Three thousand hectares will be mechanized — 2,000 ha for irrigated rice and 1,000 ha for rainfed dryland crops. Soybean is now planted, but dryland rice and maize are possible future crops. An additional 2,000 ha will be farmed by smallholders, who will receive 2 ha each — 1.75 ha of irrigated land and 0.25 ha for house and garden. The smallholders, it is hoped, will participate in PATA's seed production program.

About 900 ha of irrigated rice fields have been developed, and 150 ha of dryland fields are under cultivation. Smallholder housing is under construction for 150 families who will be settled on 300 ha of irrigated land in 1981.

PROJECT LOCATION AND ENVIRONMENT

The PATA area is about 40 km west of Palembang, the capital of South Sumatra province. The latitude is about 3°S; longitude is about 104°. Three rivers border the project area — the Meriak, a tributary of the Musi on the north, the Keramasan on the east, and the Belidaon the west. The Palembang to Prabumulih highway borders the south at Kilometer 48.

The area is a 20,000 ha undrained peat swamp covered by secondary forest growth. The Indonesian term for this type of swamp is lebak. Gelam trees (*Melaleuca leucudendron*) are the predominant vegetation, The lowland area is about 4 m above sea level. The upland area (about 10% of total) is 15 m above sea level. It consists of undulating hills of sandy loam (yellowish-brown podzolic) soils covered with alang-alang grass (*Imperata cylindrica*).

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Annual rainfall averages 2400 mm. The rainy season (West Monsoon) is from October until April with a dry interval in January. The dry season (East Monsoon) completes the year and is the traditional cropping time for local farmers. Rainfall during the rainy season averages 290 mm/month. January averages 180 mm. During the dry season, rainfall averages 137 mm/month.

Temperatures range from 23° to 32°C with an average relative humidity of 84%. Sunlight-hour readings are available but not intensity. Available sunlight during a dry-season 8-hour day averages 67%, versus 39% for the wet season. Early morning ground fogs in the river valley are common. Fogs often remain until 8 am.

TIDAL SWAMP VS SWAMP

The Musi River (and the Meriak) due to tidal influence commonly rises and falls 2.5 m at Kertamulia in a 24-hour period. During the rainy season the river floods with minimal daily fluctuation. This flooding can combine with high tides to crest at 5.40 m above sea level.

The PATA area is protected from the rivers by dikes (at an elevation of 6 m) and drainage pumps. The pump drainage system within the farm has a capacity of 300 liters/minute per ha. Axial flow irrigation pumps can deliver about 108 liters/minute per hectare.

The distinction between swamp (*lebak*) and tidal swamp (*pasang surut*) is a difficult one. During the rainy season, swamp areas are flooded by the river and floodwater doesn't recede until the dry season. Standing water remains in some areas during the dry season. In swamp areas rainfall runoff is trapped in depressions next to the river. Lebak farmers plant one rice crop in the receding waters during the dry season.

Tidal swamp areas are also flooded during the rainy season, but the flood ebbs and flows with the tides. During the dry season the tidal swamp usually doesn't flood but some areas are inundated with sea water. *Pasang surut* farmers plant one rice crop during the rainy season.

LOCAL CULTURAL PRACTICES FOR RICE

Farmers have grown rice along the Meriak River for many years. The alluvial clay soils are called *upper lebak* areas. Traditional varieties are grown once a year during the dry season. The following is an account of the traditional cultural practices of a farm bordering PATA.

Sdr. Muchtar works for PATA and also farms adjoining land in his spare time. He has grown rice there since 1973. He owns his 2.5 ha, but many other farmers are share croppers.

Land preparation begins in December after the monsoon has flooded the fields. Grass is cut and left in the water to rot.

A seedbed is planted on the river bank or on a levee in March. While waiting for the seedlings to mature, the field is cleared. Grasses that are difficult to control are piled on levees to decompose. In April 30-day-old seedlings are transplanted in bunches (five plants to a bunch) at the center of the field, where they remain 1.5 months.

In mid-May the remainder of the field is transplanted (2d transplanting). The entire operation is repeated if one of the stages fails along the way due to flooding, drought, or rats.

Harvesting is done in September. Yields (1.5-2 t/ha) are often reduced by rats and weeds. Crops may fail completely due to unseasonable rainfall and flooding. No fertilizers are used. Insect pests are armyworms and stink bugs.

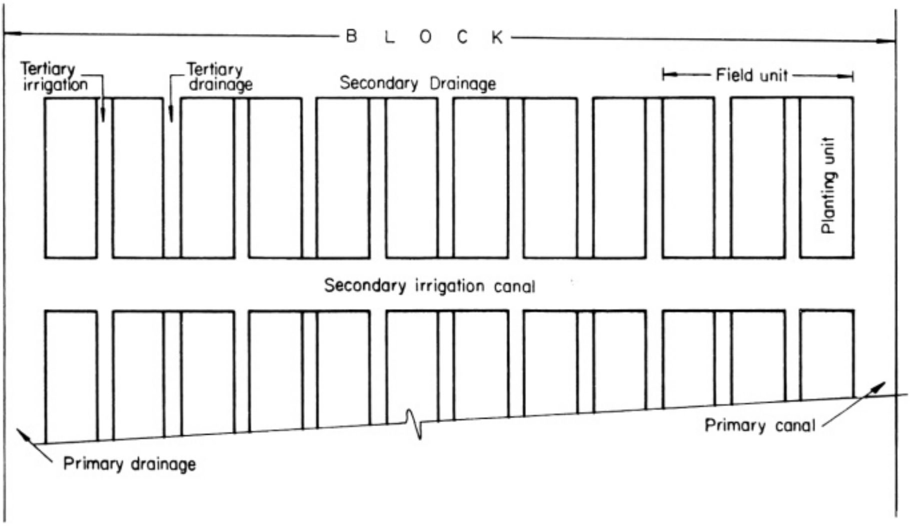
PATA'S DESIGN AND CULTURAL PRACTICES FOR RICE

One of the first large-scale mechanized rice projects in the tropics was started by the Dutch in Surinam, South America, in 1949. Some 6,000 ha of coastal swamp were developed for irrigated rice production and many Javanese went to Surinam as a labor force (DeWit 1960).

PATA's field design is based on the Surinam project. The basic planting unit is not more than 10 ha (Fig. 1). This unit can be subdivided, or benched, for further leveling of fields. Two planting units share a tertiary irrigation ditch and are bordered by drainage ditches. Three or more planting units are farmed together as a field unit. Four or more field units constitute a block, which can cover 400 ha or more. Currently eight of the field units have been developed into a block unit. Two block units share a secondary irrigation canal and a drainage canal. PATA is being developed a block at a time as swampland is isolated with dikes and drained.

Irrigation canals are maintained at 5.1 m to gravity feed the fields. Drains are pumped to a level of 2.5 m so that fields drain by gravity.

Cropping is continuous in a system much the same as the IRRI continuous rice production model. Every month as much as 100 ha are planted and another 100 ha harvested. Land preparation and application of fertilizers and pesticides are continuous.



1. Schematic representation of basic planting unit for PATA (not to scale). The basic planting unit does not exceed 10 ha. Three or more planting units constitute a field unit; four or more field units constitute a block.

Currently IR38 and IR42 are grown. They were selected primarily for blast resistance, yield potential, and general disease and insect resistance in that order.

Fields are flooded after harvest. The basic tillage tool is a spike-tooth cylinder pulled by a small crawler tractor. The effect is similar to rototillage but more passes are required. Initial land preparation is followed by a second in 2-4 weeks, depending on the planting schedule. Kumpai grass *(Hymenachae amplexicaulis)* is then collected by hand and carried from the field. If the field is uneven it is either water leveled with a bulldozer blade or puddled. If phosphorus fertilizer is required, it is applied by air as triple superphosphate (TSP) at a rate of 46 kg P_2O_5/ha.

Seeding is by air into mud, using pregerminated seed (soaked for 24 hours and incubated for 24 hours). The rate is 100 kg/ha of viable seed. If land preparation is late, direct seeding into water is possible in clay soils if there are no ducks. The field is then drained after 24 hours.

The fields remain drained until the stand is established — usually 18-22 days after seeding (DS). Fields are then flooded and herbicide is applied for grass and sedge control. Thiobencarb is applied at a rate of 2 kg a.i./ha by air. Flooding is maintained for 4 days, during which urea and potassium chloride are applied by air (34.5 kg N/ha and 45 kg K_2O/ha).

If further sedge control is required, a field is drained and 2,4-D applied at a rate of 0.75 kg a.i./ha. MCPA is often substituted at a rate of 1 kg a.i./ha. Water is reintroduced after 24 hours and flooding is maintained until harvest.

Nitrogen is applied three times. The second application is about 30 DS at a rate of 34.5 kg N/ha. A third application with potassium chloride at the standard rate occurs at panicle initiation. Trials have indicated a significant response to nitrogen at rates as high as 138 kg N/ha but rates have been kept low because of problems with blast disease.

Phosphorus and potassium are applied to newer fields. Soil and plant analyses indicate major nutrient levels are adequate in older fields (those at least 4-year-old), where only nitrogen is applied. An extra application of 34.5 kg N/ha is often used for varieties of long growth duration if there is yellowing prior to heading.

Fields are inspected at 14 DS for weeds and weekly for insects. Insects are controlled mainly with carbaryl at a rate of 1.275 to 1.7 kg a.i./ha. Acephate is used for stink bugs at a rate of 1.125 kg a.i./ha. Insect pests include armyworms *(Spodoptera mauritia),* case worms *(Nymphula depunctalis),* leaf rollers *(Susumia exigua),* black stink bugs *(Scotinophara lurida),* rice bugs *(Leptocorisa acuta),* and stem borers *(Chilo suppressalis).* Insecticide applications are with an aircraft or by hand (mist blowers), depending on the size of the infestation and aircraft availability.

Aerial applications are by contract with Satuan Udara Pertanian, the agricultural spraying unit of the Department of Agriculture. The aircraft is a Cessna Agtruk equipped with a low-volume T-jet nozzle spray boom and an ultra low-volume Micronair spray system. Solids (fertilizers, seeds, and granular herbicide) are applied with a Transland Spreader.

Harvest starts when grain moisture reaches 24%. Combines (New Holland 1545's or Claas Mercator 75's) are used where possible. The machines tend to "belly out" under boggy field conditions. The Claas has proved most effective due to its high axle clearance. PATA is currently developing a low-ground-pressure combine with the assistance of New Holland and Quality Marsh. That combine will be mounted on pontoons for harvest in boggy fields. Labor is now used to handharvest boggy fields or parts of boggy fields. Labor is seasonally unavailable (local farmers are planting and harvesting their own fields) and unreliable (grain theft).

Yields currently average about 2 t/ha. Production fields had yields higher than 3 t/ha several times during 1980, but rats, disease, soil problems, and weeds continue to limit production.

Grain processing is done in a Kongskilde silo drying system. Paddy is dried to 14% moisture and stored in 80-ton aerated storage silos. The system can dry up to 10 t/ha and store 480 tons in bulk silos. Paddy for consumption is cleaned to Bulog standards (3% inert matter) and bagged for sale in 70 kg bags. There is no milling on site. Paddy intended for seed is cleaned to Department of Agriculture standards.

CONSTRAINTS TO PRODUCTION

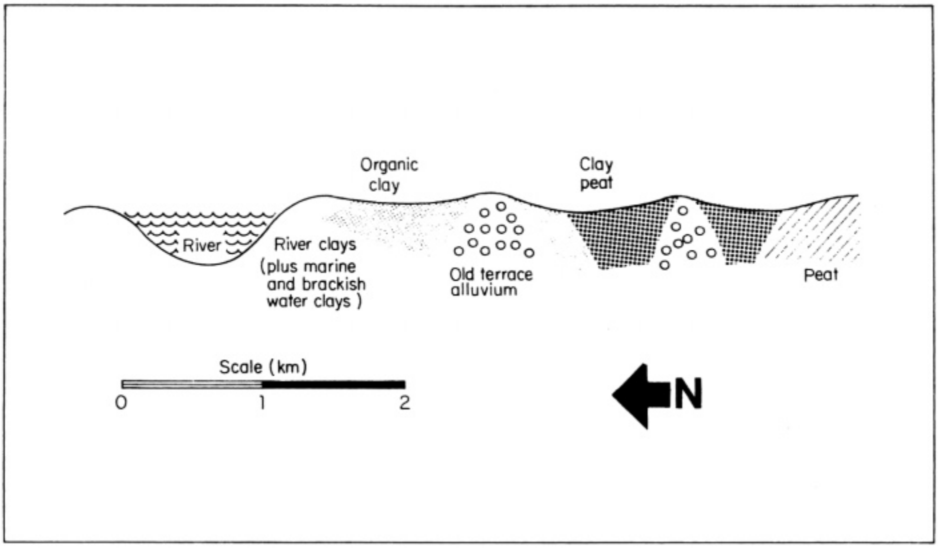
The major constraints to rice production in the PATA area are adverse soils, pests, diseases, and weeds.

Soils

Soils are mostly organic and overlie clay. There are five different soil units (Fig. 2) s one moves north to south across the area of the PATA project (van Breemen 978 unpub.).

1. Next to the river are river clays of low organic matter content and relatively low acidity (pH 5.5). These upper lebak swamp areas have been farmed by local farmers for quite some time.
2. Moving south the clay content decreases and the organic matter increases. This type of soil is termed highly organic (up to 20%) clay soil and is also called humic gley by PATA. The organic horizon is less than 40 cm.
3. A clayey peat soil that has organic matter of (20-50%) is much more predominant. The organic horizon is more than 40 cm thick. This is called an organic soil by PATA.
4. Soils identified as old terrace alluvium are found in ridges or islands throughout the area. They consist of stiff red mottled clay and have low organic matter content and low pH.
5. Peat soils are of 50-100% organic matter with low pH. The soil texture is silty as opposed to the clayey peat soil, according to PATA.

Soil types 2 through 5 may occur in one area (creating a soil complex). But highly organic clay soils predominate on the eastside of the area and peat soils on the west. Such soils cause problems with plant nutrition and equipment afficability. The pH can be 3.5-4 at development and improve to pH 5 over time. Plants growing in highly organic clay soils, clayey peat soils, and old terrace alluvium have had symptoms of iron and aluminum toxicities. Some newly



2. Cross section of the major soils at PATA.

reclaimed soils emit a hydrogen sulfide smell and are toxic to seedlings. Soil analyses indicate that new fields are deficient in phosphorus and potassium. Tissue analyses show a lack of copper, magnesium, and silica. Fertilizer trials indicate a significant response only to nitrogen.

Rice pests

Local farmers work the river clay soils between the river and PATA. After their harvests in September, the river floods and rats from their harvested fields move to dry ground. From November through January tens of thousands of rats invade PATA. It is not unusual for 100 ha to be destroyed at a time.

The PATA area is baited with anticoagulant rat bait set out in plastic bags or bamboo bait stations. Zinc phosphide is used for large outbreaks. Rat dogs are used to dig out rat holes and kill rats in field at harvest time. Fumigation with sulfur is also effective in place of dogs. Baiting has also been extended outside PATA into farmers' fields in an attempt to reduce the rat invasion and planting has been rescheduled temporarily so that there are no harvests during November-January.

Ducks and birds are seasonal pests. The lesser tree duck (*Dendrocygna javenica*) damages newly seeded field and the Eurasian tree sparrow (*Passer montanus*) damages fields ready for harvest. A species of dove also eats rice seedlings.

The black stink bug (*Scotinophara lurida*) invades the area at the period of full moon in April and November. Populations are high and injury to booting plants can be severe. Control with air application of acephate insecticide is effective. The brown planthopper is not a problem at PATA.

Diseases

Rice blast (*Pyricularia oryzae*) races are particularly virulent at Kertamulia. Attempts at blast control with benlate and dithane have been unproductive. IR30 and IR36 are not grown because of their susceptibility. Sheath rot (*Acrocylindrium oryzae*), narrow brown leaf spot (*Cercospora oryzae*) and seed fungus (*Curvularia*) are common problems.

Weeds

Weeds include *Hymenachae amplexicaulis, Echinochloa crus-galli,* and *Paspalum paspalodes* among the grasses. There is a variety of sedges. *Hymenachae amplexi caulis* (kumpai grass) is the most common weed. Plants generated from seeds can be controlled with herbicides. Plants from stolons cannot be controlled. This grass establishes on newly cleared land prior to final development. Kumpai grass stolons are difficult to eradicate and tillage helps spread the grass. Fields have to be hand cleared of stolons after final land preparation.

Echinochloa is a problem in spots, as is *paspalum.* The former outgrows the rice plant and the latter has rhizomes that are difficult to kill.

FUTURE PROSPECTS AT PATA

Because clayey peat and peat soils limit mechanized production, development of new PATA lands is now directed toward the eastern side where highly organic clay soils predominate. Smallholder participation will be increased to help develop farms on soils with low equipment trafficability. The effect of flushing and liming on soil acidity and toxicities is being studied. Both macro- and micro-nutrient fertilizer trials are underway in cooperation with Lembaga Pusat Penelitian Pertanian. It is hoped that varietal screening for problem soils will be possible in 1981.

Although smallholders will farm with IRRI-type implements, large-scale mechanization will continue. Komatsu D20 PL tractors, with half the ground pressure of the Caterpillar D4E-LGP's now used, will be introduced shortly. However, the main harvesting in boggy areas will be by hand. It is hoped that an integrated labor-and-capital-intensive approach will increase productivity by double cropping.

Control of rats will require that PATA increase its extension activities with local farmers. The rat baiting program for local farmers is now in its second year. In 1981 it should cover 400 hectares between PATA and the Meriak River. Duck and bird control needs investigation.

Disease resistance will be best resolved through varietal development. PATA has a varietal screening program with Lembaga Pusat Penelitian Pertanian. Wetland and dryland varieties are being screened.

Weed control research is also a cooperative effort with national programs. Biotrop has assisted in weed collection and identification, as well as staff training. Lembaga Pusat Penelitian Pertanian and PATA conduct cooperative herbicide trials for both wetland and dryland crops.

There has been some discussion about creating a new class of rice in Indonesia — one that is suitable for a particular problem area. Such a variety would not be released nationally unless there was a widespread need. PATA is in a unique position to screen varieties suitable for the problem soil and climatic conditions of the Musi River Valley, an area targeted for widespread transmigration settlements. Likewise, PATA has the capability to rapidly increase and process seed due to its new lands, mechanization, and smallholders' labor force.

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TIDAL SWAMP RICE IN PALEMBANG REGION

O. KOSWARA and F. RUMAWAS

Since 1975 food production in Indonesia has lagged behind population growth, and since 1973 the country has been dependent on food imports. In 1977 Indonesia imported some 2 million tons of rice — about one-third of the world's international trade in rice.

The population explosion has become a national issue and an integrated approach to solve it is necessary. Transmigration is moving people from densely populated areas of Java, Bali, and Madura to the outer islands; it should be accompanied by efforts to increase food production in newly opened agricultural land and should be synchronized with the regional development of the receiving province. At the same time, a family planning program should be planned and implemented.

Because rice is a major staple food of the Indonesian people, agricultural land development should be directed toward lands with abundant water and level areas. This is one reason why tidal swamp development was started in the early seventies. The expansion of this project in the First and Second Five Year Development Plans (Pelita I and II) led to many studies including soil survey and soil mapping.

This paper focuses on the potential and problems ofestablishing rice culture in the tidal swamp area of the Palembang Region, South Sumatra.

TIDAL SWAMP DEVELOPMENT

Tidal swamplands comprise coastal areas having soils formed by the overflowing of freshwater rivers at high tides, particularly during the periods of high discharge n the rainy season. Developing such lands involves drainage and control of water levels. Of 7 million hectares of tide-influenced swampland, 5 million hectares, mainly in Sumatra and Kalimantan, were tentatively identified as having potential or tidal swamp rice cultivation.

The development of tidal swamplands has been carried out by the Directorate of Swamps under the Directorate General of Water Resources Development, in the prooject called "Proyek Pembukan Persawahan Pasang Surut" (P4S). A subproject is located in each province where tidal swamps are being developed (Fig. 1) — Riau, Jambi, and South Sumatra in Sumatra; and West and South/Central

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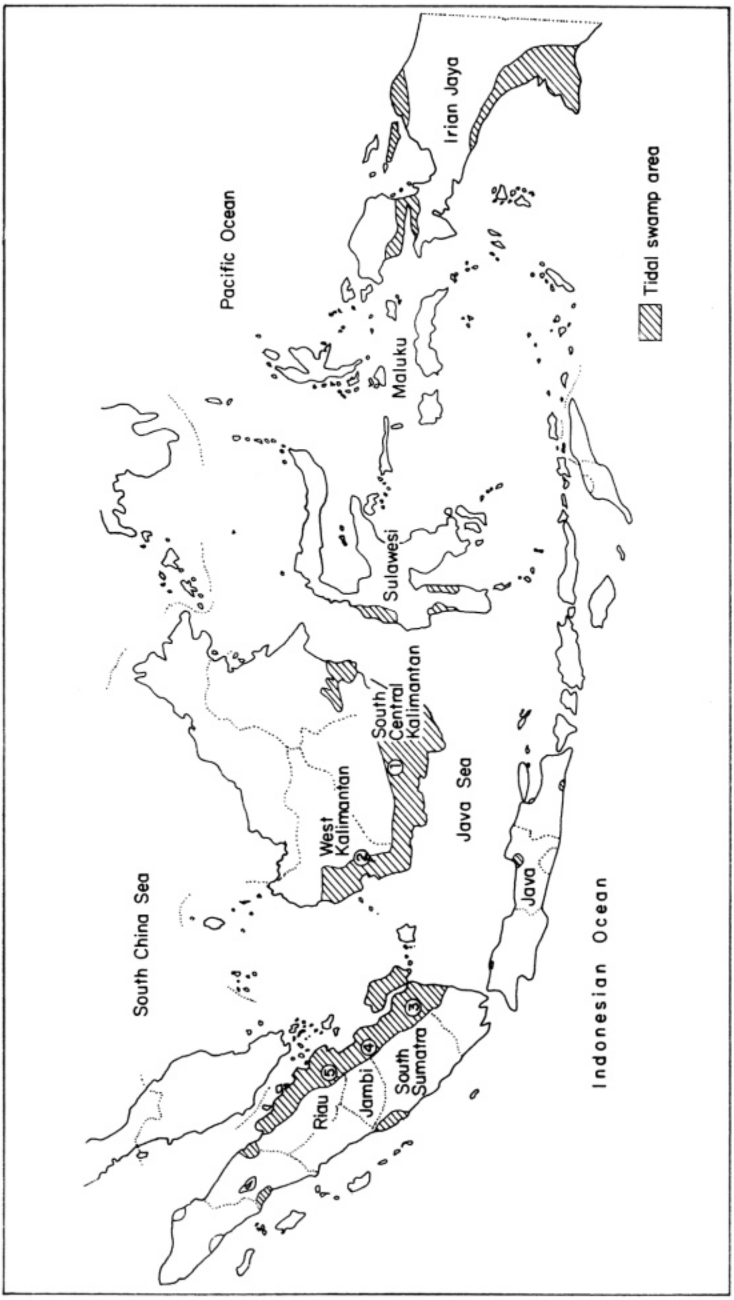
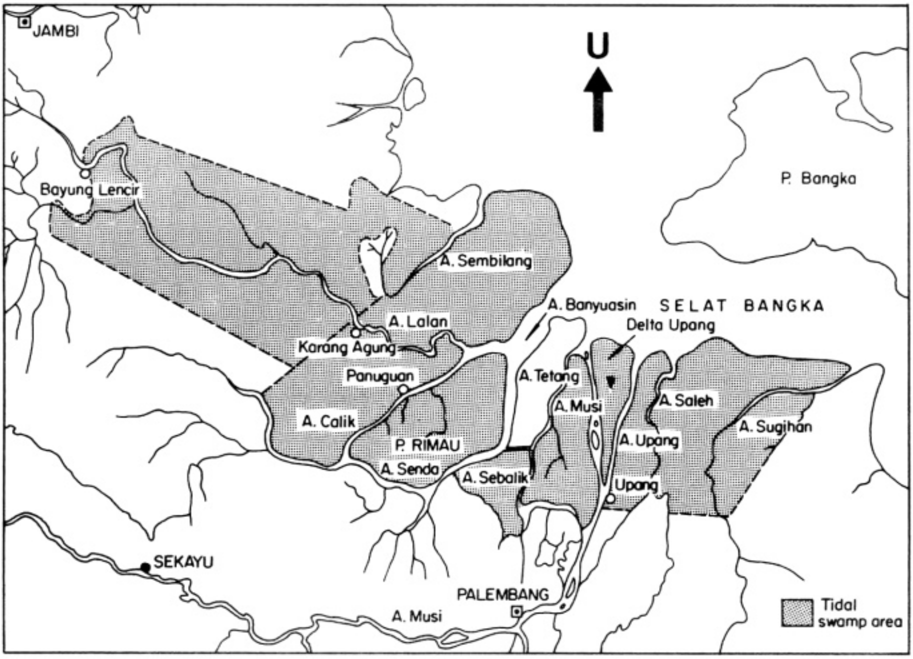


1. Head office and subprojects of the tidal swamp development program in Indonesia.



2. Soil survey area in the tidal swamps of South Sumatra, Indonesia.

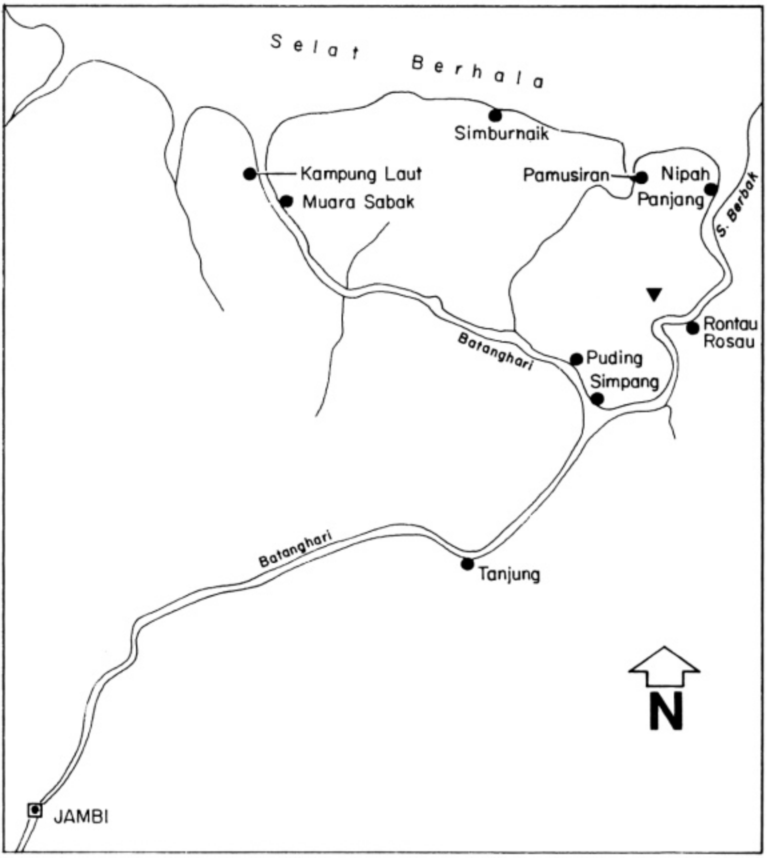
Kalimantan. During Pelita I (1969-1974) the pilot projects covered 35,000 ha, about 22,000 ha of which are in the province of South Sumatra and Jambi. In Pelita II (1974-1979) 250,000 ha were scheduled to be cleared, and in Pelita III another 400,000 ha. The present development strategy concentrates on opening new tidal swamp areas in South Sumatra and Central/South Kalimantan.

When the P4S was established (1969), the project was directly under the Minister of Public Works. Investigations, studies, surveys, and design were carried out with the assistance of various institutions in Indonesia: Institut Pertanian Bogor (IPB), Institut Teknologi Bandung (ITB), and Universitas Gajah Mada (UGM) Jogyakarta.

Since 1969, the IPB has conducted soil surveys and soil mapping, while hydrological and engineering-design aspects are carried out by the ITB (Fig. 2). IPB and ITB involvement is mainly in Sumatra, and UGM in Kalimantan.

The IPB also operates small test farms at Upang (South Sumatra) and Rantau Rasau, Jambi (Fig. 3). Most experiments are on crop adaptation and variety testing, and fertilizer trials for paddy. Upland crops (maize, peanut, soybean, and sweet potato) and some tree crops (coconut, clove, rambutan) have also been tried.

During Pelita I, IPB surveyed 400,000 ha in Jambi and South Sumatra. During Pelita II, an additional 500,000 ha, mainly in South Sumatra, was surveyed. The survey included mapping of soil types and depth of the organic layer. Chemical and physical soil properties were determined in the Soil Laboratory of P4S-IPB at Bogor. The following chapter discusses the soil survey method and the extent of soils in the tidal swamp area of South Sumatra.



3. Site of the Test Farm P4S-IPB (p) in the Berhak Delta, Sub P4S Jambi, Indonesia.

SOILS OF THE TIDAL SWAMP AREA OF SOUTH SUMATRA

This section elaborates on the main criteria for soil mapping and soil survey and shows that different soil types are found, besides the much dreaded acid sulfate soils.

In the early 70s, the soil surveys made several traverses along the river at 1- or 2-km intervals. Observations in the traverse were 500 m apart, and focused on the thickness of the peat and the depth of the pyrite layer.

Entering Pelita II (1975), the criteria required by the World Bank were expanded to depth of peat, amount and type of organic matter, presence or absence of acid sulfate horizons (by measuring their depth from the surface), and their pyrite content, salinity, and acidity. The occurrence of potential acid sulfate layers at a depth of less than 50 cm makes the area unacceptable for development.

In 1976, the first soil survey and mapping supported by the World Bank and assisted by the Nedeco Euroconsult was carried out in Karang Agung, South Sumatra (200,000 ha). In 1978 the activities were extended to Lalan (180,000 ha) and Masuji (50,000 ha).

The method of soil survey and the criteria used in Land Classification as agreed upon by the P4S-IPB and Nedeco Team (1977 and 1980) are discussed briefly in the following paragraphs (IPB 1978).

Survey methods

The base map (1:50,000) was prepared by the Soil Sciences Department of IPB from aerial photographs of the area. The planned traverses, 1 km apart, were plotted on the base map by the Soil Team for soil mapping.

Observations and measurements on soil properties were made at 500-m intervals in the traverses. The soil properties were color, texture, consistency, degree of ripeness, and occurrence and depth of acid sulfate horizons. Where possible, depth and degree of decomposition of organic matter were also determined and recorded. The presence of acid sulfate soils was determined from the result of measurements of soil pH with pH paper. The measurements were carried out twice: before and after oxidation by 30% H_2O_2. During soil color determination, other measurements were made, e.g. gley depth and total reduction depth.

Samples were collected from layers of several soil profiles. Bulk samples for evaluating fertility status were collected from the 0-40 cm top layer. Ring samples were taken at several observation points for bulk density, permeability, and pF (soil water tension) determination.

Hydraulic conductivity, electrical conductivity, flood level, groundwater depth, and groundwater pH were also measured.

Water content of the samples was determined in the laboratory and the results were used for standardizing the date of other analysis.

Land suitability classification

The method of land suitability classification in the survey is a method agreed upon by the P4S-IPB and the Nedeco teams. The land is grouped into three categories: 1) order, 2) class, and 3) subclass.

Order is determined by the limiting factors present in the land that are very difficult to manipulate. They are solum depth, peat cover, slope, aquic moisture regime, soil ripeness, and salinity for rice or exchangeable sodium for upland crops. Based on those factors, land may be suitable, conditionally suitable, or unsuitable.

Factors used in determining classes are factors used for determining order plus other factors such as peaty mineral thickness, texture of mineral material, drainability, sulfate acidity, fertility status, subsidence hazard, and electrical conductivity of groundwater.

Classes are determined by the intensity of the limiting factors concerned. Soils may have 1) slight limitation, 2) moderate limitation, or 3) severe limitation.

Subclass indicates the kind and degree of the most severe limiting factors. And the factors being evaluated are solum depth, peat thickness, peaty material thickness, texture of mineral materials, slope, aquic moisture regime, drainability, depth of sulfate acidity, fertility status, soil salinity, exchangeable sodium percentage, subsidence hazard, and electrical conductivity of groundwater.

Some factors that are controversial in assessing the agricultural potential of tidal swamp areas are discussed briefly.

For upland crops, the parameters used to assess the fertility deficiency in the survey area are exchangeable potassium, available phosphorus, and exchangeable aluminum; for paddy rice, only exchangeable potassium and available phosphorus are considered.

Based on the soil taxonomy system and the preceding criteria, the soils in the Karang Agung area (IPB 1978) belong to 3 orders: Entisols cover 134,900 ha (66.7%), Inceptisols 31,070 ha (15.3%), and Histosols 36,310 ha (18.0%). The Histosols consist of two great groups (Sulfihemist and Tropohemist) and occupy 13,130 ha or 18.0% of the total survey area. The organic deposits forming Histosols are either peaty materials or peats with thickness of 40-130 cm, 130-200 cm, and deeper than 200 cm.

Rice is suitable for 168,000 ha or 83.5% of the area, and upland crops for 6,350 ha or 3.1%. Of the survey area, 9,020 ha or 4.5% is settled, hence 159,000 ha or 79.0% is available for transmigrant settlers. Since more than three-fourths of the survey area is available for new settlements, the Karang Agung area is suitable for a large-scale transmigration project.

The extent or distribution of the organic soils or Histosols as compared to the mineral soils (Entisols and Inceptisols) in the tidal swamp area of South Sumatra is presented in Table 1.

Using the tidal swampland as a rice bowl in increasing food production has limitations and problems. The problems include 1) regulating the depth of drainage to avoid acid sulfate conditions, 2) saltwater intrusion and its effect on crop production, 3) the reliability of topographic measurements under muddy and

Table 1. Distribution of soils and their suitability for rice production in the South Sumatra tidal swamp area, Indonesia.[a]

Survey area	Area (ha)				
	Histosols with OM of indicated thickness		Entisols and Inceptisols with OM of indicated thickness		Suitable for paddy rice
	40-130 cm	>130 cm	<10 cm	10-40 cm	
Air Sugihan	18,004 (43.8)	365 (0.9)	9,541 (23.2)	13,210 (32.1)	31,619 (76.9)
Air Saleh	30,712 (23.1)	5,281 (3.9)	–	57.1 10 (42.1)	95,453 (70.7)
Upang	4,800 (19.0)	–	4,200 (16.1)	17,000 (65.0)	21,800 (84.0)
Muara Telang	6,701 (35.6)	–	5,395 (28.6)	6,761 (35.8)	12,840 (69.1)
Musi-Banyuasin	6,272 (9.5)	775 (1.2)	16,586 (25.2)	41,981 (64.1)	61,695 (94.1)
Banyuasin-Calik	30,200 (26.2)	3,920 (3.4)	43,010 (37.2)	38,230 (32.2)	69,140 (59.9)

[a]Numbers in parentheses refer to parcentages of the total surveyed area. OM = organic matter.

flooded conditions, 4) outbreaks of pests and diseases, including weeds, because of lack of water control and decrease in soil fertility, 5) rice yield reductions over time, and 6) subsidence of the peat layer.

RICE PRODUCTION IN THE TIDAL AREA

Cultural practices

Two distinctly different methods of rice production are observed in the tidal swamp area. The traditional method of the indigenous population and Buginese settlers is common along river banks. Transmigrants from Java and Bali use rice production technology of their place of origin.

Traditional culture. The swamp forest is felled manually and small trees, branches, and twigs are burned. Stumps and trunks are left in the field and repeatedly burned over the years (4-5 years) until the field is completely clean. Drains are dug manually, and therefore limited in length to a few kilometers from the banks.

The first crop of rice is planted without land preparation between the tree stumps and tree trunks. Only one crop of rice is grown in the rainy season, and the land is left fallow in the dry season. A lush vegetation of grasses and sedges takes over. Land preparation of old clearings consists mainly of slashing and trampling this secondary vegetation up to three times, after which tall rice seedlings are transplanted in the soft mud with the use of a planting stick.

Tall and very late-maturing varieties are used. Depending on the number of nurseries and variety, rice is harvested 7 to 9 months after sowing.

At the onset of the rainy season in October or November, nurseries are started on the ground in very dense clumps (*tugal*) or on bamboo platforms covered with banana or palm leaves and soil (*semir*). After 10 to 15 days, the small seedlings are transplanted to a nursery where they are left between 30 to 50 days. If necessary, a third nursery may be prepared. This system allows phased transplanting into the field. It is used to avoid flood damage to small seedlings in the middle of the rainy season, to spread labor evenly over a longer period, and as a form of weed control because tall seedlings are transplanted into the field. This traditional practice and the choice of tall varieties control weeds sufficiently. If necessary, the rice fields are hand weeded once. Some farmers use herbicides (2,4-D amine). Insect pests are controlled by diazinon.

An important activity, started before land preparation, is keeping the ditches open. Standing water is avoided, for it inhibits rice growth and reduces yield.

Rice grown traditionally is harvested between May and August. Accurate yield figures are not available, but yields are obviously variable (Table 2), depending on soil fertility, weeds and other pests, variety, and floods or droughts in a particular season.

Farmers also maintain home gardens on high ground and grow perennial crops such as coconut, coffee, and rubber. Coconut is also grown on dikes or hills in the paddy fields.

Transmigrants' culture. Rice production by the transmigrants is often more intensive than the traditional way. Basically it is an adaptation of irrigated rice production practices of Java and Bali.

Land is cleared with chain saws. Trunks and branches are cut, piled in the field, and burned. No heavy equipment is used, except for digging the main canals, which is done mechanically. Because land thus opened is further inland from the river banks, transmigrants are cultivating land with an organic layer thicker than that farmed by indigenous and Buginese farmers.

Local Javanese or Balinese and modern early-maturing rice varieties are grown. Table 3 shows the varieties used and yields obtained in different villages on the Upang Delta. Samples harvested from 100-m^2 plots showed that in four of five villages, IR32 was top yielder. The higher yields at Pandowoharjo are probably the result of a well-maintained water supply and drainage system and the fact that the rice fields there are the most recently cleared.

Nurseries are started in October or November, often close to the house, about 3-5 weeks before the rice fields are ready. Most nurseries are kept flooded.

Transmigrants use short hoes for light land preparation. Where possible, they build small dikes around paddy fields to impound rain or river water and gain some degree of water control. The most successful farmers keep their ditches clean, allowing free water movement. In Pandowoharjo, the ditches are maintained by the community.

Rice fields are hand weeded at least once. When labor is available, most farmers weed twice or, occasionally, even three times. Chemical weed control is uncommon. Insecticides and rodenticides, on the other hand, are government subsidized.

Rice is harvested between February and April. The difference in periods of activities between transmigrant rice production and traditional rice production benefits both groups, since they help each other out.

True to Javanese and Balinese tradition, most farmers attempt a second crop of grain legumes or maize after rice. They usually do not double-crop their entire 2-ha land, but only those areas closest to their houses. Some farmers have tried two crops of early-maturing rice a year, with varying degrees of success. Multiple cropping of maize and a grain legume is common. A dam culture, known as the sorjan system, is also popular. In this method wide dams or dikes are built by piling the peaty soil, and alternate strips of rice and any upland crop are planted.

Coconut, fruit trees, banana, and vegetables are planted in the yard. Animal husbandry is limited to a few chickens, goats, ducks, and beef cattle.

Problems

Pests and diseases. Pests and diseases affecting rice yields in the tidalswampland do not differ from those in other rice-producing areas (Satari and Sosromarsono 1979). They consist of insects, diseases, rats, and weeds.

A serious pest in newly transplanted fields is the mole cricket (*Gryllotalpa hexadactyla*). It is destructive in uninundated areas of the rice field and is an indication of poor leveling or failure to impound water. Other insect pests are the yellow stem borer (*Tryporiza incertulas*), the white stem borer (*T. innotata*), a black stink bug (*Scotinophara vemiculata*), and the rice stink bug (*Leptocorisa acuta*) (IPB 1977). In the Upang Delta, the brown planthopper (*Nilaparvata lugens*) was also reported as a serious pest (Satari and Sosromarsono 1979).

Rice blast (*Pyricularia oryzae*) and *Helminthosporium oryzae* are the most common diseases in the area, and at times can be serious (Satari and Sosromarsono 1979). Rat infestation is reduced by flooding the field and removing potential nesting places. Rats are eradicated with Warfarin and zinc phosphide poisoned baits. Losses due to plant pests and diseases can amount to 60% (Satari and Sosromarsono 1979).

Serious weed problems occur in excessively drained areas with labor shortages (Nedeco 1978). Yield losses due to weed competition can amount to 50%. The cost of manual weed control is about 40% of the total production cost (Tampubolon et al 1979).

Water control. Water has determined the chemical, physical, and biological characteristics of the tidal swampland. Land clearance and the construction of canals have increased the magnitude and number of fluctuations of the water level. The amount and duration of water in the field or the degree of flooding now depends solely on 1) fluctuation in the discharge of the rivers, 2) rainfall in the area, and 3) the tidal movement. Only the tidal movement occurs with regularity.

Because of financial constraints, no water control structures were included in the design of the canals, except for some experimental gates, which turned out to be a failure. The design only specified that ground water levels were not to drop deeper than 50 cm below the soil surface. Excessive drainage of some areas, however, could not be avoided.

Drainage and agricultural activities in the Upang Delta resulted in a loss of 2.0 to 5.0 cm of peat annually between 1969 and 1977 (Chambers 1979). Transmigrants impound water in their rice fields, but in so doing risk the adverse effects of standing water.

Flooding, dry spells, and saltwater intrusion have probably caused the large variations in rice yields in similar soils and the erratic response to fertilizer applications. Cat-clays or acid sulfate conditions are not considered a threat to wet rice production

Soil fertility maintenance. Rice yields in unfertilized plots increase for the first 2 or 3 years after clearance and drop off until they stabilize at around the sixth year. Response to nitrogen and phosphorus fertilizer applications show up after the third year (Astiana and Rachim 1979, Soepardi et al 1979, Sabiham et al 1979), but yields never attain the previous levels,

Another phenomenon is that results are variable, making fertilizer recommendations difficult, if not impossible. This may be caused by the deficiency or excess of other nutrients or substances. Liming, copper, magnesium, and nitrogen improved yields of rice grown on peats of different thickness (Leiwakabessy and Wahjudin 1979). Another observation is that vegetative growth appears normal, but yields are decreased by increase in sterility (Leiwakabessy and Wahjudin 1979, Seopardi et al 1979). Another possible cause is the confounding effect by factors such as weed competition (Tampubolon et al 1979) or variations in the soil moisture regime.

Areas with peat depths in excess of 1 m are usually not recommended for rice culture because of the poor yields obtained. Leiwakabessy and Wahjudin (1979), however, showed that the soils can be made productive with proper liming.

Improvements

Productivity of the tidal area can be increased by improving conditions that influence rice growth and eliminating limiting factors.

Water control. Since water is the most important enviromental factor affecting rice yield in the tidal area, improving water control is the logical approach. At the moment, however, construction of expensive waterworks and pumping stations is

Table 2. Rough rice yields of traditional farmers in the South Sumatra tidal swamp area, Indonesia.

Site	Rice variety	Yield (t/ha)	Source of data
Marga Telang		2.0-3.0	IPB 1975
Marga Sungsang		1.0-4.0	IPB 1975
Marga Upang		1.0-1.5	IPB 1975
Air Saleh		1.0-3.0	IPB 1976a
Air Sugihan Kiri	Nugu	1.5	IPB 1976b
	Duku	1.0-1.2	IPB 1976b
	Suwarambe	2.0	IPB 1976b
	Kuatik	1.5-1.8	IPB 1976b
Karang Agung		2.0	Nedeco 1978
Hilir Mesuji	Ampai	1.2-1.4	IPB 1979
Mesuji		1.1-1.9	IPB 1980a

Table 3. Rough rice yields in five transmigrant villages in the Upang Delta, South Sumatra, Indonesia, 1980 rainy season (IPB 1980b).

Village	Rice variety	Samples (no.)	Yield (t/ha)
Pandowoharjo	Pelita I/1	19	4.0
	IR32	3	4.4
	IR38	2	3.2
	Tiga Dara	1	5.9
Tirta Kencana	Pelita I/1	4	2.2
	IR32	3	3.3
	Tiga Dara	8	2.1
	Siam	8	2.3
	Local	2	2.8
Makarti Jaya	Pelita 1/1	13	2.4
	IR32	7	3.4
	Siam	4	2.1
	Glutinous	1	2.0
Puwodadi & Purwosari	Pelita 1/1	1	1.2
	IR32	4	3.5
	Tiga Dara	1	2.4
	Siam	4	2.7
	C4-63	2	2.1
	Local	4	2.7
	Glutinous	4	3.3
Tirta Mulya	Pelita I/1	3	1.6
	IR32	1	4.8
	Tiga Dara	2	2.0
	Siam	18	1.9
	Local	1	3.0

out of the question. Two less expensive small-scale approaches have been successful. One is the cooperative effort to control water flow in Padowoharjo (IPB 1980b), where tertiary blocks are treated and managed as single units. Yields have been good and stable. The other is the sorjan system where alternating strips of wet rice paddies and wide dikes for upland crops are grown. This system increases cropping intensity to 28% and stabilizes rice yields (Situmorang 1979).

Cultural practices. An integrated system of pest and weed control has been proposed by Satari and Sosromarsono (1979) to keep losses to an economic minimum. Present yield losses due to pests and diseases can reach 25 to 60%.

Double-cropping seems promising. The second crop may be a legume or another grain crop. Where water is abundant in the dry season, a second crop of rice may be profitable. Currently a trial in the Upang Delta involves some 300 farmers planting maize and an early-maturing rice variety (IR36) as second crops in the dry season.

Fertilizer recommendations have to be formulated in the not-too-distant future. If Chambers (1979) is correct, farmers in the Upang Delta, which was cleared in 1969, will need fertilizers in 1984 when the peat layer is all but gone. Currently macronutrients and micronutrients have been shown to improve yields, and liming seems to improve the previously troublesome thick peats.

Varietal improvement. Tables 2 and 3 show the variability in rice yields. It is apparent that among the varieties, IR32 is a consistently good yielder. This is an indication that varietal improvement for the tidal environment is possible. The rice variety should be a reliable yielder under such conditions as floods, dry spells, and the possibility of saltwater intrusion and acidity. A stable yield of around 3.0 t/ha seems reasonable.

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UTILITY OF RICE CROPPING STRATEGIES IN SEMUDA KECIL VILLAGE, CENTRAL KALIMANTAN, INDONESIA

G. A. WATSON

Agricultural development projects within secondary regions of Indonesia must provide socially sound, environmentally responsive, and economically productive development strategies to succeed. Improvement of rice cultivation in tidal and tidal-influenced areas is particularly problematic. Climatological and hydrological variation occurs on a microgeographical scale. This paper examines the planting practices and rice varieties employed by farmers of Semuda Kecil Village located near the Java Sea on the Mentaya River of Central Kalimantan, Indonesia. A total of three discrete cropping systems and 37 rice varieties are utilized in the peat swamp area. Farmer strategies ensure that harvests are adequate for home consumption and that there are small volumes for export. These strategies are related to plant characteristics, pest predation, andenvironmental variables. Indigenous agricultural knowledge of farmers is compared to actual farming practices. This rice cropping system reduces the risk of widespread crop loss, but modification in soil preparation, fertilizing, and weeding will improve crop yields. There is a high probability that farmers will adopt improved rice varieties if these can be integrated into the present system. Rice researchers are encouraged to incorporate traditional farming systems into their research planning and methodology.

During the past decade, the Indonesian Government has encouraged the regional development of tidal swamp ecosystems within a framework of transmigration and rice agriculture (Guinness 1977, Hardjono 1977, Subiyanto et al 1978). The east coast of Sumatra and the south coast of Kalimantan are major areas under development; other areas include Irian Jaya and Sulawesi. Indonesia's agricultural institutes have begun to examine existing methods of rice agriculture and associated cropping systems within these tidal areas (Noorsyamsi et al 1980, Noorsyamsi and Hidayat 1974, Team Inventarisasi Pasang Surut Kalimantan Selatan 1969). Breeding programs for the improvement of tidal rice varieties are in progress.

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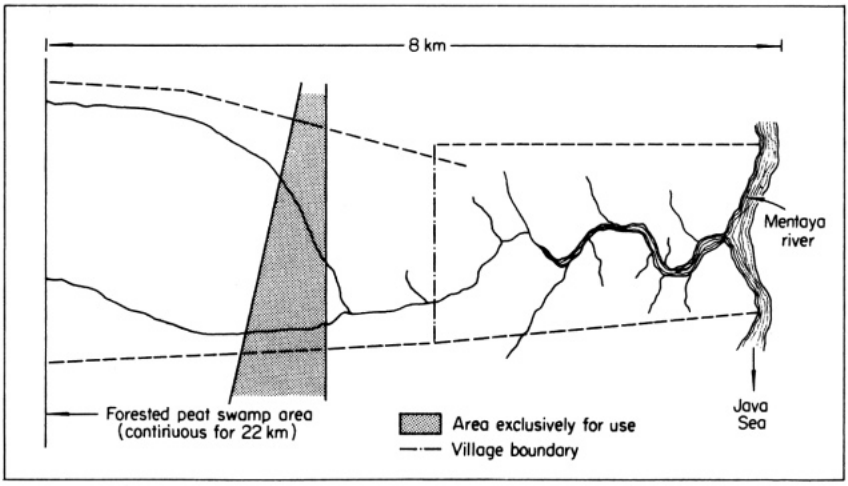
Economists, ecologists, agriculturists, and concerned social scientists have recognized that human resources are an integral part of the development of environmental management strategies. However, few studies on cropping systems of indigenous tidal swamp populations have centered on farmers' social responses to environmental constraints. Indeed, many investigators often assume farmers' methods to be unchanging and unresponsive to shifting economic or natural conditions.

Some sociocultural studies have focused on traditional agricultural systems emphasizing low-risk, low-yield crop production through the variation and intercropping of plant varieties within a scheme of integrated resource management which ensures adequate harvests. Farmers' insights and methods of coping with problems such as drought or floods can provide new strategies for cropping systems management. Marginal improvements of traditional farming strategies may provide greater productivity and socially desirable outcomes than radical changes in agricultural systems (Bernsten and Herdt 1977).

This paper is based on a survey of rice cropping strategies within the rice/coconut cultivation system of farmers in a tidal swamp region of Central Kalimantan, Indonesia. It provides data on the relation among environmental variables and the diversity of the rice farming system, and how indigenous agricultural knowledge mediates between the two. Semuda Kecil Village presents some interesting prospects and challenging problems for the establishment of more productive rice cultivation within tropical tidal regions.

THE ENVIRONMENT

For the past century, Banjarese migrants have effectively settled and cultivated land along the Semuda Kecil River of Central Kalimantan. This river drains into the Mentaya River, which empties into the Java Sea. The present village site extends from the alluvial levee at the river mouth to a peat basin swamp forest 8 km



1. Semuda Kecil Village, Central Kalimantan, Indonesia.

inland. The village land area is 2 km wide and 30 km long: 44 km^2 are still under peat swamp forest cover (Fig. 1). A total of 1,050 ha is planted to coconut, and 400 ha to rice.

Geography and climate

The Mentaya River area, a slowly aggrading delta of Central Kalimantan, is composed of brackish and freshwater peat swamp forests. The peat is bordered at the river edge by narrow levees of mineral alluvial material that underlies the peat and slopes gently toward a peat forest basin (Andriesse 1974). Before the agricultural use of these areas, the deposits of alluvium along the river banks were colonized by mangrove species, and coastal peat swamp forest was well established (Andriesse 1974, Yamada and Soekardjo 1980). The groundwater shows strong seasonal fluctuation. The recent opening of these swamps to agriculture has promoted tidal fluctuation of the water table, although at 7-8 km inland, this variation rarely exceeds 15 cm. Cultivation has also resulted in subsidence of peat in this backswamp basin.

Rainfall

Annual rainfall in the Semuda Kecil areavaries considerably, from less than 1,700 mm to 3,000 mm (average of 2,200 mm/year) (Table 1). The pronounced dry season generally lasts from July through October but the onset of the rainy season may be from August to December. During this period, flooding is unpredictable: backwater swamps, which experience the least tidal drainage, are most severely affected.

Temperature

The average daily temperature ranges between 28 and 32°C throughout the year. Nighttime temperatures during the dry season may drop to 19°C, and midday temperatures may reach 36°C.

Tidal variation and salinity

Semuda Kecil village is located 15 km from the mouth of a large bay which feeds into the Java Sea. The Semuda Kecil River extends perpendicularly from the

Table 1. Rainfall patterns in the Semuda Kecil area, Central Kalimantan, Indonesia.

Year	Rainfall (cm)											
	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
						Kotawaringin Timur Provine[a]						
Av 1964-74	256	155	126	173	218	234	324	242	299	336	241	211
						Semuda Kecil						
1979-80		100	151	81	141	218	307	200	199	152	257	138
1980-81	197	31	60	40	77	129	219	68	170	387	213	88

[a] Rainfall for Kotawaringin Timur Province is substantially higher than in the Semuda Kecil area, primarily because the data were gathered in Sampit, a city 40 km further inland on the Mentaya River. Data for rainfall in the Semuda area are not available before 1979.

mouth of the Mentaya River through the alluvial plain into the peat swamp basin (Fig. 1). At the mouth, the tidal amplitude is ± 1.90 m. Two kilometers inland, it is ± 1.60 m. Four and one-half kilometers toward the forest, at the site of the oldest ricefields, tidal variation is ± 60 cm, although this is offset in the ricefields by bunds. In the backswamps, tidal amplitude is slight, 20-10 cm at 6 and 7.5 km. During the year, the standing water levels are simultaneously influenced by tides and rainfall, but rarely exceed 50 cm in older fields closer to the Mentaya River or 1 m in the backswamps. During the dry season, soils dry to a depth of 2-5 m. At times the river is completely drained, navigation by boat is impossible, and drinking water is scarce.

Tidal inundation varies the salinity levels of surface water throughout the year. During the rainy season, the salinity is mitigated by rainfall, and salt levels are low. At the end of the rainy season, river water becomes increasingly salty until it is no longer potable. During the dry season, there is no available drinking water near the soil surface 4-5 km inland, although potable water can be obtained from deep wells. With the onset of the rainy season salt content gradually decreases and salinity generally does not affect rice plants.

Soils and pH

The soils in Semuda Kecil are of two types, resulting from the two processes of fluviatile sedimentation and peat formation. The former is classified as a Dystric Fluvisol, and is high in mineral content (FAO-UNESCO 1974, FAO 1977). Peat soils in the area are Histosols, and have an organic horizon averaging 44-62 cm (FAO-UNESCO 1974: cf. natural fluctuations in peat levels, Andriesse 1974:10-11). The peat is underlain by a highly organic mineral soil 50-60 cm deep, which gives way to a grey clay. The composition of these soils and the moderately shallow depth of the peat make them suitable for rice cultivation (Driessen 1978:771, Andriesse 1974:33-37).

Climatological, hydrological, and botanical regimes cause pH to fluctuate considerably in relation to field site distance from the Mentaya River and along secondary canals leading away from the Semuda Kecil River. During the wet season, the pH of standing water is 5.0 at the Semuda Kecil River mouth, 4.8-5.3 in older ricefields with coconut intercrop, and 4.5-4.8 in areas bordering the peat forest. The highest pH is along a secondary canal about 200 m from the river mouth, where it gradually increases from 5.0 to 6.3 about 200 m away from the Semuda Kecil River. In older ricefields, pH varies from 5.0 to 5.6 five km inland, while water covering newly opened forest remains stable at pH 4.5 during April, May, and the beginning of June.

CULTIVATION METHODS

Site selection and preparation

Rights to cultivate land in Semuda Kecil are awarded by the village head. Because land is plentiful, such rights are not difficult to obtain. A farmer can cultivate the land, own its resources, or transfer them to another person. The average size of a holding is about 1.5 ha.

The selected forest site is first cleared of weeds, shrubs, and trees. Most farmers employ hired labor to Cut down forested areas for land preparation. Clearing of a 1.5-ha site takes 20-22 workdays, and is done in July. Brush and weeds are cut first and then the trees are felled. The site is left to dry until mid-September, or just before the first heavy rains, and then burned.

In case of an incomplete burn, unburned branches are gathered, left to dry, and fired again. Except in the case of a good bum and a long dry season, newly opened fields are not cultivated for 1 or more years to allow larger trunks and branches to decay and settle in the peat. Larger trunks are sometimes moved to form an elevated, rough path for easier mobility in the peat lands.

Planting strategies

Although 156 t of rice was exported from the village during 1980, rice cropping is basically a subsistence activity.

Because of the unpredictable length of the dry season, variable depths of standing water in ricefields, and the desire to reduce labor expenditure, Semuda Kecil farmers have developed an extremely complex and variable rice cultivation system.

The rice cropping system incorporates 3 strategies: the *teronokan, tuggalan,* and *tabur* methods.

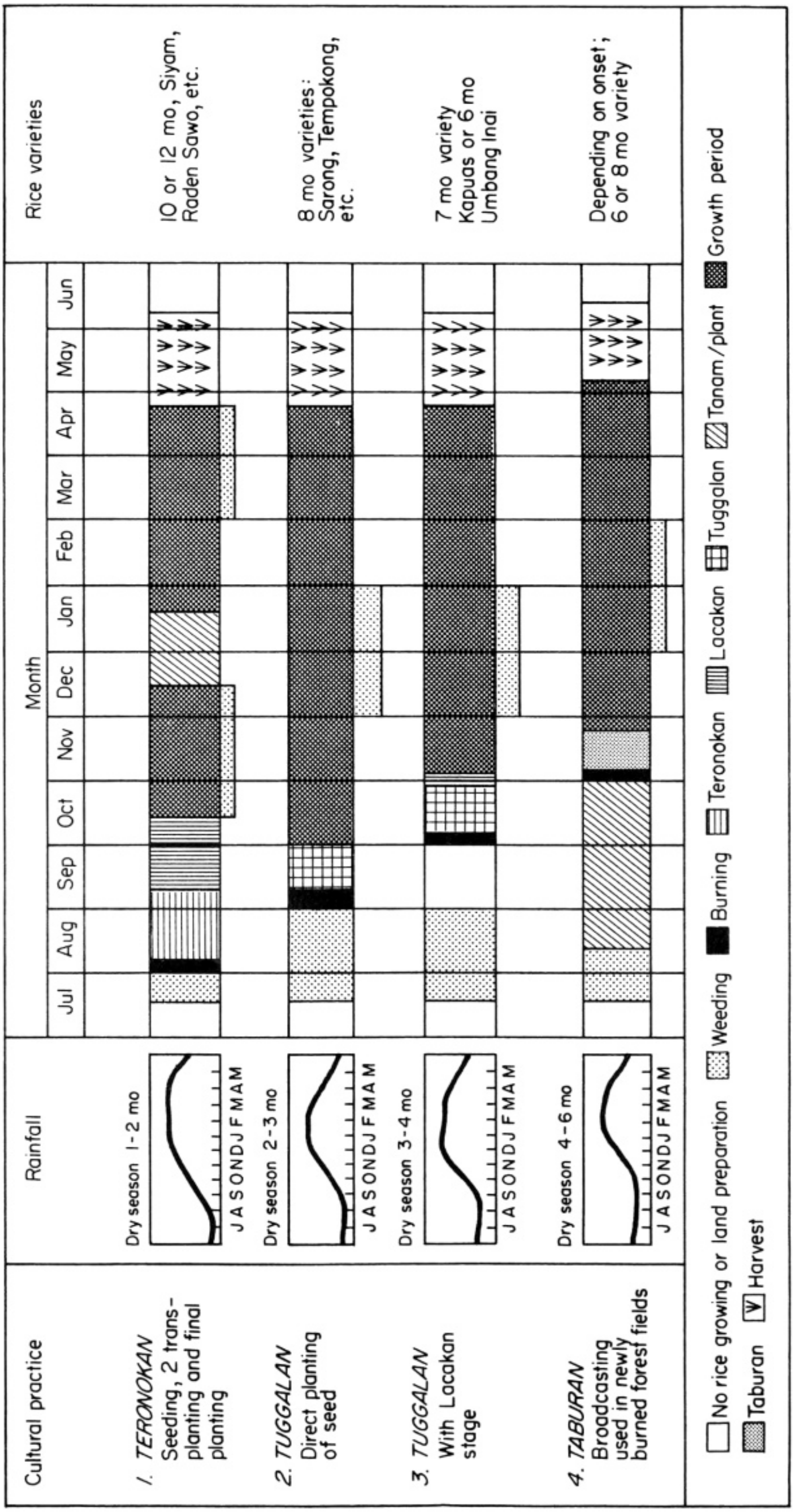
In each method, rice (varying in length and maturity) is transplanted to ripen at the end of the wet season. Harvest season begins in mid-April and ends in mid-June, with the major portion of the crop being harvested in May.

Teronokan cultivation

If the rainy season begins early, water levels will likely rise rapidly in September or October, and field inundation will be pronounced and prolonged. The onset of early rains means that tall, healthy seedlings that can withstand deep water and sporadic submergence must be planted. Ten-month varieties are used.

The method used for seedling propagation under these conditions is teronokan. This method includes a seedling nursery and intermediate transplanting of the rice plants before they are finally planted in the field. Teronokan nurseries are begun in July or August on drier ground in old fields or in front yards. Presoaked or unsoaked seeds are planted in holes 6-10 cm in diameter and 5 cm deep. About 100 seeds/hole are planted using a 2-m dibble stick. About 63 kg of seed is needed to produce enough seedlings to plant 1 ha. The seeds are covered with a thin layer of soil or dried weeds to prevent birds from eating the seeds. The seeds germinate in about 10 days; then the brush cover is removed and the seeds remain in the nursery beds for 20 more days.

At the end of the 20 days in the nursery, lacakan transplanting takes place. The seedlings from each teronokan hole are separated into 4-8 clumps and planted in plots bordering forest land. Residual moisture lasts longest there and the plants are more likely to survive drought. The seedlings are planted in 5 cm deep by 3 cm diameter holes spaced 25-30 cm apart. Seedlings remain in the lacakan stage until there are heavy rains for 5 days or until they are 15-45 days old. The lacakan seedlings are then dug, their roots are trimmed and their upper leaves clipped, and



2. Farmers' rice planting strategies in Semuda Kecil Village, Central Kalimantan, Indonesia.

the seedlings are separated into 3 or 4 parts and planted the final time. Seedlings are spaced 20 cm apart.

Final transplanting begins in more moist soil near the forest borders and continues toward drier land. That ensures plants subject to the most inundation will root and elongate first. The crop is harvested in May.

Farmers respond to an anticipated long wet season by:

- using later maturing, flood- and drought-tolerant varieties;
- transplanting to encourage growth, tillering, and elongation; or
- varying the length of the lacakan stage.

If the dry season is longer than anticipated, farmers can lose entire crops. Their loss is compounded by the large amount of seeds used to establish teronokan nurseries. Farmers who have a supply of a 6- or 8-month variety rice seed can resort to the tuggalan system.

Tuggalan cultivation

Tuggalan cultivation takes its name from the tuggal stick, a 60-cm-long planting tool that is used to make 3-cm-diameter holes in which rice seedlings are transplanted.

If the dry season lasts 3 months or longer, the probability of flooding or high water standing in the field is reduced. Water levels will rise only moderately in October or November. Moderate droughts are likely if the onset of the rainy season is sporadic. If the rains begin in October, standing water will reach a depth of about 1 m in back field swamps, and 0.5 m in older, more well-drained fields in January or February. Farmers use the tuggal cultivation method (Fig. 2) under these conditions and choose varieties that mature in 7-9 months and that are drought and flood tolerant.

Fields are cleared and burned in September or October before the onset of the first heavy rains. When the ground is soaked, the tuggal stick is used to drill holes 3-10 cm deep and 3 cm diameter about 30-40 cm apart; 10-15 seeds are planted in each hole. About 21 kg seeds is needed to plant 1 ha. If seeds do not sprout after a week, the holes are seeded again when the ground has sufficient moisture. If rains are moderate, a 1-ha field can be planted in less than a week.

If rainfall is excessive after tuggalan planting is begun, and standing water will apparently prevent rooting of seeds, a modified transplanting system is employed. Seeds that have been planted first in lower areas of the fields will have sprouted and begun to root. After 12-20 days, seedlings from the original planting are removed from their holes and separated: one seedling remains in the original site and the second seedling is transplanted to the inundated bare field. A prolonged dry season of 5 or 6 months may force farmers to use 6-month rice varieties. Early-maturing rice varieties generally are not submergence tolerant and unusually heavy downpours can cause rapid crop loss.

Most farmers prefer the tuggalan method. Because seeds germinate and grow to maturity where they are planted, there is no need for double transplanting. The tuggalan system requires about one-third the seed required by the teronokan method. Except for 6-month rice varieties, crops cultured by either method yield about the same.

The tuggalan system does leave the farmer open to the risk that his crop will be wiped out by floods. For this reason farmers tend to use both methods and incorporate 6-, 7-, 8-, and 9-month maturing varieties in the same field.

Tabur cultivation

Every 10 or 15 years a long dry season is followed by continuous heavy rains in October or November. Farmers who have newly cleared and thoroughly burned forest land can broadcast seeds. This seedling method is called taburan.

Tabur cultivation probably originated from the slash-and-burn cultivation practices of interior populations of Central Kalimantan. The layer of ash from the burned forest is an excellent fertilizer and seeds quickly root in the peat soil. The varieties used are of 6- to 8-month maturity.

Farmers report that yields from taburan planting in a new field are higher than those from older fields where tuggalan cultivation is practiced.

Harvesting

Rice is harvested between mid-April and mid-June, with most of the harvest done in May. This timed harvesting minimizes the risk of excessive bird or rat damage and ensures sufficient sunny days to dry the rice before the fields are overrun with rats. Because deeply flooded crops take longer to mature than shallow flooded crops, the practice of first seeding lower field areas helps synchronize the harvest. The seeds of exceptionally high yielding plants are preserved for the next year's planting.

Harvesting is done manually with ani-ani, a hand-held wooden tool with a razor blade as a cutting edge. Harvesting with a sickle is not practicable—panicles mature unevenly because of variations in the water level, and different varieties mature at different times. Rice is deposited in a large stiff basket carried on the back or in a smaller stiff basket carried in front at waist level. Harvesting is most often done by the immediate or extended family. In share harvesting, harvesters receive about 3.5 kg (about one-seventh share) of unhusked rice per day plus an afternoon meal. A farmer may also hold a *kebijaksanaan,* a 1-day harvest in which he or she invites friends or relatives and furnishes them a large meal in return for their labor.

Grain preparation and storage

Grain drying and threshing may be done in the field in structures specially built for this purpose, or grain may be prepared for storage in front of the farmer's home. Two methods of threshing are employed. In one method, the thresher stands on a platform and threshes by foot on top of an open weave mat through which grains fall through to another mat below. In the second method, the thresher stands on a mat piled with ripe rice panicles and threshes them with his or her feet.

There are four methods to winnow grain. The most efficient employs a wooden box with a handcranking mechanism to drive a fan that blows away the chaff. Two methods use the wind. In one, a worker sits atop a 3-m-tall platform and tosses threshed grain into the wind. Filled grains are caught on mats placed at the foot of the platform. Farm women may also place grain in a flat, square basket and toss the grain up and down in the wind. Some farmers load threshed paddy into a small canoe and fill it with water. That floats unfilled grains to the top.

Grain is dried in the sun 1 or 2 days and then stored behind the house or in a wooden storage bin inside. Grain is dehusked by a mortar and pestle or by having it milled by machine.

WEED AND WATER MANAGEMENT

Water management is done in two steps. During the dry season after the second harvest of newly-opened fields, farmers hire laborers to dig 40-60 cm deep, 1-2 m wide canals every 25.5 m throughout the field. These canals cause moderate drainage of the peat soils, making the soil surface drier and more suitable for rice cultivation.

In 4- to 10-year-old fields, the bunds are sometimes used to control standing water. Bunds constructed at the end of a canal nearest the Semuda Kecil River conserve the water runoff from the nearby swamp forest. Tidal fluctuation in the field is also reduced by bunding.

Farmers claim that canal building is necessary because a 2- to 3-year accumulation of decaying weeds and woody debris in the field reduces soil stability. In that case, rice plants cannot root firmly, and lodging and sterility increase. Labor efficiency is also diminished because walking in the fields becomes progressively difficult.

Weeding, and burning or piling of weedy materials is done before the final planting. Weeding late in the season depends entirely on the growth rate of weeds against rice plants. With the teronokan planting method, weeding is rarely necessary because the plants are already tall and healthy. In tuggalan cultivation, weeding begins 2 months after seed germination if weed growth is excessive. Weeding is tedious and clearing a 1-ha field requires one person working 6-8 hours a day for 2 months.

PESTS AND DISEASES

Animal populations

The 1981 rice harvest in Semuda Kecil suffered the worst rat damage in 7 years, probably because the 1980-81 dry season was long, and rains were moderate during the planting season. Birds are also a constant problem. Two parrot species feed on the rice crop and can carry off an entire panicle of grain. Rat poison is not widely used in Semuda Kecil. Birds are routed through the use of paper, cloth, and tin scarecrows placed in the field.

The rice bug is the most destructive insect pest in the Semuda Kecil area, significantly reducing rice yields annually. Because rice is grown continually in over 10-12 months, the pest is difficult to control. Rice bug nymphs and adults alike feed on the grain, so pesticides application and control has not been good (Mueller 1974).

The mole cricket is generally a minor pest in this tidal swamp region. The creature can attack the rice plant only when there is no standing water in the seedling or young plant stage (Moormann and van Breemen 1978). The mole cricket feeds on rice plants especially in lacakan fields and tuggalan sites when the rainy season is late.

Rice black bugs are omnipresent, but outbreaks are infrequent. Cutworms and armyworms infest flooded rice fields where they cause moderate to severe damage. Locusts are few and attack only occasionally.

Luwai is a disease that causes young teronokan seedlings to turn yellow, wilt, and die. It may be caused by mineral deficiencies in the soil. No direct observation of this problem has been made by the researcher.

Helminthosporium and Cercospora leafspot are widespread in all rice varieties. Damage is not severe, and appears to cover 0.5-3% of total leaf area(Jennings et al 1979), and may well be related to the salinity of the water (Mueller 1974), or the histolic nature of the soils (Moormann and van Breemen 1978).

NUTRITIONAL, HYDROLOGICAL, AND SOIL DEFICIENCIES

Salinity may inhibit the growth of rice plants, especially in deepwater areas where salt residues may accumulate (Mueller 1974). Farmers have to contend with the combined effects of the uneven soil surface, high water acidity (Furukawa 1980), and nutritional deficiencies of peat soils (Andriesse 1974, Anwarhan et al 1979, Van Wijk 1951, IBPGR-IRRI Rice Advisory Committee 1980). These problems are particularly severe near forested areas where water levels are deepest and acidity is highest. In general, plants in newly opened areas have lower tillering ability, exhibit partial panicle exsertion and partial awning (IBPGR-IRRI Rice Advisory Committee 1980), higher incidence of leaf spot, increased sterility, and more spotty growth than rice plants grown in older fields.

All plants exhibit moderate to good tolerance for drought or flooding.

On the whole, pH is not low enough to inhibit plant root formation (Soewardi et al 1980), but it almost certainly has adverse effects on rice production (Driessen 1978) in the backswamp lands.

VARIETAL CHARACTERISTICS

Rice varieties in the Semuda Kecil tidal swamp are diverse in height, flood and drought tolerance, and pest resistance (Table 2). Farmers can select appropriate varieties for diverse weather, soil, and water regimes. Because environmental factors change yearly, field management must be fine tuned. The range of plant types works in conjunction with the variable rice cropping methods to reduce the risk of crop loss and ensure adequate yields.

Rice varieties in Semuda Kecil can be roughly divided into three groups: 10- to 12-month varieties, which are predominantly from the Banjarmasin region of South Kalimantan; the 7- to 9-month varieties, which are predominantly medium to tall plants from the interior, tidal-influenced areas of Central Kalimantan; and 6-month varieties from Central and West Kalimantan, which show no flood tolerance and whose height suggests that they originated in a freshwater, nontidal zone.

Table 2. Rice crop mix by growth duration reported by farmers in Semuda Kecil, Central Kalimantan, Indonesia, 1980-81.[a]

Growth duration (mo)					Farmers reporting (no.)
10					1
10	9				1
10	9	8	7		1
10		8			2
10		8	7		1
10		8	7	6	1
10		8		6	1
10			7		1
	9	8			1
	9	8	7		a
	9	8	7	6	1
	9		7	6	1
		8			13
		8	7		38
		8	7	6	6
		8		6	3
			7		9
			7	6	1
				6	1
Total					91

[a] Farmers selected one or more varieties of rices of growth durations of 6, 7, 8, 9, and 10 months.

Farmers plant an average of three major rice varieties and seven or eight subsidiary varieties. Altogether 37 rice varieties are cultivated in the tidal region. Seven- to eight-month varieties are predominant although the ratios of differentially maturing rices varies annually. Varieties are 80–175 cm tall.

Ten-month varieties

The 10-month rices are invariably tall, drought tolerant, moderately to strongly flood tolerant and, except for Siyam, do not lodge readily. These characteristics are necessary for growth during an early rainy season, when water levels are high. Tillering ability is good (more than 20 culms/plant). Panicles are long, although the number of grains per panicle is moderate. Two varieties, Karang Dukuh and Siyam, have an excellent taste and command a high market price that may account for the predominant planting of Siyam by Semuda Kecil farmers.

Seven- to nine-month varieties

Two 9-month varieties, Palingkau and Lakatan Gadur, can be cultivated using the teronokan or tuggalan method. Farmers prefer the latter because the varieties are not drought tolerant. Palingkau provides a stopgap strategy for farmers who do not want to transplant twice. Lakatan Gadur has been recently introduced from the Banjarmasin area and is used on a limited area.

The 8-month varieties have been cultivated for various periods. The Lakatan group of glutinous rices are cultivated for sale in the market where they bring from $0.56 to $0.64/kg. Many families grow small stands of the crop for making desserts. Nonglutinous 8-month rice varieties vary considerably in height and lodging resistance. Allare at least moderately flood tolerant. Layang and Layang Kuning are widely used because they are resistant to rice bug and have high yields. Tempokong Putih is preferred to the better-tasting Tempokong Kuning, because of its greater lodging resistance. Farmers claim that Layang, Layang Kuning, Lakatan Lakatut, and Kapuas have bitter hulls which make them unappetizing to rats. Sarang Burung, a recently introduced variety is high yielding and has excellent ratooning abilities.

Kapuas, a 7-month variety, is high yielding and good tasting. It ratoons well and is resistant to rice bug but it tends to shatter and has weak stalks.

Farmer responsiveness to new ideas and methods is apparent in their long- and short-term modification of their farming systems. The 9-, 8-, and 7-month varieties were probably introduced when farmers began to extend their agriculture to the point where tidal influence was reduced. This would have called for integration of those earlier-maturing varieties — an aspect of long-term change that requires further research.

A recent and pronounced change in varietal use occurred through the introduction of Layang and Layang Kuning rices to the Semuda Kecil region 5 years ago. Farmers quickly recognized their higher yields, greater market value, and excellent eating qualities. Along with Kapuas, they are now the most widely used rice in the area.

Six-month varieties

The Umbang varieties have had long-term use in Semuda Kecil primarily because of their short growing period. These varieties are drought tolerant but submergence intolerant and are prone to lodging. They are short to medium, moderate to low yielding in the tidal backwater areas, and have poor ratooning ability. Panicle stalks of Gadabung, Umbang Inai, and Kencana tend to break at maturity.

Photoperiod sensitivity

Photoperiod sensitivity ensures that an indigenous rice variety will mature after a rainy season (IBPGR-IRRI Rice Advisory Committee 1980). This characteristic is frequently attuned to the flooding pattern of a particular region. The Semuda Kecil area is only recently settled, and has a more severe and variable climate than the South Kalimantan tidal region or many parts of interior Central Kalimantan. Because indigenous varieties are photoperiod sensitive, farmers can stagger rice cultivation and ensure that their crop will be harvestable after the rainy season in May.

YIELDS AND PLANTING STRATEGIES

Farmers report that rice yields vary depending on the location of rice fields and the number of years a site has been cropped. The standard harvest ranges from 1.3 to 2.0 t/ha. Yields may be as low as 0.7 t/ha on newly opened riceland, but land that cannot be cropped because of excessive water depth or buildup of woody debris is included in the yield calculation. Yields of 1.7 t/ha are considered excellent, although it is lower than in other tidal swamp areas in Kalimantan (Van Wijk 1951, Noorsyamsi and Hidayat 1974).

Agricultural development programs must promote food cropping systems strategies that are socially acceptable and environmentally sound. That is one reason for studying indigenous farming systems that are relatively well adjusted to their environment and for testing the hypothesis that traditional farmers are responsive to changes in their environment (Chambers 1974, Jecquier 1976, Barlett 1977, Rutz 1977, Vayda 1979). The resulting information is useless, however, if it does not provide developers with data on actual practices in an area. The theories farmers hold and their behavior may not intermesh.

In the following section, the planting practices of Semuda Kecil rice farmers will be charted against rainfall patterns and rice varieties used.

RAINFALL PATTERN AND PROBABLE RESPONSES

The 1980-81 dry season was long (Table 1). The previous season had been quite wet, and may have led farmers to assume that the dry season again would be short. Even moderate rains did not begin until October, although the relatively continuous rainfall from the middle to the end of the month would have produced conditions adequate for tuggalan seeding of 8-month varieties. Farmers would probably have burned the weed cover in the fields before October and taken advantage of the enriched soils. However, seedlings planted in October would have undergone minor drought stress for a few weeks because November rainfall was sporadic. But the rainy season never begins later than December, and farmers would have been assured of heavy rains shortly. Onset of the rainy season is heralded by almost daily downpours, but rains drop slightly as the new year begins. The rainfall data for 1980-81 (Table 1) show that rice crops propagated by the teronokan method would have undergone severe drought stress, and 9-month varieties would have been drought stressed in the seedling and tillering stages. Given the rainfall pattern for 1980-81, the wisest choices would have been 8-, 7-, and 6-month varieties.

Cropping history for 1980-81

Farmer responses to environmental conditions were mixed. Table 2 shows the rice crop mix by growth duration of 91 farmers in Semuda Kecil in the 1980-81 crop season. Table 3 shows the varieties of differing growth duration that farmers reported in their rice crop mix. Farmers often chose more than one variety of a given growth duration as part of their 1980-81 rice cropping strategies.

Nine of the 91 farm families raised a substantial portion of their 1980-81 rice crop in a 10-month variety (Table 2). Only one chose not to plant an earlier maturing variety to supplement his production of the 10-month variety.

Thirteen farmers included a 9-month variety in their crop mix and all of them used Palingkau exclusively (Table 3).

Seventy-six farmers planted at least one 8-month variety (Table 2), and 55 of them used the high-yielding variety Layang (Table 3).

Sixty-eight farmers included 7-month varieties in their cropping strategies and only 15 farmers planted 6-month varieties (Table 2). Of the 15 farmers who

Table 3. Characteristics[a] of rice varieties available to farmers in Semuda Kecil, Central Kalimantan, Indoneria, 1980-81 crop season.

Variety[b]	Height[c] (cm)			Tillers[c] (no.)			Drought tolerance			Submergence tolerance			Lodging resistance			Grains (no./panicle[c])			Glutinous[c]	Av yield (t/ha)		
	<125	125-135	>135	<16	16-20	>20	G	F	P	G	F	P	G	F	P	<275	275-375	>375		0.9	1.2	1.5
10-month varieties																						
Bayar Kuning (1)			●	●			●						●			●						●
Kamuning (1)			●	●			●						●					●				●
Karang Dukuh (0)			●			●			●				●				●					●
Raden Sawo (1)			●	●					●		●		●				●			●		
Sivam (6)			●		●		●				●				●		●					●
9-month varieties																						
Lakatan Gadur (0)			●		●				●	●					●	●			●		●	
Palingkau (13)		●			●			●			●		●				●				●	
8-month varieties																						
Banih Hirang (3)			●		●		●			●					●		●					●
Biji Nangka (11)			●	●				●			●							●		●		
Bilis (3)			●		●		●			●					●		●				●	
Darun (3)		●		●			●			●			●				●			●		
Delapan (2)			●		no data				●	●			●				●			●		
Gadibal (1)			●	●			●			●					●		●				●	
Katumbar (1)	●			●			●			●			●				●			●		

Kriau (2)			●			●		●			●				●		●				●	
Lakatan Hirang (3)		●				●		●		●					●		●		●		●	
Lakatan Kuning (2)			●			●	●			●					●		●		●		●	
Lakatan Lakatut (3)	●				●		●			●					●	●			●			●
Lakatan Pahu (1)		●				●	●		●	●					●	●			●		●	
Layang (55)	●				●		●			●			●			●						●
Layang Kuning (2)	●				●		●			●			●			●						●
Pekat (1)			●		●		●			●			●					●			●	
Sarang Burung (8)			●	●				●			●				●		●				●	
Sibung Tinggi (4)			●		●			●			●				●			●			●	
Tempokong Putih (22)		●		●			●				●		●					●		●		
Tempkong Kuning (8)		●		●			●				●			●				●		●		
7-month varieties																						
Kapuas (56)		●			●		●			●			●					●				●
Lemo (3)			●			●	●			●				●		●					●	
Randah Padang (28)		●				●		●			●		●					●		●	●	
6-month varieties																						
Kantol (0)	●			●			●					●			●	●				●		
Sibung Rendah (5)	●					●			●		●		●				●				●	
Umbang Gadabung (3)		●		●			●					●			●		●				●	
Umbang Kencana (1)	●				●		●					●			●	●					●	
Umbang Inai (7)	●			●			●					●			●		●			●		
Umbang Kabatik (1)		●			●		●					●			●		●			●		
Umbang Sampahitang (0)		●		●			●					●			●			●		●		
Umbang Putih (11)		●			●		●					●			●		●					

[a] G = good, F = fair, P = poor. [b]The number in parenthesis is the number of farmers who planted that variety. Because the 91 farmers surveyed often planted more than one variety of a particular growth duration, the totals of the varieties chosen exceed the number of farmers surveyed. For example, where Table 2 show that 76 farmers included 8-month varieties in their rice planting, this table shows that 55 of the 76 planted the 8-month variety Layang. [c]Measured by author.

planted 6-month varieties, 6 relied on those varieties exclusively, although they would have no crop if their 6-month varieties were subjected to high water levels, Only one farmer limited his crop to a 6-month variety in 1979-80.

Intercropping

Sixty-six farmers planted at least two rice crops of differing maturity as insurance against the loss of an entire crop during submergence or drought in the seedling stage. Kapuas and Layang, the two most preferred varieties (Table 3), were considered by farmers as the best choice under any circumstances – they are drought and flood tolerant, lodging resistant, high yielding, and command a high price.

Farmers apparently mixed rice culture techniques and varieties to suit environmental conditions. Only two farmers lost their rice crops to drought, and one farmer lost his 7-month crop because he planted it too early in the season. The cultivation system in Semuda Kecil seems to be responsive to environmental contingencies.

POSSIBILITIES FOR INTRODUCING HIGHER YIELDING TIDAL SWAMP HYBRIDS

New rice varieties presently being tested for tidal swamp areas in Indonesia are the 10-month Bayar and Siyam varieties and a few other tall types which use the transplant cultivation method (Subiyanto et al 1978, Siwi and Beachell 1980). Although these varieties could be incorporated in the teronokan cultivation system, the proportion of the yearly crop harvested in a 10-month variety is not likely to increase.

For the Semuda Kecil and Mentaya River area, a 7- or 8-month high yielding variety would probably receive widespread adoption. Layang and Kapuas are promising lines that could be used as parents for hybridization.

The 4-month PB varieties[1], which are presently used in South Kalimantan to double-crop rice fields, are not recommended for the Semuda Kecil area. These PB varieties were introduced in Semuda Kecil in 1976 with disastrous results. The normally high yielding plant bore an average of 5 tillers and did not undergo panicle initiation. The N fertilizer ran off in the heavy rains of the early wet season. The plant was not sufficiently tolerant of soil conditions, and lodging was severe. Plants could not root sufficiently well in the peaty soils where they had to be planted to ensure adequate moisture.

Presumably a 4-month drought- and flood-tolerant, lodging-resistant variety could be developed for the area, but improved land preparation and the introduction of a suitable 8- or 9-month rice probably would be wiser.

IMPROVEMENT OF RICE FIELD CONDITIONS

Minor adjustments in farming methods and techniques may considerably strengthen rice production in the Semuda Kecil area and remove the possibility of

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[1] Editors' note: PB = Peta Baru. PB5 is IR5, PB8 is IR8. It is not clear which PB variety is meant.

these lands being converted to coconut areas.

Green manuring (Team Inventarisasi Pasang Surut Kalimantan Selatan 1969) might be successfully incorporated with weeding practices in older fields. Weeds are cut and burned before tuggalan planting. That destroys or reduces the peat layer. Teronokan fields have the cleared weeds piled to one side, which ignores the potential composting properties of the weeds. Weed composting or green manuring would provide nutrients to rice plants over a longer period.

Ground leveling before planting should be encouraged. Farmers practice some leveling in older fields, but irregularly. Leveling is difficult or impossible in 1- or 2-year-old fields.

Harvests in newly opened swamp areas and older fields could be considerably increased through increased fertilizer efficiency. Fertilizer application now is wasteful and uneconomical because the fertilizers run off. Seed or seedling soak fertilizing is one method of increasing fertilizer efficiency.

The problematic nature of land subsidence in the tidal peat basin and subsequent drainage of excess water make the transition from rice cultivation to coconut cultivation the most practicable means of reclaiming the basin swamp. The maintenance of shallower irrigation (Noorsyamsi and Hidayat 1974, Guinness 1977, Hardjono 1977) and a reduction in burning may permit permanent rice cultivation.

CONCLUSIONS

Lack of adequate water control, the variable length of the dry season, and the low nutrient content of peat soils are major problems in the tidal swamp village of Semuda Kecil. These conditions lower rice yields and encourage short-term rice cultivation. Farmers have responded to the uncertainty of the climate and incidence of pest populations by incorporating diverse rice varieties into a three-method cropping system. This ecologically responsive agricultural system demonstrates the innovative, adaptive, and flexible characteristics of indigenous farming systems.

The Semuda Kecil area, and indeed all areas where cultivation has been practiced over a long period, can provide rice breeders with a natural genetic bank of microgeographically suitable crop types.

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RICE CULTIVATION IN THE TIDAL SWAMPS OF BANGLADESH

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Bangladesh has 10.4 million hectares under rice cultivation. Vast coastal areas are crisscrossed by innumerable rivers, canals, beels, and creeks. At high tide southern Bangladesh is inundated to a considerable depth. Usually, the water contributes to the nutrition of the growing rice plants, but uncontrolled it devastates rice fields.

Historically, the southern districts had a surplus of rice. They produced the famous, fine quality balam varieties preferred by city dwellers. At that time, the new alluvial soils were productive and population pressure was low. But with a rapidly increasing population and the decline in soil fertility, the area has become rice deficient. Bangladesh farmers at higher elevations have taken advantage of the high yield potential of modern varieties to increase rice yields, but to the marginal farmers in the tidal swamp area, the green revolution is still a dream.

Tidal swamps cover about 1 million hectares in the southwestern districts of Khulna, Barisal, and Patuakhali, and the coastal areas of Chittagong and Noakhali districts (Ahmed 1976). The area is between 21-23°N latitude and 89-92°E longitude (Fig. 1).

Rice cultivation in the tidal swamps is rainfed. Coinciding with the unimodal rainfall pattern, photoperiod-sensitive transplanted aman varieties are widely cultivated. These local varieties are tall, nonelongating, submergence tolerant, and salinity tolerant to some extent. In some areas local aus varieties are grown followed by transplanted aman. Boro varieties are grown to a limited extent along the river banks. Zero or minimum cultural practices are generally followed.

THE ENVIRONMENT

Rainfall pattern

Rainfall is unimodal and peaks in July. Adequate precipitation occurs from June to October. Table 1 shows monthly rainfall distribution at 10 sites; annual rainfall ranges from 213 to 375 cm, with an average of 286 cm.

Tidal pattern and water level in rice fields

The tide is semidiurnal, originates in the Indian ocean, and travels rapidly through the deep Bay of Bengal. It is directed toward western Bangladesh from the southwest (International Bank for Reconstruction and Development 1972).

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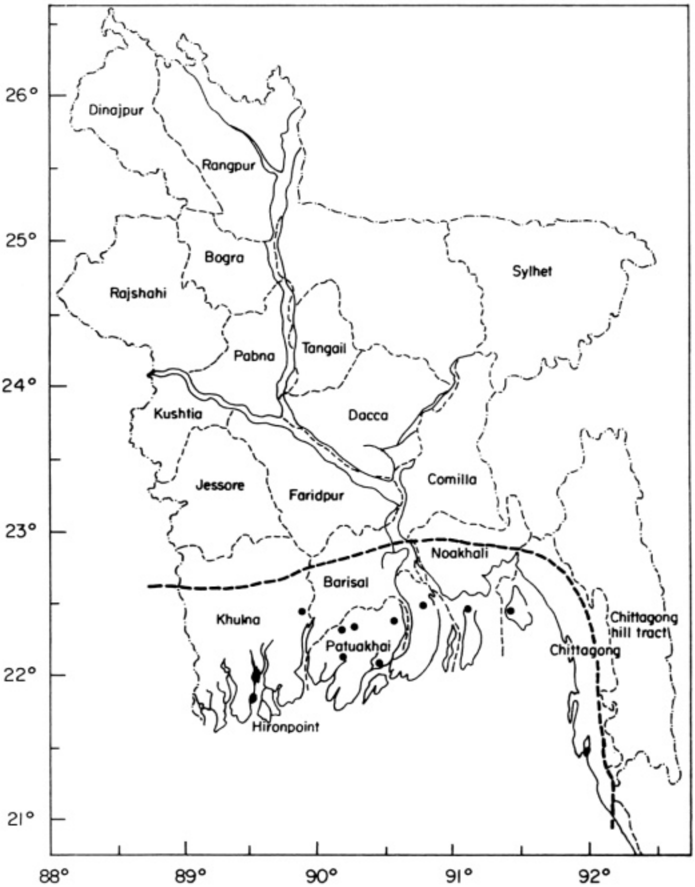

1. Tidal swamp area of Bangladesh.

Cyclones associated with tidal borers are common in the coastal districts during October-November and April-May. During a tidal bore, a rising wall of water with high waves inundates the coastal areas. Tidal bores affect even the Barisal regional station of the Bangladesh Rice Research Institute (BRRI) 60 miles north of the sea where the water level normally fluctuates between 40 and 80 cm during high and low tides (Table 2).

Tides increase at fortnightly intervals corresponding to new and full moons. The high tides inundate vast areas of rice fields and very often persist for 2-7 days, depending upon wind velocity. Seedlings are submerged during June and July because of high tides. Modern varieties are not suitable for this area because they cannot tolerate submergence.

Temperature

Average monthly maximum and minimum temperatures, and annual mean temperatures are given in Table 3. Average maximum temperature ranges from 25 to 33°C and minimum temperature ranges from 14 to 26°C. The diurnal range varies from 4-12°C. The main cropping season (June-October) has more or less constant temperatures.

Table 1. Mean monthly and annual rainfall of me tidal swamp areas in Bangladesh, 1900 to 1972.[a]

Site	Rainfall (cm)												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Morrelganj	1.2	2.2	4.2	7.6	16.4	40.2	49.4	43.5	28.5	16.8	2.9	0.7	213.7
Bamna	2.0	1.8	7.2	7.4	16.1	48.0	56.0	47.0	34.7	24.9	7.9	5.1	258.7
Barguna	0.9	1.9	5.1	8.5	20.5	57.6	65.7	57.0	33.6	25.2	3.8	1.3	281.0
Baufal	0.9	1.4	4.4	9.8	20.4	47.7	56.5	48.7	36.0	17.8	4.9	1.2	249.9
Galachipa	1.2	3.0	6.3	10.4	15.0	54.1	57.5	68.2	49.1	37.2	8.4	4.2	314.5
Patuakhali	1.3	2.4	6.1	11.1	27.0	59.5	65.9	58.6	40.5	27.9	5.9	1.3	306.7
Burhanuddin	0.8	2.6	4.9	11.8	21.0	56.3	54.0	52.2	43.1	21.3	9.3	4.9	282.3
Hatia	0.9	2.4	6.5	13.3	29.8	57.1	69.6	67.0	44.3	25.3	7.6	4.8	328.4
Katubdia	2.5	2.7	7.2	12.1	27.8	65.0	81.8	75.0	36.3	19.9	8.4	5.8	344.5
Sandwip	0.6	0.7	3.9	18.7	26.0	67.4	94.2	84.4	43.8	28.6	5.1	2.3	375.6

Source: Manalo (1976). [a]Data for at least 35 years at each site.

Table 2. Monthly maximum and minimum tidal marks in transplanted aman seasons at Barisal Regional Station, Bangladesh Rice Research Institute, 1979-80.

Date	High tide marks (cm)			Date	Low tide marks (cm)		
	High-land	Medium land	Low-land		High-land	Medium land	Low-land
13 Jul 1979	56	71	86	16	0	18	33
8 Aug	87	102	117	4	3	18	33
8 Sep	46	61	76	30	5	20	35
6 Oct	49	64	79	15	0	0	0
27 Jun 1980	15	30	45	15	0	0	0
30 Jul	64	79	94	10	0	0	0
28 Aug	74	89	104	6	0	8	23
8 Sep	51	66	81	20	0	0	0
5 Oct	33	48	63	12	0	0	0

The soil

The tidal swamp soils are separated into five groups (The International Bank for Reconstruction and Development 1972).

Heavy clay soil. Heavy clay soil predominates central and northern Barisal and Khulna districts, but loams are also found on ridges. Soils are slightly to moderately saline in the dry season.

Heavy loamy soil. Bhola subdivision of Barisal and coastal areas of Chittagong districts have heavy loamy soil. Soils are slightly saline during the dry season.

Acid sulfate soil. The soils of Sundarbands of Khulan and Chakoria of Chittagong districts are acid sulfate. The condition is more severe in southwest Sundarbands.

Alluvial silts. Western Bhola is composed mainly of alluvial silts.

Calcareous silts. Calcareous silts occur in southern Noakhali and the islands of Hatia, Ramgati, and Sandwip. Most of the islands have been provided with coastal embankments, but breaches may occur in the outer embankments by normal coastal erosion or overtopping during cyclonic storm surges.

Salinity

The effects of salt water intrusion have long been recognized as a limiting factor to the full development of agriculture in southern Bangladesh. There are three problem regions in the tidal swamp area:

Khulna region. Penetration of salinity with a concentration of 1,000 ppm extends about 85 miles inland. The salinity is somewhat opposed by the freshwater flow in the Gorai/Modhumati River and by local inflows via the Kobadak and Nabogonga Rivers.

Noakhali region. The Bara khal/Noakhali khal, the little Feni River, and other small drainage outlets are subject to tidal influences and salt intrusion.

Barisal and Patuakhali region. Salinity of 1,000 ppm penetrates only about 25 miles inland. Saline intrusion is apparently limited by freshwater mainly from the lower Meghna.

Cropping pattern

Different cropping patterns are followed in the coastal plains. The most common practice is to grow a single transplanted aman rice with photoperiod-sensitive,

Table 3. **Mean monthly maximum and minimum temperature in tidal swamp areas in Bangladesh. 1900-1972.**[a]

Location		Temperature (°C)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Noc	Dec
Barisal	Max	25.8	28.3	32.4	33.8	33.4	31.8	30.6	30.8	31.4	31.2	28.8	26.4
	Min	13.4	16.2	20.9	24.2	25.6	25.7	25.8	25.8	25.9	24.3	19.1	14.6
Noakhali	Max	25.9	27.7	31.0	32.3	31.9	30.6	29.9	30.1	30.5	30.7	28.7	26.4
	Min	14.0	16.6	21.1	24.4	25.5	25.7	25.8	25.7	25.7	24.4	19.6	15.3
Khulna	Max	26.3	29.2	33.4	34.6	34.3	32.6	31.2	31.3	31.7	31.3	29.1	26.7
	Min	13.6	16.1	21.0	24.2	25.6	26.1	26.2	26.2	26.0	24.3	19.1	14.7

Source: Manalo (1976). [a]Data for at least 35 years at each site.

traditional varieties. Some farmers at higher elevations grow broadcast aus followed by transplanted aman. Jute, mungbean, and chilies sometimes precede the aman crop. Another widely distributed cropping pattern found in the area is broadcast aus combined with broadcast aman. The broadcast aman is different from the typical deepwater rice and is essentially nonelongating.

CULTURE

Land preparation

Land preparation is minimum for rice cultivation in the tidal swamp areas. Normally one or two plowings are done in standing water with or without laddering (pulverizing the soil). For sowing aus or other crops in the dry season, more plowings and ladderings may be done.

Seedling nursery

Seedbeds are prepared in strips at higher elevations, usually near housing settlements and in kitchen gardens, which do not receive tidal water. Sometimes floating seedbeds are prepared on banana rafts loosely tied to bamboo sticks so that they rise and fall with the water level. A dense seeding rate is used to allow seedlings to grow taller. Seedlings are transplanted at 6-8 weeks; often they start tillering at transplanting.

The land is usually prepared when the fields have 20-30 cm water; transplanting is at low tide. Plant spacing is 40-50 cm between hills with 6-8 seedlings/hill. More seedlings in a hill create a bushy canopy to cover open spaces and balance the resulting seedling mortality due to the shock of sudden uprooting and initial submergence. Physiologically mature seedlings have tolerance for tidal submergence of 3-7 days.

The *para* method is another common practice in the tidal swamp area. Pregerminated seeds are thickly sown in the field when there is no standing water. After they are established, tidal flow is allowed to resume. When the seedlings attain a height of 60-90 cm after 40-50 days, some are pulled, leaving the rest at regular spacing. The pulled seedlings are transplanted in another field.

Fertilizer practices

Farmers do not apply chemical fertilizers, but after harvest the ,rice stubble is burned and incorporated into the soil. Tidal water carries silt and nutrients that add to soil fertility. Tidal swamp areas are rich in potassium. Because of standing water, application of nitrogen fertilizer is ineffective and not practiced. Deep placement of fertilizers in the form of mud balls, however, may be tried.

Weed management

Weeds generally are not a serious problem in the tidal swamp areas. Grasses, sedges, and some water weeds are the common ones. If weeding is done at all, handweeding is the only method practiced.

Water management

Tidal water cannot be controlled, but in some areas coastal embankments regulate the flow of saline water into rice fields. They also conserve fresh rainwater within the embankments. Farmers occasionally construct levees around their plots to hold the water in.

Harvesting, drying, and storage

Tidal swamp rice varieties mature at about the same time (November and December). This results in an acute shortage of hired laborers and harvesting is often delayed. The varieties have strong seed dormancy, hence they do not germinate in the field. The crop, which is from 1 to 1.5 m tall, is cut about 30 cm above the ground with sickles and tied into bundles. The grain is threshed in the open, either by beating the bundles against a metal drum or by having cattle trample them. The threshed grain is hand winnowed, sun-dried, and stored in bamboo baskets or big earthen pots.

VARIETIES

Potentials and limitations of the present varieties

Tidal swamp rice varieties are essentially tall, nonelongating, and photoperiod sensitive. Some varieties such as Rajasail and Kajalsail mature early and can avoid drought that can follow the early termination of the monsoon. Varieties such as Kumragoir, Kachamota, and Dudmona are submergence tolerant and to some extent salinity tolerant. But most traditional varieties are susceptible to lodging and many diseases. BRRI recently conducted a survey of the available germplasm resources of the country. About 600 varieties were identified in the tidal swamp areas, but only a few have been collected. The popular traditional varieties are

District	*Variety*
Barisal	Aguni, Bashful, Bashpair, Betichikon, Bhikos, Bochuri, Badai chikon, Betag, Chengai, Chaulamagi, Depos, Dudkalmi, Dholamota, Dhal-kachua, Garcha, Gheos, Ghanda kastori, Haldegota, Joina, Kalajira, Kala-gora, Kalamona, Kalamatari, Kartiksail, Kaialsail, Kutisail, Kutiagni, Kumragoir, Kholni, Lotor, Lakma, Latamona, Lalmota, Lalchikon, Lohasura, Matichal, Monteswar, Monor, Noldok, Nonasail, Nona-korchi, Patijal, Parijat, Rajasail, Rupeswar, Seetabhog, Sadamota, Sadachikon, Sakkar-khora, and Tepusail.
Patuakhali	Bohuri, Chaprash, Chingrigushi, Gopalbhog, Kachachikon, Kutiagni, Kharigojal, Laxmibilash, Matichak, and Seetabhog.
Khulna	Bajramuri, Ghunsi, Hoglapata, Horkacha, Jamailaru, Khejurchari, and Nona-korchi.

Table 4. Performance of some local tidal swamp rice varieties and advanced breeding lines. Seeded 24 June 1980 and planted 6 August 1980, BRRI, Barisal, transplanted aman, 1980.

Rank	Variety/line	Parentage	Plant ht (cm)	Flowering date	Duration (days)	Yield (t/ha)
1	Ka chamota	–	138	16 Nov	188	3.6
1	Dudmona	–	154	11 Nov	173	3.6
3	Kajalsail	–	137	6 Nov	1 65	3.5
3	Kumragoir	–	155	12 Nov	177	3.5
5	BR111-124-2-1	DA29/IR20	135	31 Oct	157	3.4
6	Garcha	–	143	9 Nov	167	3.3
6	BR4 (ck)	IR20/IR5-114-3-1	108	12 Nov	169	3.3
8	BR111-140-1-1	DA29/IR20	142	1 Nov	158	3.2
9	BRB11-461-1	IR8/SR26(B) T.C.	137	30 Oct	156	3.1
10	BRB8-2B-74	IR20/Kumragoir	132	22 Oct	149	2.6
11	BRB11-448-14	IR8/SR26(B) T.C.	132	10 Nov	166	2.3
12	Rajasail	–	111	7 Oct	134	2.1

Noakhali	Garcha, Ghigaj, Modhumalati, and Nakpechi.
Chittagong	Ashail, Ajabbeti, Chakkol, Chandmoni, Gheos, Gobindabhog, Lembura, Moidal, Modhumalati, and Nakpechi.

Some of these varieties could easily yield 3-4 t/ha (Table 4). But their potential is never realized because of the prevailing cultural practices and climatic factors.

BRRI-released BR3, BR4, BR10, and BR11 are not popular in the coastal areas because of their photoperiod insensitivity and their inability to survive occasional submergence. At higher elevations, these varieties have shown merit.

Breeding objectives

Although considerable progress has been made in breeding rices for the irrigated and rainfed areas of Bangladesh, research on tidal swamp rice has lagged behind. Two regional rice research stations for the tidal swamp areas have been established at Barisal and Noakhali. The breeding objectives for tidal swamp adapted varieties are

- photoperiod sensitivity,
- taller seedlings and intermediate plant height,
- tidal submergence tolerance,
- salinity tolerance,
- disease and insect resistance,
- fertilizer responsiveness,
- lodging resistance,
- acceptable grain quality, and
- high yield.

So far more than 80 crosses have been made with the leading traditional varieties such as Kumragoir, Kachamota, Kajalsail, Dudmona, Hoglapata, and with modern varieties such as IR8, IR20, BR4, BR10, and BR11. Some F_1 and F_2 materials are being evaluated.

PESTS AND DISEASES

Insects and diseases of rice in the tidal swamp areas are the same as those in other parts of the country. The known insects are rice stem borer, hispa, thrips, leafroller, mealybug, rice caseworm, swarming caterpillar, and ear-cutting caterpillar. Bacterial leaf blight, bacterial leaf streak, leaf scald, stem rot, brown spot, sheath rot, and sheath blight are the major diseases. Recently ufra, a nematode disease, has been found.

Pest control measures are not generally practiced unless insects or diseases become epidemic. Then the Plant Protection Department sometimes uses aerial spraying to control the ear-cutting caterpillar or hispa. Individual farmers rarely use insecticides as sprayers and insecticides are scarce.

CURRENT RESEARCH

To attain self-sufficiency in food, Bangladesh must increase its rice yields in vast tidal swamp areas. This poor region can prosper only through the development of high yielding rice varieties along with related technology. The present low average yield of 1 t/ha in the tidal swamp areas can, with appropriate technology and inputs, be increased substantially.

BRRI research programs for improving tidal swamp rice are concentrated on varietal improvement and improved cultural practices.

Varietal improvement programs include

- collecting all the germplasm of the area,
- screening germplasm materials for submergence tolerance,
- hybridization of local materials with modern varieties and selecting suitable plant types, and
- testing new materials in the regional stations and in farmers' fields.

Some trials on fertilizer management and other cultural practices are being conducted. A senior breeder has been posted at the Barisal station; the Noakhali station is still being developed.

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RICE CULTIVATION IN THE TIDAL SWAMPS OF THAILAND

S. ARUNIN and D. HILLERISLAMBERS

Tidal lands of Thailand are in the coastal area of the Central Plain, the southeastern coastal area of the Gulf of Thailand, and along both sides of the Southern Peninsula extending to the Malaysian border. Rainfall, tidal movements, salinity, and fresh water supply from rivers and rainfall differ from region to region and rice varietal needs differ accordingly. During the past several years, varietal trials with local and introduced cultivars in the Central Plain coastal area have shown potential benefits from salinity tolerance and local adaptation, the latter being of overriding importance. Breeding strategies and land improvement procedures to improve rice culture in Thailand's tidal lands are discussed.

The tidal land areas of Thailand are divided into three parts: the coastal area of the Central Plain near Bangkok, the southeastern coastal area near Chantaburi and Trat, and the southern swamps widely distributed along both sides of the Southern Peninsula that extends from Chumporn to the Malaysian border (Fig. 1).

The tidal swamp rice production is mainly in the Central Plain and along the east coast of the Southern Peninsula (Fig. 1). The area devoted to the tidal rice cultivation is 358,000 ha in the Central Plain, 346,000 ha in the Southern Peninsula, and 112,000 ha in the southeastern coastal area.

ENVIRONMENT

The soils

Active tidal flats. The soils of the active tidal flats are mostly clayey Hydraquents and Sulfaquents. They were formed from recent marine sediments and occur in essentially level tidal swamps with elevations not more than 1 m above sea level. Most of the soils (Tha Chin Series) have high moisture content, low bearing capacity, low sulfur content, and some calcium carbonates. They are not potentially acid and have soft, reduced, greyish green mud clay within 50 cm of the surface.

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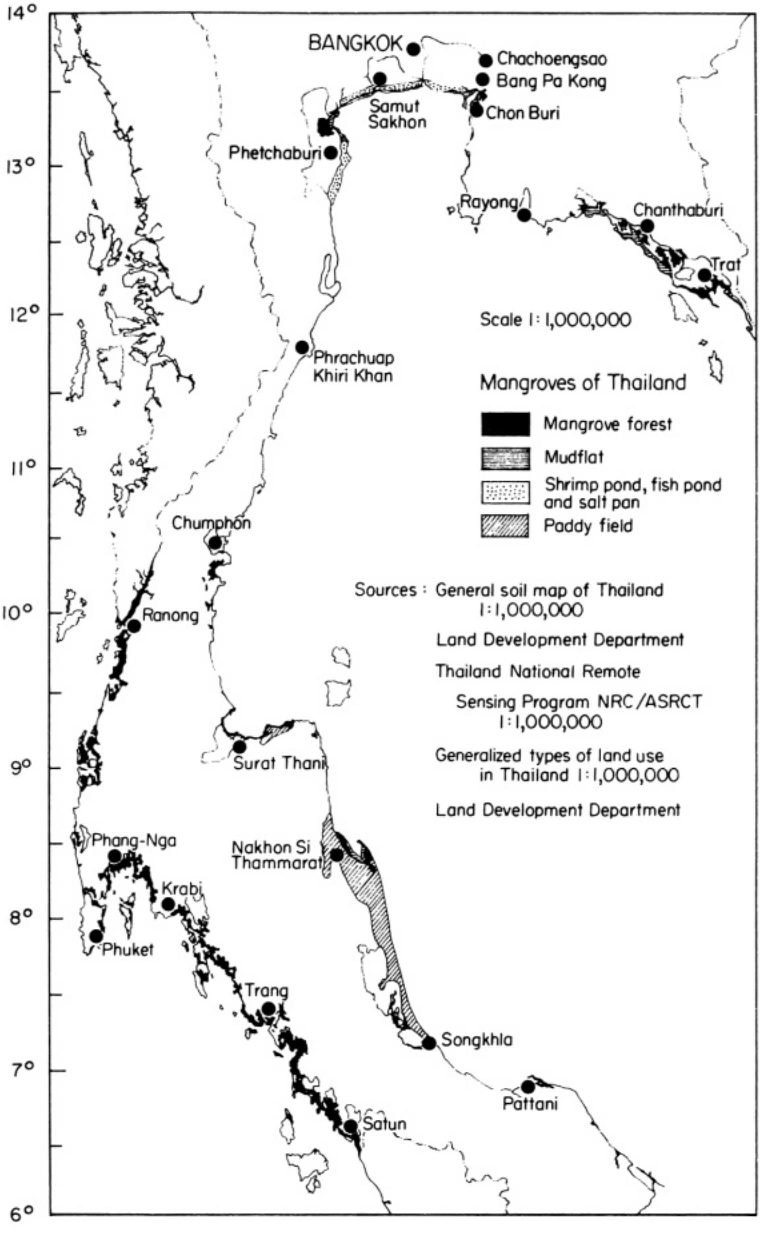
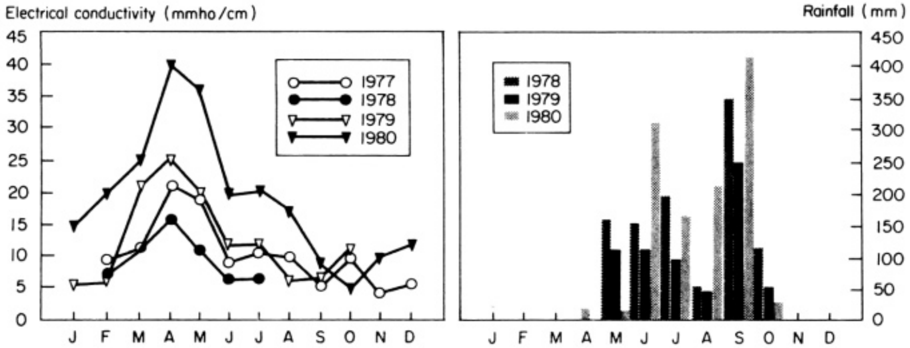


Sources : General soil map of Thailand 1 : 1,000,000
Land Development Department
Thailand National Remote Sensing Program NRC/ASRCT 1 : 1,000,000
Generalized types of land use in Thailand 1 : 1,000,000
Land Development Department

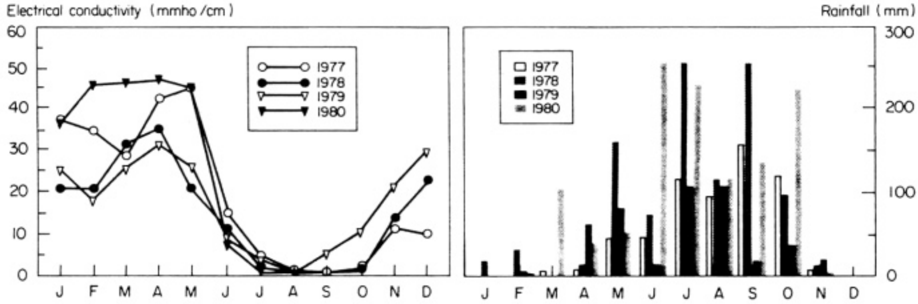
1. Tidal swamp land of Thailand (Van der Kevie and Yenmanas 1972).

In some small areas there are potentially acid soils (Bang Pa Kong Series) that are also soft and lack calcium carbonates. The active tidal flats of about 600,000 ha are used for (or left to) mangrove forests, fishponds, and salt pans.

Former tidal flats. Former tidal flats of 600,000 ha are farther inland. Soils are clayey and some loamy acid Tropaquepts, formed from marine and brackish water deposits (Bangkok series). They are no longer subject to tidal flooding. Relief is



2. Rainfall and salinity patterns at Samut Sakhon Station, Thailand.



3. Rainfall and salinity patterns at Bang Pa Kong Station, Thailand.

flat, with elevation ranging from 1.5 to 4 m above sea level. In a narrow zone just behind the mangrove swamps are similar soils, somewhat less ripened and still slightly saline (Samut Prakan Series).

Former tidal flats mainly support transplanted rice although there are some coconuts and other tree crops.

Salinity

Salinity of the tidal swamp areas gradually decreases inward from the seashore. It is caused by flooding with seawater during the high tides and ingress of seawater along the estuaries, creeks, drains, and rivers, especially in the dry season. Generally, salinity of the water in the estuaries and creeks in the rainy season fluctuates, depending on the amount of rainfall in the area, tidal movements, and discharge of fresh water from the inland area (de Glopper and Poels 1972).

Figures 2 and 3 show rainfall and salinity patterns of the water in the creeks at Samut Sakhon and Bang Pa Kong Stations. The salinity as measured by electrical conductivity (EC) ranges from 2 to 6 mmho/cm in the rainy season, which starts in June or July, and increases sharply to 15-30 mmho/cm during the dry season. After the drought of the last few years, the salinity of the water was higher than usual in both wet and dry seasons. Consequently, water in the creeks during the wet season was used even if its salinity exceeded the limit for irrigation water. With initial soil salinity of more than 10 mmho/cm, using the brackish water with 2-4 mmho/cm would be a reasonable measure to leach out the salt.

Rainfall

Rainfall tends to reduce the wet season salinity of the irrigation floodwater in tidal lands. Rainfall data from the Meteorology Department showed the average annual rainfall between 1951 and 1975 was 1,491 mm for the Central Plain and 2,160 mm for the southeastern coastal area. The west coast of the Southern Peninsula had a higher average annual rainfall than the east coast (2,942 mm vs 2,098 mm).

The general rainfall patterns of the coastal areas of the Central Plain and the Southeast and Southern Peninsula (east and west coasts) are shown in Figure 4.

The main coastal rice-growing areas of the country are in the Central Plain and on the east coast of the Southern Peninsula. In the Central Plain the rainy season ranges from 120 to 160 days; in the Southern Peninsula it is 180 days or more. As a consequence, the main rice varieties grown in these regions differ in growth duration. Farmers have 2 weeks to a month for desalinization, depending on the initial level of soil salinity.

Tidal fluctuations

Tidal curves differ markedly among localities (Fig. 5). The tidal curve at Laem Sing (southeastern coast) is diurnal (Hydrographic Department 1973). Bangkok Bar (coastal Central Plain area) has mixed diurnal-semidiurnal. The tidal curve for Pattani (east coast of the Southern Peninsula) is irregular semidiurnal and that of Phuket (west coast) is regular semidiurnal.

The tidal curves plotted at the mouths of the three main rivers emptying into the Gulf of Thailand near Bangkok correspond closely to the tidal curve at Bangkok Bar and are not presented in this paper. Many large and small creeks are connected to the main rivers, but the tidal range in small creeks is much smaller than that in large creeks.

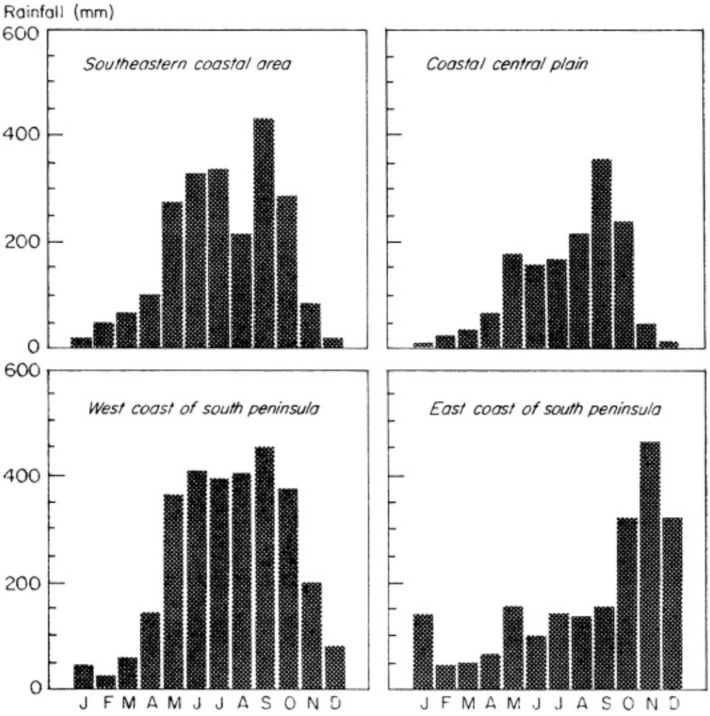
Land use

The pattern of land use varies among as well as within the three tidal land regions, depending on geography, environment, and socioeconomic conditions (TISTR 1980).

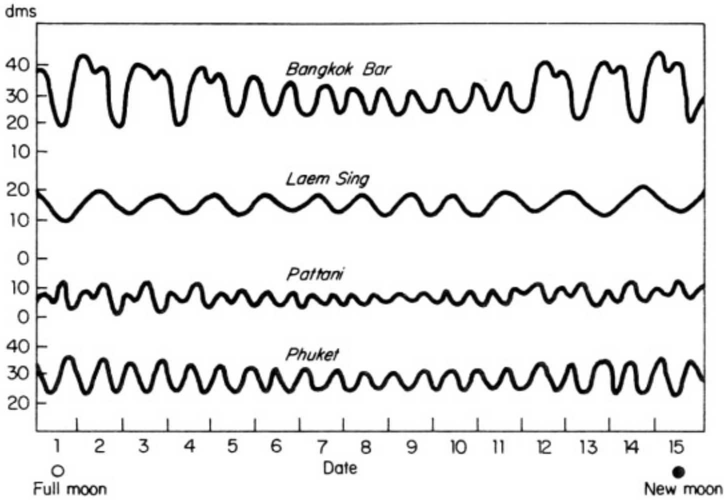
The major part of the tidal swamps is in the coastal area of the Central Plain. The coastal area extends from east of the mouth of the Chao Phya River to the Bang Pa Kong River, then from Chon Buri, and west of the Chao Phya River covering Tha Chin and Mae Klong Rivers to Petchaburi.

Present uses for land in the tidal area vary considerably, but all are adapted to brackish to saline conditions (de Glopper and Poels 1972). The highly saline land close to the sea is used for shrimp, fishponds, or salt pans, or is under saline swamp vegetation, primarily mangrove and nipa palm with some grasses, rushes, and sedges, and scattered bare spots. Coconut and horticulture occur near the tidal lands where creek water is fresh during part of the year. Rice cultivation is further inland and mostly in areas where water is fresh throughout the year.

Rice experiments were carried out at two tidally affected sites: Samut Sakhon and Bang Pa Kong, west and east of the Chao Phya River. The area around Samut Sakhon has coconut and other horticulture crops, while rice cultivation becomes important further inland. In Bang Pa Kong, rice cultivation is most common, with shrimp and fishponds closer to the sea.



4. Rainfall pattern of coastal areas of Thailand.



5. Tidal curves at some areas in Thailand.

RICE CULTIVATION

Farmers in tidal swamp areas provide land with high bunds and sluice gates to control the water level in the rice fields. Water level fluctuations in such fields do not go beyond 60 cm. The farmers usually grow only one crop per year, but in areas under an irrigation scheme two rice crops can be obtained. When water salinity in the creeks is low (usually June or July), farmers prepare land and seedbeds. At the beginning of the spring tide when the seedlings are about 60 days old, they are transplanted into the fields that have been flushed to leach out the salt.

Direct seeding has not been successful in areas where soil salinity is high and water is frequently deep. But elsewhere, farmers direct-seed pregerminated seed. Azolla has been introduced in some fields, but cannot survive at an electrical conductivity value higher than 4 mmho/cm.

Nitrogen and phosphorus fertilizers are applied at low rates as basal and topdressing with small amounts of ammonium sulfate. The fields are harvested during November and December.

Rice varieties grown are tall or intermediate depending on the water level in the rice fields. Tall traditional local varieties — Gaw Diaw Bow, Khao Tah Oo, Khao Pak Maw, and Khao Dawk Mali — are used because they give reasonable response to low rates of applied fertilizers. The farmers prefer nonglutinous, long-grain, and intermediate-amylose types. They use photoperiod-sensitive varieties in the wet season and photoperiod-insensitive varieties in the dry season when good quality irrigation water is available. Seedlings, 50 days old or older, are transplanted.

CURRENT RESEARCH

Reclamation of salt-affected soil

Leaching of soluble salts by flooding has been most effective in areas unfit for rice cultivation, provided that the groundwater level can be controlled by opening and closing the access to the creek (de Glopper and Poels 1972). At the beginning of reclamation, the soil salinity increased with depth, from 8 to 44 mmho/cm. Flooding 7 times (from 1975 to 1978) with creek water of low salinity levels leached out 40% of the soluble salt from the profile of 0-100 cm. The most desalinized depth of the profile was 20-60 cm (Tandatemiya 1979b).

In another desalinizing trial, field ditches 1.5 m deep and 10, 15, 20, and 30 m apart were constructed. Intrusion of brackish water was controlled through bunds and culverts. The results showed desalinization with ditches up to 20 m apart. Those that were 30 m apart produced much less desalinization (Tandatemiya 1979a).

Field screening rice varieties for salt tolerance

Local rice germplasm was collected from different saline soil areas. Some were supplied by the Rice Division and some through IRRI. Between 1976 and 1980, yield and survival trials at Samut Sakhon and at Bang Pa Kong tested local varieties and foreign introductions with low basal applications and topdressing of nitrogen and phosphorus fertilizers (Hongto 1980, Sinanuwong 1980). Because of the high salt content of the soil and poor water quality in the dry season, the screening tests were confined to the wet season. Harvest was in November and December. The varietal composition changed for every test because poor performers were progressively discarded for new materials.

Table 1. Varieties with good adaptation to local conditions or acceptable yield levels in Samut Sakhon and Bang Pa Kong Stations, Thailand, 1976-80.

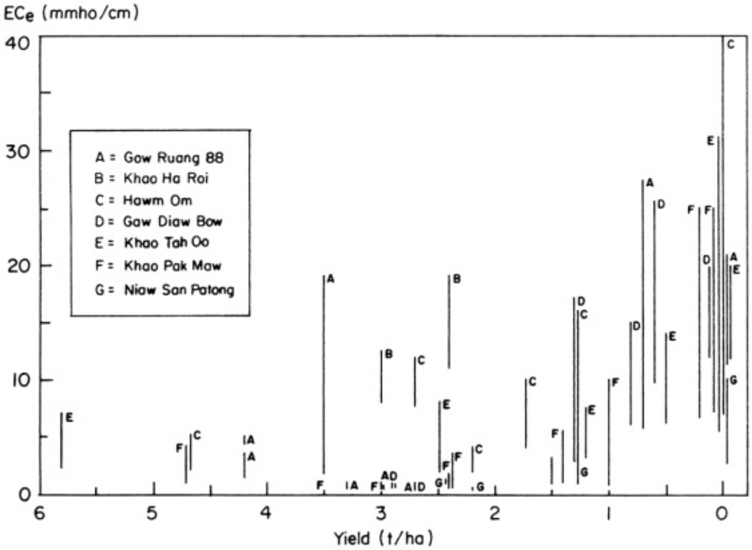
Variety	Av yield (t/ha)	Av salinity score[a]
Thai traditional		
RD8	3.5	3.4
Niaw San Patong	3.1	3.7
RD6	2.9	3.0
Khao Dawk Mali 105	2.7	3.7
Hawm Om	2.7	3.0
Gaw Diaw Bow[b]	2.0	2.6
Khao Tah Oo[b]	1.8	3.1
RD15	1.6	4.4
Gow Ruang 88	1.5	3.2
Khao Tah Haeng	1.5	3.6
Khao Pak Maw[b]	1.3	5.9
Foreign traditional		
SR26B	2.1	2.2
Patnai 23	2.0	2.9
Getu	1.8	3.6
BG11-11	1.8	3.7
Nona Bokra	1.5	4.2
Pokkali	1.3	3.2
Thai modem		
RD11[c]	3.4	2.3
RD9	2.6	3.7
RD3	2.1	2.5
RD1	2.0	3.5
RD2	2.0	2.5
RD5	2.0	3.5
RD4	1.7	3.0
RD7	1.5	4.0
IR modem		
IR2071-1054-5	2.2	3.9
IR2070-820-2-3	2.2	6.2
IR4630-22-2-17[d]	1.8	4.7
IR45954-1-1336	1.7	3.9
IR2061-522-6-9	1.6	3.8
IR4432-28-3	1.5	4.7
IR2153-263-5-2	1.2	5.2

[a] 1980 Standard Evaluation System for Rice: 1 = growth and tillering nearly normal, 9 = almost all plants dead or dying. [b] Currently popular variety. [c] Data from only one experiment. [d] Pokkali is one parent.

The entries that performed best in the various trials are listed in Table 1. The main varietal characteristics are

- ability to recover, especially during the flowering stage, after long exposure to salinity;
- growth duration to fit into the low salinity period (July to October) as shown in Figures 2 and 3; and
- ability to withstand fluctuating salinity levels.

Figure 6 shows the yields of seven Thai varieties under different salinity ranges



6. Yields of 7 varieties grown under different salinity ranges. Bars indicate the range of EC_e during the growing period.

during the growing season. Gow Ruang 88, Khao Ha Roi, and Hawm Om yielded more than 2 t/ha at peak electrical conductivities (extract) well over 10 mmho/cm. Khao Ha Roi and Hawm Om were subjected to minimum conductivities of 8 mmho/cm or more.

There seems to be an association between better yield performance and lower (more resistant) salinity tolerance scores. This association is by no means complete, however; local Thai varieties yielded highest at relatively susceptible salinity reactions (Fig. 6). RD11 and RD9, both Thai modern varieties, have the highest yields at low salinity scores; IR2070-820-2-3 with a very high score also has a high yield. Thus salinity tolerance scores by themselves are insufficient to explain the performance of the varieties tested. Other traits may be as important.

FUTURE BREEDING STRATEGY

Varieties for tidal lands near the Central Plain should have the following traits:

- *Appropriate maturity date.* Varieties should not mature too early, in the middle of the rains, nor should they flower too late and risk growth at increased salinity levels. November harvesting dates are common to all locally successful Thai traditional varieties in the adaptation test. Modern varieties are grown in bunded areas where the water levels can be manipulated and photoperiod sensitivity is not a requirement.
- *Suitability for late transplanting.* The uncontrolled-water areas need varieties that can withstand late transplanting — up to 60 days seedling age. Such varieties should be photoperiod sensitive or must have a long basic vegetative period.
- *Salinity tolerance and avoidance.* During the growing season, salinity levels

equivalent to electrical conductivity of around 5 mmho/cm may be encountered (see Fig. 3), and the crop has to be out of the field before salinity rises to intolerable levels.

- *Drought tolerance.* Drought tolerance is necessary to survive low tides and lack of rainfall up to 14 days during the rainy season.
- *Good growth and yields with low fertilizer applications.* Adaptation to current farmers fertilizer practices implies the need for tall stature in areas of uncontrolled water levels.
- *Submergence tolerance.* Tall plants are one way of increasing survival after submergence. Submergence tolerance has not yet been evaluated as a potentially useful trait for the tidal areas of Thailand.
- *Resistance or tolerance for pests and diseases.* Resistance to brown planthoppers, stem borers, and blast and tungro diseases is needed.
- *Tolerance for high sulfur content.* Plants for some continuously flooded acid sulfate areas need tolerance for high soil sulfur.
- *Acceptable grain appearance.* Long, slender, nonchalky grains and intermediate amylose content are desirable. The variety Khao Dawk Mali 105 is becoming popular, and new varieties should approximate this high quality variety.

It is clear that introduction of varieties, be they salinity-tolerant Indian varieties or IRRI lines derived from them, is not the answer to the varietal needs of the tidal lands of the Central Plain. Salinity tolerance is an important factor in the survival and yield of rices in the coastal tidal area, and that trait appears to have its highest expression in varieties from outside Thailand (Table 1). A crossing program with adapted Thai varieties and salinity-tolerant foreign varieties can be helpful. Hybrid progenies should be tested in fields under farmers' conditions. The possibility of reducing plant height while at the same time increasing submergence tolerance should be evaluated.

Physiological screening

Some salt-tolerant rice varieties undergo physiological and morphological changes to survive under saline conditions. Tolerant varieties grown in salinity develop smaller vascular bundles and thicker cuticles and cell walls than when they are grown in the absence of salinity (Land Development Department 1980).

Agronomic improvement of survival percentages

To increase survival percentage, simple trials were set up to study the effects of number of seedlings per hill (Disataporn 1980), age of seedlings, and spacing on the survival and grain yield of rice (Land Development Department 1980). Soil amendments such as rice hulls, gypsum, and manure were applied at different rates to assess their effectiveness in reclaiming salt-affected soil for rice growing (Land Development Department 1980).

Preliminary results (Land Development Department 1980) show that closer spacing and older seedlings lead to higher survival and more grain yield. Moderate amounts of gypsum and rice hulls seem to increase survival because they facilitate leaching the salt.

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RICE CULTIVATION IN THE TIDAL SWAMPS OF SAMBORONDON, ECUADOR

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The major rice areas of Ecuador are less than 10 m above sea level. The tidal swamp rice areas, which are below the 3-m elevation, are a portion of all swamp rice areas called *pozas veraneras.* The Samborondon project area is shown in Figure 1.

This paper emphasizes the many types of data, observations, and subjective decisions necessary to determine and develop solutions to the problems of rice production in the tidal rice swamps of Ecuador, particularly on the lower Guayas River floodplains below Samborondon. Interamerican Bank and World Bank loans have supported the Instituto Nacional de Investigaciones Agropecuarias (INIAP) participation in the project.

Pozas veraneras are shallow depressions that fill with fresh water during the January-May rainy season and are transplanted to rice as the water level recedes during the long May-December dry season. The area elevation is lower than 2.8 m at maximum high tide and higher than 0.8 m at minimum high tide. Some pozas veraneras, however, are now outside the range of tidal influence. This paper concentrates on the areas between 0.8 and 2.8 m elevation in the Samborondon project. The areas are within the potential tidal range, but silting of tidal estuaries and roads has isolated most of them from tidal influence. Future roads, drains, and tidal gates could use the positive effects of the tidal range and reduce the negative effects on perhaps 50,000 ha of tidal swamp rice.

Pozas veraneras yields average about 3.2 t/ha on 25,000 ha and are about 25% of Ecuador's annual rice production.

Farms are small with an average rice area of 3.1 ha per agricultural production unit in the 1974 census. The special environment has favored manual methods and small farmers; the Ecuadorian rice farmer has much in common with his Asian counterpart.

THE ENVIRONMENT

Temperature pattern and the Humboldt Current

The Humboldt Current creates a desert climate along the Pacific coasts of Chile, Peru, and about half of Ecuador. This cold current lowers the average monthly

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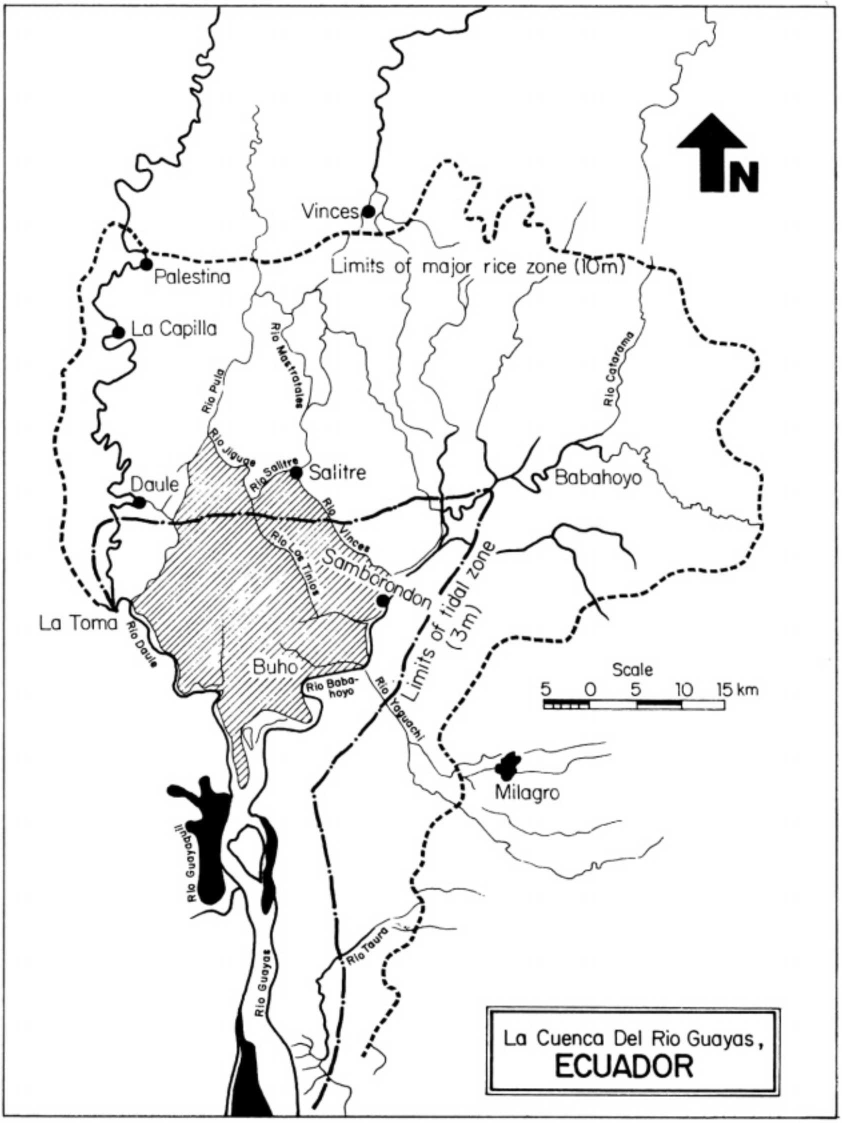


1. Rice-growing areas of Ecuador.

temperatures of Guayaquil to between 24 and 25°C while equivalent sites in Asia have average temperatures of 27 to 28°C. The seasonal change of 2°C in average temperature seems small, but is important to the rice farmer. The cold waters of the Humboldt are nearer the coast of Ecuador during the dry season and during dry years.

As the warmer waters of the Niño Current displace cold waters of the Humboldt, the wet season begins and its length increases in proportion to the time and distance of seasonal and annual displacement. Temperature and rainfall are largely determined by the position of the two currents.

Table 1. Average monthly precipitation for given periods in the rice areas of Ecuador.[a]

Month	Precipitation (mm) Guayaquil 1926-75	 Milagro 1926-75	 Babahoyo 1930-75	 Vinces 1949-50 1964-75	 Daule 1949-52 1963-75
Jan	216	332	374	337	247
Feb	276	384	444	309	228
Mar	297	386	435	375	276
Apr	175	230	347	243	169
May	52	73	99	105	84
Jun	14	13	27	62	19
Jul	2.0	4.5	6.0	2.6	9.3
Aug	0.5	0.8	1.0	0.9	0.9
Sep	0.8	2.6	2.9	12	0.8
Oct	3.0	4.2	7.4	11	2.6
Nov	3.5	5.8	5.1	9.8	0.4
Dec	25	52	66	84	53
Annual	1064.8	1487.9	1814.4	1551.3	1090.0
1939 maximum annual	2120	3218	3536	2289[b]	1846[b]
1968 minimum annual	397	495	635	750	438

[a] Data adapted from Heras Rodriguez (1980). [b] Maximum annual precipitation recorded in 1965.

Rainfall pattern

Rain begins in late December and virtually stops in May (Table 1). There are floods from January until mid-May and severe drought from August until late December. The monthly rainfall varies greatly with time and site within the rice area. Guayaquil and Daule receive less rainfall than Milagro and Babahoyo. Average rainfall exceeds 150 mm/month from January through April. But during dry years, such as 1968, the annual rainfall may be less than 500 mm. During years with maximum rainfall, such as 1939, the greatest monthly rainfall exceeded 1,000 mm at some sites, and the annual rainfall ranged from 2,000 to 3,500 mm in the rice area.

River discharge pattern

Rio Guayas is formed by the junction of the Rio Babahoyo and Rio Daule in Guayaquil. The two major rivers discharge an average of 35,500 million m^3/year into the Ocean — enough to irrigate more than 2 million ha of rice if it were available where and when it was needed. The problem is that the river discharge pattern closely follows the rainfall pattern (Table 2). Maximum discharge occurs so near 19 March that it is traditionally referred to as the San Jose annual flood.

The Daule-Peripa Dam, now under construction, is expected to conserve 6 billion m^3, or about 50%, of the normal Rio Daule discharge. The dam will significantly alter the Rio Daule discharge pattern. Additional storage sites will be needed to fully utilize the water. There are no major water storage sites on the Rio Babahoyo and Rio Daule except for the 25,000 ha of swamp rice, which store between 120 and 240 million m^3 of water for the dry season.

Table 2. Maximum, average, and minimum computed discharge from the Rio Babahoyo and Rio Daule into the Rio Guayas in Guayaquil, Ecuador, for the period 1926 to 1975.[a]

Month	Discharge (million m³)					
	Rio Babahoyo			Rio Daule		
	1939 max	1926-75 av	1968 min	1939 max	1926-75 av	1968 min
Jan	3,832	2,718	1,457	1,672	989	182
Feb	9,276	5,120	2,554	3,547	1,909	620
Mar	10,280[b]	5,410	2,834	5,678	3,127	809
Apr	9,810	4,613	2,164	5,006	2,427	794
May	5,606	2,525	1,060	2,934	1,293	187
Jun	1,573	1,083	502	647	609	101
Jul	1,188	660	312	612	316	77
Aug	738	370	218	313	162	62
Sep	540	285	214	210	119	54
Oct	527	278	216	202	103	45
Nov	404	257	215	155	88	41
Dec	1,036	758	225	365	293	33
Total	44,810	24,077	11,971	21,341	11,435	3,005

[a] Data adapted from Heras Rodriques (1980). [b] Original publication value was 1,280, an apparent error changed to 10,280 as best estimate.

Table 3. Salinity[a] in the Rio Babahoyo and the sum of the average monthly flows of the Rio Vinces and Rio Zapotal into the Rio Babahoyo, Ecuador, 1978-79.

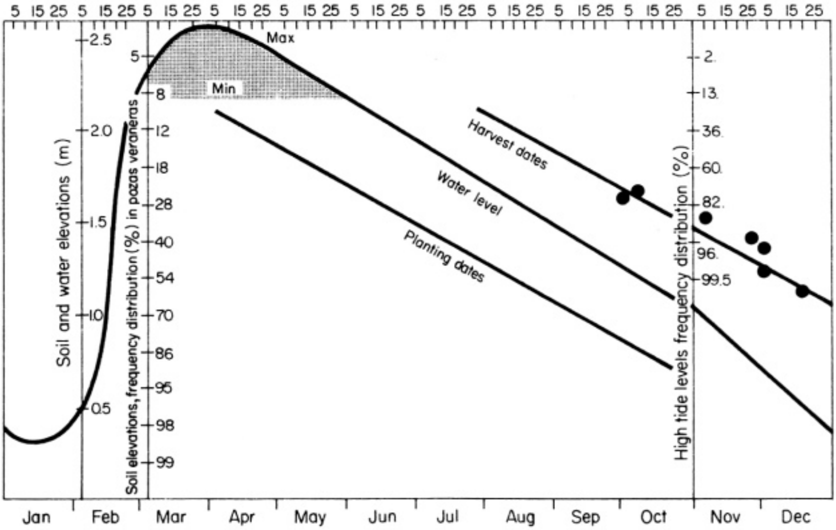
Month	Electrical conductivity (mmho/cm) at indicated distance from junction with Rio Guayas					Sum of av monthly flows (m³/s)
	0	10 km	20 km	30 km	40 km	
Jun 1978	2.4	0.32	0.18	0.12	0.11	209
Jul	7.0	2.7	1.06	0.42	0.15	114
Aug	12.0	6.5	3.4	2.2	0.32	72
Sep	16.0	10.4	8.2	5.6	2.6	54
Oct	19.0	33.8	10.0	7.4	5.1	43
Nov	22.0	17.0	13.0	7.5	3.5	34
Dec	23.0	16.0	10.2	7.0	3.8	53
Jan 1979	6.8	2.1	0.50	0.16	0.12	194
Feb	0.18	0.14	0.14	0.10	0.082	561
Mar	0.16	0.12	0.11	0.092	0.086	1053
Apr	0.11	0.11	0.094	0.088	0.086	725
May	1.4	0.24	0.14	0.14	0.120	325

[a] Salinity data from Aviles Cervantes (1981) and Mestanza (1981) (unpubl.). Av flows from CEDEGE (1980, unpubl.).

Tidal patterns

The high tides range from 1.2 to 2.8 m above sea level. Low tides are 1.2 m to 1.6 m below sea level in the Guayas River, low enough to leave the tidal estuaries completely drained at low tide.

The farmer in the tidal swamp rice zone adjusts his schedule to the tide each day. He drains his fields at low tide and fills them at high tide. He plans his boat trips according to the tidal height and direction of flow. The highest tides, which



2. Soil elevations, water and high tide levels, and distribution in the *pozas veraneras* areas of Ecuador.

coincide with the new moon and full moon every 14 days, bring water further inland and assure an extra 0.5 m to 0.7 m tidal range for a few days. The farmer uses this extra water even though its salinity is higher than normal.

Salinity patterns

The salinity of the Rio Babahoyo varies greatly with time, tide, and seasonal river flow (Table 3). There is an almost linear increase in electrical conductivity (EC) with time and with distance from mid-August until mid-October. The maximum salt content occurs nearer the ocean or at maximum high tide; the minimum occurs in areas farther from the ocean or at low tide. This tidal excursion or the correction for time and distance between low and high tide ranges from a distance 10 to 20 km and can change the EC at one site from 3.5 mmho/cm to 12 mmho/cm between low and high tide (Waite 1976).

General description of the soils and water levels

Because the soils in the tidal swamp rice zone were deposited by tidal action, more than 95% of the land is less than 2.8 m above mean sea level. Floods and tides greater than 2.8 m that deposit silt or clay are rare, and any points above 2.8 m are usually man-made for *house* sites. The lowest areas planted during 1980 were 0.8 m above mean sea level and about 3 km from the nearest functional tidal estuary. They dried out for planting in October 1980 and were harvested during mid-January 1981.

Figure 2 shows the tidal effect on the Guayas River for 1979, and the height of the water and percent of area flooded at different water levels for 1979, 1980, and part of 1981. Most of the tidal swamp rice soils are marine clay deposits due to the flocculation of the clay mineral in highly saline waters late in the dry season. This reaction of the clay particles and the saltwater rapidly silts up tidal estuaries when excessive vegetation reduces the erosive tidal velocities.

Table 4. Average grain and straw production, and other data from 141 crop cuts. Ecuador, 1980.

Date	Crop cuts (no.)	Variety	Straw (t/ha)	Grain (t/ha)	Elevation (m)			Soil pH	Electrical conductivity (mmho/cm)
					Field	Water	Difference		
				Farmers' fields in pozas veraneras					
1 Oct	20	Brasilero	9.3	4.0	1.62	1.23	.39	6.0	0.957
7 Oct	20	Donato	8.4	4.7	1.65	1.18	.47	5.7	0.814
6 Nov	10	Pico Negro	8.1	5.8	1.52	0.99	.53	5.6	1.636
26 Nov	10	Pico Negro	10.1	2.6	1.44	0.77	.67	5.6	2.155
3 Dec	4	Pico Negro	10.3	6.1	1.38	0.68	.70	4.7	5.50
3 Dec	6	Brasilero	5.9	4.9	1.25	0.68	.57	5.0	3.62
18 Dec	10	Donato	6.6	3.7	1.14	0.49	.65	4 2	3.885
				INIAP [a] varietal trials					
20-26 Nov	9	(INIAP trials of 9 varieties)	6.7	3.7	1.36	0.70	.58	4.29	4.14
				Farmers' tidal swamp					
21 Oct	10	Pico Negro	11.5	3.4	–	Tide	–	5.25	7.62
23 Dec	10	Pico Negro	12.6	4.9	1.56	Tide	–	5.37	6.75
				Farmers' irrigated fields					
14 Oct	10	INIAP-6	9.9	5.9	2.65	1.14	1.55	6.7	4.400
30 Oct	10	INIAP-6	13.7	3.5	2.95	1.04	1.91	6 5	5.070
20 Nov	12	INIAP-6	3.8	2.4	2.60	0.84	1.76	6.8	3.100

[a] Instituto Nacional de Investigaciones Agropecuarias.

Because much of the soil is under fresh water for several months each year, the top 0.5 m is leached of salts annually. Late season irrigation with high salinity water on higher elevations, however, results in problem soils. Thirteen sites were harvested during 1980. Nine to twenty circular crop-cuts of 10 m^2 each were made at each site. For each sample, yields of grain and straw as well as site elevation, soil moisture, pH, and EC were recorded (Table 4). There was significant correlation between yield and elevation on some sites, and between yield and pH and EC on others. The average production of 9.0 t straw/ha and 4.2 t grain/ha under a wide range of soil and water variables indicates the adaptability of swamp rice varieties and farmers in Ecuador.

Cropping pattern

Between the elevations 2.5 to 7 m, small farmers direct-seed most of the higher land to dryland rice with the first rains in January to fully utilize the short 4-month wet season. The National Rice Program (1978) reported that in 1975 52% of the farmers used the *espeque* system (the farmer opens a conical hole with a pointed stick, places 30 to 40 seeds in the hole, and covers it with his foot). The espeque method depends upon rainfall and shallow flooding over the river banks. Farmers harvest rice in May and June and plant a second crop of maize and beans by the same espeque method.

The larger farmers with adequate water control may direct-seed with a drill, but more often they puddle the soil and direct-seed from an airplane. They usually plant the first rice crop in January or as soon as good quality irrigation water is available. This crop is harvested in May and June and followed by a second crop if adequate water is available. The second crop may require the use of water with EC of 4 to 7 mmho/cm during the last 30 to 60 days.

The tidal swamp rice at elevations of 2.1 to 2.5 m may be espeque-planted with the first rains of January and survive the shallow floods. This area is minor at present, but shows promise. Most of the tidal swamp rice farmers transplant tall seedlings in 35 cm of water as the water level falls over a long season from March until September. Very few areas are planted after mid-October or below 0.8 m because of the high risk of February floods (Fig. 2).

CULTURE

Land preparation

Flooding. Flooding is the most important phase of land preparation in the swamp rice area. The farmer welcomes early and deep flooding that completely submerges and destroys existing vegetation. Weeds that are not submerged by late, shallow flooding must be cut below the water and submerged or removed to leave a clean, flooded field before transplanting. Long flooding softens the soil for transplanting and converts the organic matter into nitrogen for the rice crop.

Grazing. Cattle grazing is an important part of land preparation. The cattle owners place large herds of cattle into the swamp rice areas from late November until the heavy rains begin in January. This extra, late season pasture is necessary because of the drought from May until January, and the overgrazing of the higher pastures. Grazing after the rice harvest controls vegetation until the rainy season begins. Some rice growers charge a small fee for permission to graze. Often the cattlemen graze their herds without permission, causing damage to the late-season rice before harvest or to the direct-seeded early planting.

Plowing. Small farmers often use a disk plow to control weeds not grazed by cattle and those difficult to control by machete and flooding. The weedy areas are plowed and left to dry in the late dry season.

Manual cleaning and burning. Certain weeds and grasses as well as the rice straw are gathered and burned in the late dry season before the rains make burning impossible.

Planting methods

Seedling nurseries are established on levees and high knolls which were once house sites. These are above the normal flood levels so that the seedling nurseries are under upland conditions. The seeds are pregerminated and 30 to 40 seeds are planted 10 cm apart by espeque. Water is splashed daily on the nursery if there is no rain. The constant moisture and occasional use of extra nitrogen fertilizer sometimes result in blast disease in the nursery. After 30 days the seedlings form a dense hill about 30 cm tall, which can be easily pulled as a complete unit for the first transplanting. The first transplanting is necessary to give the seedlings more space and time to elongate. The seedlings (as a complete unit or bunch) are transplanted about 30 cm apart in water about 15 cm deep. For the next 20 to 30 days the seedlings grow and become conditioned to the water, but the dense clusters apparently delay tillering until the final transplanting.

The final transplanting of 50- to 60-day-old seedlings is in water 25 to 35 cm deep. About 6 to 8 seedlings are placed in hills 40 cm apart. The average planting density ranges from 4.8 to 12.8 hills/m^2.

Regression analysis of 10 to 20 samples/site indicated no yield difference within sites due to hill density. The relatively wide spacing of 4-8 hills/m^2 reduces the labor cost for transplanting and manual harvest as well as the risk of lodging and blast on the tall varieties used by the farmer.

Fertilizer practices

Cuello and Maldonado (1980) report that only 15% of the swamp rice growers used fertilizer, and there were no significant differences in yields. INIAP data for 1979 and 1980 showed no significant difference in yields in numerous fertilizer trials on swamp rice in the Samborondon Project area. The evidence to date indicates that fertilizer is uneconomical for Ecuadorian swamp rice, but fertilizer application at panicle initiation has not been tested.

Weed management

Transplanting tall seedlings into deep water in weed-free fields essentially eliminates any weed problem in the swamp rice areas of Ecuador.

Water management

During the wet season, farmers block the main drains to retain water for flooding their fields rapidly and deeply to reduce land preparation and weed control costs.

Later water is released to maintain normal flood levels of 2.25 to 2.50 m.

If the normal decline in water level is less than the nursery schedule, water is released from April to July to lower the water level for transplanting of old seedlings.

From June to August water is readily available. Water from the lower *pozas* is pumped to irrigate the higher areas left dry by the 5-7 mm/day decline in water level. Lateral seepage from the high areas returns to the pozas, irrigating the intermediate areas. The spread of water over a larger area results in a more rapid decline in water level — from 6 mm/day without pumping to 8 mm/day with pumping.

From August to September water supplies become scarce. Each farmer blocks his drain outlets to retain his lower pozas for supplemental irrigation of his higher fields. He and his neighbors try to open the tidal estuaries and connecting drains to replenish their water supply.

From September to December water supply becomes critical because of blocked drains, silted and weedy tidal estuaries, and salinity in the Rio Babahoyo. Farmers with adequate water from lower pozas or tidal action have good yields; those without additional water suffer either yield reductions or total losses.

Water stress. Water stress may be estimated as days without standing water or as millimeters of total water stress. The water level decline of 6 to 7 mm/day is a good estimate of total rice water requirements as observed in Ecuador (Fig. 2) and reported by Wickham and Sen (1978). The initial water depth of 250 to 350 mm is adequate for 40 to 50 days, but an additional 60 to 80 days and 360 to 560 mm of water are needed to complete the rice crop. In Ecuador pozas veraneras with no supplemental water after 50 days suffer severe to total loss in grain yield. Wickham and Sen (1978) reported that IR20 yielded an average of 6.2 t/ha under no stress and 0.5 t/ha under stress from 20 days before flowering until harvest. The difference in water use between the two treatments was 435 mm, equivalent to the supplemental water required to complete a poza veranera crop.

Cuello and Maldonado (1980) reported 67 pumps for 75 farmers with 855 ha of pozas veraneras. The farmers had an average pump capacity of about 60 liters/minute per ha. During 1980 the farmers used a 3-inch pump for 100 to 140 hours/ha. At 540 liters/minute, the 3-inch pump supplied 324 to 454 mm water. The supplemental water applied by pumps is very near the approximate difference of450 mm observed between the elevation of fields being harvested and the water surface in nearby pozas (Fig. 2).

Yield reduction. The decrease ingrain production for 3 replications and 9 lines in pozas veraneras with one irrigation was 7.5 kg/mm of water deficiency at flowering (Ampuño 1981). Eleven of twenty-seven nonirrigated plots were harvested for grain. Eighteen of twenty-seven plots with one irrigation of 100 to 150 mm of water 41 days after transplanting (DT) were harvested for grain. The INIAP-6 plots flowered 15 days after the single irrigation and produced 2.2 t/ha from the residual soil moisture. No grain was produced in 3 replications of 3 lines that flowered from 35 to 50 days after the single irrigation.

Yield reduction and yield productivity refer only to grain. A better estimate of the importance of water would be the total dry matter production (TDM) vs water used in evapotranspiration (ET).

Total dry matter. IRRI (1967) reported TDM productivity vs ET as 23.6 kg/mm water. A water requirement investigation in Japan (Tokai-Kinki Agric. Exp. Stn. 1965) gave the equivalent productivity of TDM of rice grain and straw as 22.8 to 32.6 kg/mm water.

De Wit (1958) reported TDM productivity of cereals as 24.5 kg/mm for wheat, 26 kg/mm for oats, and 32 kg/mm for maize.

Grain production. Grain production occurs during the 35-day period — 10 days before flowering until 10 days before harvest. The hulls and stems are largely formed a few days before flowering while the grains are filled later. Grain production may be computed as 26 kg/mm water × 35 days × 6.5 m/day = 5.9 t grain/ha if adequate water is available before and during grain formation. The 5.9 t/ha computed grain production from a healthy, well-irrigated rice crop is within the yield range of most IRRI (International Rice Research Institute) and CIAT (Centro Intemacional de Agricultura Tropical) well-managed experimental plots and the international yield trials. This example is used to emphasize an economic relationship of 2.2 to 3.3 kg of dry matter/m^3 water utilized by the rice crop, especially the 450 mm of supplemental irrigation in pozas veraneras so essential from 50 DT until harvest. This 450 mm water plus the 300 mm at transplanting should permit a grain production of 5.6 t/ha in pozas veraneras (750 mm × 7.5 kg/mm= 5,625 kg/ha).

Harvesting, drying, and storage

Double transplanted pozas veraneras are harvested manually. The plants are cut near ground level and dried on top of the stubble for 1 to 3 days. The cut plants are piled in a semicircle about 4 m in diameter. A threshing cloth made from rice bags is placed on dry ground within the semicircle. The thresher gathers a bundle of plants about 0.20-m diameter at the base and threshes it by striking the panicles against the cloth and previously threshed grains.

Easily threshed varieties with long straw are sought by Ecuadorian farmers. The long straw permits a thresher to stand and strike the bundle against the ground. The grain must thresh easily after only two or three impacts between the bundle and the ground cloth. Harder-to-thresh varieties are struck against a stone or piece of wood. Nonshattering varieties are presently rejected as too difficult and costly to thresh manually.

Drying occurs partially in the field before threshing and continues on a drying floor at the rice mill. The farmers sell their grain in sacks of 90 kg paddy at 18 to 22% moisture. There is little price incentive for the farmer to sell at lower moisture content.

After drying, grain is stored in bags or bins at independent rice mills.

VARIETIES

In 1980 traditional varieties averaged 4.4 t/ha with no fertilizer at 6 sites in pozas veraneras. Pico Negro was the best variety with an average yield of 4.6 t/ha on 4 of 13 harvest dates (Table 4). It is the preferred variety in pozas veraneras, but its major limitation is its long duration. Brasilero and INIAP-6, which flower 20 to 25 days before Pico Negro, suffer less from late water stress.

Modern varieties are planted on higher areas that are leveled, irrigated, fertilized, and direct-seeded or transplanted once at close spacing. INIAP-6 yields averaged 3.9 t/ha for 3 harvest dates under conditions of modern infrastructure during 1980. However, none of the farmers plant it in their pozas veraneras.

Comparative yield trials

Comparison of modem and traditional varieties under poza veranera conditions was started by INIAP in 1979. The trials continued in 1980 and 1981. Ampuño (1981) tested Pico Negro, INIAP-6, INIAP-415, and six other experimental lines in the field during 1979. Moisture deficiency at flowering was the key element in yield differences. INIAP-6 flowered 23 days before Pico Negro and 11 days before INIAP-415. One poza veranera trial with 9 varieties and 3 replications was irrigated 15 days before INIAP-6 flowered. INIAP-6 yields averaged 2.2 t/ha; INIAP-415, which flowered 26 days after irrigation, had average yields of 1.5 t/ha; Pico Negro and other lines that flowered 38 days or more after irrigation produced no grain.

All varieties suffered severe late water stress and yield reductions of 7.5 kg/mm of water deficit at flowering. To be valid, any comparative varietal yield trials must be corrected for moisture differences due to flowering dates and field elevations.

Comparative yield trials of 19 tall traditional varieties and 5 modem short varieties were conducted under normal close spacing, fertilizer application, and weed control during the 1979 dry season and 1980 rainy season. When irrigated, the short modern varieties were significantly better in only one of four trials. In the single upland trial the 14 tall varieties were significantly better (Table 5). The tall traditional varieties have a potential stable yield of 4 to 6 t/ha under the trial conditions, but lodging due to close spacing and fertilizing reduced the yield.

Future yield trials of traditional varieties should use the farmers' spacing of about 40 cm between hills to reduce lodging and include 50% or more upland and pozas veraneras that more closely approximate the farmers' conditions.

Submergence tolerance

Submergence tolerance tests of 15 deepwater rice lines and 5 varieties were initiated in 1977 on the INIAP-Boliche experiment station with 1 m of clear water. All the lines and varieties survived and yielded from 1 t/ha for INIAP-6 to 3.8 t/ha for BKN6986-45-1. The best lines were transplanted in pozas veraneras in 1978. In January 1979 and January 1980 all the available deepwater germplasm was planted in Cooperative Buijo in the Samborondon Project. The initial floodwaters were black and apparently high in aluminum and iron sulfates. Only 3 of 108 lines survived in the field in 1979. The surviving lines were tall traditional floating rice varieties, which had leaves above the water at all times. None survived in 1980 — all the materials were submerged in water of 0.7 to 1 m deep and died in less than 7 days.

Shallow water observational trials were initiated in January 1979 and continued in 1980. In 1979 the lines were planted on a slope and levee to assure different water depths. All materials planted above 1.9 m had leaves above the 2.35-m water

Table 5. Results of comparative yield trials of 14 selected, tall, traditional varieties and 5 modern, short-strawed varieties in Ecuador, 1979 dry season and 1980 wet season.

Variety	Growth duration (days)	Height (cm)	Blast rating[a]	Yields (t/ha)				
				irrigated				Rainfed
				Boliche		Daule		
				1979	1980	1979	1980	1980
Tall								
Chileno	142	152	8	5.1	48	5.8	4.1	4.1
Cafuringa 1	140	157	4	5.8	4.8	5.3	3.5	3.2
Cafuringa 2	139	155	2	5.7	4.7	5.5	3.5	3.9
Donato	146	148	1	4.4	4.6	5.3	4.0	2.8
Canilla	144	154	5	3.4	5.0	5.3	4.1	3.6
Canuto	149	157	2	3.9	4.5	5.5	3.6	3.5
Chato rayado	138	141	5	4.7	4.3	4.8	4.5	2.6
Brasilero	143	151	6	4.2	5.0	5.4	4.8	3.2
Pacho Vera	143	146	6	4.6	4.8	4.9	3.9	3.6
Pico Negro	154	157	4	6.7	-	5.4	5.8	2.5
SML	145	165	8	5.6	3.7	5.8	3.2	4.0
Papayo	160	132	2	3.5	-	5.0	3.8	2.6
Cenit	146	141	4	5.5	4.0	-	3.6	3.4
Fama	139	149	5	4.5	3.9	4.9	4.4	3.0
Average				4.8	4.5	5.3	4.0	3.3
Short								
Chato (IR8)	140	112	5	5.4	6.5	4.6	4.0	2.8
Chato aristado	145	99	8	4.7	5.9	-	3.1	2.4
INIAP-6 (CICA-4)	137	92	9	3.5	5.0	5.6	3.7	1.8
INIAP-7	141	110	1	4.7	5.0	6.0	3.8	2.5
INIAP-415	149	107	4	5.4	5.8	7.5	3.6	1.9
Average				4.7	5.6	5.9	3.7	2.3

[a] By 1980 Standard Evaluation System for Rice Scale: 1 = small brown specks of pinhead size, 9 = all leaves dead,

Table 6. Agronomic characters of 4 INIAP rice varieties.

Characteristic	Variety			
	INIAP-9 (Pankai)	INIAP-6	INIAP-7	INIAP-415
Cross	Peta/Tangkai rotan	IR8/IR12	CICA-4//IR665-23-3-1 /Tetep	IR930/IR579// IR930/IR22
Pedigree	IR5-1143-1	IR93031-1	P918-25-15-23-1B	P1042-2-23-1B
Yield, irrigated (t/ha)	6.6	5.8	5.1	6.2
Yield, swamp[a] (t/ha)	4.3	3.6	4.0	3.5
Height (cm)	123	96	108	106
Tillers (no./plant)	33	33	31	35
Vegetative cycle (days)	159	133	136	142
Lodging[b] (%)			70	35
Grain length[c] (mm)	6.5	6.5	7.0	7.2
Milling percentage	68	63	68	69
Blast rating	Moderately susceptible	Susceptible	Resistant	Moderately resistant
Hoja blanca rating	Moderately resistant	Moderately susceptible	Moderately susceptible	Moderately susceptible

[a] The maximum water depth was 0.60 m. Brasilero, the local check, yielded 3.4 t/ha. [b] Direct seeding by broadcasting. [c] Long grain.

level and survived; the rice on lower ground was submerged and died.

Areas with plants at elevations between 1.9 and 2.2 m in 1980 and 1981 gave encouraging results. During 1980, in water depths of 60 cm, the tall variety Brasilero was superior to BKN6986-45-1 and equal to Pelita I-1; Pankaj, however, gave the best yield of 4 t/ha. Pankaj, which yields well under a wide range of conditions, has been named INIAP-9 for release as a variety in Ecuador (Table 6).

Germplasm collection

Germplasm collection and purification of traditional varieties were started in 1978. Seeds were sent to CIAT and IRRI. Traditional varieties Brasilero, Cafuringa 1, Chato rayado, and Donato had excellent submergence tolerance ratings of 1 in greenhouse tests at IRRI (B. S. Vergara, pers. comm.). The same varieties had salinity tolerance scores of 5 to 9 and alkalinity scores of 3 to 5. SML had an excellent tolerance score of 3 for salinity and alkalinity, but its tolerance rating for submergence was a poor 9.

Germplasm for Ecuador's rice program has come from the many international trials sponsored by CIAT and IRRI. By 1978, INIAP had introduced 2,516 lines and collected the 32 locally used lines. The introduced germplasm of stable lines has provided a wide range to select from, and has permitted the small INIAP rice program to introduce IR8, IR22, and CICA-4 as varieties and to select INIAP-7, INIAP-415, and INIAP-9 (Pankaj) from lines introduced for local trials (Table 6). The vast range of available germplasm has required greater selectivity.

Breeding objectives

Breeding for Ecuadorian conditions should include germplasm from traditional varieties that have had stable yields for many years on farms. Test conditions for selection also must be comparable to on-farm conditions.

The major breeding objectives for the Samborondon Project are:

- Drought and submergence tolerance for upland and pozas veraneras, especially during the early seedling and maturing stages;
- Early-maturing varieties to reduce the late season drought problems;
- Initial vigor for competing with weeds and seedling height that prevents submergence of the plants during rapid initial increase in floodwater;
- High tillering of old seedlings transplanted into 25 to 35 cm water to maintain the present low costs of land preparation and transplanting;
- Easy threshing for manual harvest in the pozas veraneras: The use of combines and threshers is not feasible at present because of the complete intermixture of planting dates between low and high zones, the lack of grain crossings or roads, and lack of capital to purchase equipment and develop infrastructure;
- Long straw preferred by the farmers for water depth, weed control, and easy threshing. Hard-to-thresh and short-strawed varieties are not acceptable to farmers who must harvest manually;
- Resistance to hoja blanca, blast and other diseases, problem soils, etc.

Table 7. Distribution of costs and yields of pozas veraneras and irrigated rice in kilograms per hectare.[a]

	Paddy (kg/ha)	
	Pozas veraneras	irrigated
Costs		
Land preparation	634	408
Planting	450	181
Fertilizer	–	623
insecticide	–	344
Herbicide	–	332
Irrigation	226	708
Harvest	323	634
Transport	96	74
Total costs	1729	3304
Yield	2764	4834
Distribution of yield		
Equipment and supplies		
Imported inputs	175	2580
Local inputs	82	131
Labor wages	1472[b]	593[c]
Returns to capital, land, and administration	1035	1530
Wages + returns	2507	2123

[a] Data from Cuello and Maldonado (1980). [b] Equivalent to 88 man-days/ha. [c] Equivalent to 12 man-days/ha.

PESTS AND DISEASES

Known insect pests are *Rupela albinella, Spodoptera* spp., *Sogatodes oryzicola,* and spider mites. *R. albinella* is the most visible pest, but spider mites have caused serious damage in some fields before the farmers became aware of the problem. Trichlorfon and carbofuran are the widely used insecticides (Cuello 1979); however, only 33% of the sample farmers used insecticides in pozas veraneras. There were no significant differences in yield from the use of insecticides in pozas veraneras.

Diseases usually are not a problem in pozas veraneras although hoja blanca is often observed in Ecuador and is an ever-present threat. Blast may occur in well-fertilized seedbeds, but is rare in pozas veraneras. No control measures are used for either disease.

ECONOMICS AND ENGINEERING

The costs and yields of traditional pozas veraneras and modem irrigated rices are given in Table 7. The use of kilograms paddy per hectare as a monetary unit reduces the problems of inflation over time as well as national prices and currency exchange rates.

Cost of land preparation and planting are higher for the traditional pozas veraneras because of the greater use of labor for manual land preparation and double transplanting.

Yields of modern irrigated and direct-seeded rice are higher because of the absence of water stress plus the use of modern fertilizer-responsive varieties. The present limiting factor for pozas veraneras is water stress. Adequate water must be provided to remove the present yield ceiling.

Distribution of yield into imported inputs, local inputs, wages, and returns to capital, land, and administration is a controversial socioeconomic problem. Traditional pozas veraneras rice areas provide more local employment and use less foreign exchange. But modem irrigated rice areas generate more business for the Guayaquil import houses and more returns to capital, land, and administration.

Land reform in Ecuador has concentrated on the traditional upland and pozas veraneras. The two are areas of cooperatives and small farmers. The same land reform has frightened the modem irrigated rice farmers who have developed the higher areas above the normal flood levels. High yields depend on the investment and organization necessary to supply adequate water control.

Engineering for water control will require an integrated design of infrastructure for irrigation, drainage, roads, and bridges. Earth from excavation for canals should be used as fill for flood protection levees, which are the elevated base for rural roads. Culverts for road crossings over drains should also serve as water control structures. An estimated maximum earth movement for water control in the tidal swamp area may be based upon the 6,000-ha Wageningen Rice Project in Surinam (De Wit 1960). It required an average earth movement of 750 m^3/ha for levees, roads, and drains. Johnson (1979) estimates a minimum earth movement of 355 m^3/ha for the Samborondon Project area. The capital cost of earth moving to provide water control and the base for rural roads is 5 kg paddy/m^3 or 1,775 to 3,750 kg paddy/ha. The total capital cost of infrastructure for basic water control should not exceed 7,500 kg paddy/ha to permit 2 crops a year in the tidal swamp area of Ecuador. Total futed and operating costs should not exceed 700 kg/ha per crop season to be comparable to the farmers' present irrigation cost.

Repayment of 7,500 kg paddy/ha capital investment in 25 years at 5% interest with 50 semiannual payments would require payments of only 265 kg paddy/ha per crop season. The expected yield difference of 2,070 kg/ha per crop would pay for extra inputs and operating costs, and provide the extra employment and food required for the growing population.

Low interest rates of 5% or less should be attractive to the Organization of Petroleum Exporting Countries (OPEC) group and investment bankers because the annual kilograms per hectare payments are reduced for inflation. The use of kilograms per hectare also should awaken the policy makers, investors, and researchers to the comparative costs and returns for fertilizer, insecticides, herbicides, and irrigation.

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RICE CULTIVATION IN THE TIDAL SWAMPS OF SRI LANKA

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The major portion of Sri Lanka's low-lying lands lies in a belt (roughly 16 km wide) along the western coast from Wennappuwa to Dondra. Elevation ranges from below sea level to about 1.5 m above mean sea level. About 75,000 ha in the coastal floodplain still remain unproductive because of impeded drainage and submergence which have created unfavorable soil conditions for rice cultivation.

Because of those factors, rice farming in the low-lying lands remains unprofitable and most of the paddies are either not regularly cultivated, or cultivated only one season a year. As no other crop can be grown in those lands, farmers continue to grow rice when conditions are favorable. An important factor is that these low-lying lands are in the most densely populated areas of Sri Lanka and the farming community lives close to the unproductive lands.

Depending on the depth, duration, and frequency of submergence, which, in turn, depend on several factors such as elevation, topography, tidal variation, and floods of major rivers, farmers attempt to grow a rice crop either during the southwest or northeast monsoon. They plant before the rainy season so that plants can withstand submergence during peak rainfall. Varieties with growth durations of 160- 180 days are grown. This system of cultivation does not encourage farmers to use high yielding varieties and good management. Yields are usually around 1 t/ha.

To meet Sri Lanka's ever-growing food requirements it has become urgent to bring these unproductive lands into properly managed rice production. The improvement of yields within the existing system of cultivation, calls for attention to the following:

- drainage improvement,
- irrigation during land preparation and maturity,
- prevention of salt water intrusion,
- better varieties, and
- better cultural practices and fertilizer use based on different land systems.

The strategy to increase yield in these areas is based on varietal improvement, an increase in cropping intensity, and better management.

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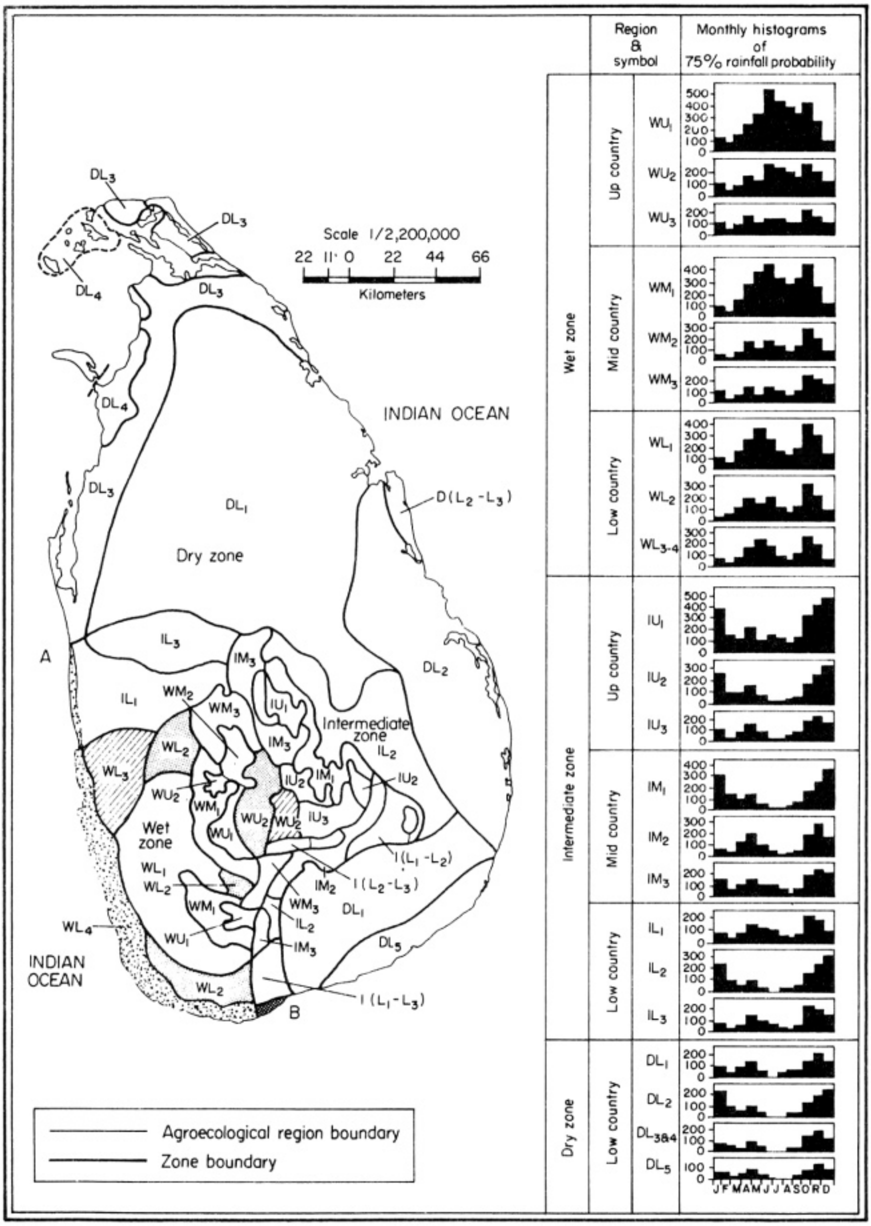
RAINFALL PATTERN

Based on rainfall, vegetation, soils, and present land use, Sri Lanka divides into wet, intermediate, and dry major agroclimatic zones. On the basis of elevation, the major zones are further subdivided into low-country (less than 300 m), mid-country (between 300 and 1,000 m), and up-country (more than 1,000 m).

The agroecological map of Sri Lanka (Fig. 1) shows the demarcation of the



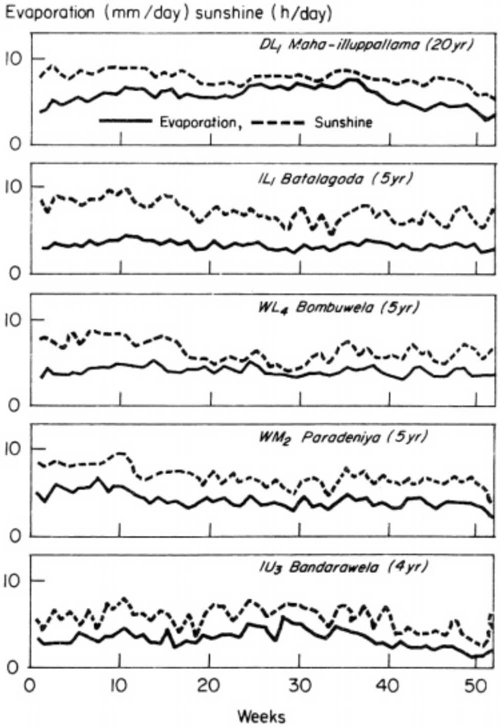
1. Agroecological regions of Sri Lanka.

country into 24 agroecological regions. The annual sequence in rainfall probability is also indicated. The main coastal floodplain where low-lying paddy fields extend from west to southwest is marked from point *A* to *B*. The wet zone of Sri Lanka, which receives about 2,500 mm of rainfall a year includes 10 agroecological regions (Fig. 1). The low-lying paddies in the coastal floodplain fall within the agroecological regions of IL_3, WL_3, and WL_4.

Rainfall in Sri Lanka is distinctly bimodal, with peaks between April-May (*yala* season) and September-October (*maha* season). The island's topography results in rivers radiating toward the coast. Rivers flowing to the western and southwestern coasts carry about half the annual runoff. Because the island is skirted by a broad peneplain it is ideally suited to form the floodplains. The large flood volume the rivers carry has therefore to occupy the entire floodplain, which has created an unfavorable environment for successful rice farming in the low-lying areas of the wet zone.

During the southwest monsoon, the water level in the low-lying areas rises about 1 m. However, flood levels of more than 50 cm are of short duration — not more than 10-14 days. Floods of this nature often occur one after the other. Crop failures are not significant when floods are 3-7 days and when their frequency is less than 2.

Flood frequency is generally high during the yala season; therefore, a limited area is cultivated during that season. Floods also occur during the maha season but considerable low-lying area is planted to long-duration photoperiod-sensitive varieties.



2. Weekly average evaporation in mm and bright sunshine hours in five agroecological regions of Sri Lanka.

Average weekly maximum and minimum air temperatures are given in Figure 2. Bombuwela (WL_4) represents the temperature conditions for the low-lying areas. The difference between maximum and minimum air temperature is high during the maturing period of the maha season (10-20 weeks) rice crop and is often considered the reason for high yields during this season.

Most of the low-lying lands are of alluvial origin. Most of the soils in the coastal floodplain belong to the category of very poorly drained bog and half-bog soils. The presence of half-bog soils depends mainly on elevation and drainage. Bog soils with organic matter content of more than 30% are observed to a depth of at least 30 cm if drained and 45 cm if not drained. During floods these soils — commonly called Histosols — smell, the bulk density becomes lower, and the soils often float away causing damage to the rice crop. The organic matter content of half-bog soils ranges from 15 to 30%. The half-bog soils are considered relatively better than the bog soils for field management.

The most characteristic physiological problem in the low-lying area is the reducing condition, which at higher elevation causes iron toxicity. Salinity due to intrusion of sea water is a problem in some areas of the southern coast during crop establishment.

CROPPING PATTERN

The major cropping patterns practiced by farmers in the wet zone are shown in Figure 3. The patterns evolved to suit respective land systems and to avoid floods and drainage problems. Double-cropping with medium- or short-duration varieties is practiced in areas where land potential is high and flood problems are minimum.

Cropping pattern I (yala season)

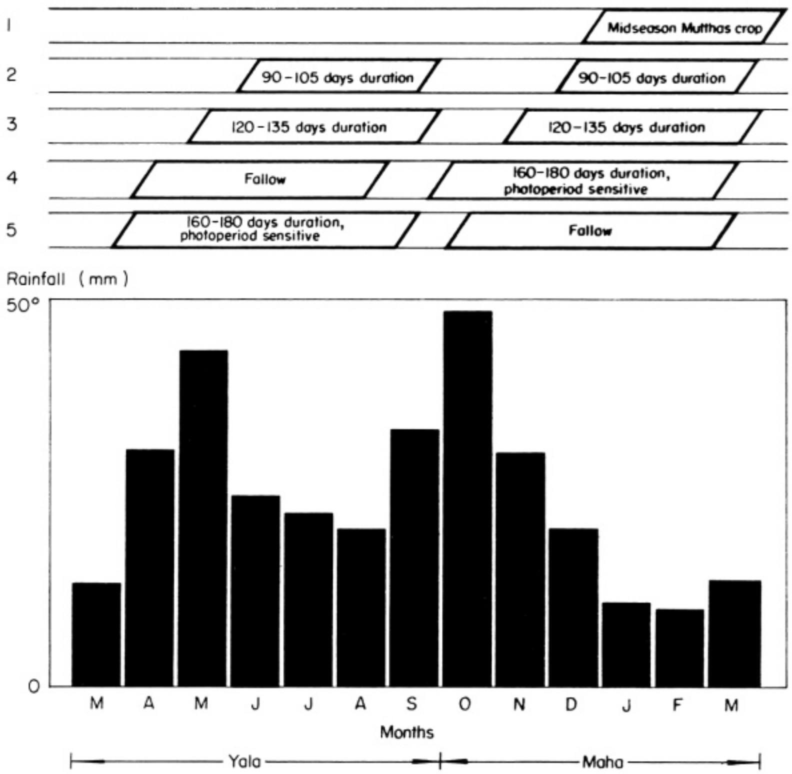
Cropping pattern I is practiced in thelow-lying areas of the coastal floodplains where flood frequency is high during yala. These areas are usually subjected to long submergence and the depth and duration of submergence do not permit the establishment of a 4-month rice crop. Photoperiod-insensitive varieties of 160 to 180 days duration are used. Thus, the practice is to prepare the land during the dry period and establish a crop before 15 March. During peak rainfall in May the crop is tall enough to stand submergence for about 10 days.

Cropping pattern II (maha season)

Cropping pattern II is practiced mostly in the inland floodplains. It is also used in the river systems and in western Sri Lanka. Farmers plant photoperiod-sensitive varieties of 160 to 180 days duration. To avoid flood and drainage problems during monsoons, farmers in those areas establish a rice crop during the dry period (July or early August) and the crop withstands floods during the heavy northeast monsoon.

CULTURE

Land preparation in the low-lying areas is done during the dry period by conventional plows or by hand, using conventional hoes.



3. Cropping patterns in the wet zone of Sri Lanka.

Crop establishment is by broadcasting on dry soil. With initial rains seeds germinate. Weed control is a serious problem. Often a higher seed rate is used to obtain a stand that will smother weeds.

Because rice cultivation in the low-lying areas is always at a high risk, chemical weed control and application of fertilizers are rare. However, farmers often apply a basal complete (NPK) fertilizer. Topdressing of nitrogen fertilizer is done only if field conditions are favorable. Harvesting usually coincides with the dry spell. Most of the crops often lodge, making harvesting difficult and causing high losses if wet weather prevails.

Most of the varieties grown in the low-lying areas are traditional types that have low yield potential. They possess some degree of drought resistance at the seedling stage. Farmers usually retain the harvest for their consumption. Special characteristics such as seed viability, resistance to storage pests, and good cooking quality after a long period of storage have made the traditional varieties popular. The modern varieties often lose viability due to long storage; furthermore, their eating qualities are poor.

Yield potential of modern varieties is 3-4 t/ha; that of traditional varieties is 0.75 to 1 t/ha. One of the main limiting factors of the modern varieties is their poor competitive ability with weeds. Traditional varieties have growth vigor at the seedling stage and their early height helps them withstand flooding and compete well with weeds. Weed competition is considered one of the most important adverse factors because land preparation is poor and chemical weed control is not practiced.

STRATEGY TO INCREASE PRODUCTION

The strategy to increase rice production in the low-lying areas is based on varietal improvement. It is emphasized that rice cultivation in those areas will continue to remain a high risk for farmers. Therefore, an objective is to rectify some of the defects in the traditional varieties and to increase their yield potential moderately while retaining some of their important agronomic traits such as ability to compete with weeds.

The present cropping pattern, which avoids flooding by early crop establishment of long-duration varieties, will continue to be best in the low-lying areas. Because submergence is due to flash floods, deepwater varieties or characteristics of the deepwater varieties, such as elongation, are considered highly undesirable.

Special characteristics

Special characteristics needed in rice for low-lying areas include

- tolerance for drought at the seedling stage,
- tolerance for salinity at the seedling stage,
- tolerance for submergence at the seedling stage,
- early growth vigor,
- resistance to lodging,
- seed viability and cooking quality after long periods of storage,
- resistance to storage pests, and
- 160- to 180-day photoperiod-sensitive varieties.

Many crosses have been made using popular traditional rices. However, little or no varietal improvement has resulted mainly because most of the traditional rices are poor combiners. Furthermore, the techniques to evaluate submergence tolerance and drought tolerance at the seedling stage are complicated, and little is known about the inheritance of those Characteristics. Varieties like Devareddiri and Podiwee have been successfully used as parents to transfer long duration and photoperiod sensitivity to improved varieties. Techniques to screen varieties and segregating populations for submergence tolerance have been developed and varieties possessing submergence tolerance and improved plant type have evolved. The traditional varieties Molligoda, Karamana, Soola, and Devareddiri have submergence tolerance at the seedling stage.

The following crosses have been made for submergence tolerance and segregating populations from the F_2 onward were subjected to 30-cm-deep submergence for 10 days from 5 days after seeding. At the end of the submergence plants standing erect were removed and planted in the field. Subsequently field selections were made for other characteristics and the selected material was again subjected to submergence in the following season. This procedure was followed to the F_5 and promising lines are being tested for yield.

Crosses made for submergence tolerance

BW281/Karamana
BW281/Molligoda
Devareddiri/C4-63//BW 267-3///BW 78-7/Bg 304-1
Obeus/BW 254-1///IR8/Devareddiri//Bg 276-3
*Devareddiri/Bg 276-3
*Karamana/Bg 276-3
Soola/LD125
Pelita I-1/BW 242-5-5
*BR 51-74-6/T442-57///IR8/Devareddiri//Bg 276-3
Karamana/BW242-5-5//BW 242-5-5
Soola/Bg 400-1//Bg 400-1
Soola/Bg 11-11//Bg 12-1
Soola/Molligoda//BW 265
IR8/Devareddiri//Bg 276-3
IR8/Devareddiri/Bg 401-1
Karamana/BW85//Bg 334-1
Soola/BW85//Bg 334-1
Soola/BW100//BW267-1
Soola/BW100//BW265
BW242-5-5/Bg 276-3///IR8/Devareddiri//Bg 276-3
BW242-5-5/62-356///IRWDevareddiri//Bg 276-3
BW100/BW 242-5-5///IR8/Devareddiri//Bg 276-3
Bg 400-1/BW 254-1//Bg 276-3
IR2071-586/Bg 402-3//BW267-1
IR2071-586/BW85//BW 265///IR8/Devareddiri//Bg 276-3
IR2071-586/BW100//Bg 304-1///Bg 276-3
IR2071-586/BKN7022-6//Bg 400-1///Bg 276-3
Devareddiri/IR2070-434-5-5//BW100
Devareddiri/C4-63//BW267-3///Bg 400-1
Devareddiri/C4-63//BW267-3///BW78-7/Bg 304-1

*Lines from these crosses have been able to stand the submergence test up to F_5; these lines are being further tested.

RICE IN COASTAL SALINE LAND OF WEST BENGAL, INDIA

T. S. SINHA and A. K. BANDYOPADHYAY

About 0.8 million hectares of coastal land in West Bengal, India, are highly saline and therefore relatively uncultivable, especially during winter and summer (Mukherjee 1978). Submergence is also a problem. Although a third of this area has been brought under cultivation by putting earthen bunds along the margins of tidal rivers and estuaries to prevent tidal inundation, the total production per unit area remains low. The low yields may be due to excessive rainfall during the monsoon, poor drainage, lack of good quality water for irrigation, or high soil salinity during rabi cultivation. Annual rainfall in this area is about 1800 mm, but 85% occurs from June to September. The water table remains shallow throughout the year. Soil texture varies from silty clay loam to silty clay. Chloride and sodium are the dominant anions and cations, respectively. The salinity of the surface soil changes in different months and ranges from 3 to 11.8 mmho/cm (Bandyopadhyay 1977). However, salinity in some locations was recorded as high as 35 mmho/cm (Bandyopadhyay et al 1978).

The response of different crops to salinity varies from tolerant to semitolerant to sensitive. Evidence indicates that intraspecific variability also exists, which opens the possibility for development of cultivars which will be better suited to saline conditions. However, tolerance for salinity is influenced by different environmental conditions such as soil type and management practices.

An intensive survey undertaken by the Research Station at Canning indicated that vast areas remain highly saline even in October at the close of the rainy season. The main reasons for such soil salinity appear to be heavy soil texture with low permeability; the highly saline, shallow water table; and the absence of drainage channels to help in washing away the salt (Bandyopadhyay 1977, Bandyopadhyay et al 1978).

At the Canning Research Station, a large number of rice genotypes have been screened for salt tolerance. Damodar (CSR-1), Dasal (CSR-2), Getu (CSR-3), Nona Bokra, and Nonasail (Sel.) have been identified as promising salt-tolerant cultivars. CSR-1, CSR-2, and CSR-3 are weakly photoperiod-sensitive cultivars and can be grown as boro crops. Nona Bokra and Nonasail (Sel.) are photoperiod-sensitive, tall indica cultivars and are grown in the wet season only. The superiority of Damodar to Jaya, a high yielding and widely adopted cultivar, has

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been reported (Sinha and Dutt 1974). A high yielding potential for Damodar, Dasal, and Getu compared with IR8 in the saline soil of West Bengal was recorded. These three varieties were found promising in other saline parts of the country as well (Bhattacharyya 1976). It was further observed that Getu, Damodar, Nonasail (Sel.), and Nona Bokra have an advantage over many cultivars in so far as their salt tolerance is concerned. In the IRSATON trial coordinated by the International Rice Testing Program (IRTP) at IRRI at five sites in Asia in 1977, Nonasail (Sel.), Getu, and Dasal did well both at the vegetative and ripening stages. Getu and Nonasail (Sel.) were among the top 16 varieties selected for their tolerance at the vegetative stage, and Dasal (CSR-2) and Nonasail (Sel.) were among the top 7 varieties selected for their tolerance at both the vegetative and ripening stages. Using general observations, the IRTP monitoring team for problem soils rated Getu as a promising cultivar for northeast Thailand. In addition, two cultivars, Matla and Hamilton, developed through selection from the primitive varieties Banisail and Nona Bokra, respectively, at the Rice Research Station at Chinsurah, are under cultivation in saline soil (Dutt et a1 1978). All these cultivars are tall. Among them, genotypes CSR-1 and CSR-3 are being used as donor parents in combining salt tolerance and high yield in otherwise well adapted high yielding cultivars. At this Research Station, Damodar has been used extensively in hybridization programs with IR20, IR24, and IR2153-43; a few lines derived from these crosses gave 15% more yield than the better parent under conditions of 6-8 mmho/cm surface salinity. One of the most promising crosses yielded about 26% more than the better parent. The crosses isolated differ in crop period and plant type. A few were tested for salt tolerance at IRRI and 3 were rated highly tolerant (8-9 mmho/cm) at the seedling stage (Ikehashi 1978). A few crosses of SR26B/IR8 also seem promising (Bandyopadhyay et al 1978). One yielded 2.6 t/ha more than Jaya in the dry season in the salinity range of 11.0 mmho/cm at planting. This cross is semitall and photoperiod-insensitive. Recently the crosses Jaya/IR2071-88-8-10 and JayaAR2153-26-3-5-2 were found promising in the lower range of salinity (Sinha and Rai 1976). The two produced 1.9 t/ha more yield than the better parent, Jaya.

Apart from the hybridization program, mutation breeding approaches have also been tried. From induced mutation breeding for salt tolerance and high yield, two promising crosses — Mut-1 (CSR-4) and Mut-2 — were evolved from IR8. Both are semidwarf and mature in about 95-105 days in the wet season and in about 125-130 days in the dry season. CSR-4 has better yield potential and outyielded a number of promising cultivars including Ratna, Kanchi, IR8, IR20, and IR24 in the coastal belt of Sunderbans. CSR-4 was also outstanding in soil of pH 9.0-10.4 in Punjab State. It outyielded the local check as well as high yielding varieties and produced 74.0% more yield than Jaya (Yadav et al 1979). In the second International Rice Salinity and Alkalinity Tolerance Observational Nursery trial conducted at 5 sites in Asia, CSR-4 was among the top seven varieties selected for their tolerance at both vegetative and ripening stages (IRTP 1978). Recently, many cultivars were screened under IRTP in coastal saline soils. A few entries — IR4432-28-5, IR4630-22-2-5-1, IR4630-22-2-5-1-3, and IR4630-22-2-17— performed well (Table 1).

Table 1. Scores of International Rice Salinity and Alkalinity Tolerance Observational Nursery entries in saline soils, 1977.

Entry no.	Designation	Height (cm)	Scoring[a]		Heading duration (days)	Survival at maturity (%)
			Vegetative	Maturity		
48	Getu mutant	95.0	5.0	5.0	108	68
58	IR4432-28-5	90.0	5.0	5.0	105	79
61	IR4630-22-2-5-1	104.0	5.0	5.0	106	89
62	IR4630-22-2-5-13	104.0	5.6	4.3	105	87
63	IR4630-22-2-17	104.0	5.6	4.3	108	88
83	Sensitive check	83.0	8.3	9.0	101	69
88	Nona Bokra	146.0	4.3	4.3	128	79
89	Nonasail	144.0	3.6	3.6	133	92
98	Resistant check	151.0	7.6	6.3	112	75

[a] 1 is best and 9 is poorest

Studies of many cultivars included saline water submergence at different growth stages. Plants were submerged completely in saline water (9.0 mmho/cm, pH 7.2, Na^+ 70.1 meq/liter, $C1^-$ 87.0 meq/liter), at 3 stages of crop growth: tillering, panicle initiation, and spikelet formation, for 24 hours and 48 hours, respectively (Bal 1975). The results indicated that Damodar (CSR-1) gave the significantly highest yield in all treatments where plants were submerged with saline water. Yield was found to decrease significantly in such high yielding varieties as Jaya, IR8, Pusa-2-21, and others because of significant decreases in tillers per plant and spikelets per panicle as well as an increase in spikelet sterility percentage. Thus, for future improvement of the cultivars under saline conditions, CSR-1 may be used as one of the donor parents.

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RICE CULTIVATION IN FLOODED COASTAL LOWLANDS OF VIETNAM

NGUYEN VAN LUAT

Rainfall, hydrologic regime, temperature, and adverse soils limit rice production in flooded rice fields in the coastal lowlands of Vietnam. The seasonal influence of those factors on rice yields in the Mekong Delta and in the Red River Delta is explained. Cultural practices for growing rice in the coastal lowlands are described. Desired varietal characteristics are discussed and cultivars suited to the different rice-growing environments are evaluated.

Flooded rice fields in coastal lowlands of Vietnam occupy about 12% of the total rice cultivated areas. About 60% is in the Mekong Delta, and 30% in the Red River Delta in the northern part of the country. About 60% of the total national rice production comes from the Mekong Delta. Farmers cultivate rice on about 400,000 ha of 1 million hectares in the coastal areas that are flooded in the wet season. Rice yields are low and unstable because of high acidity, salinity, and flooding.

In the South, farmers grow rice once a year during the wet season, using floating rice as well as double transplanting of tall varieties. In the North they grow rice twice a year by single transplanting because irrigation facilities are better. In both the North and the South, soybean, sweet potato, banana, pineapple, and coconut are grown in addition to rice.

ENVIRONMENT

Mekong Delta

Rainfall, hydrologic regimes, and temperature. Annual rainfall ranges from 1,200 to 2,400 mm. Sometimes rainfall is as high as 2,700-2,800 mm. The dry season is from December to April during which about 12% of annual rainfall is received. The remaining 88% comes in the wet season. Average monthly rainfall in the dry season is about 35 mm. In some months rainfall decreases to 3-4 mm. Average monthly rainfall in the wet season is 270-280 mm. In July, August, September, or

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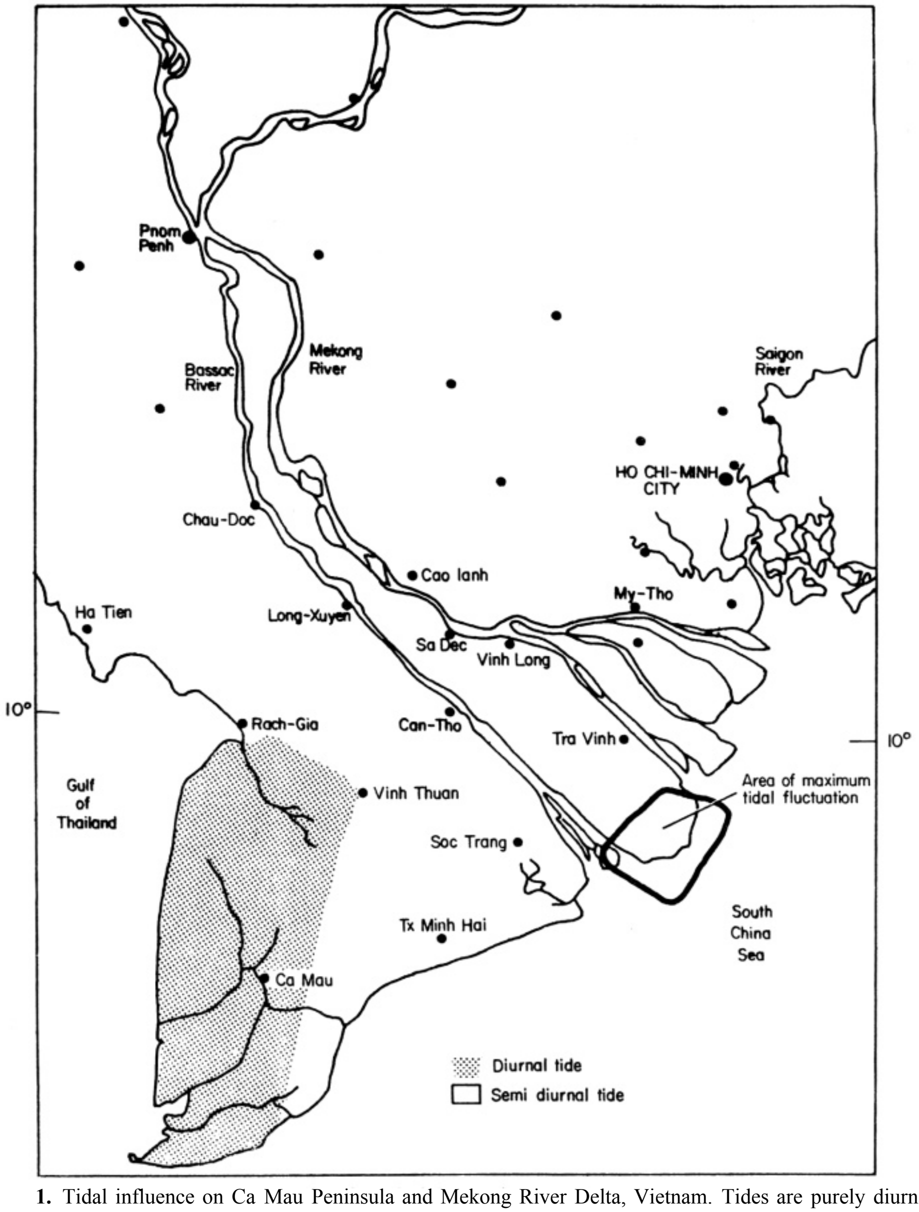
October, monthly rainfall increases to 350-360 mm.

Hydrologic regime is affected chiefly by rainfall, and by rising river water and tide. Flooding begins in June. The first peak is in the middle of July and the second, more important, peak occurs in the last 10 days of September or in the first 10 days of October.

The tide is purely diurnal on the Gulf of Thailand in the western half of the Ca Mau Peninsula; mainly diurnal with semidiurnal components on the South China



1. Tidal influence on Ca Mau Peninsula and Mekong River Delta, Vietnam. Tides are purely diurnal on the western side of the Ca Mau Peninsula; mainly twice daily from Vinh Thuan to the east.

Sea from Vinh Thuan District to the east (Fig. 1). Small slope and the influence of semidiurnal components result in slow drainage, about 1-3 cm a day. Flooding time therefore is sometimes prolonged until March of the next year. Most acid sulfate soil is in the zone of flooding.

Floating rice is grown in the area of deepest flooding in the Ha Tien plain. Flooding decreases from 2-4 m at Chau Doc to 1-2 m at Long Xuyen. The water depth continues decreasing (about 0.5-1.0 m) and covers a larger area to the southeast toward the sea.

Average temperature in the Mekong Delta is 26.8°C in the dry season and is 27.2°C in the wet season. In January, temperature sometimes decreases to 15° or 16°C; temperatures that low are rare and brief. In the dry season, with adequate water, rice yields are higher than those in the wet season because of abundant solar radiation and the absence of typhoons.

Soil condition. Almost all soil in the flooded region, far from irrigation and difficult to drain, is acid sulfate with a pH of 2.5-3.5. Soil is very heavy, 40-60% clay. Active iron ranges from 800 to 1,000 ppm. Free aluminum exceeds 160 ppm. Soil is high in organic matter (OM) and low in phosphorus. Pyrite (FeS_2) is oxidized and forms H_2SO_4 in the dry season. If rainfall is inadequate at the beginning of the wet season, acid sulfate increases in the cultivated soil layer. Acid sulfate often appears in April and May, but begins to decrease in June. Rice plants are safe from acid sulfate from June to December.

Northern Vietnam

The coastal lowland in the North lies in Haiphong, Hanam Ninh, and Thanh Hoa Provinces, 19°-21°N latitude (Fig. 2). In addition to flooding in the wet season and high acidity and salinity in the dry season, the area has low winter temperatures. Temperature averages 19°C in the dry season. The lowest temperature occurs in January: In December or February, temperatures may reach 5 to 10°C for 5 to 10 days, but average monthly temperature is about 17°C. Average temperature in the wet season is 26.7°C.

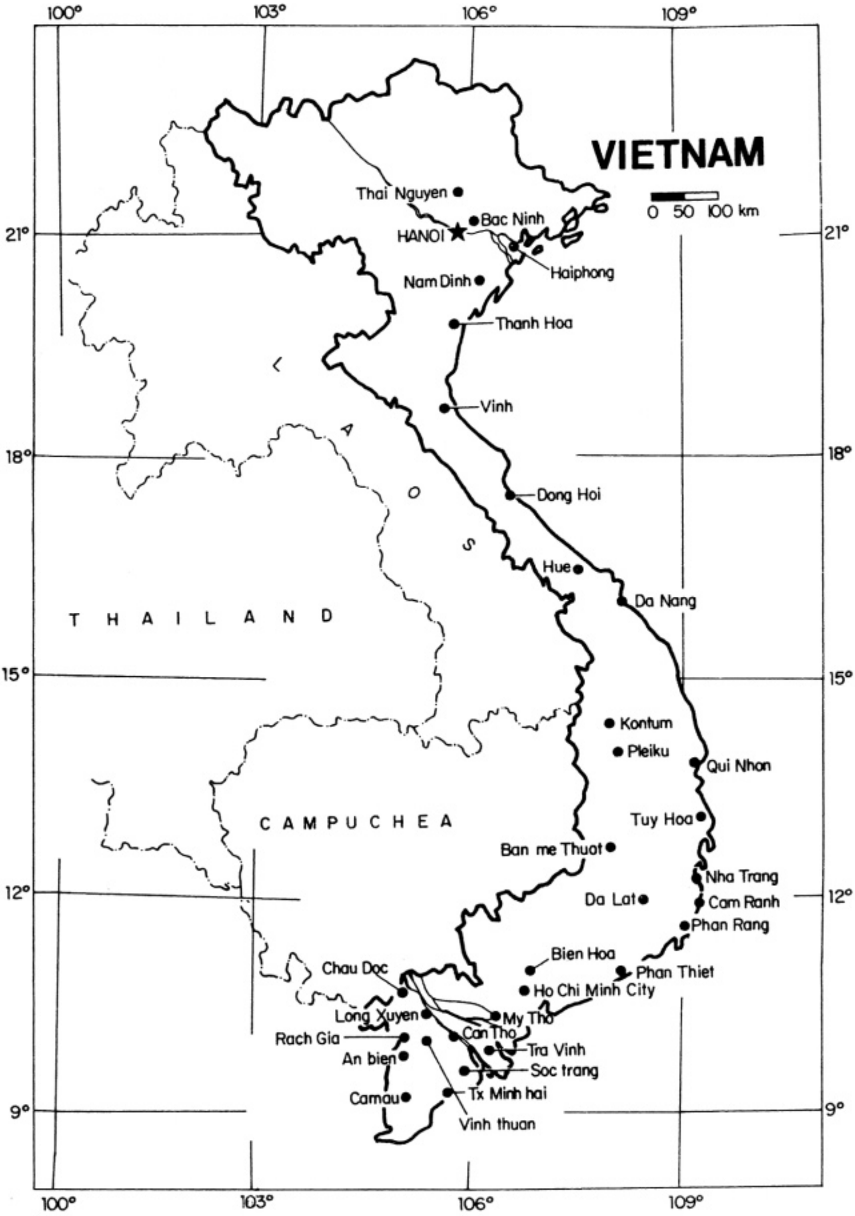
Annual rainfall is 7,700 mm. Soil is very heavy and there is no hardpan under the plow layer. Soil is rich in OM and low in phosphorus, pH is 2.5-3.5, and salinity is 4-4.5 EC_e in the dry season. Acidic toxicity is not a problem in the wet season. Maximum water depth generally ranges from 0.5 to 1.0 m, but may reach 1.5 m. Farmers plant rice twice a year — a winter or spring crop and a summer crop.

CULTIVATION

Land preparation

The methods and timing of land preparation for flooded coastal lowlands are different from those of irrigated areas.

Generally, farmers practice minimum tillage for two reasons: they lack labor and soil pH increases with plowing and harrowing. In the Mekong Delta, farmers use a scythe or long knives to cut tall grasses in the field (about 25 labor hours/ha) and put them in a pile (8-16 labor hours/ha). Then they puddle the field with



2. Area of flooded coastal lowlands in northern Vietnam.

rotary puddling equipment such as a broad five-bladed roller. Rice is transplanted or direct-seeded. Sometimes farmers plant rice in the grass piles. Only occasionally do farmers practice maximum tillage because it requires about 100 labor days/ha.

Farmers in the South construct raised beds (9 m wide) and plant rice on them with minimum tillage. Between the raised beds there are ditches 40 cm wide and 40-50 cm deep. These raised beds can be used for 3-4 years with minimum tillage before they have to be redug. In the North, farmers allow the soil to dry after plowing if soil moisture content is higher than usual, then they flush out the acid with ample irrigation water.

Planting methods

Farmers in the Mekong Delta must direct seed floating rice and direct seed or double transplant nonfloating varieties, depending on the season. Farmers in the North can grow improved high yielding varieties with a single planting. Single transplanting is preferable because less labor is required.

Double transplanting. Farmers double-transplant when water is about 0.5-1.0 m deep to control weeds and to limit lodging on soils high in fertility and rich in OM. The varieties used have 180 days duration or longer. Seedlings are prepared on a dry seedbed. The first transplanting is done when seedlings are 40 days old. The ratio of the first transplanting field area to the seedbed is 7:1. The second transplanting is done 60 days after the first transplanting. The ratio of the second transplanting field area to the first transplanting area is 5:1. By double transplanting, farmers economize on seedlings because they ultimately plant an area 35 times the size of the initial seedbed. The disadvantage is that double transplanting requires high labor inputs.

Direct seeding. Farmers in the Mekong Delta dry seed nonfloating rice and harrow to cover the seed before the rainy season begins. This method is used for *hot* acid sulfate soil when acidity is due to high active iron. On *cold* acid sulfate soil, in which free aluminum is the chief toxic agent, farmers sow pregerminated seed on the wet field.

Floating rice varieties are direct-seeded in May. By the time flooding begins the plants are 0.5-0.9 m tall and have about 8-12 tillers each. The local varieties used yield about 0.8-1 t/ha.

Plant population and seeding rate

Plant population for transplanting ranges from 4 to 20 hills/m^2. For direct sowing, the seeding rate is 80 to 200 kg/ha, depending on soil fertility, weed development, water depth, and incidence of pests such as rats (the most important), birds, fish, and crabs. Farmers in the flooded coastal lowland of the Mekong Delta generally leave the field alone from planting until harvest. They may use 2,4-D or butachlor once or twice for weed control. In the north, farmers use a high rate of superphosphate (400-700 kg/ha) on rice fields that are high in OM and in which pH is below 4. Lime usually has no effect and nitrogen response is negative if no phosphorus fertilizer is used.

VARIETIES

Local varieties are used for floating rice and double transplanting. We have no new or improved varieties for these types of rice culture. Yields of floating rice seldom exceed 1 t/ha, but we can obtain 3, even 4 t/ha by double-transplanting, especially on raised beds.

Flooding time and water depth vary with site and year. In the coastal lowlands of Vietnam we need a range of rice varieties from early-maturing (80-90 days) to late maturing (200-220 days). All should have tolerance for acidity and resistance to lodging and to brown planthopper.

Varieties suited to the conditions in the Mekong Delta include early-maturing (120-130 days) Puang Ngeon, Samo Ran, and Giau Dumont; medium-maturing (150-185 days) Ca dung, Doc phung, and Mong chim; and late-maturing (185-220 days) Nang thom, Soc nau, and Ve vang. Nang thom and Baxe varieties are suited to water depths of 50-70 cm, Gio day for water depths of 70-85 cm, and Truong hung, Nang tay dum for water depths of 80-150 cm.

We have evaluated about 50 imported varieties in which plant height is about 2 m: Taduang Po, Leb Mue Nahng, Yodaya, Jalay, and IR5853-189-2-17, as well as CNL and BKN lines. New and improved varieties used on a large scale in the North are: NN75-2 (IR5/314), IR2151, IR2153, and B9C for winter and spring rice crops; and M_1 and NN75-8 (Moc Tuyen/828) for the summer rice crop.

Environmental Problems

HYDROLOGY OF TIDAL ADJACENT PARTS OF COASTAL PLAINS

R. BRINKMAN

Most surface sediments in coastal plains were deposited as tidal swamps, but only small parts of coastal plains are now under tidal influence. The physical and chemical hydrology of coastal plains ranges from deep seasonal inundation to shallow, daily tidal flooding. Floodwaters range from salt to fresh and from neutral to extremely acid, depending on rainfall regime, distance from the sea, and nature of the sediments. Small parts of coastal plains can be irrigated or drained with use of tidal fluctuations. Tidal influence can be extended a few kilometers by canals from the tidal rivers. Compositions of surface water and soil water are strongly affected by reduction and oxidation, especially in acid sulfate areas. Controlled drainage to shallow depth, use of tidal fluctuations, and removal of acids by flooding with saline or fresh water are methods to minimize or avoid damage by acid sulfate in coastal plains. There is good reason to breed rice cultivars that efficiently take up phosphate at low levels of availability and that are tolerant of high iron concentrations. For most other problems in coastal plains, answers are found in reclamation, adapted management, or crop choice rather than in breeding.

Swamps are wetland areas. Some authors attach the restriction forested, and refer to open, grassy wetland areas as marshes. I do not make this distinction.

Tidal swamps are wetland areas influenced by the daily or twice-daily tides. Such areas, which cover a small part of the globe, are mostly saline and are, or were, mainly covered by mangrove forest. Within the tidal swamps, still smaller areas of freshwater tidal swamp are used for tidal swamp rice in the strict sense of the term.

Additional areas are subject to regular or occasional tidal inundation with saline water in the dry season only, when the land is fallow or supports some salinity-tolerant weeds. During the wet season, however, there is no tidal influence. The land is flooded by rain or river water, or both, which removes the salt accumulated in the dry season. Rice is transplanted and a normal rainfed wetland rice crop is grown. Although the rice does not grow in tidal swamp conditions, there may be some influence of salinity owing to tidal intrusion at the beginning and end of the rainy season. This crop could be called tidal swamp rice in a wide sense.

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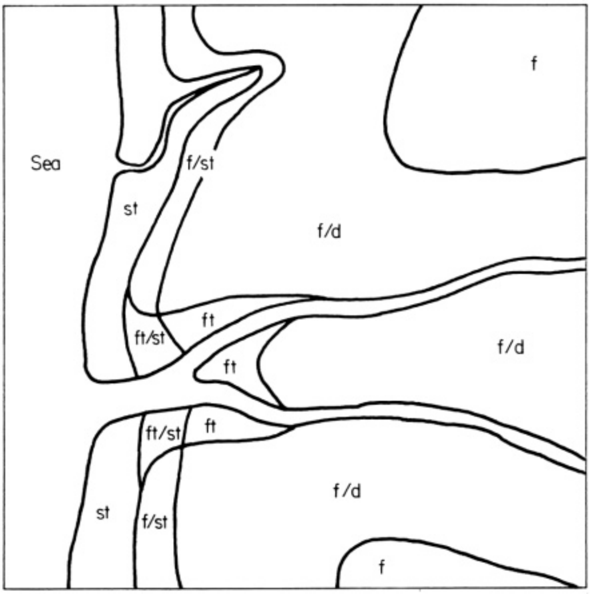


1. The hydrologic subdivisions of a coastal plain: st, saltwater tidal inundation throughout the year; ft/st, seasonally alternating freshwater and saltwater tidal inundation; ft, freshwater tidal inundation throughout the year; f/st, freshwater flooding in wet season and saltwater tidal inundation in dry season; f/d, freshwater flooding in wet season and dry in dry season; f, freshwater flooding in wet season and flooded or wet in dry season. Soils are mainly mineral; peat soils occur in f and locally in st.

Large areas of coastal plains and estuary plains (Fig. 1) were deposited as tidal swamps but have not been under tidal influence for hundreds or thousands of years. Those areas also have major problems for wetland rice cultivation because of the soils and the hydrology. These problems are distinct from those in tidal swamps, but their solution may require an approach integrated with that for areas presently under tidal influence.

There are two approaches:

1. Rice varieties should be adapted to a specific physical or chemical hydrology, even if only the most favorable season is considered, or,
2. Considerable changes need to be made in the hydrology of each of these environments to make cultivation of a range of high-yielding varieties possible.

I will touch upon tides and their influence on rivers and on soil hydrology in different landforms; the nature of inundation water in coastal plains; man-made changes in the extent of tidal influence; and the relation between rice cultivation and the different hydrologies prevailing in tidal swamps and adjacent parts of coastal plains.

TIDES

On a small island in an open ocean, the tide appears as a twice-daily, roughly sinusoidal rise and fall of the sea level with a range of about a meter. The tidal fluctuation is not a simple sine wave but consists of mainly semidiurnal and diurnal components as well as other longer- and shorter-term components.

In seas of a certain size that are not wide open to the ocean, for example the South China Sea, the resonance frequency of the water body is about 1/day. In

Table 1. Tidal constituents for Immingham (Humber estuary, North Sea) and Do Son (Red River estuary, South China Sea).[a]

Name of component	Speed (°/h)	Coefficient	Immingham		Do Son	
			Phase (°)	Amplitude (cm)	Phase (°)	Amplitude (cm)
Diurnal species						
Lunisolar	15.04	0.26	279	15	91	72
Larger lunar	13.94	0.19	120	16	35	70
Larger solar	14.96	0.09	257	6	91	24
Semidiurnal species						
Principal lunar	28.98	0.45	161	223	113	4
Principal solar	30.00	0.21	210	73	140	3
Larger lunar elliptic	28.44	0.09	141	45	100	1
Lunisolar	30.08	0.06	212	18	140	1

[a] Summarized from Hansen (1974).

such seas, the amplitudes of the diurnal components become much greater than those of the semidiurnal ones, resulting in a once-daily fluctuation of the sea level (Table 1).

Tidal influence on rivers

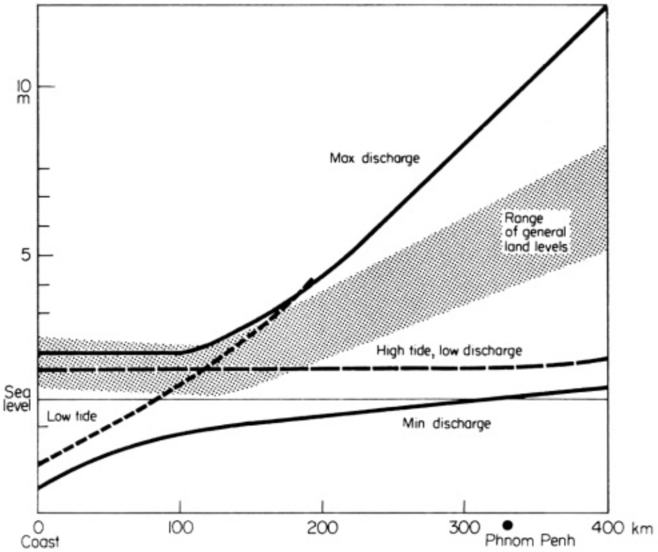
The distance to which tidal fluctuations are observed in rivers depends on the elevation of the river bed, the river discharge, and the tidal range and period. In periods of low discharge, the tidal influence may extend as far inland as the land is essentially level and the streams through it are at or below the elevation of high tide. In the Casamance River, Senegal, saline tidewater intrudes more than 200 km upstream in the dry season; in the Gambia River, more than 500 km (Marius 1982). During the wet season, high river discharge and seasonal inundation cause higher water levels. These override tidal influence except in a narrow band along the coast.

A diurnal tidal regime tends to extend further inland than a semidiurnal one with the same range in sea levels. Kalimantan and the eastern coast of Sumatra have broad, flat, recent coastal plains with wide rivers and a mainly diurnal tidal regime with at least a moderate range. The tidal influence in these areas is among the most extensive in the world.

A schematic longitudinal cross-section of the Mekong Delta (Fig. 2) shows the extent of tidal influence on the Mekong River in wet and dry seasons.

Possibilities for tidal irrigation or drainage

The benefits of the tides do not extend as far as their influence can be detected. The tidal fluctuations can be used for drainage only where the low-tide level is below the land surface in the wet season, when drainage is most needed. This is generally the case in a narrow band along the coast. Conversely, tidal irrigation is possible only on land lying below local high-tide level and where the tidewater is fresh in the dry season. This, too, is the case in a small part of most deltas. The extent of land in the Mekong Delta amenable to tidal drainage in the wet season or



2. A schematic longitudinal cross-section of water levels in the Mekong Delta, Vietnam. Generalized from data in Netherlands Delta Development Team, 1974.

irrigation or intake from fresh tidewater during the dry season is shown in Figure 3.

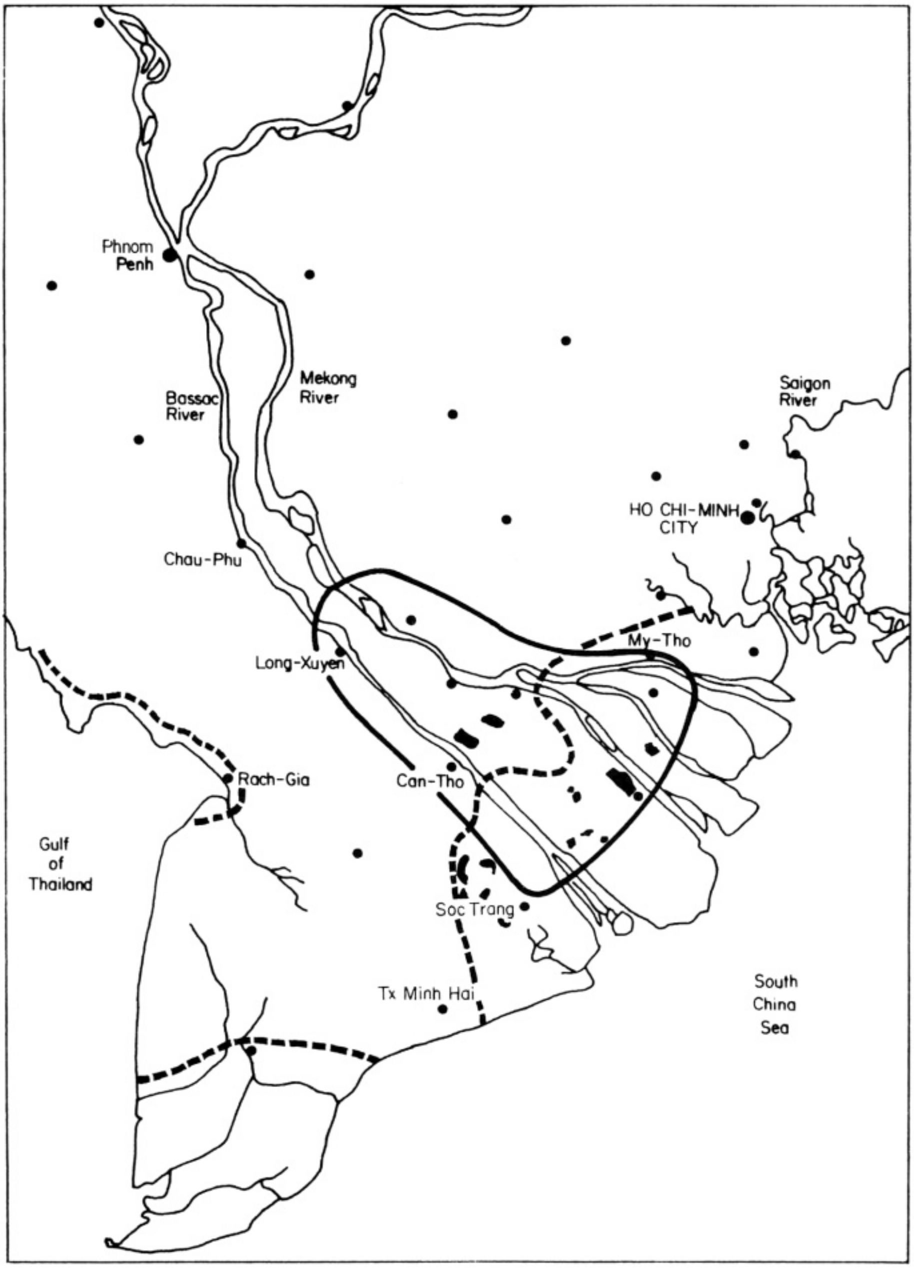
Saltwater and freshwater tidal inundation; vegetation and land use

Much of the world's tidewater is saline. In the tropics, land inundated by saltwater or brackish-water tides generally supports a mangrove vegetation. In a temperate climate, low tidal flats are barren and higher parts are covered by Spartina or other mainly herbaceous, low vegetation in the saltwater zone; brackish-water tidal areas may have a reed (Phragmites) vegetation.

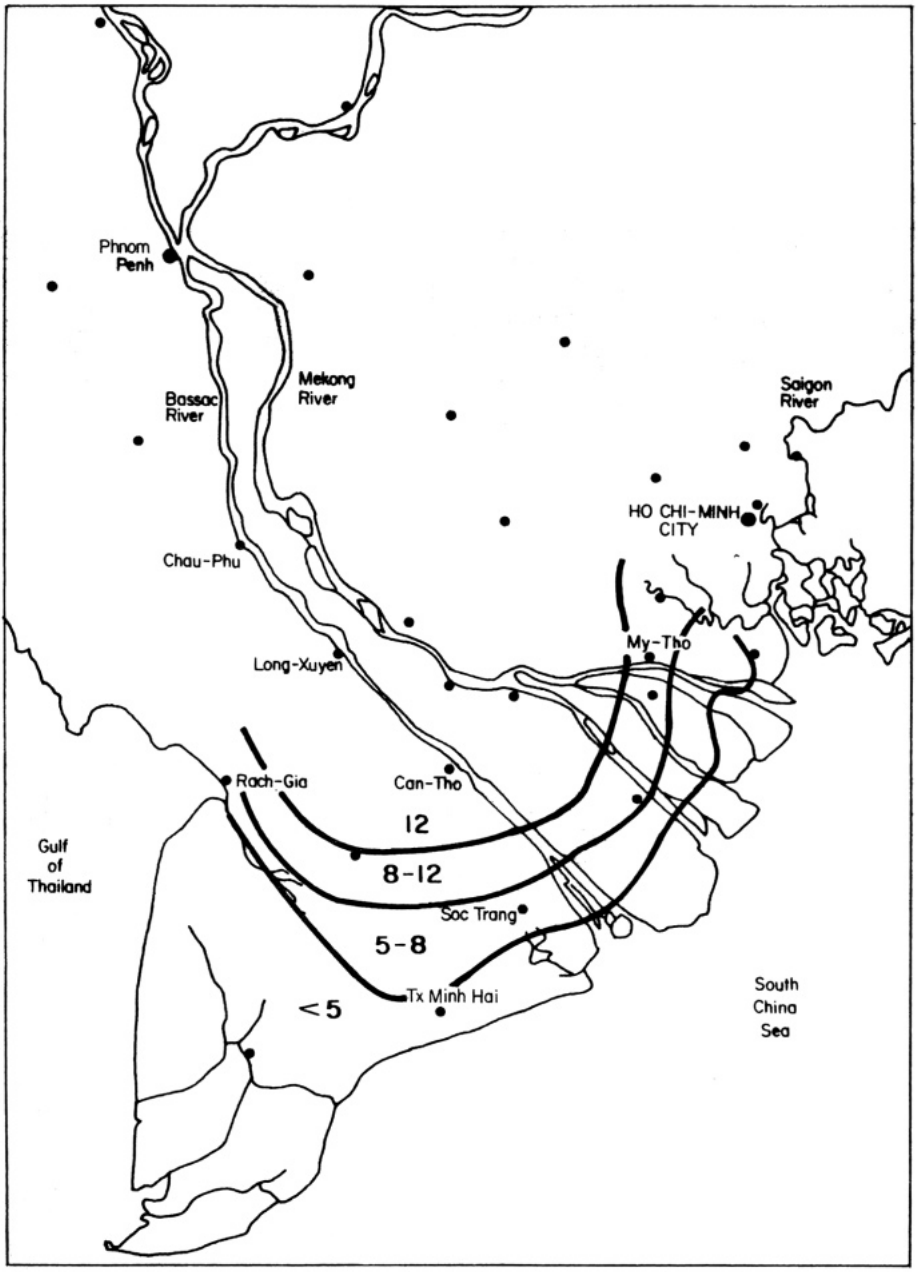
The few freshwater tidal areas I know are, or were, used for wetland rice essentially without water control in the tropics, and for willow (Salix) coppice in a temperate climate. (Willow branches and shoots were used for baskets and for large, barge-sized mats that protect sea dikes during construction.)

In some of the major deltas with a strong seasonal fluctuation in river discharge, there is a broad zone that is alternately fresh and saline. The land is flooded by fresh water to shallow or moderate depth, desalinized, and used for single wetland rice crop in the wet season. During the dry season, it remains fallow and subject to tidal inundation by saline water. Figure 4 shows the areas of the Mekong Delta with perennially or seasonally fresh water and areas that are saline throughout the year.

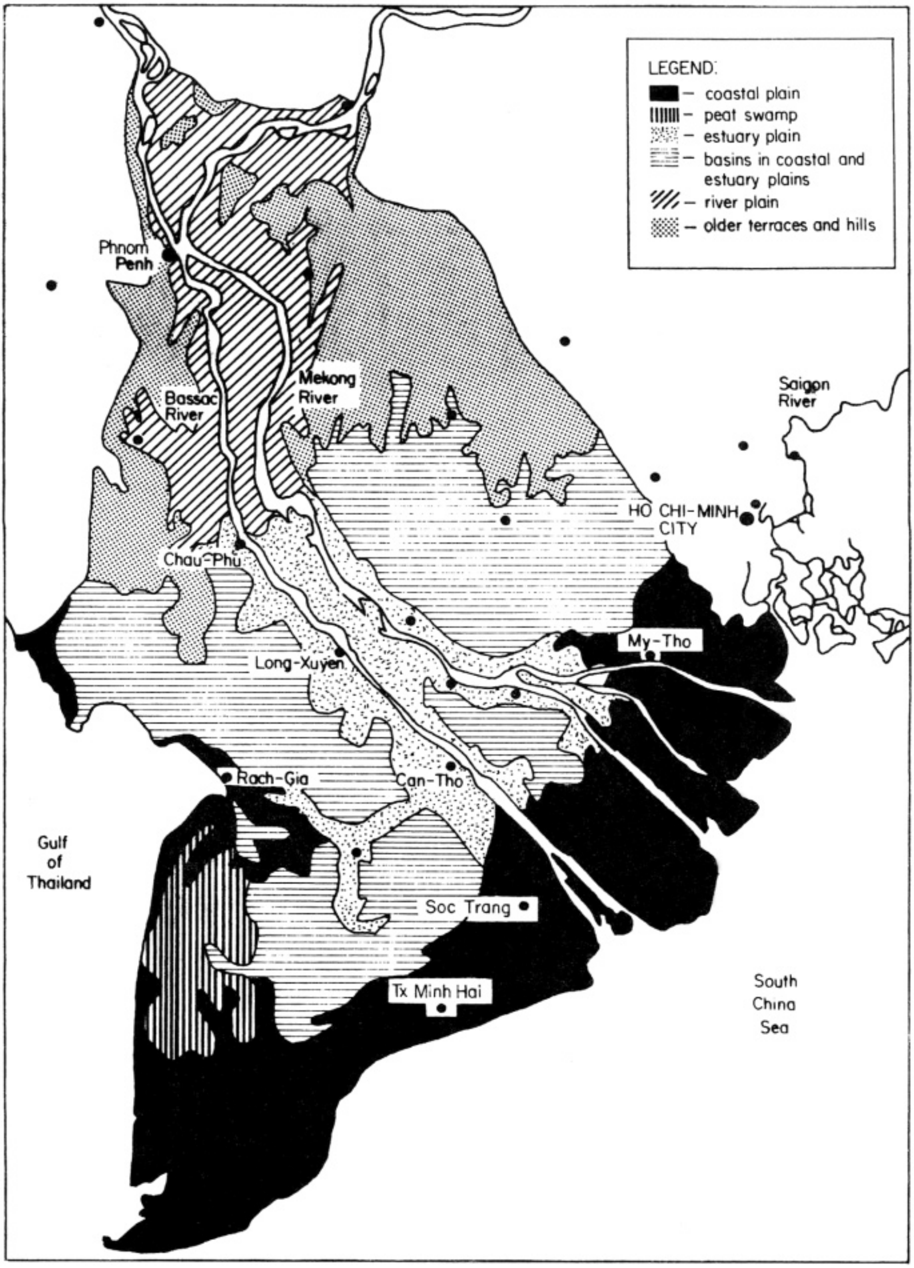
Reed as well as some of the mangroves have a dense system of thick roots (several mm to more than 1 cm diameter) that may give rise to a system of large tubular pores after the roots have decayed. Such pore systems are found in subsoils of coastal plains not under tidal influence, indicating that those were once subject to tidal inundation.



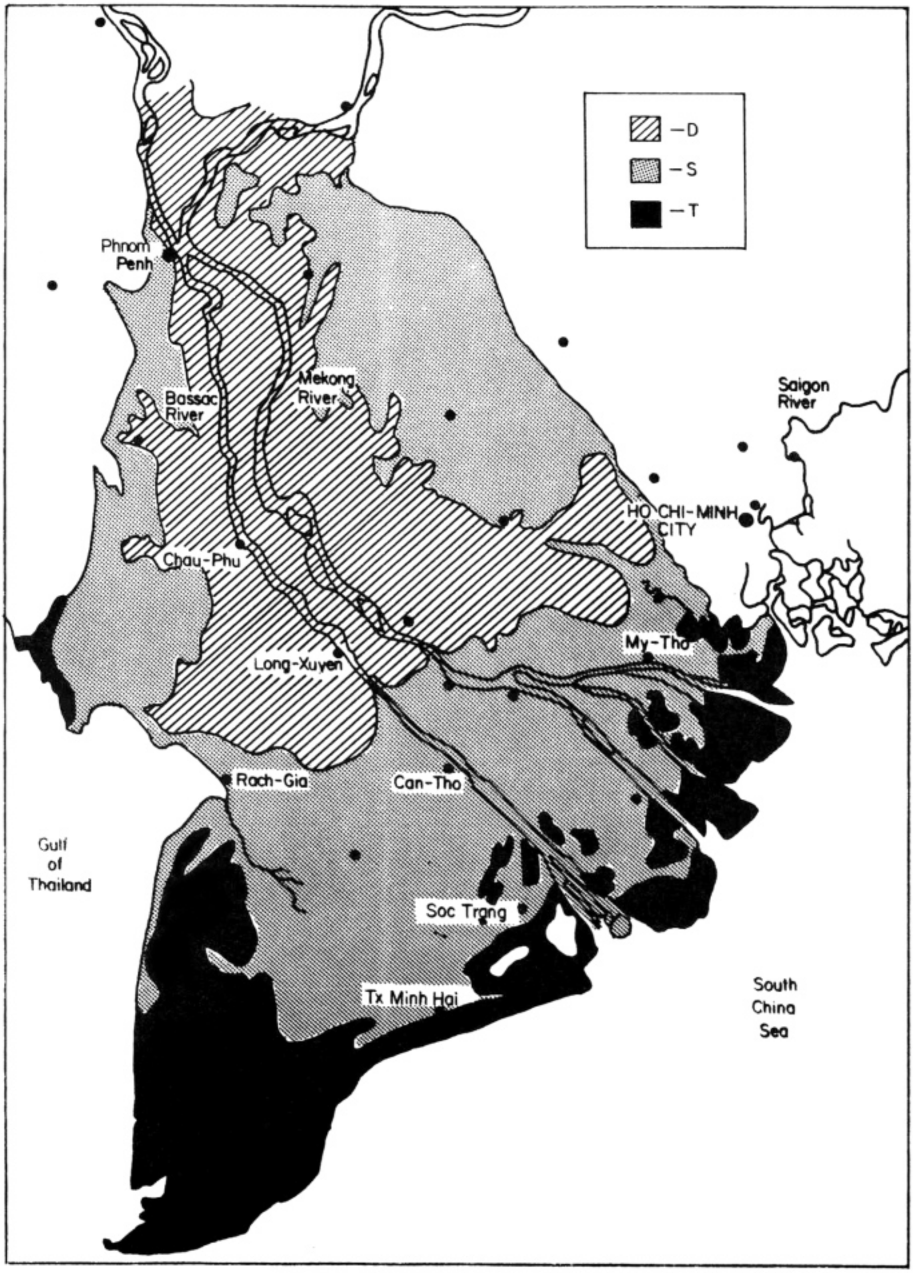
3. Areas with potential for tidal irrigation water intake or drainage in the Mekong Delta, Vietnam. Summarized from data in Netherlands Delta Development Team, 1974.
Solid line: In enclosed area, water intake by gravity is feasible during high tide. Farmers will have to extract water from irrigation canals by low-lift pumps.
Black areas: Potential areas for irrigation by gravity during high tide.
Dashed lines: Inland limit of areas that can be drained by gravity at low tide.



4. Availability of fresh water in the Mekong Delta, Vietnam. The numbers indicate months per year. From Netherlands Delta Development Team, 1974.



5. Landforms of the Mekong Delta, Vietnam. Generalized from Netherlands Delta Development Team, 1974.



6. Seasonal deep flooding and tidal inundation in the Mekong Delta, Vietnam. Generalized from Netherlands Delta Development Team, 1974.

Figure 5 shows the main landforms of the Mekong Delta and Figure 6, the extent of the seasonally deeply flooded and the total extent of the land annually subject to tidal inundation.

TIDAL INFLUENCE ON SOIL HYDROLOGY

Where tides are high enough to cause regular flooding, their influence depends on the slope away from the tidal channel and the degree to which vegetation slows down progress of the floodwater.

Where large tidal flats or basins adjoin a relatively narrow tidewater rather than the open sea, the high-tide elevation is determined by the elevation of the land. Once flooding starts, the volume of inundation water moving inland increases strongly with a small rise in water level. This effectively buffers the high-tide level for as long as several hours, until the falling tide ends the flooding period. Then the inundation water recedes, generally through a system of ebb creeks in the lowest part of the tidal basin, cut by the recurrent outflow toward tidal channels. Although flooding depths may be moderate or small, the floodwater moves overland rapidly, especially near the tidewater.

The tidal range of rivers and creeks may be reflected in similar fluctuations of the hydraulic potential in soils on their banks. These diurnal or semidiurnal fluctuations diminish rapidly with distance from the waterway and are probably negligible beyond a few hundred meters. In the few places where peat soils are under tidal influence, as near the western coast of the Camau Peninsula, Mekong Delta, the fluctuations may extend several kilometers from open tidewater.

In soils adjacent to tidewater, or inundated once or twice a day at high tide and with a land level above low tide, the hydraulic potential fluctuates in a narrow range between about 0 and –10 kPa (–0.1 bar). Even with an actively growing vegetation, such as mangroves, the evapotranspiration rate is too slow to cause higher moisture tensions.

Where there are many tidal creeks, as in the Saigon River Delta, this tidal influence on the soils' hydraulic potential is more extensive than where there are only a few large rivers or where the coast is closed, as in the Mekong Delta (Fig. 5).

Soil reduction and oxidation under tidal hydrology

In soils subject to regular tidal inundation, the low moisture tension during drainage and the short time span until reflooding allow air entry only in the largest pores. The main soil mass remains perennially water-saturated, even though the hydraulic conductivity may be high. The water in the saturated soil mass is not stagnant but is gradually replaced by exchange with water from successive inundations on the soil and in the large pores.

Most soils in coastal plains contain some organic matter throughout their depth. On the basis of this energy source microbial activity in the absence of oxygen causes reduction of iron oxides to soluble Fe^{2+}. Sulfate may also be reduced to sulfide, depending on the reactivity of the iron oxides (hydroxides) and the rate of microbial activity. The resulting iron (11) sulfides have an extremely low solubility and persist as stable solids as long as the soil remains reduced, either under tidal influence or later by perennial flooding or saturation by fresh water.

Part of the dissolved Fe^{2+} diffuses toward the large pores that are periodically air-filled. There, it is oxidized and an iron oxide (hydroxide, goethite or another crystalline form) is precipitated in and on the pore wall. Thus, the existing system of large tubular pores acquires a high mechanical stability. Soils with such a well-developed, stable macropore system do not seem to be extensive, but after reclamation they are among the most productive and versatile coastal plain soils, both for wetland rice and for dryland crops, because their hydrology is highly responsive to management.

SOIL HYDROLOGY AFTER CESSATION OF TIDAL INFLUENCE

In perhumid and humid climates, land in coastal plains beyond the reach of tides generally develops into a peat swamp. The mineral soil under the peat cover is or becomes nonsaline but remains perennially wet and reduced. In dry years, the surface layer or most of the peat may dry and burn, as in the Surinam coastal plain about 1964, but the mineral soil material generally remains wet throughout.

In climates with a strongly expressed dry season, most of the land beyond the reach of tides dries every year and is oxidized to depths ranging between about 30 cm and 1 m. Only small areas of deep depressions are perennially wet and develop a peat cover. In dry climates, as in Senegal, land beyond the reach of tidal inundation and outside the range of seasonal freshwater flooding develops into a bare salt flat.

The composition of the soil water, which was originally seawater, varies in these different soils. The main causes of the changes are dilution with rain or fresh river water; concentration by evaporation in more arid conditions; and in acid sulfate soils, oxidation of sulfides to sulfate, dissolution of clay minerals and precipitation of gypsum, jarosite, and amorphous silica.

Table 2 summarizes such changes for two saline estuary areas in West Africa. The chemistry of the groundwater in the mangrove swamp, which is subject to tidal inundation, differs little from that of the open tidewater, except for a 1.5 times concentration by evaporation in one of the cases.

The groundwater in the adjacent dry flat, inland of the mangrove fringe and' beyond the reach of tidal inundation, is 1.5 to 2 times more concentrated again and has become extremely acid by oxidation of iron (II) sulfides. The disproportionate increases in silica and magnesium concentrations reflect dissolution of clay minerals by the acid.

In the grass swamp, still further inland, seasonal freshwater flooding has diluted the groundwater, which is otherwise similar to that in the salt flat.

Table 3 shows irrigation water, supernatant water, and groundwater in a freshwater part of the Thailand Central Plain. Salinity levels are much lower than in Table 2. The groundwater has become very strongly acid by sulfide oxidation in a dry period and has dissolved some material from clay minerals. Although the irrigation water is much less acid and contains less total salts, it still shows a certain family relationship with the groundwater. The irrigation water may in fact contain some drainage water from similar acid sulfate areas upstream.

Acid sulfate soils tend to have a higher hydraulic conductivity than nonacid marine soils, not only because of stable tubular pores that may be formed in tidal conditions but also because the physical ripening after cessation of tidal influence produces a stable system of cracks.

Table 2. Composition of tidal creek water and groundwater in mangrove swamps, salt flats, and grassland swamps, West Africa.[a]

Estuary	pH	EC[b] (mmho/cm)	Ionic equivalents (mmol/liter)							H4SiO (mmol/liter)
			Cl	½SO4	HCO_3	½Ca	½Mg	K	Na	
Senegal, Casamance										
Tidal creek	7.2	46	600	105	2.4	23	118	10	510	0.06
Mangrove swamp	6.2	67	920	104	2.1	37	192	16	780	0.10
Bare, dry flat	3.6	103	1690	230	0.2	35	451	19	1430	1.34
Grassland swamp	4.3	86	1 300	127	0.2	34	275	22	1090	1.06
Gambia										
Tidal creek	7.6	44	360	51	0.9	12	72	10	340	0.18
Mangrove swamp	7.9	40	340	43	2.0	11	72	10	310	0.19
Bare, dry flat	2.8	108	1000	129	0.0	44	224	24	820	1.33
Grassland swamp	3.5	75	680	86	0.0	28	148	16	590	1.06

[a] Summarized from Marius (1982). [b] The EC of seawater is about 50 mmho/cm.

Table 3. Composition of irrigation water, water standing in the rice field, and groundwater, Rangsit Experiment Station, Thailand.[a]

	pH	EC (mmho/cm)	tonic equivalents (mmol/liter)								H_4SiO_4 (mmol/liter)
			Cl	½SO_4	HCO_3	½ Ca	½ Mg	K	Na	½ Fe	
Irrigation water	5.0	1.1	1.7	4.4	0.1	1.0	1.1	0.5	2.2	0.04	0.03
Standing water	4.4	1.2	2.1	4.0	0.0	0.9	0.9	0.3	2.6	tr.	0.10
Groundwater	2.9	1.5	11.1	20.3	0.0	3.6	8.3	2.10	12.6	0.4	0.50

[a] Summarized from Wada et al (1982).

As soil materials dry for the first time after deposition — when tidal influence has ceased — clayey soils, especially, shrink and crack into progressively smaller blocks. When the soil becomes wet again, it swells less than the degree of original shrinkage, so that some cracks remain open. The irreversible part of the initial shrinkage is termed physical ripening. This results in a higher hydraulic conductivity of such soils than would be expected on the basis of their clay content. In nonacid marine soils, such cracks tend to collapse again, or to be filled with slaked soil material from the surface, during subsequent inundation or heavy rainfall, so that the high hydraulic conductivity is short-lived.

The high mechanical stability of the aluminum-saturated clay in acid sulfate soils largely prevents collapse and soil slaking, so that subsoils of acid sulfate soils can remain permeable for long periods. This stability persists even after toxic free acids have leached or diffused out. As a result, management of reclaimed acid sulfate soils tends to be easier than that of nonacid marine soils, to the extent that dryland crops can be grown on them. Where surface peat layers are thin or absent, these soils can still be made to conserve floodwater by puddling the surface horizon, even when the groundwater level is well below the soil surface.

NATURE OF SURFACE WATER IN COASTAL PLAINS AND ITS EFFECTS ON RICE

Surface waters in coastal plains vary widely in composition — from rainwater to seawater, from pH above 8 to less than 3, and without or with dissolved organic matter. River water at high discharge stages tends to be low in salts, similar to the rainwater flooding large backswamp areas that is impounded by *water dams* in rivers.

The nature of these floodwaters may change during overland passage, however. Water out of large peat areas in coastal plains may contain dissolved organic matter that will hinder rice production. The early floodwater coming out of acid sulfate areas that have been dry in the previous season contains aluminum sulfate and free acid besides dissolved silica and magnesium and other ions. On well-buffered, near-neutral soils such water does little harm to the rice crop, although it acidifies the soil. On strongly acid soils, for example on partly reclaimed acid sulfate soils, such water has a more severe effect and can depress rice yields to low levels or cause crop failure.

Irrigation water from rivers containing dissolved calcium carbonate, such as from the Mae Klong River in Thailand, has the opposite effect. By its use, acids in the soil are progressively neutralized, with a positive effect on rice yields.

Saline water, too, can be used to improve rice-growing conditions on acid sulfate soils, if they are flooded in the dry, oxidized state. Then, the saline water dissolves free acid and part of the exchangeable aluminum. After removal of the extremely acid saline water, rice can be grown after desalinization by fresh water. Rapid reclamation of large acid sulfate areas in this way may, however, have disastrous consequences not only on rice fields downstream, as indicated before, but also on fish and mangroves downstream (Dent and Raiswell 1982). The rate of reclamation or the extent of the area to be reclaimed per year will need to be limited to provide a safe rate of dilution and removal of the acids.

CONTROLLED DRAINAGE AND USE OF TIDAL FLUCTUATIONS

Intensive, shallow drainage has transformed the hydrology of large areas of acid sulfate soils in several countries, for example Malaysia (Toh Peng Yin and Poon Yew Chin 1982) and Vietnam (Vo-Tong Xuan et al 1982). Formerly the acid sulfate soils in the southern part of the Mekong Delta were seasonally dry, containing toxic concentrations of acid, and seasonally flooded, containing toxic concentrations of soluble iron during part of that season.

After the installation of an intensive system of open drains (at 10-m intervals, 1 m wide and 0.3 to 0.6 m deep), oxidation in the dry season produces even more soluble strong acids in the surface horizons than before drainage. The first rains, however, remove much of the soluble acids from the surface soil horizons to the drains. As more rain falls, the soils become water-saturated, reduction starts, and the remaining soluble acids are partly neutralized by iron reduction. A part of the acids is also reduced again to insoluble compounds.

Where the drains are connected to the rivers, most of the acids are removed with the increasing river discharge; where the drains are isolated and not connected into a complete system most of the acid is immobilized by strong reduction in the ditch bottoms. Weeds are thrown into the ditches to speed up this process.

Thus a small change in hydrology, i.e., forcing a limited amount of water through and across the surface soil containing soluble, toxic acids, brings about a major improvement in rice-growing conditions. Where saline water is available or can be pumped in, the reclamation process can be hastened by one or two saltwater inundations at the end of a dry season, preceding the regular procedure.

In some areas with acid sulfate soils, cultivation of wetland rice and some dryland crops has been made possible by controlling groundwater levels with the aid of tidal fluctuations in nonsaline tidewater (Van den Eelaart 1982).

Drains to remove excess rainwater in the wet season have been provided with stop logs (small wooden weirs) to prevent a drop of the groundwater below their level. The main drains are connected with tidal rivers through an automatic flap gate structure for most of the year. Near the end of the dry season, water is allowed into the drains at high tide to prevent too great a drop in groundwater levels by evapotranspiration.

RICE BREEDING AS AN ALTERNATIVE TO WATER MANAGEMENT

Rice varieties for freshwater tidal swamps should stand up to rapid flow of water and to intermittent medium-deep or deep or deepwater (>1 m) inundation.

Rainfed wet season rice varieties for land salinized by tidal inundation in the dry season must survive short periods of moderate salinity in the early growth stages or, for a second rice crop, during grain filling. If they are early-maturing, double-cropping would be possible even though the effective wet season is shortened by the time needed to desalinize at least the plowed layer.

Varieties for partly reclaimed acid sulfate soils should tolerate high Fe^{2+} concentrations and low phosphate availability. Rapid, deep rooting may increase effective tolerance because at least the soluble iron levels tend to be highest in the upper, periodically oxidized horizons. Aluminum toxicity for those varieties can be avoided by transplanting after 2-4 weeks of preflooding.

Varieties for nonacid marine soils may encounter strong soil reduction, giving rise to zinc deficiency, which in some cases will be combined with sulfur deficiency and nitrogen deficiency because of slow ammonification.

Varieties for use in the large, oligotrophic peat areas of a coastal plain would face a formidable array of stresses, involving soluble organic compounds that appear to inhibit seed set and multiple deficiencies including zinc, copper, and the macronutrients. These challenges should not be confused with the much less severe ones posed by the patches of eutrophic peat found locally in, for example, volcanic toeslopes or extinct craters, on which IRRI presently screens some of its lines.

Should resources be allocated to breeding varieties for all these environments? Probably not for the oligotrophic peat. The hydrological management and agronomic problems for this land have not been solved and such land is used in few places. Once the hydrological problems are solved and it is possible to keep the water table slightly below the surface of the peat, the copper deficiency becomes correctable and rice varieties designed for the better-quality peat soils would have a chance. The nonflooded soil might have major weed infestation and other agronomic problems, however.

The margins of the peat area, where the peat layer is thin over clayey material that is generally acid sulfate, are shallowly drained and used for a range of dryland crops, among others oil palm, with more success than for rice — for example, at the peat experiment station near Kuching, Sarawak.

The alternative to breeding for these rice-growing environments is changing their hydrology. After diking, the land now subject to freshwater tidal flooding could be fully irrigated and drained by gravity using tidal fluctuations; yields of normal, modern varieties should be high in these conditions.

Land presently subject to tidal inundation by saline water during the dry season can also be protected by dikes and control structures in seasonally tidal channels. With adequate irrigation water, the land could then be used for high-yielding varieties throughout the year. Without irrigation water, the effective cropping season would still be extended — the early rains, now used for desalinization, could be used to start a crop instead; dryland crops could extend into the dry season on intermittent rain and residual moisture, without a salinity hazard.

For the acid sulfate soils, an optimal management of the hydrology by controlled drainage followed by shallow flooding would minimize but not eliminate high soluble iron concentrations; also, the poor phosphate availability and the fixation of applied phosphate would persist. There seems to be good reason for breeding phosphate-efficient varieties tolerant of high iron concentrations.

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SOILS AND SPECIFIC SOIL PROBLEMS OF TIDAL SWAMPS

P. M. DRIESSEN and M. SUDJADI

Most coastal landscapes are dominated by fine-textured marine sediments deposited some 11,000 years ago. The flat and level marine plains are traversed by wide rivers with faint levees. Their basins consist of fine-textured fluvial material on top of a marine substratum. With progressing lateral accretion of land, newly deposited tidal flats are quickly colonized by mangroves, which follow the shoreline in a shifting belt. They are bordered on the inland by areas with grasses, ferns, reeds, and forest. Interior parts of extensive coastal plains are often covered with vegetal debris accumulated as freshwater peat. Water control is the most pressing problem in coastal lowlands. Soil acidification coupled with severe phosphorus deficiency confront rice growers on certain marine soils. Apart from this, coastal swamp soils generally have a low and ill-balanced nutrient status. Most swamp soils can still be used for tidal rice production, provided that they are properly managed. Groundwater peat soils are comparatively well suited for the cultivation of rice, but the much more extensive rain-dependent raised bogs cannot be used for rice production at all, presumably because of a physiological inhibitor in the peat water.

GENESIS OF COASTAL LANDSCAPES

The genetic history of many coastal landscapes is dominated by eustatic sea level changes that occurred during Pleistocene glacial and interglacial periods. The sea level was at times more than 100 m lower than at present but rose again during interglacials. Glacial periods were very cold in northern regions, but there is evidence that only moderate changes occurred in the tropics.

Verstappen (1975) states that rainfall in Southeast Asia was about 30% lower during glacial periods than at present, and temperatures were 3 to 5°C below those of today. Temperatures are believed to have been 2 to 3°C higher than at present during interglacial periods. The drier and cooler conditions affected the vegetation, which was less abundant during glacial periods. This fact, combined with the lower erosion basin of the rivers and less intensive chemical weathering in the

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hinterland, led to the deposition of widespread coarse-textured Old Alluvium on top of the Tertiary land surface. Verstappen (1975) concludes that the sedimentation of the Pleistocene alluvial complex took place as nonconcentrated surface wash on dry land with a savannah-like vegetation. Survey teams of the Soil Research Institute of Bogor, Indonesia, studied soil development in outcrops of Old Alluvium in the coastal plains of Sumatra and encountered mainly Plinthudults with advanced profile development. After the last regressional phase, which took place at the Pleistocene-Holocene interface some 11,000 years ago, the seas rose gradually and temperatures went up. Rainfall increased as well and the chemical weathering of rocks gained prominence. The fine-textured weathering products were transported toward the sea and sedimented as near-shore clay blankets. The seas reached their present level some 5,500 years BP and from that crucial moment onwards, the lateral accretion of coastal land increased.

The low gradient of the clay-blanketed coastal plain areas is associated with wide but shallow rivers with a low stream velocity and a low bed load of fine-grained material. This explains the low, clayey, and only vaguely defined river levees characteristic of rivers in extensive coastal plains. Studies of Barito River sediments (South Kalimantan) showed downstream levees to consist largely of rewashed marine plain material; the coarser weathering products from the hinterland are deposited more upstream (Driessen and Soepraptohardjo 1974). In less extensive coastal lowlands or in places where rivers cut along their course into outcrops of Old Alluvium or other old formations with a low structure stability, the formation of coastal lowland could proceed very rapidly. Reinders (1961) mentions accretion of an average rate of 9 m/year during the past 4,500 years near the mouth of Baram River in Sarawak. Settlers near the mouth of Rokan River, Sumatra, stated that the coastline has progressed 1,700 m since 1932, an average accretion of 40 m of coastal land each year. Ashton (1972) found fossils 5,200 years old at a distance of 26 km from the present shoreline on the Perlis Plain, Malaysia, and presumed that a slight drop in sea level took place during Holocene times. Local tectonic movements of the land surface cannot be ruled out either.

The young sediments are first colonized by mangroves, which follow the progressing shoreline in a shifting belt. Inland the mangroves are bordered by belts of ferns, grasses, and reeds. Tidal fluctuations are felt only near the shore or a few kilometers or less from creeks and rivers. The more inland basin areas are commonly stagnant. Vegetal debris, incompletely decomposed under the permanently waterlogged marsh conditions, may accumulate as groundwater peat. Such peats have a relatively high content of mineral admixtures because they are frequently subject to river floods. The incidence of such floods decreases as the peat mass builds up. At the same time plant roots find it increasingly difficult to take up nutrients from the underlying mineral strata. The vegetation adapts itself to the changing environment and turns gradually into a rain-dependent freshwater swamp forest. Eventually, the forest vegetation relies for its growth on a limited quantity of cycling nutrients. Losses of nutrients from the root zone during further vertical growth of the raised bog require continual adaptation of the flora until ultimately a stunted forest of few low-nutrient-demanding species remains on top of 7 to 10 m of extremely poor peat.

The genetic history of coastal landscapes makes it clear that two main soil groups can be expected to occur:

- Mineral alluvial soils, both fluvial and marine; and
- Organic soils, both under the influence of the groundwater (topogenous peat) and rain-dependent (ombrogenous peat).

MINERAL SOILS

Physiographic variations within the coastal alluvial landscape are as important to rice growers as are soil differences. Because tidal fluctuations are restricted to the low-lying areas, elevated lowlands such as river levees and terraces will not be discussed in this paper. Instead, attention will be focused on the soils of river basins and marine plain areas where rice growing is the obvious land use.

Soils of river basins

Basin soils are commonly fine-textured and show little horizon differentiation. Redistribution of iron is among the first signs of beginning pedogenesis in these soils.

The presence of ferric iron in the aerated surface horizon is shown by yellowish-brown colors. Strong brown to black colors occur where organic matter has accumulated in the surface soil, with a histic surface layer as the extreme condition.

Blue subsoils indicate the presence of dissolved ferrous iron, formed through the reduction of ferric iron under low redox conditions. Van Breemen and Moormann (1978) describe the process as follows:

$$\underset{\substack{\downarrow\\ \text{(redicible}\\ \text{iron)}}}{Fe\,(OH)_3} + \frac{1}{4_n}\underset{\substack{\downarrow\\ \text{(organic}\\ \text{matter)}}}{(CH_2O)_n} + \underset{\substack{\downarrow\\ \text{(low}\\ \text{pH)}}}{2H^+} \rightarrow Fe^{2+} + \frac{1}{4}CO_2 + \frac{11}{4}H_2O$$

Hydrogen ions are needed in the reduction process, which explains to some extent why the pH of undrained basin soils is normally near-neutral. In their natural state basin soils are poorly ripened and feature little structure development.

Basin soils typically have a low hydraulic conductivity. Their chemical characteristics depend largely on the origin of the sedimented material. Weathering material from intermediate or basic igneous rock or from limestone is normally high in bases; unfortunately most tropical coastal lowlands consist of acid material and contain precious little weatherable minerals. The clays are commonly kaolinitic and well crystallized, but smectite clays are common as well.

Problems of river basin soils. Rice growers in coastal river basin areas experience a score of problems caused by, or related to, the specific environment and soil conditions that prevail. The most pressing is the difficulty of water control. The shallow river levees offer little protection against floods whenever precipitation exceeds normal values in the hinter land. Dikes would curb the flood hazard but their cost is often prohibitive. Water is ample in normal circumstances, but river water levels are often low during dry spells. In downstream parts saline or brackish water creeps in from the sea; in such cases good quality water for irrigation or leaching must be obtained by tapping the river well upstream of the irrigation area. The low gradient of the terrain makes it necessary to use long and expensive primary canals to avail of the required hydraulic head and to avoid influx of saline water during prolonged dry periods. Excess water is commonly discharged from the system through automatic flap gates that close at high tide. Where tidal influence is minimal or absent altogether, satisfactory drainage can only be achieved with the aid of pumps. Adequate water control is particularly important where shallow base-poor fluvial sediments occur on top of pyritic marine strata. Excessive aeration of such soils causes severe soil acidification, and related problems such as aluminum toxicity and low levels of plant-available phosphorus (Pons 1980).

The low base saturation and low organic matter content of many basin soils result in a low structure ability of the aerated surface soil. That, together with heavy texture, low hydraulic conductivity, and uncertain water regime, explains the poor workability of many basin soils. Cropping is hindered by unfavorable soil physical conditions and generally suboptimal chemical conditions. The electrolyte composition of the soil solution is generally ill-balanced and locally ions may occur in quantities toxic to plants.

Soils of marine plains

The marine plains comprise bare tidal flats, mangrove swamps dissected by tidal creeks, and, more to the inland, marshes with a vegetation of adapted herbs and trees. The tidal flats and mangrove swamps are virtually always saturated with water and show minimal soil development. They consist of permanently reduced silty or clayey sedimentary material with varying contents of raw vegetal debris. Pedogenesis starts where the sediments are above mean water level and surface: soils become aerated. Where the land is silted up to mean high water level and above, as in parts of the mangrove belt and in the adjacent marshland, profile development becomes conspicuous. However, the course taken by pedogenesis depends very much on the chemical and physical properties of the sedimented material and this, in turn, is related to conditions prevalent at the time of sedimentation.

The formation of potential soil acidity is particularly important in this context because it seriously limits the suitability of the land for most agricultural uses. Potentially acid sediments contain pyrite (FeS_2) in excess of inherent acid-neutralizing substances. The pyrite oxidizes upon aeration of the sediment and this produces — among other compounds — sulfuric acid. Thus, the soil reaction changes from near-neutral pH values in (reduced) potentially acid sulfate soils to values lower than pH 4 in (aerated) true acid sulfate soils. This acidity directly hinders the growth of most crops, and is harmful because it helps generate toxic levels of aluminum and iron, associated with severe phosphorus deficiency.

The regional distribution of pyritic sediments, the quantities of pyrite present in the sedimented material, and the depth at which potentially acid strata occur determine to a great extent the use that farmers can make of these soils and the measures to avoid soil deterioration.

Formation of potentially acid sediments. The formation of potentially acid sediments involves the bacterial reduction of sulfate to sulfide, which is subsequently transformed to disulfide, with ferric iron and oxygen as oxidants. Pons et al (1980) present the overall reaction equation:

$$Fe_2O_3 + 4SO_4^{2-} + \frac{8}{n}(CH_2O)_n + \tfrac{1}{2}O_2 \rightarrow 2FeS_2 + 8HCO_3^- + 4H_2O$$

The process involves iron-containing minerals, sulfates dissolved in seawater, metabolizable organic matter, sulfate-reducing bacteria, and anaerobic conditions alternating with limited aeration. The intensity of pyrite formation differs among sites; the quantities of metabolizable organic matter and reducible iron compounds and the rate at which dissolved alkalinity (formed in the process of sulfate reduction) is removed from the sediments are the main determinants. The quantity of pyrites in a sediment is further determined by the time during which sulfate reduction takes place. The hazard posed by the accumulated pyrite depends not only on the pyrite content but also on the inherent acid-neutralizing capacity of the soil material, and on the depth at which the pyritic material occurs.

Bare tidal areas normally contain very little carbon. The absence of carbon is thought to retard pyrite formation in tidal flats and creek bottoms with no vegetation (Pons 1965). Tidal flats under mangroves or reeds and sedges are well supplied with organic matter and often feature very high pyrite contents. Most tropical coastal lowlands have old, iron-rich formations in their hinterlands; the presence of reducible iron is normally not a limiting factor in the formation of pyrite. Only where slow sedimentation of iron-poor mineral material takes place in the presence of ample organic matter would the system fall short of iron. Indications are that the accumulation of pyrite is accelerated where tidal flushing of the sediments is strong, e.g. where a dense system of tidal creeks exists and sediments are permeable because of abundant root channels and plant remains. Tidal flushing removes bicarbonate ions formed in the process of sulfate reduction and supplies dissolved oxygen. It also removes acid-neutralizing sedimentary carbonate and thus increases the potential acidity of the sediment (Pons et al 1980).

The quantity of pyrites is the highest where their accumulation could continue uninhibited for a long time. Where sedimentation after the last glaciation kept pace with the rising sea level, thick formations of highly pyritic sediments developed.

When the sea level stabilized, lateral accretion of coastal land caused the intertidal zone to shift. Rapid coastal aggradation is associated with a short duration of favorable conditions for pyrite formation and, consequently, with sediments free of potential acidity. This explains why potential soil acidity is often pronounced in the old interior parts of river deltas and coastal plains (examples: the Bangkok plain, the Mara formations of Surinam, the delta Pulau Petak in South Kalimantan), whereas the most recent sediments near the present shoreline are not acid (Moormann and Rojanasoonthon 1967, Brinkman and Pons 1968, Kamerlingh 1974). When the land gradient levels off with progressing lateral accretion of land, the rivers carry less sedimentary material. Where sedimentation rates have remained high, or increased recently as a result of deforestation or erosion of upstream river levees, there is little pyrite in the younger sediments. Appreciable quantities of pyrite accumulate in young deposits if sedimentation rates are low and tidal flushing is strong. The Sunderbans of Bangladesh are an example of this situation (FAO 1971).

Even highly pyritic sediments will not acidify upon aeration if they can supply sufficient bases to neutralize the formed acidity. The total acid-neutralizing capacity of a soil material is determined by its carbonate content, the quantity of bases at the exchange complex, and the mineral assemblage.

Calcium carbonate is immediately available for the neutralization of sulfuric acid, but unfortunately most tropical marine sediments contain very little carbonate because of the commonly acidic nature of rock formations in the hinterland. Even if some calcium carbonate is initially present, it is presumably (partly) removed in the course of sulfate reduction by the combined action of the generated carbon dioxide and tidal flushing.

Pons et al (1980) state that a calcium carbonate content of 3% can neutralize the acidity from about 1% pyrite-S. The acid-neutralizing capacity of adsorbed bases depends on the clay content, the exchange capacity of the clay, and the base saturation percentage. Adsorbed bases are readily available for neutralization. However, although most marine plain soils are fine-textured, their adsorbed alkalinity should not be overestimated. Pons et al (1980) estimate that less than 0.5% pyrite-S makes kaolinitic sediments potentially acid, even if the complex is fully saturated with bases. Smectite clays have a higher exchange capacity and (can) perform better. In addition there is evidence that ferric iron is extracted from smectites and replaced by magnesium during pyrite formation in tidal swamps. This process stores alkalinity in smectite as MgO that becomes available for neutralization of acidity when the pyrites oxidize and the iron-magnesium exchange is reversed (Van Breemen 1980).

In summary, potentially acid sediments can form where slow sedimentation of base-poor material takes place in the presence of ample metabolizable organic matter and reducible iron compounds. Extreme potential acidity can be expected in stable intertidal areas dissected by a dense system of tidal creeks. This general picture is blurred locally because of variations in environmental conditions.

Marine soils with acid sulfate problems. Acid sulfate soils develop where pyrite in potentially acid sediments oxidizes to the extent that the pH falls below 3.5 (4.0 in Inceptisols) in the upper 50-cm soil layer. This oxidation is aided by autotrophic microbes. Basic ferric sulfate is formed in the process and shows up as straw-yellow jarosite mottles. Major occurrences of these soils are in East and Southeast Asia (notably in the Mekong Delta, the Bangkok Plain, the Malesian region, and along the Bay of Bengal), along the African west coast, and along the northern coast of Latin America. Most of the 12.6 million ha of acid sulfate soils that have been identified are situated near the equator.

The seriousness of the acidity problem depends not only on the quantity of pyrite-S for which the soil has no compensation in terms of acid-neutralizing substances, but also on the rate at which the available alkalinity can be mobilized and the rate at which sulfuric acid is allowed to form. The calcium carbonate content of most pyritic sediments is insignificant or nil, but the clays will normally buffer the soil pH at values close to 3.8. Where the formation of acid exceeds the compounded buffering capacity of the soil material, pH values drop to 2-3. Excess acid breaks in at the clay structures and liberates aluminum, magnesium, and silica. Such extreme conditions are normally confined to places where sudden deep drainage causes the excessive aeration of highly pyritic strata. Driessen and Soepraptohardjo (1974) report the occurrence of glass-like crusts with 3.86% aluminum on the soil surface near a newly constructed drainage canal in Pulau Petak, southern Kalimantan. The corresponding field pH was as low as 3.0 and naturally no vegetation survived.

Once the general mechanism of acid sulfate development is understood, the precautions to be taken to prevent soil acidification become obvious. One approach is to restrict drainage of potentially acid sediments to minimum and to avoid abrupt aeration of the pyritic strata at all times. This is illustrated by the fact that natural tidal land is commonly free of acute acid sulfate problems: soil aeration is shallow and intermittent. However, the opposite has also been done in some places with excellent results. Intensive oxidation of pyrites and forced leaching of the developed acidity in an array of alternating drainage ditches and ridges (spill from the ditches) yielded good coconut groves along the Tamban canal in South Kalimantan. This practice has the disadvantage that extreme acidity precludes cropping altogether in the first few years after construction of the ridges. Elimination of the acidity hazard in rice land by generous liming poses technical difficulties and is clearly not economic (Coulter 1973, Driessen and Soepraptohardjo 1974). Moderate liming, preferably in combination with leaching of the soil, will often suffice to eliminate the acidity developed during a limited period of aeration and will reduce aluminum and iron in the root zone.

Properly managed tidal land makes productive rice land. Buginese farmers in Kalimantan produce up to 3 t rice/ha on highly pyritic soil material, thanks to careful water control including (tidal) flushing of the topsoil. They use a system of parallel, densely spaced but shallow drains that effectively removes any acidity developed in the surface layer while keeping the subsurface soil saturated with water.

Prolonged inundation of acidified land raises the soil pH, particularly where soil reduction is enhanced by high organic matter contents. Rice farmers in Kalimantan restrict soil tillage to superficial peeling of the uppermost soil layer and leave weeds and sods on the land as a mulch (Driessen and Ismangun 1973). They also developed a system of rice cultivation using varieties with a 9-month growth period and tolerant of deep inundation and probably also of high levels of dissolved iron (Ikehashi and Van Breemen 1977).

Tidal water fluctuations should not be obstructed; poor maintenance of canals and ditches results in dramatically reduced rice yields (NEDECO 1965). Where tidal influence is absent altogether, deep aeration of the soil may occur during dry spells. Stagnant coastal swamplands are at best moderately productive (say, 1.5 t rice/ha) but pose immense problems if highly pyritic soil layers occur at shallow depth. Likewise, the construction of dikes without adequate provisions for irrigation and drainage has often led to disastrous levels of iron and aluminum in the surface soil. Costly liming is one method to restore the productivity of such spoiled land. In practice, such fields are nearly always abandoned and turn to grassy marshes without much economic value as their natural recuperation takes a long time.

Other problems of marine soils. Adequate water control is essential in marine lowlands for a number of reasons. Excessive drying of poorly ripened marine soils often leads to uneven subsidence of the land surface. Inundation with saline or brackish water, not uncommon near the shore or tidal creeks, can be beneficial in removing noxious substances from the root zone, but high salt levels hinder the growth of rice (Kamerlingh 1974). Desalinization of nonacid soils by leaching with fresh water will cause peptization of clays and reduced hydraulic conductivity unless adequate amounts of lime or gypsum are supplied.

In many coastal lowlands crop security is lowered by the incidence of (fresh water) flash floods. Complete water control in the level coastal plain areas involves empoldering and the construction of separate drainage and irrigation canals, and is extremely costly.

Where fine-textured potentially acid marine soils are cultivated, poor ripening of the soil material occurs and is associated with a low bearing capacity and a narrow workable moisture range.

Apart from toxic levels of iron or aluminum, and associated low levels of available phosphorus, many coastal soils have an ill-balanced, generally low nutrient status. Driessen and Ismangun (1972) report that rice yields on nonacid marine soils in southern Kalimantan increased by 50% upon application of 70 kg sea salt/ha. The sodium ions replace potassium at the exchange complex, or perhaps the effect is caused by some minor element in the salt. De Groot (1966) has shown that considerable losses of trace elements occur during transport of sedimentary material, especially in the presence of decomposing organic matter. Copper, zinc, and manganese contents are low in many coastal soils, particularly where a histic surface layer furthers loss of heavy metals through formation of chelates and successive leaching. The organic acids *per se* can damage rice crops at low pH.

Soil problems are most serious in the (potentially) acid stagnant marshlands that occur in the interior parts of many coastal plains. The reclamation of such lands requires the use of pumps and separate facilities for irrigation and drainage, and should be discouraged unless its economic feasibility is proven.

Soil problems are less serious (and project costs lower) if intelligent use can be made of the tides. In any case, adequate maintenance of canals and waterworks is a precondition for sustained production of rice.

ORGANIC SOILS

According to the definition used in Indonesia, peat soils are thicker than 50 cm and contain more than 65% organic material. Shallower organic deposits and mucky soils with little less than 65% (normally well-decomposed) organic matter are not uncommon in coastal lowlands but are not termed peat soils.

Tropical lowland peats cover an estimated 32 million ha of which more than 20 million ha are in Southeast Asia. Their formation started when the postglacial rise of the seas leveled off and lateral accretion of coastal land accelerated. The newly aggraded land was colonized by a sequence of mangroves, grasses, and swamp forests which produced abundant organic debris. Organic matter decomposition was extremely slow under the conditions of oligotrophy and permanent waterlogging characterizing the lowlands, and peat began to accumulate.

Carbon datings on coastal peats from Southeast Asia confirm that the growth of most well-developed coastal peat bodies started between 4,000 and 5,000 years BP. Most tropical peats consist of ombrogenous raised bogs, which are never influenced by the tides. They deserve attention, however, because of the problems they pose to rice growers, both in the peat area itself and on adjacent marine land.

Topogenous peat forms mostly in the stagnant interior parts of coastal plains but is also found in tidal areas. It can make good rice land but requires management, particularly where it occurs on top of potentially acid marine sediments.

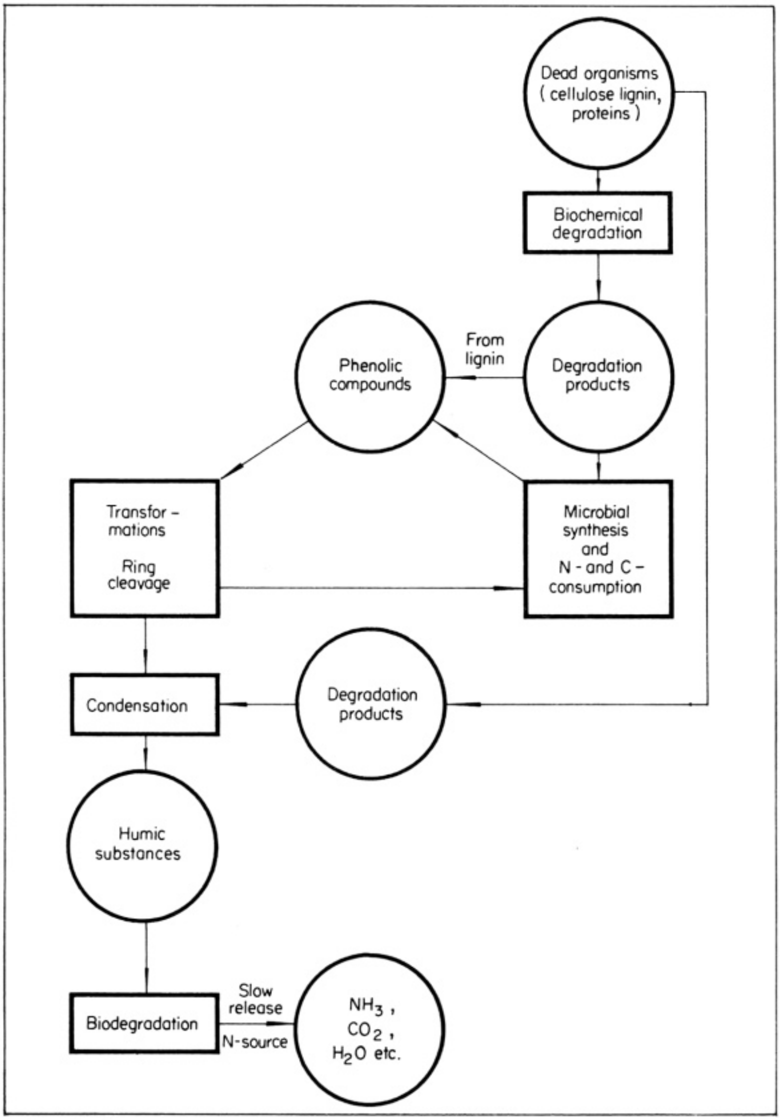
Soils of topogenous peat areas

Peat consists of partly transformed vegetal debris, largely composed of cellulose, lignin, sugars, and proteins. In the course of (bacterial) transformation another organic fraction is synthesized: the humic substances, a mixture of humins and humic and fulvic acids. Flaig (1975) summarized present knowledge of the synthesis of humic substances in a chart, which is reproduced in a slightly modified form in Figure 1.

The composition of a specific peat body is thus dependent on the floral composition of the vegetation that produced the organic debris, the intensity and duration of transformation processes, and locally also of the selective removal of organic constituents from the peat mass.

Topogenous peats can form under different conditions and types of vegetation. Peat that formed in the brackish water zone under a mangrove or nipa vegetation is commonly shallow and confined to filled-in depressions. It is saline, sometimes pyritic, but always poorly decomposed and relatively rich in wood. The raw character of such peats is probably due to reduced microbial activity at high electrolyte concentrations, possibly in combination with increased removal of fine-grained organic material through tidal flushing.

Topogenous peat formed in the interior coastal plain is strictly freshwater peat. Its formation starts in shallow depressions, which are filled in with plant debris and mineral material brought in by occasional river floods. There is normally a sharp boundary between the mineral substrata and the overlying peat body, but a thin gyttja-like transition layer may occur as well, particularly in the nucleus areas from where peat growth extended over the marine plain. Progressive vertical peat growth leads to gradually drier conditions and less frequent flooding. This explains why topogenous freshwater peats tend to contain more mineral admixtures near their base than in the surface tiers. In addition, the floral composition shifts from true aquatic plants and grasses in the deeper tiers toward a



1. Synthesis of humic substances (after Flaig 1975).

predominance of ferns and shrubs in the surface layer.

Coastal topogenous peats represent the first stage of a process that leads to the formation of a rain-dependent raised bog with a topogenous base. They cover relatively small areas and are by nature shallow. Buried peats with a mineral cover occur but are rare in extensive lowlands where sedimentation rates are low.

Mineral admixtures account for the relatively high bulk density values of most topogenous peats: typically between 0.22 and 0.40 kg/dm^3. The corresponding specific weight values range from 1.5 to 2.0 kg/dm^3, which suggests a total pore space of 80 to 85% by volume. Topogenous peats are relatively rich in plant nutrients. Nitrogen becomes available upon disintegration of organic matter;

mineral nutrients and trace elements are taken up from underlying strata or supplied by the exchange complex or by dissociating mineral admixtures in the peat.

Apart from a higher degree of decomposition of the surface tiers, reclaimed topogenous lowland peats show little evidence of pedogenesis. They are often stratified and heterogeneous, but the condition will normally improve with prolonged land cultivation.

Problems common to topogenous peat soils. The shallow and relatively firm topogenous peat formations pose only moderate problems to farmers. Their main disadvantage is land subsidence after drainage, caused by compaction of the peat mass, shrinkage of drying-out peat structures, and increased mineralization of organic matter. The problem is rarely serious where the peat is only shallow, but with deep peats subsidence can lead to disruption of drainage systems and other structures and to leaning of top-heavy crops and tree fall.

Malaysian agronomists advocate drainage and burning of shallow peat and histic surface layers in areas where rice is to be grown (Coulter 1950). This practice may temporarily improve the fertility status of the topsoil and increase soil pH. Even though they are comparatively rich in nutrients, most topogenous lowland peats require liming and fertilization for optimum productivity. Table 1 presents indicative macronutrient contents of topogenous freshwater peats from Kalimantan, Indonesia (Driessen et al 1975).

Surface peat should be conserved at all times if it occurs on top of potentially acid marine sediments. Peat accumulated under a mangrove vegetation may itself be pyritic or contain pyritic mineral admixtures. Such soils acidify if deeply drained and develop high levels of iron and aluminum (Sudjadi and Sediyarso 1973). Highly reductive conditions can develop in stagnant paddies on peat and toxic quantities of H_2S may build up if the root zone contains insufficient free iron to balance the condition (Green 1957).

Rice fields on shallow peats within the zone of tidal influence will normally receive ample good-quality irrigation water and produce satisfactory yields provided that nutrient imbalances are adequately corrected (LPT 1973).

Soils of ombrogenous raised bogs

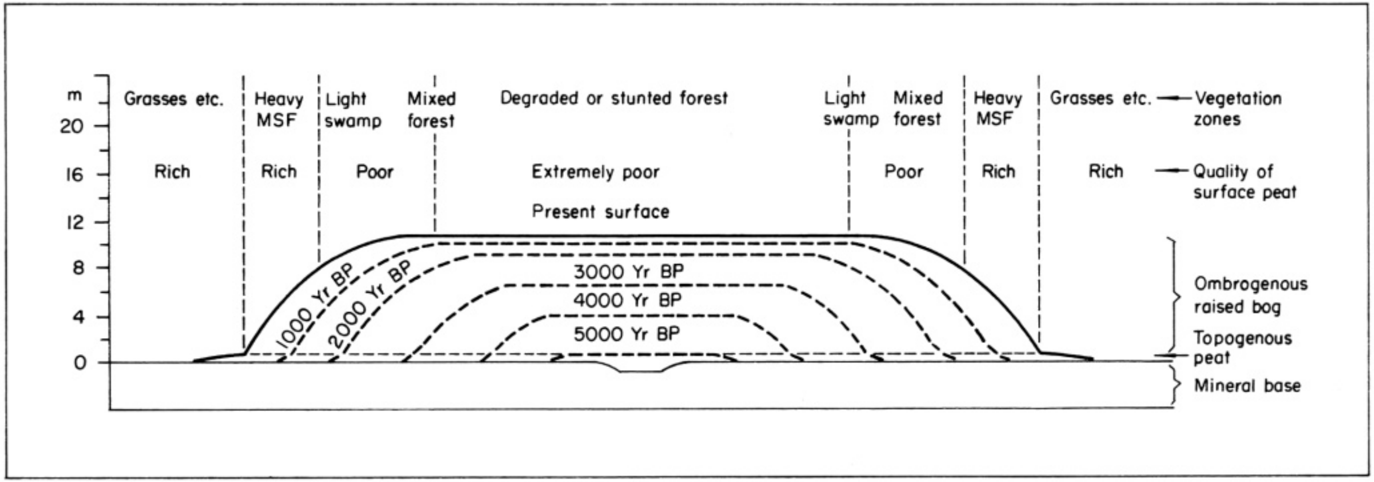
Soil formation in rain-dependent dome peats is largely a function of the properties of the organic parent material. These, in turn, reflect the development stage of the bog and vary in time and space. Figure 2 presents a cross section of a coastal raised bog in which lines of equal age demonstrate the typical course of vertical and horizontal peat growth in time.

Genetically young domes and the fringe areas of well-developed older domes are chemically richer than interior dome areas where losses of cycling nutrients have occurred for thousands of years and natural fertility has become low. The richer dome areas are commonly less elevated and the peat is better decomposed. Such areas support a heavy mixed swamp forest, which produces much organic debris. Initial peat growth is therefore comparatively rapid. The rate of peat accumulation decreases with time as the quantity of cycling nutrients is lessened. Accordingly, the climax vegetation becomes lighter and less varied. Old central

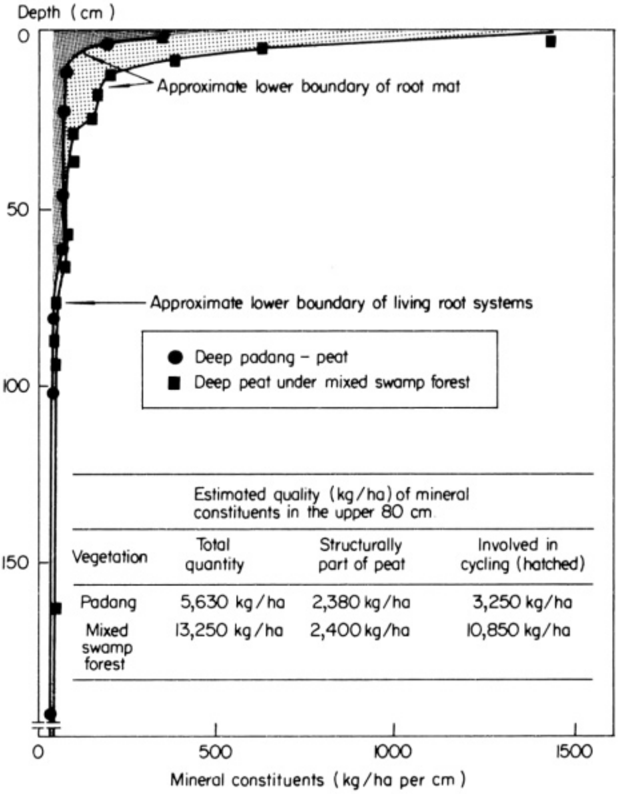
Table 1. Indicative chemical properties of Indonesian topogenous freshwater peats.

	Ash (%)	Bulk density (kg/dm^3)	C-N ratio	pH (H_2O)	P_2O_5 (kg/ha per 0.2 m)		K_2O (kg/ha per 0.2 m)		Cation exchange capacity (meq/100 g)	Base saturation (%)
					Total[a]	Available[b]	Total[a]	Availableb		
Moderately rich	5-1 0	0.2	25-55	3.5-4.8	160-600	20-200	120-330	60-200	120-180	7-20
Rich	10	0.3	15-35	4.0-6.0	360-1200	30-300	130-720	90-300	60-140	7-30

[a] In 25% HCl extract. [b] In 2% citric acid extract.



2. Schematic of the growth of an ombrogenous raised bog and the typical vegetational differentiation. BP = before present. MSF = mixed swamp forest.



Estimated quality (kg/ha) of mineral constituents in the upper 80 cm

Vegetation	Total quantity	Structurally part of peat	Involved in cycling (hatched)
Padang	5,630 kg/ha	2,380 kg/ha	3,250 kg/ha
Mixed swamp forest	13,250 kg/ha	2,400 kg/ha	10,850 kg/ha

3. Distribution of mineral constituents in two deep ombrogenous forest peats from Kalimantan, Indonesia.

dome areas have only a dense monotonous *padang* forest with low nutrient requirements and low production of organic debris. Ultimately, this forest dies and peat growth stops altogether.

The low base content of genetically old dome peats and their low pH hinder the microbial decomposition of organic material. Central dome peats are poorly decomposed (fibric). They have a skeletal structure because a slow but continuous lateral water flux removes fine-grained and soluble organic material from the peat mass. Subsurface padang peat has very low bulk density values (typically 0.05 to 0.10 kg/dm^3); the surface tier contains more solid material and has a bulk density of 0.10 to 0.15 kg/dm^3. The specific weight of the ash-poor padang peats is always close to 1.43 kg/dm^3 (Driessen and Rochimah 1976), which agrees with measured total pore space values of some 90% by volume in the surface soils of padang peats. Subsurface tiers have only 5 to 7% solid matter.

The nutrient content of ombrogenous lowland peat is extremely low. Figure 3 presents the distribution of mineral constituents in two deep ombrogenous forest peats from Kalimantan. The minerals involved in cycling are concentrated in the upper few decimeters of the peat. This reflects the root distribution of swamp forest trees, which have a dense root mat but no taproots. Mutual entangling of the individual root systems provides the anchorage which the peat itself cannot give.

The composition of the cycling mineral constituents is far from ideal for normal cropping. Driessen and Suhardjo (1975) found evidence that silica has an important physiological function in Dipterocarp forests; it can make up 80% of the ash of deep virgin lowland peats but disappears from the system once the forest is cleared.

Problems of ombrogenous peat soils. Well-developed raised bogs pose formidable problems because of their extremely high porosity and low mineral content (often less than 1%). Their elevated position permits simple gravity drainage, but this removes groundwater buoyancy and causes the drained peat mass to collapse under its own weight. The resulting land subsidence is uneven because of local differences in wood content and density of packing of the peat. In addition to causing peat compaction, drainage leads to shrinkage and to accelerated decay of the peat structures. Excessive drying of drained peat exposed to direct solar radiation causes irreversible colloidal transformations associated with serious degradation of the surface soil and increased sensitivity to erosion.

Subsidence is most explicit in deep central dome areas where reclamation should not be attempted at all. The shallower peats in dome fringe areas offer slightly better prospects for agricultural use, but their essential characteristics make sustained and profitable farming beyond the reach of the common settler. The extreme acidity and oligotrophy of most ombrogenous raised bogs (Table 2) require high and recurrent investments in terms of lime, nutrients, and trace elements, which is justified only in capital-intensive agriculture. Flourishing horticultural farms on ombrogenous peat exist near big cities or markets such as Kuala Lumpur, Kuching, and Pontianak. Similar enterprises in more remote areas are doomed to fail because of the generally poor infrastructure and high costs of transport. Commercial farming on rain-dependent peat is limited to the cultivation of few low-demanding crops, e.g. pineapple. However, the high costs of freight and canning, the uncertain market situation, and the present excess capacity of established industries preclude a successful entry in the canned pineapple market (Winnen 1977).

A wide variety of crops can be grown on lowland peat, even at low inputs

Table 2. Indicative chemical properties of Indonesian ombrogenous peat soils.

Property	Oligotrophic	Oligotrophic/mesotrophic
Ash (%)	2	2 - 7.5
Bulk density (kg/dm^3)	0.1	0.15
C-N ratio	50 - 85	20 - 80
pH (H_2O)	3.5 - 4.5	3.5 - 4.5
P_2O_5 (kg/ha per 0.2 m)		
Total[a]	80	45 -300
Available[b]	20	15 -150
K_2O (kg/ha per 0.2 m)		
Total[a]	60	60 - 240
Available[b]	40	30 - 120
Cation exchange capacity (meq/100 g)	160 - 240	140 - 200
Base saturation (%)	2 - 10	4 - 11

[a] In 25% HCl extract. [b] In 2% citric acid extract.

(Driessen and Sudewo 1977), but continuing disintegration of the peat and an increasingly unfavorable nutrient status are bound to cause serious problems in the long run. The cultivation of wetland rice would make deep drainage superfluous and would supply an important staple food and conserve the peat at the same time.

The reasons for the generally high spikelet sterility in wetland rice on deep peat, and sometimes even on nearby mineral soil, should be investigated. Several authors attribute the disorder to noxious substances in the irrigation water (Van Dijk 1937, Van Wijk 1951, Kanapathy 1975). This hypothesis is supported by Van der Voort (1942) who observed empty panicles in rice on mineral soils irrigated with acid peat water from adjacent deep peat formations. It is backed by reports of successful rice growing on certain Japanese peat soils, but only if the soil is continuously leached with good quality river water (Driessen and Suhardjo 1976).

PRIORITIES IN TIDAL SWAMP RESEARCH

The complexity of the coastal landscape is associated with widely varying soil properties. It is imperative that any research on specific aspects of tidal swampland utilization be preceded by proper land evaluation. Such a study can help select priority areas for development and guarantee the transferability of research findings.

The reclamation, use, and conservation of coastal soils, both mineral and organic, are very much a matter of controlling the water regime. Hydrological research should have highest priority. It should focus on the protection of farmland against floods and on (tide-assisted) irrigation and drainage.

Complete elimination of the flood hazard normally involves the construction of dikes and waterworks and is expensive. Limited flood protection, however, can significantly contribute to crop security and can frequently be achieved with modest investments. A feasibility study, including the statistical processing of hydrological and meteorological data and a cost-benefit analysis, is certainly justified.

Irrigation and drainage based on the tides will often suffice to maintain low levels of noxious substances in the surface water. Research in this area should emphasize the prevention of *in situ* formation of toxic levels of aluminum and iron in the soil and on the prevention of influx of soluble salts or noxious organic compounds. The leaching technique and the effect of leaching water quality deserve attention.

Water control measures influence the ripening of the soil material and consequently the workability and bearing capacity of the land. Research on optimum soil management supplements water control studies and is essential for the development of conserving land use techniques. Traditional management practices must be carefully analyzed.

Many coastal swamp soils need fertilizing and sometimes also liming for sustained productivity; however, there is little quantitative information on the long-term effects of such measures. Field and pot trials supplementary to the excellent work already done (e.g. at research stations in Malaysia) provide better insight into the processes that determine nutrient availability and help in developing techniques to raise crop response to costly fertilizer dressings.

Other aspects of crop production not directly related to swamp soil conditions will not be discussed in this paper. We make one exception: ecological research must be given a higher priority than it enjoyed in the past.

Controversial ecology-related issues such as large-scale mechanized forest clearing, the need for replanting, the "controlled" burning of organic surface soil, should be scientifically evaluated. Production-oriented research is needed but should be balanced by research geared at preserving the delicate coastal ecosystems.

The complexity of the coastal swamps and the disastrous and irreversible effects of their mismanagement make it necessary to create permanent and on-the-spot facilities for multidisciplinary research. A capable information and extension service to disseminate the findings of this research among interested parties must be formed.

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THE NUTRIENT STATUS OF TIDAL SWAMP RICE IN KALIMANTAN AND SUMATRA, INDONESIA

M. ISMUNADJI and M. DAMANIK

Tidal swamps usually high in organic matter cover millions of hectares mainly in Sumatra and Kalimantan (Soepraptohardjo and Driessen 1976). The Government of Indonesia is attempting to reclaim tidal swamp areas and convert them to productive agricultural land.

Most farmers plant well-adapted local varieties such as Pandak, Bayar Kuning, and Bayar Putih, using minimum tillage and rarely applying any fertilizer. Crop yields are low: 0.7 to 1.0 t/ha on newly reclaimed land and up to 2.2 t rough rice/ha on long-established tidal swamp rice fields.

Plant growth in the tidal swamps varies enormously depending on the soil. Adverse soil conditions such as acidity, nutrient deficiency, and toxicity are the major problems that limit crop growth and yields. Although the results of fertilizer experiments often have been contradictory, proper fertilizer could increase rice yields. The challenge is to find effective ways to apply fertilizers and to determine proper nutrient combinations to obtain high yields in tidal swamp areas. The problem of fertilizer application in tidal swamp areas is the uncontrollable water regime (Noorsyamsi 1975, 1979) that makes fertilizing difficult and could be the cause of inconsistent results of fertilizer experiments. At present there are no clear fertilizer recommendations for tidal swamps. In the framework of Indonesia's mass guidance program, fertilizer application is optional.

RICE GROWTH

The local varieties planted by most farmers have about a 9-month growing period and are well adapted to the adverse soil conditions of the tidal swamps. They are tall and can tolerate rather high water levels. They produce numerous tillers, but the low productivity of the tillers results in low yields.

Numerous diseases are often observed. They are likely to be closely related to the nutrient status of the soil, e.g. high nitrogen or low potassium and silicon content. The high yielding, early-maturing, semidwarf varieties are more susceptible to disease. Diseases common in tidal swamp rice are brown leaf spot, bacterial blight, narrow brown spot, leafstreak, leaf and neck blast, sheath blight, and panicle blight. Ponnamperuma (1979) reported that IR42 is suitable for

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Table 1. Chemical analyses of rice straw from 8 tidal swamp sites in Kalimantan and Sumatra, Indonesia.

Origin	Variety[a]	Macronutrient content (%)							Micronutrient content (ppm)		
		Si[b]	N	P	K	Ca	Mg	S	Fe	Zn	Mn
Delta Upang, South Sumatra	IR32	3.62	0.85	0.14	2.24	0.24	0.22	0.08	409[d]	87	90
	Blirik	1.79	1.30	0.08[c]	1.82	0.16	0.18	0.16	236	23	98
	Sungsang	3.01	0.95	0.15	0.88[c]	0.16	0.20	0.11	488[d]	54	44
Talang Parit, South Sumatra	IR variety	2.91	0.60	0.15	2.70	0.18	0.22	0.08	454[d]	58	342
	Siam	4.42	0.38	0.16	3.26	0.14[c]	0.19	0.15	293	51	234
	Buluh	5.92	0.51	0.16	1.28	0.09[c]	0.21	0.07	230	48	68
	Pelita I-1	3.24	0.42	0.16	2.80	0.16	0.22	0.06	546[d]	91	507
	IR variety	3.67	0.60	0.11[c]	2.34	0.16	0.22	0.30	566[d]	53	176
	Buluh	4.65	1.21	0.26	1.50	0.13[c]	0.22	0.10	379	65	172
Musi Banyuasin, South Sumatra	Padi Merah	3.06	0.37	0.07[c]	1.28	0.10[c]	0.19	0.12	983[d]	38	142
	Ketek Jernadi	4.04	0.49	0.04[c]	2.00	0.13[c]	0.22	0.10	1106[d]	63	424
West Kalimantan	Unknown	5.55	0.80	0.19	1.40	0.12[c]	0.21	0.09	431[d]	43	39
Samarinda, East Kalimantan	Manis Babuntut	2.49	0.52	0.15	1.60	0.16	0.21	0.09	575[d]	60	293
	Pandak	3.52	0.42	0.06[c]	1.40	0.20	0.20	0.07	954[d]	23	215
	Manis Biasa	4.84	0.51	0.20	1.28	0.13[c]	0.21	0.06	353	49	102
Kota Waringin Barat, Central Kalimantan	Pandan Harum	3.01	0.40	0.17	1.60	0.13[c]	0.20	0.09	359	81	49
	Umbang Pantat Ulat	5.08	0.48	0.12	2.00	0.18	0.20	0.08	322	71	146
	IR26	3.52	0.52	0.11	2.40	0.24	0.22	0.07	583[d]	82	122
Banjar Barat, South Kalimantan	B10436-Mr-184-2	2.40	0.66	0.21	0.68[c]	0.17	0.21	0.09	683[d]	53	44
	Pudak Sirih	1.60	1.24	0.21	0.78[c]	0.14[c]	0.21	0.09	603[d]	78	20
Bangko, Riau-	Dayang	7.80	0.59	0.15	1.70	0.15[c]	0.15	0.08	1006[d]	40	239
	Embotan	2.91	0.55	0.14	1.28	0.13[c]	0.22	0.08	517[d]	47	278

[a] Plant samples were at maturing stage, except for varieties Manis Babuntut, Manis Biasa, an Embotan, which were at heading stage. [b] All varieties analyzed were deficient in silicon. [c] Deficient in the given element. [d] Element present at toxic level.

problem soils. IR42 has good agronomic characteristics, yields well at low levels of nitrogen and phosphorus fertilizers, and has moderate tolerance for salinity, alkalinity, iron toxicity, excess organic matter, and zinc deficiency. It is considered a promising variety in an organosol at Palembang Rice Estate, where its average yield is 3 t/ha. IR42 has been screened in a tidal swamp area in South Kalimantan and is among the varieties that perform well.

RICE PLANT NUTRIENT STATUS

Rice plant samples were collected from provinces in Sumatra and Kalimantan to assess the nutrient status of tidal swamp rices. The straw was separated from the roots and panicles, ground, and analyzed for macronutrients as well as micronutrients (Table 1). All samples were extremely low in silicon. Most contained toxic levels of iron, probably because of the low pH of the soil, which is normal in tidal swamps. There was no indication of nitrogen deficiency.

Low silicon and potassium content combined with high nitrogen sometimes stimulates disease incidence in tidal swamp areas (Ismunadji 1976, Trolldenier and Zehler 1976). Therefore high nitrogen fertilizer application in a tidal swamp area is not advisable.

SUBTRACTIVE TEST EXPERIMENT

Subtractive (minus one element) test experiments in pots were conducted in glasshouses in Bogor and Banjarmasin with 3-week-old rice seedlings. Topsoil samples from Belandean, Handilmanarap, and Banjarmasin substations were used. The chemical analyses of the three soil samples are presented in Table 2. Each pot contained 1.75 kg air-dried soil. The complete treatment received all of the essential elements. There were 14 treatments with two replications: complete nutrients, −N, −P, −K, −Ca, −S, −Mg, −B, −Fe, −Mn, −Zn, −Cu, −Si, and IR42

Table 2. Physical and chemical properties of soil samples from South Kalimantan, Indonesia.

Property	Belandean	Handilmanarap	Banjarmasin
Texture:			
Sand (%)	12.9	3.3	8.8
Silt (%)	54.2	72.4	29.9
Clay (%)	32.9	24.3	61.3
pH (H_2O)	3.36	4.96	5.00
Total N (%)	0.40	0.07	0.21
Total C (%)	5.75	1.56	3.41
Available S (mg/100 g)	82.0	4.66	9.78
Available P (mg/100 g)	2.40	6.70	8.60
Ca (meq)	0.43	1.39	6.07
Mg (meq)	7.94	7.17	3.93
K (meq)	0.43	0.38	0.60
Na (meq)	1.25	0.95	1.20
CEC (meq)	41.1	26.0	20.8
Mn (mg/100 g)	1.85	22.5	4.15
Active Fe (ppm)	7.82	1.55	5.65

Table 3. Effect of nutrient treatment on growth of rice shoots in pot experiments with soils from 3 sites in South Kalimantan, Indonesia.

Nutrient treatment	Dry matter weight (g/Pot)		
	Belandean[a]	Handilmanarap[a]	Banjarmasin[b]
Complete	13.0	9.2	18.0
–N	2.8	2.2	11.0
–P	10.5	2.4	16.4
–K	9.8	10.5	15.2
–Ca	8.2	10.5	16.6
-Mg	9.4	11.0	14.7
-S	12.6	8.7	15.6
–Fe	13.6	9.3	—
–B	10.4	9.5	14.1
–Mn	13.8	10.3	15.0
–Cu	10.8	10.6	15.3
–Zn	10.8	10.0	16.6
–Si	10.4	10.8	13.8
Check	2.8	2.0	7.0

[a]Harvested 7 weeks after transplanting (WT). [b]Harvested 6 WT.

as the check. The rice plants were harvested 6 or 7 weeks after transplanting, and the dry matter weight of the shoots was determined (Table 3).

When there was no nutrient input (check treatment), the dry matter weight of the shoots was low for all three soils. Significant response was observed on the minus-N treatment as well; for Belandean and Handilmanarap soils the response was dramatic. The results indicate that a starter nitrogen fertilizer is necessary to promote rice growth in a tidal swamp area. The dry matter shoot weight of the minus-P treatment was also extremely low for the Handilmanarap soil. Potash, calcium, and magnesium were slightly deficient in Belandean soil.

The study reconfirms what we know intuitively — that tidal swamp soils cannot all be treated the same. Wherever we attempt to utilize these lands, site-specific soils analyses and screening of suitable rice varieties will be required.

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PESTS AND DISEASES OF RICE IN THE TIDAL SWAMP AREAS

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Indonesia's national objective of self-sufficiency in food has been attempted not only through massive crop intensification programs on the technically well-irrigated lands but also through reclamation of tidal swamp rice areas.

Indonesia has about 5 million ha of tidal swampland: 3 million ha stretch along the coast of East Sumatra and 2 million ha in South Kalimantan. Only 110,000 ha in South Kalimantan and 40,000 ha in Central Kalimantan were cultivated before 1969. During the first and thesecond 5-year plans (1969-1974 and 1974-1979), the government reclaimed 223,000 ha in South and Central Kalimantan and 3 10,000 in South Sumatra (Subiyanto et al 1977). These vast reclaimed tidal swamp areas could contribute substantially to rice production in Indonesia.

The seasonal occurrence and abundance of any rice pest species in the tidal swamp areas are closely related to the environment and the cropping systems. Those areas have maximum and minimum daily tide levels, which may differ by as much as 2.5 m. The areas directly influenced by the tides may extend to 10 km or more from the rivers. The annual rainfall ranges between 2,000 and 3,000 mm. The soil is wet and in most of the year large parts are submerged. Abundant small and broad-leaved weeds form an ideal breeding place for rats, and some weed species serve as alternate hosts for pests.

TIDAL SWAMP AREA OF SOUTH KALIMANTAN

Information on the occurrence of rice pests and the extent of damage they cause on tidal swamp rice in Indonesia is available mainly from South Kalimantan.

On the tidal swamp area of South Kalimantan, the seedbeds of the main rice crop are sown in November or December. There are two kinds of seedbeds: dry and wet. The dry seedbed has no standing water. Often seeds are eaten by rat (*Rattus rattus* spp.) common in those areas (Samino 1975). Seedbeds are also destroyed by the seedling fly *Atherigona exigua.* To replace the seedbed, a wet seedbed — a bamboo raft floating on the water — is prepared. The seeds are sown on 5-10 cm thick mud spread on the raft. This minimizes the danger from rats, but not from the seedling fly. In both seedbeds the seedlings are practically free from rice stem borer attack. Forty days later, the first transplanting of seedlings is

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carried out and the second transplanting done 40-45 days later (usually in January). The third transplanting is in March-April (Zain and Noorsyamsi 1979).

Some borer damage may occur on the second transplanting. Damage caused by the leafroller *Cnaphalocrocis medinalis* is common at this stage of plant development.

Borer damage usually increases after the third transplanting, at the approach of the dry season because of the gradual buildup of the borer population.

PEST SPECIES

The recorded species of rice pests in the tidal swamp areas in South Kalimantan are the same as those in technically well-irrigated rice areas in Java. The pests are classified into four categories (Susanto Hadi et al 1976):

Most important rice pests. Pests in this category cause significant damage, occur in every rice season, and are widely distributed.

Occasional rice pests. These species sometimes cause limited damage and are confined to certain areas.

Potential rice pests. These are pests that may cause damage if conditions are favorable.

Migrant rice pests. These are pests of rice originating from outside the tidal swamp rice area (surrounding forests). They may cause significant damage to the rice plant.

Among the most important rice pests is the slender rice bug *Leptocorisa oratorius.* This pest of tidal swamp rice areas occurs in large numbers during the milk stage of the rice plant and causes empty grains. During the off-season, the insect survives in large numbers on grasses. Because several varieties with different maturing times are planted, there are always rice fields at various maturity stages. This situation enhances the development of the pest and makes control more difficult.

The green leafhoppers (GLH) *Nephotettix virescens* and *Nephotettix nigropictus* are important vectors of the rice tungro virus (RTV). The tidal swamp rice areas in South Kalimantan have had severe outbreaks of the RTV (Oka 1969). All local varieties are susceptible to the disease.

R. rattus argentiventer and wild pigs are important rice pests. The rats destroy the rice plants in the seedbeds or in the first or second transplanting, and devour the grains during the generative phase. Rat control is difficult because there are vast uncultivated areas that are ideal for hiding and breeding.

Among the occasional rice pests are three species of armyworms (*Spodoptera mauritia, Laphygma exempta,* and *Leucania unipuncta*). They cause damage mostly toward the dry season or in the dry season. At night they devour all plant parts at any growth stage. Thick layers of organic remains and debris are ideal places for their survival.

Most of the recorded rice pests in tidal swamp areas are either potential or minor ones. They are the brown planthopper (BPH) *Nilaparvata lugens,* the whitebacked planthopper (WBH) *Sogatella furcifera,* and the zigzag planthopper *Recilia dorsalis.* Under present ecological conditions they do not cause significant damage to the rice plant and occur only occasionally. Stem borers are minor pests. They include the white rice stem borer *Tryporyza innotata,* the yellow rice stem borer *Tryporyza incertulas,* the striped rice stem borer *Chilo suppressalis,* and the pink rice stem borer *Sesamia inferens.* Their population now is relatively low and they cause little damage, perhaps because of the definite break of rice seasons and the effective action of their natural enemies — *Trichogramma* spp., *Phanarus* spp., and *Tetrastichus* spp. as egg parasites; and braconids and ichneumonids as larval parasites.

Leafrollers *Nymphula depunctalis* and *Cnaphalocrocis medinalis;* seedling fly *Atherigona esigua;* mole cricket *Gryllotalpa africana;* black rice bug *Scotinophara* spp.; grasshoppers *Patanga luteicornis, Acrida turrita,* and *Anlarches miliaris* are also found but do little damage.

The migrant pests include *Rattus rattus* spp. Its habitat is the forest and vast areas covered with shrubs. It climbs the maturing rice plants and cuts the panicles just below the base, making the attacked fields look like it has just been harvested.

Recorded rice diseases in South Kalimantan tidal swamp areas are *penyakit habang,* lately identified as RTV (Tantera 1972); bacterial leaf blight (BLB) *Xanthomonas oryzae;* sheath blight Rhizoctonia spp.; brown leaf spot *Helminthosporium oryzae;* bacterial leaf streak (BLS) *Xanthomonas translucens;* and narrow brown leaf' spot *Cercospora oryzae* (Susanto Hadi et al 1976).

RTV is the most important disease. An outbreak in 1968-69 showed different degrees of severity in about 10,000 ha. Local long-duration varieties Lemo, Karang Dukuh, Kencana, Pandak, and Raden Rata were very susceptible, but IR5 was resistant (Oka 1971).

The disease again attacked substantial areas in 1974, 1975, and 1976 (Susanto Hadi et al 1976).

More than 100 weed species occur in tidal swamp rice areas in South Kalimantan. Several are alternate host plants for a number of pests (Soedaroedjian 1975): *Hymenachne* spp., *Sclera* spp., *Scirpus* spp., and *Cyperus* spp. provide food and shelter for the black rice bug *Scotinophara* spp. *Imperata cylindrica* is an alternate host plant for armyworms and several grasshopper species. The stink bug *Nezara viridula* survives on *Anoxopus compreneus. Paspulum conjugutum,* found in abundance in the area, is an alternate host plant for *Helminthosporium* sp.

EXPERIMENTS WITH SOME MAJOR PESTS

Rats

Damage due to rats was estimated during the 1973-74 rice season. Fifty samples were taken at random across the Barambai Test Farm and surroundings. Rat damage on the rice plants was estimated by counting the destroyed plants and expressing the data in percent. In the seedbeds the damaged seedlings ranged from 4.5 to 7.6%. The damage to the 2- to 3- month-old plants ranged from 1 to 20%. Damage to maturing plants reached 34% (Samino 1973).

Caged rats (*R. rattus argentivencer*) originating from South Kalimantan appear more cannibalistic than the same species found in Java. The South Kalimantan population can stay in water and in mud, making their holes in heaps of organic matter intended for compost and in decayed logs. They also make grass nests aboveground in areas overgrown with grassy weeds. They damage cassava, maize, and other secondary crops (Samino 1975).

Field experiments for rat control were carried out in Barambai and surroundings throughout the 1973 rice growing season. Three rodenticides — 1% zinc phosphide, 5% warfarin, and 5% tomorin, each mixed with 5 g rice grain in a bamboo container — were distributed 5 m apart on the dikes. Chemical efficiency was determined by recording the amount of bait consumed by the rats.

Zinc phosphide appears to be most effective (Table 1). The baits consumed throughout the rice-growing season ranged from 7 to 63%. Bait consumption was highest in the dry type seedbeds (*teradakan*). During the off-season, up to 63% of the baits were consumed (Samino 1975).

Treatments of rat holes with poisonous gas (sulfur gas) and mechanical killing during soil preparation are also common rat control practices.

Rice stem borer

The occurrence of rice stem borer species was investigated from 1971-72 to 1974-75 rice seasons at Barambai Station and in farmers' fields (Samino and Waluyo 1975). The white rice stem borer *Tryporyza innotata* appeared dominant, followed by striped rice borer *Chilo suppressalis* and the pink rice stem borer *Sesamia inferens.* The percentage of whiteheads was higher on the introduced rice varieties than on local ones at the Barambai Station. But in farmers' fields, the introduced varieties had fewer whiteheads (Table 2).

Field trials tested the efficacy of some pesticides against rice stem borers. Diazinon 10G, cyanofenphos EC, Sevidol 8G, Birlane 10G, BHC 4G, and Sandoz EC seemed promising but need further testing.

Brown planthopper

At present the BPH is a minor rice pest in South Kalimantan. Surveys indicate that the BPH population consists of biotype 1. As rice culture is intensified, the present long-duration, moderate-yielding, but pest-susceptible varieties will gradually be replaced with high yielding ones with some resistance to certain pests. Thirty local varieties and 30 promising lines for tidal swamp areas — 14 lines of B922c (Short Sigadis/Basmati//T442-36), 11 lines of B1050c (Pelita I-2/T442-36), and 5 lines of B1050f — were tested for resistance to BPH in the greenhouse. Only five showed moderately susceptible reactions to BPH. They were B922c-Mr-18-1, B1050c-Mr-6-1, B1050c-Mr-7-1, B1050c-Mr-18-1, and B1050c-Mr-53-3. The remaining lines and local varieties were highly susceptible (Trimurti Mahyoedin 1977).

Rice tungro virus

RTV, reported for the first time in 1962, occurs sporadically in South Kalimantan. The local varieties Lemo, Karang Dukuh, Kencana, Pandak, and Raden Rata were most susceptible to the disease. In the experimental fields of Banjarmasin, Pantai Hambawang, the varieties Syam Panangah, Randah Padang, Kencana Hantasan, Baliman Putih, Cempaka, and Lalantik Bamban were also susceptible. The

Table 1. Percentage of baits consumed by rats throughout the rice-growing season in Barambai Station and surroundings, Indonesia, in 1973.[a]

Growth stage of rice plant	Rodenticide consumed (%)					
	Barambai Experiment Station			Farmers' fields		
	Zinc phosphide	Warfarin	Tomorin	Zinc phosphide	Warfarin	Tomorin
Dry seedbed	47.5	5.00	2.50	55.00	10.00	0.00
Second transplanting	56.25	1.25	2.50	24.37	0.00	0.00
Young plants	36.25	1.25	0.00	21.87	0.00	2.50
Booting stage	30.25	1.25	0.00	22.50	0.00	2.50
Flowering stage	25.62	0.00	0.00	16.87	7.50	0.00
Ripening stage	7.50	0.00	0.00	10.62	0.00	0.00
After harvest	56.25	2.50	0.00	63.12	2.50	2.50

[a] Source: Samino 1973.

Table 2. Percentage of whiteheads on the local and nonlocal (introduced) rice varieties at the Barambai Station and in farmers' fields, Indonesia.[a]

Variety	Whiteheads (%)			
	1971-72	1972-73	197374	1974-75
	Farmers' fields			
Local	7.5	14.28	6.37	4.91
Nonlocal	8.6	3.43	4.35	3.00
	Barambai Station			
Local	8.6	6.0	—	—
Nonlocal	13.2	18.6	4.8	—

[a] Source: Samino and Waluyo 1975.

varieties Gembira, Sri Makmur, Syntha, Dara, and the then newly introduced varieties IR5, C4-63, and Dewi Ratih were disease-free. Each diseased plant hill had 10-15 GLH *Nephotettix* spp. The disease symptoms, abundance of GLH, and reactions of IR5 (resistant) and IR8 (susceptible) indicated it could have been caused by the tungro virus (Oka 1971).

Inoculation experiments carried out by Tantera (1973) confirmed that the disease was caused by the RTV. He further investigated the reactions of 145 lines or varieties of the Central Research Institute for Food Crops (CRIFC) (formerly the Central Research Institute for Agriculture) and International Rice Research Institute (IRRI) to RTV in the experimental fields in South Kalimantan. The tolerant varieties were C4-63, IR20, Ptb 18, Pankhari 203, and Habiganj DW8. IR577-11-2-3/1/1, IR663-65-3/11/3, 531b/Tk/49/4, and IR661-2-16-1/B/4 showed moderately resistant reactions. IR20, IR22, C4-63gb, BPI-76 (blast resistant), E666, RD20, Ratna, BG11-11, Triveni, Pankhari 203, Latisail Aman, Habiganj DW8, Ptb 18 and 21, Gam Pai, Malagkit Sungsong, ARC7140, 10226, 10531, and 11254 showed moderately resistant to resistant reactions.

PROSPECTS OF INTEGRATED RICE PEST MANAGEMENT

Intensification of rice culture in tidal swamp areas in Indonesia may alter the pest pattern. Some pest species such as the BPH, GLH, ragged stunt, grassy stunt, tungro, BLB, and sheath blight, are likely to become important. Most tidal swamp rice varieties are susceptible to the pests. Nitrogen fertilizers are known to enhance pest development. Staggered plantings of crops will always provide food for the pests.

Pest control strategies suited to the area should be sought. Integrated pest management may be introduced to a limited extent.

Varietal resistance

The breeding program should include resistance to BPH, GLH, tungro, BLB, BLS, and sheath blight, while incorporating characteristics such as elongation ability, acceptable flowering, grain quality, tolerance for adverse soil, vegetative vigor, and tillering (Subiyanto et al 1977).

Cultural control

Although cultural control may not give immediate results, it is reliable, economical, and nonpolluting. In the tropics where pests are active year-around, cultural control such as synchronized planting and crop rotation will break the life cycle of the pests. To make cultural control possible, the recommended varieties should have about the same growth duration.

In certain areas of South Kalimantan, food crops other than rice — soybean, peanut, and sweet potato — can be organized into a certain cropping system.

Sanitation programs should also be set up, especially in areas where rats are abundant.

Pesticides

Pesticide use may be justified to some extent, for example, for control of the slender rice bug, one of the most important insects of maturing rice plants. The insecticide may be applied when there are about 2 insects/m^2.

Farmers should regularly inspect their fields for armyworm damages. Pesticides effective against the armyworm group of insects should be made available in the dry season.

Granular pesticides may not be effective in tidal swamp areas.

For rat control, farmers should apply poisonous gas (sulfur monoxide) into the rat holes during soil preparation. Escaping rats should be killed mechanically. Baits should be distributed throughout the vegetative stage of the rice plants. During the booting and the ripening stages limited gassing and mechanical killing of rats may be done. Uncultivated areas or fields adjacent to the forests should be continuously baited if enough rat poison is available.

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STRATEGIES FOR VARIETAL IMPROVEMENT IN TIDAL SWAMP RICE

Z. HARAHAP, S. PARTOHARDJOSO, and G. S. KHUSH

In several tropical Asian countries, large rice-growing areas are where tidal action causes water depth in the paddies to vary. There is an estimated 7 million ha of tidal swampland in Indonesia — 3 million ha along the eastern coast of Sumatra, 2 million ha in South Kalimantan, and another 2 million ha in Sulawesi and Irian Jaya. However, only a small proportion of this area is planted to rice. There are more than a million hectares of tidal swampland in Bangladesh and a similar area in India (West Bengal and Orissa States). In Thailand, tidal swamp rice is grown on 816,000 ha, of which 358,000 ha are on the coast of the Central Plain and 458,000 ha on the coast of the southern peninsula. Vast areas of tidal swampland also occur along the deltas of the Irrawaddy River in Burma and the Mekong River in Vietnam.

Tidal swamp areas have unique characteristics. They are flat (0-5 m above sea level) and most of the soils are high in organic matter. Some areas have peat layers 20 to 400 cm deep. The soils have a pH range of 3.5 to 5.5, some are acid sulfate soils, and most are poor in plant nutrients. Salt damage to rice may occur in areas near the coast (Driessen and Soepraptohardjo 1974).

Tidal effects on water regimes in tidal areas are reported to be noticeable as far as 120 km upstream of major rivers and 6-7 km of their minor tributaries and branches. In the Mekong River in Vietnam the tidal action is noticeable as far as 150 km inland.

Noorsyamsi and Hidayat (1974) categorized the tidal swamp areas of Kalimantan based on the intensity of the tidal effect as

- direct tidal swamp areas where the tidal waters flood the land directly,
- indirect tidal swamps where the tidal effect is small or negligible, and
- monotonous swamp where the land is always inundated in the rainy season.

Rice production in tidal swamp areas can be increased by land reclamation and varietal improvement. The reclamation of tidal swampland faces two main problems — control of water and improvement of nutrient status of soils. The varietal improvement programs have the problem of developing modern varieties suited to the excess and fluctuating water regimes and tolerant of various adverse soils.

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RICE VARIETIES GROWN IN TIDAL SWAMP AREAS

Rice varieties in the tidal swamp areas have been selected and adapted over a number of years. The varieties in the tidal swamp areas of South Kalimantan originated from local varieties grown by farmers in upper watershed areas. Those rices adapted to tidal swamp conditions over a period of 50 years. To obtain strong seedlings of suitable height, seedlings are transplanted 2-3 times before the final transplanting of 4- to 5-month-old seedlings in the field. The indica varieties, called Bayar rice, are tall, high tillering, late maturing (9-10 months), and photoperiod sensitive.

Other popular rice varieties grown by Indonesian farmers on tidal swamplands are listed in Table 1. Yields of these varieties range from 0.7 to 1.0 t/ha in newly reclaimed areas (Table 2). In the old reclaimed areas yields are 2-2.5 t/ha.

A variety called Kuatik is grown by Buganese farmers in the tidal swamps along big rivers in Sumatra. It matures in 5-6 months and yields 2 t/ha.

Problems of varietal improvement

For higher rice productivity in tidal swampland, varieties must be tolerant of high salinity and acidity. For areas where peat soils occur, varieties must be tolerant of high organic matter. Varieties with greater seedling height, high tillering ability, sturdy and vigorous growth habit, and lodging resistance are essential. Most of the adapted varieties have long growth duration. In some areas double-cropping with rice may be possible with short-duration varieties.

At the Handilmanarap substation, South Kalimantan, double-cropping of rice with early-maturing improved varieties was tried. Improved varieties were planted as the first crop, and seedlings of local varieties for the second crop were started at the same time. After the early first crop was harvested, the tall, aged seedlings of the local variety were transplanted. The results were encouraging but the practice was not adopted because most farmers are only part-time farmers who seek other employment in the cities after transplanting and return at harvest time. Another problem in the two-crop system was that harvest of the first crop coincided with heavy rains, which made it difficult to dry the grain.

The Gajah Mada University team in Kalimantan and the Bogor Institute of Agriculture team in Sumatra have introduced double-cropping with brown planthopper-resistant varieties in tidal swampland in transmigration areas.

In Barambai, South Kalimantan, the Gajah Mada University team launched a program to grow improved varieties on 160 ha of land involving 345 farmer families during the 1977-78 wet season. Credit was provided for the purchase of 20 kg seed, 100 kg urea, and 50 kg triple phosphate for every hectare. Results of crop cuts are in Table 3. The average yield for the first crop was 4.7 t/ha. For the second crop, IR30 and IR36 were planted on 54 ha and average yield was 2.1 t/ha. The low second crop yield was attributed to poor land preparation and pest problems, such as damage by mole cricket.

Experiments at four other sites during the 1979-80 wet season in South Kalimantan indicated a great potential for growing improved varieties in tidal swamp areas. In trials with 12 improved varieties and breeding lines, IR48 was the

Table 1. Some popular varieties grown in tidal swamp areas of Indonesia, Bangladesh, and Thailand.

Varieties		
Indonesia	Bangladesh	Thailand
Lemo Halus	Kumragoir	Gaw Diaw Bow
Bayar Putih	Kachamota	Khao Tah Oo
Bayar Kuning	Dudmona	Khao Pak Maw
Bayar Isip	Hijli Digha	Khao Dawk Mali
Bayar Raden Rata	Joli Amon	
Gadabung	Lohargura	
Karang Dukuh		
Randah Padang		
Siam Halus		
Baliman Putih		
Randah Palas		

Table 2. Grain yields of 11 local varieties tested at Barambai farm, South Kalimantan, Indonesia. 1975-77.[a]

Variety	Grain yield (t/ha)			
	1974-75	1976	1977	Average
Lemo Halus	0.9	1.5	2.3	1.5
Bayar Putih	0.6	1.4	2.1	1.3
Bayar Kuning	0.9	1.0	2.3	1.4
Bayar Isip	0.6	0.9	2.7	1.4
Bayar Raden Rata	0.8	1.6	2.5	1.6
Gadabung	0.7	1.4	1.9	1.3
Karang Dukuh	0.4	1.1	2.7	1.4
Randah Padang	0.6	1.3	2.6	1.5
Siam Halus	0.9	1.7	2.4	1.6
Baliman Putih	0.6	1.3	2.5	1.4
Randah Palas	0.5	1.4	3.4	1.7

[a] Source: S. Sastrosoedarjo (1977).

Table 3. Yields of first crop improved varieties in farmers' fields in tidal swamplands, Barambai, South Kalimantan, Indonesia, 1977-78 wet season.

Variety	Crop cuts (no.)	Av yield (t/ha)
C4-63	19	4.3
IR30	7	3.8
IR32	24	5.3
IR34	3	5.0

highest yielding entry with an average yield of 3.1 t/ha, closely followed by B1050c-Mr-18-2 and IR42 (Table 4). IR48 and IR42 are known to have some tolerance for salinity and low pH. Both are somewhat tall and do well in water depths up to 50 cm.

It is obvious that varieties for tidal swamps must have tolerance for salinity and low pH, and should grow in water depths of 50-60 cm. Plant types with intermediate stature (120-130 cm), sturdy stems, and ability to tiller in medium-deep water would be more adapted. Some degree of submergence tolerance would be desirable because the crop is occasionally submerged, especially at the seedling

Table 4. Grain yields of 12 varieties or lines at 4 sites in tidal swamp areas in South Kalimantan, Indonesia, 1979-80.

Variety or line	Grain yield (t/ha)				
	Barito Kuala	KM Banjar-masin	Indragiri Hilir	KM Samarinda	Average
B1050d-Kn-46-1-1-4-3	1.1	1.1	2.1	1.5	1.4
B1050c-Mr-18-2	3.5	4.1	2.5	1.9	3.0
BKN6986-108-2	2.0	3.0	1.7	2.1	2.2
B922c-Mr-69	2.1	2.1	1.4	1.7	1.8
IR42	2.3	4.0	2.6	2.9	2.9
IR48	2.5	4.0	3.1	2.7	3.1
B2489d-Pn-1-76-8	1.0	4.3	3.0	2.0	2.5
B1043d-Sm-26-6-2-1	0.9	3.9	3.1	1.6	2.1
Siam Halus	2.3	2.6	–	–	2.4
Lemo	2.1	3.4	–	–	2.7
Cisadane	0.7	4.4	1.8	2.4	2.3
B1050d-Kn-1-1-1-1-3	1.0	1.3	1.5	2.5	1.5
CV %	52.9	31.4	52.0	10.3	

stage. Resistance to the common rice diseases and insects — brown spot, blast, cercospora, bacterial blight, tungro, brown planthopper, and stem borer — would be useful for stability of production.

BREEDING STRATEGIES FOR TIDAL SWAMP RICES

The development of high yielding rices for tidal swamp areas should receive top priority. Initial testing in the tidal swamp areas of Indonesia has shown the superiority of IR42 to the local varieties. Germplasm from national and international sources should be evaluated to identify other cultivars better than the traditional varieties. Initial screening work in South Kalimantan has identified several promising lines for tidal swamp areas (Table 5). An international tidal swamp nursery, which should include entries from various breeding programs and provide wide-scale testing for medium deepwater tolerance as well as tolerance for adverse soils, is needed.

Hybridization programs involving locally adapted parents and exotic germplasm with higher levels of tolerance for saline and acid sulfate soils should be expanded. A large number of varieties from the Indian subcontinent, such as Pokkali, Getu, SR26B, and Patnai 23, are known to have high levels of salinity tolerance. Many lines from crosses involving those varieties have excellent levels of salinity tolerance and improved plant type. Those lines (Table 6) should be used in the hybridization programs. Similarly, several breeding lines with tolerance for acid sulfate soils have been identified (Table 6). Khao Dawk Mali, a tall traditional variety from Thailand, had the best level of tolerance for such soils and should be used in the crossing program.

Breeding methods

Early generation segregating populations in a swamp rice breeding program can be handled through the modified bulk method. To speed the breeding process, the populations should be grown alternately in problem areas and in irrigated areas

Table 5. Promising breeding lines for tidal swamp rice areas.

Variety or line	Plant height (cm)	Growth duration (days)	Amylose (%)	Eating quality[b]	BPH resistance Biotype 1	BPH resistance Biotype 2	Submergence score[c]	Parents
B1050c-Mr-18-2	105-150	136	26.0	k	S	S	2	Pelita I-1/T442-36
B2489d-Pn-1-768 (M)	110-140	135	21.0	e	R	MR	2-3	Pelita//IR2166-1/IR217
BKN6986-108-2	106-180	135	28.0	k	S	S	2	IR262/Pin Gaew 56
B1043d-Sm-26-6-2-1	109-165	134	23.4	e	S	S	2-3	Pelita I-2/Bayar Melintang
Cisadane	108-130	135	20.0	e	R	MR	–	
B1050d-Kn-1-1-1-1-3	104-150	121	26.4	k	S	S	–	Pelita I-2/T442-36
IR42	98-140	134	26.0	k	R	R	3-4	
B1050d-Kn-46-1-14-2-3	110-150	118	25.5	s	S	S	–	Pelita I-2/T442-36
B922c-Mr-21	100-155	136	25.5	s	S	S	–	B96-Tk-235-5-3/T442-36
B922c-Mr-69	95-160	136	25.1	s	S	S	–	"
B922c-Mr-11-3-2	106	137	25.4	s	MR	S	–	"
BKN6986-29	107-170	150	22.4	s	S	S	–	IR262/Pin Gaew 56
BKN6987-129	107		25.1	s	S	S	5-6	IR262/Khao Nahng Nuey
BKN6986-147-2[a]	107	1361170	25.1	s	MR	S	–	
Lemo[a]	106	1501270	25.7	s	S	S	7-9	
Siam Halus[a]	106-189	1501270	25.1	s	S	S	7-9	
Pandak[a]	–	–	27.4	k	S	S	5-6	
Bayar Melintang[a]	108-164	1551270	25.1	s	S	S	7-9	
Bayar Kuning[a]	–	–	–	–	S	S	7-9	
Bayar Putih[a]	107-165	1551270	29.75	k	S	S	7-9	

[a] Photoperiod-sensitive. [b] k = poor, s = medium, e = good. [c] Standard Evaluation System for Rice (SES): 1 = 100% recovery, 9 = less than 30% recovery.

Table 6. Some improved plant type lines with tolerance for salinity and acid sulfate soils.

Tolerant of salinity	Tolerant of acid sulfate soils
IR36	IR36
IR42	IR42
IR48	IR46
IR52	IR52
IR54	IR1632-93-2-2
IR2058-436-1-2	IR2070-820-2-3
IR2153-26-3-5-2	IR2797-105-2-2-3
IR4227-28-3-2	IR4683-54-2-2-2-3
IR4432-28-5	IR9129-136-2
IR4630-22-2-17	IR9129-192
IR5657-332	IET 444
IR8241-B-BS6-2	

with good management until F_6 or F_7 when panicle selections can be grown. Very tall or otherwise undesirable plants should be rogued when the population is grown in irrigated plots. Screening for disease resistance can also be accomplished during the irrigated cycle.

If it is desirable to develop photoperiod-sensitive varieties, segregating populations can be handled through rapid generation advance. Characters that are simply inherited can be incorporated through backcrossing.

If rectification of a specific trait in otherwise well adapted varieties is required, mutation breeding can be advantageously employed. Mutations for height, maturity, and grain characters are easy to induce. Mahadevappa et al (1981) treated seeds of eight tidal swamp varieties from Indonesia with ethyleneimine and obtained shorter-statured mutants, which retained the other desirable traits of the parental varieties. Some mutants matured 1 month earlier. Some of the promising mutants of Siam Halus are now in replicated trials in South Kalimantan.

Population breeding using recessive monogenic male steriles of IR36 (Singh and Ikehashi 1981) may be profitable. A number of parents having specific traits are crossed with the male-sterile parents and F_2 seeds from the different crosses are mixed together and planted as a bulk population. About 25% of the plants of that population will be sterile but will set some seed from outcrossing with surrounding fertile plants. Seed from the sterile plants can be harvested and planted in problem areas. Outcrossing allows the formation of superior recombinants in each generation and those are favored in selection. After several generations of recombination and selection, useful genes are accumulated in the population. Fertile plants are then selected from the population, grown in panicle progeny rows, and promising selections from those tested in replicated trials.

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CROPPING SYSTEMS AND MARGINAL LAND DEVELOPMENT IN THE COASTAL WETLANDS OF INDONESIA

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and A. M. JURINDAR

The wetlands of Indonesia along the east coast of Sumatra and in South and West Kalimantan cover an estimated 43.5 million ha. At least 5.5 million ha of these swamp forests or tidal-influenced swamps have agricultural potential. Local residents, spontaneous migrants, and government-sponsored transmigrants are three major groups of settlers who are attempting to take advantage of the potential by transforming this marginal-resource swamp forest ecosystem into a rice-based cropping system.

The transformation of these wetlands is a major attempt to improve the welfare of hundreds of thousands by transferring them from densely populated, fertile regions with well-developed irrigation systems to underpopulated, marginal areas. The successful conversion depends on the fragile peat swamp soil, the location and the difficulties in maintaining production.

The main questions to answer about this on-going transformation are: what types of migrants are opening these swamp forests; how is the development being accomplished; what type of cropping systems should be promoted; what size holdings should be suggested; and what research issues should take priorities?

The major theme interwoven throughout this paper is the comparison of cropping systems and marginal land development.

GROUPS OPENING THE WETLANDS

There are three major groups who have been actively cultivating crops in coastal wetlands: the local residents who have been in the areas for generations, spontaneous migrants who are independently settling the wetlands, and government-sponsored transmigrants who are being brought in and given assistance. In each developing area, the ethnic origins vary.

In Sumatra, the local people are usually Melayu (coastal Malay). The spontaneous migrants are primarily Buginese from South Sulawesi (Wajo and Bone), although most of those in South Sumatra have come via Riau Province where they either were born or lived for awhile. The government-sponsored transmigrants in Sumatra are from Java, Bali, and Madura.

In Kalimantan, the three groups are somewhat different: in some areas the

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Banjarese are the local residents and in other areas are the spontaneous migrants. Other spontaneous migrants include Javanese, Madurese, and Buginese. The Buginese, however, are much fewer in the coastal wetlands of South and Central Kalimantan than elsewhere. The majority of the migrants in Kalimantan is the Banjarese who have been moving around from the Banjarmasin area in South Kalimantan to the coastal wetlands of South and Central Kalimantan during the last 50 years. As in Sumatra, the third group in Kalimantan is the government-sponsored transmigrants from Java, Bali, and Madura.

OPENING THE LAND FOR AGRICULTURAL USES

In the tidal-influenced swamps of Kalimantan and Sumatra, the Buginese and Banjarese have been experts for generations at reclaiming the swampy lands for production of rice, coconut, coffee, tangerine, orange, and many other food crops. In South and Central Kalimantan alone, an estimated 2 million ha of coastal swamp is suitable for rice production, as shown by rice yield averages of 2.3 t dry grain/ha annually in wetlands already in production (Noorsjamsi and Hidayat 1975). By 1975, however, only 110,000 ha in South Kalimantan and 40,000 ha in Central Kalimantan had been opened for rice production. The Government of Indonesia (GOI), strong in its desire to be self-sufficient in food crops, launched a massive transmigration program to settle Javanese and Balinese in these swampy lands. The GOI had opened the following areas for the transmigrants by 1979:

Kalimantan	
West	33,637 ha
South and Central	41,417 ha
Sumatra	
South	76,492 ha
Jambi	29,202 ha
Riau	60,207 ha

Government-sponsored transmigration projects in Kalimantan are located primarily between the Barito, Kapuas, and Kahayan Rivers (Fig. 1). Another important push in opening the lands for agriculture in Kalimantan is taking place along the Mentaya River.

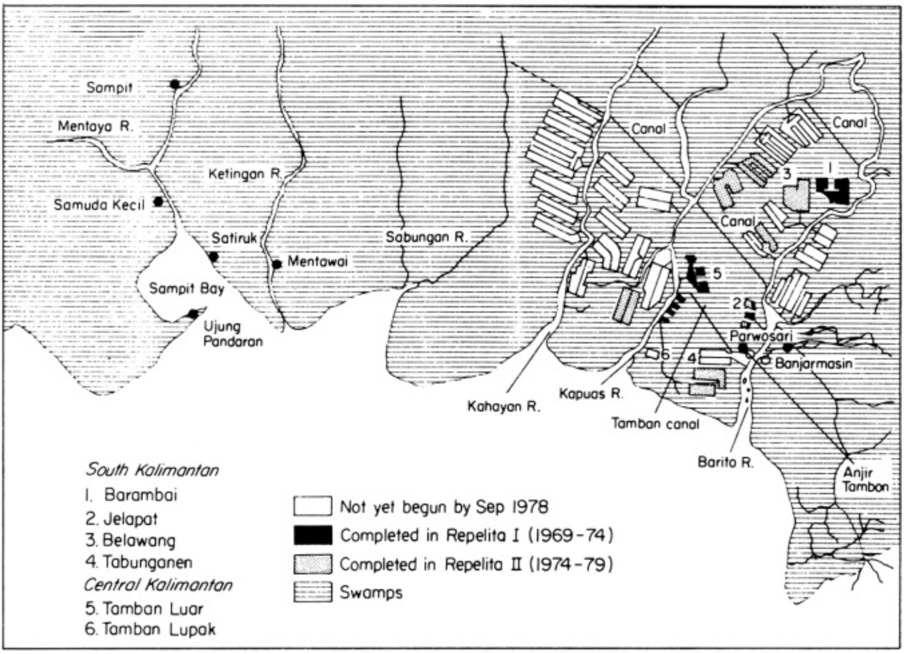
The first canals in these areas were opened in 1880-90s. The canals were improved in the late 1930s and completed in the 1960s. These canals allow the settlers to open more land for rice and coconut production by digging drainage ditches from the canals into the swamps.

The swamps in Sumatra (Riau, Jambi, and South Sumatra Provinces) are likewise being opened extensively for agriculture (Fig. 2). Government transmigration projects are underway there. Buginese spontaneous migrants have been there only since the 1960s, but have been able to open tens ofthousands of hectares of swamp forest for their rice – coconut – coffee – banana cropping system. Possibly, the local residents first settled on the levees close to the rivers (soils on fluvial deposits). Next came the Buginese spontaneous migrants who received permission to open lands behind the levees. Then, the government-sponsored transmigrants were placed in the delta centers.

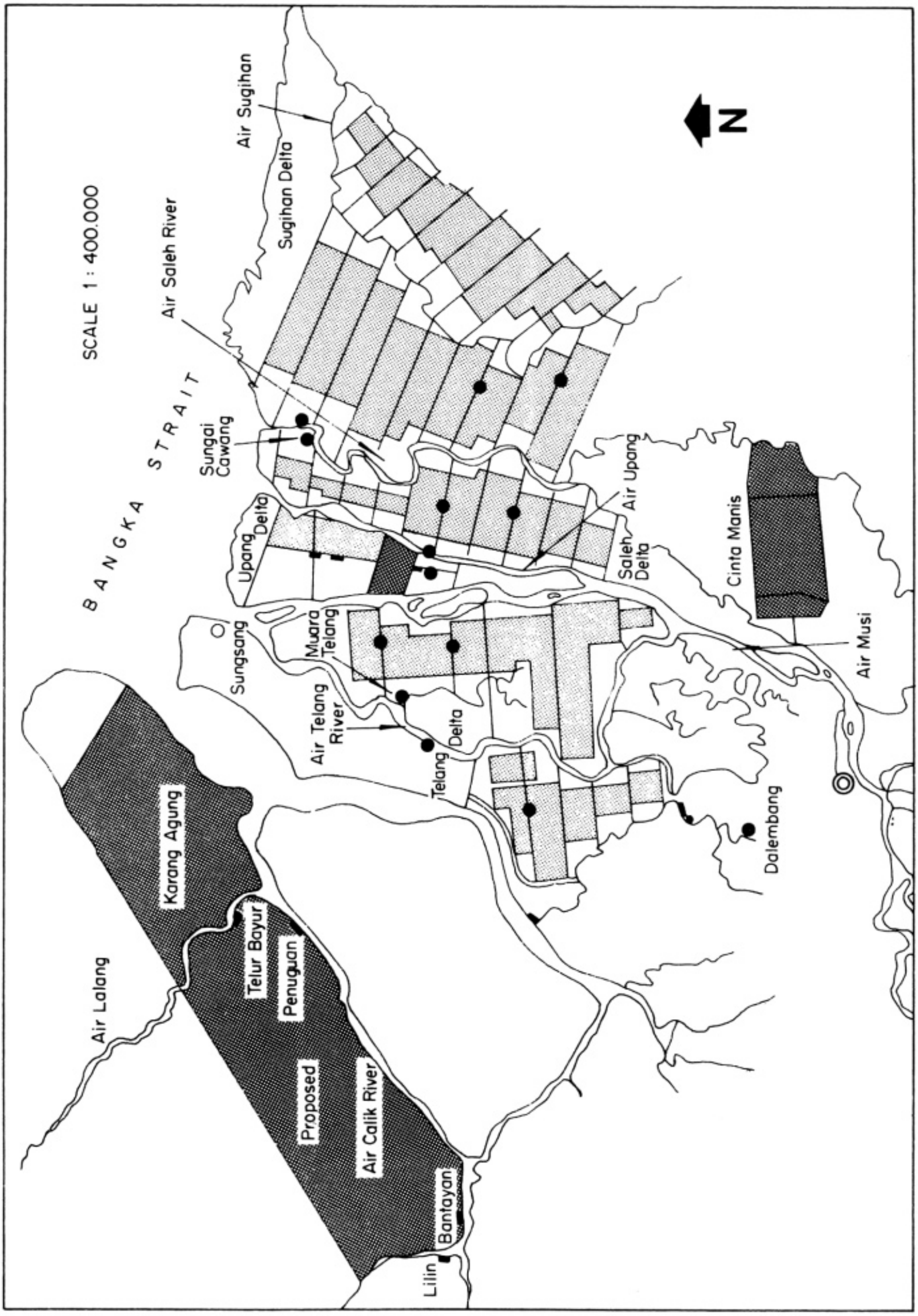
There are no reliable estimates of the area opened for rice fields and coconut plantations by only the local residents and spontaneous migrants in these Indonesian wetlands of Sumatra and Kalimantan. One general estimate places the area of rice fields in tidal-influenced swamps at 135,000 ha in Sumatra and 165,000 ha in Kalimantan. But, based on their system of first growing rice for several years, then switching to coconuts - coffee - bananas, the areaopened by these two groups for agriculture could be two to three times this conservative approximation.

CROPPING SYSTEMS IN THE COASTAL WETLANDS

In the well irrigated lowlands of Java, there is not much choice among cropping systems because the first choice of farmers is most often rice followed by rice, and possibly even a third crop of rice (Collier 1980). However, as the quality of irrigation facilities becomes poorer and the soils become less fertile and more fragile, the number of possible cropping systems greatly increases. This is especially true in these coastal wetlands that have a variety of soils and that are dominated by peat soils with depth ranging from a few centimeters to several meters. Under these soils there are often acid sulfate soils, and these peat soils must be drained in the wet season, or else a meter or more of water will cover this swampy land. The cropping system is also influenced by infestations of rats, wild pigs, elephants, and weeds. In addition, some areas can produce rice in the dry season only if the tidal-influenced river water can be forced back into the drainage canals.



1. Transmigration projects in South and Central Kalimantan.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Air Telang River
Telang Delta
Dalembang
Karang Agung
Telur Bayur
Penuguan
Proposed
Air Calik River
Air Lalang
Bantayan
Lilin

The cropping system choices in these coastal wetlands may ultimately determine the long-term viability of the farmers' operations.

In Sumatra, each of the three migrant groups has a somewhat different cropping system. Typical villages have the following systems:

Rice-based cropping systems

Rice
Rice - secondary crops
Rice - banana
Rice - coconut

Coconut-based cropping system

Rice - coconut - coffee - banana
Coconut
Coconut - coffee - other tree crops

The local residents were the first to open the swamp forest and therefore have the best soils and water control because they are nearest the rivers. They have a few permanent ricefields and coconut smallholdings. The average farm size of local residents ranges from 0.85 to 9.7 ha. Farm size tends to be dependent on how long the residents have been in the area. A few families have been able to clear up to 50 ha. In addition to their crop incomes, the local people (coastal Malay) often have part-time activities such as fishing, trade, or river transportation.

Depending on the type and depth of the soil, the Buginese spontaneous migrants in Sumatra have a rice-based cropping system, or a rice-based system that will become a coconut-based system in 5 or 10 years. Usually they prefer to begin planting coconuts in their rice fields several years after opening the swamp forest. They feel returns are much better, labor needs much lower, and size of operation much larger in the coconut-based system. The Buginese are recent migrants, but already some have developed holdings of 10 to 20 ha.

There is one major difference between the two groups. When the Buginese spontaneous migrants locate a promising area, they send word to their relatives and friends in Sumatra (Riau, Jambi) and South Sulawesi. In contrast, the local residents have lived there for generations and do not encourage great numbers of people to move into their area.

Generally, the government-sponsored transmigrant farmers in Sumatra use the rice-based cropping system, rice indefinitely being the primary crop. Upon arrival, transmigrants receive 0.25 ha of house garden, 1 ha of opened and drained field for rice cultivation, and 1 ha of unopened land that can eventually be used for rice or secondary crops. Their cropping system in these wetlands is almost always limited to one crop of rice a year because of insufficient water during the dry season. They do have their house gardens with a wide variety of crops. They can also grow secondary crops such as cassava on the bunds of their land and in the fields during the dry season. Some transmigrants plant a few bananas and, in situations where the peat is too deep for satisfactory rice cultivation, they are beginning to plant coconuts in drained fields. Still, their rice-based cropping system is almost entirely rice. However, if they have been in the project for a long period, perhaps 10 years as in the Upang Delta, they may have purchased additional fields and planted tree crops.

The cropping patterns in Kalimantan's coastal wetlands are similar. The Banjarese choose their cropping systems according to the soils, the depth of the peat, and water control. After they dig the drainage canals, they either plant rice for a long period, or first plant rice then intercrop with coconut and coffee a few years later until the coconut takes over the fields. Some Banjarese may plant tree crops immediately if the peat is too deep for rice.

There are major differences in cropping systems between local/spontaneous migrants and the government-sponsored transmigrants in Sumatra and Kalimantan.

Transmigrants	*Local/Spontaneous*
1. rice-based cropping system	1. coconut-based cropping system
2. intensive cultivation	2. extensive cultivation
3. swamp forest opened by GOI	3. swamp forest opened by the migrants
4. canals and land clearance by GOI	4. canals and land clearance by the migrants
5. 18-month food supply by GOI	5. no assistance from GOI
6. 2 ha of land	6. land area based on time, family size, and capital

RICE YIELDS IN THE COASTAL WETLANDS

One of the major unresolved issues in the coastal wetlands of Sumatra and Kalimantan is long-range rice yields. There are many reports indicating that the yields are relatively low and decline over time. Because all the areas are surrounded by swamp forest, a variety of predators are causing problems. In Sugihan Delta, the transmigrants reported that a herd of 20 elephants have been destroying their fields. Wild pigs and rats are problems in all areas. Weed infestations become severe after 4 or 5 years, forcing locals and spontaneous migrants to move or plant tree crops.

Based on personal interviews and many visits to these sites, we believe that Buginese and Banjarese achieve higher yields than the Javanese transmigrants for the first 5 to 10 years. Then, as the transmigrants gain control of their environment, open up large areas, and learn local techniques, their yields may be the same or higher than those of the local residents. However, in the same time period, these spontaneous/local people will open up a much larger area and plant coconut and banana. Table 1 shows the yields from 1976 to 1980 in South Sumatra and Jambi.

It is quite probable that the sites chosen for the transmigrants are poorly selected and not adequately cleared. The chances for failure are much higher for a transmigration project than for a project in an area selected by local residents or spontaneous migrants.

Table 1. Estimated average yields of rice from 1976 to 1980 in the swampy lands of South Sumatra and Jambi, Indonesia.[a]

Type of farmers and location	Average rice yields by year (t/ha)				
	1980	1979	1978	1977	1976
Local residents					
Muara Telang[a]	1.3	1.4	1.3	1.0	1.6
Rantau Rasau, Jambi	0.6	0.6	0.8	0.7	0.8
Panuguan	1.0	1.0	1.3	1.2	1.1
Buginese spontaneous migrants					
Sungai Senang	2.0	2.5	1.6	1.0	1.0
Sungai Cawang	2.6	2.2	1.9	1.4	2.5
Muara Telang	2.0	2.0	2.0	1.8	1.7
Teluk Bayur	-	1.5	1.6	1.9	1.6
Penuguan	1.7	2.4	2.0	1.7	1.6
Mendahara, Jambi	3.0	2.6	2.3	2.5	1.7
Javanese transmigrants					
Purwosari, Upang Delta	2.0	2.3	2.4	2.7	2.8
Telang II, Unit V	0.3	–	–	–	–
Telang I, Unit I (Jalur III)	0.1	0.2	0.1	–	–
Telang I, Unit V (Jalur VIII)	0.2	0.3	0.1	–	–
Bangun Karya, Rantau Rasau (n = 24 to 30)	1.2	o.a	0.9	0.9	0.8

[a] From interviews of selected respondents by the Sriwijaya University research team in January 1981. Dash (–) = no data.

Table 2. Comparison of average yearly income of farmers in the swampy lands in South Sumatra and Jambi in 1980, and those in the coastal wetlands of South and Central Kalimantan in 1979.

Farmer classification	Av annual income (US$)	
	South Sumatra and Jambi[a]	South and Central Kalimantan[b]
Local resident	796	456
Spontaneous migrant	1055	563
Government-sponsored transmigrant	113[c]	507

[a] Data from Sriwijaya University, January 1981. [b] Data from Lambung Mangkurat University, 1980. [c] The 29 farmers surveyed in the government-sponsored transmigrant village of Purwosari, Upang Delta, had an average income of $1077, which was higher than the average income of the spontaneous migrants in South Sumatra and Jambi.

COST, RETURNS, AND FAMILY INCOMES IN THE COASTAL WETLANDS

The coastal wetlands are marginal environments for rice cultivation; therefore, the costs and returns can be used only as success level indicators. There were great variations among respondents, between locations, and in length of time.

As indicated in Table 2, the spontaneous migrants appear to have the best family incomes, with those in South Sumatra and Jambi earning more than those in

Kalimantan. The government-sponsored transmigrants fare the worst, except in long-established Purwosari in the Upang Delta, South Sumatra. Many of the other transmigrants are still clearing land and have not yet produced their first income crops.

UNIQUE ASPECTS OF AGRICULTURE IN THE WETLANDS

Several villages have unique aspects which broaden the picture of the development of these marginal tidal swamps. For instance, the village of Sungai Cawang, located on the Saleh Delta along the west bank of the Air Saleh River, has been settled with remarkable speed. Between 1971 and 1981, Buginese spontaneous migrants opened 3,000 ha of swamp forest for agriculture. At no cost to the government, they dug 62 major canals and many branch canals in this peat swamp.

The first rice crop was produced in 1973 by a group of five pioneers. Later that year, 62 families asked permission to open more swamp forest and dig canals. In 1974, permission was given for 200 more families to open land. By 1980, there were 1,929 spontaneous migrant families in the area.

A second unique feature in this marginal land development is an operation near Muara Telang, a village located along the Air Telang River and opened by the Buginese. The local pesirah (or headman of the traditional governing system) has a rice-based cropping system of rice - coconut - banana, which is an excellent example of an intensive system of swamp cultivation.

The pesirah has 15 rice and coconut fields totaling 55 ha. He cleared his first field of 2.7 ha in 1955. The field is still producing rice, though it also has 8 ridges, each 2.5 m by 200 m by 0.6 m high, with 157 coconut trees. To cultivate his rice crop, he sharecrops the field and gives 7 of 10 shares to the sharecropper. Even though he has been cultivating this field every year since 1955, he still had a yield of 1.85 t/ha in 1980. His coconut trees yielded 4,200 nuts during the year

Table 3. The pesirah's holdings, cropping systems, and net returns in 1980.[a]

Field	Year opened or purchased	Area (na)	Cropping system	Net return ($)
A	1955	2.7	Coconut, rice	661
B	1968	10.0	Coconut, rice, bananas)	5,479
C	1968	4.0	Coconut, rice, bananas)	
D	1972	2.4	Coconut)	173
E	1972	13.5	Coconut)	
F	1973	2.5	Rice	244
G	1975	2.0	Rice	423
H	1976	0.5	Coconut, rice	-
I	1977	7.a	Rice	508
J	1976	0.6	Coconut	116
K	1976	0.6	Coconut, rice	128
L	1976	0.6	Coconut	213
M	-	2.0	Coconut, banana	612
N	-	3.5	Coconut, rice, banana	978
0	-	3.0	Coconut, rice	657
		55.95		(10,194)

[a]Based on the records of the pesirah.

(harvested every 2 months), and his net return was $372.00.

In 1968, the pesirah opened 2 more fields of 10 and 4 ha, where he planted rice, coconut, banana, and other crops. The 10-ha field has 2,332 coconut trees, but only 600 were mature enough to produce 12,000 nuts ($1,064) in 1980. The 4-ha field has only 28 coconut trees that produced 600 nuts ($58). Rice cultivation yielded 17 t rough rice in the larger field and 7 t in the smaller field in the same year. The 2 fields also had 3,000 banana plants that produced 600 stalks of bananas.

The pesirah's yearly crop production from the two fields for this rice-based cropping system is shown below.

Year	Rice (t)	Banana (stalks)	Coconut (nuts)
1969	12.0	–	
1970	15.0	–	–
1971	16.0	–	–
1972	11.0	–	–
1973	22.0	–	–
1974	34.0	400	–
1975	30.0	450	5,000
1976	30.0	450	6,000
1977	28.0	500	7,000
1978	28.0	500	8,000
1979	26.5	600	10,000
1980	24.0	500	12,000

It is clear that the primary aim of this rice-based cropping system is to eventually become a coconut-based cropping system.

According to local tradition, when a group of farmers open a new canal, they give the pesirah an opened field to show their appreciation for his approval. When new canals were opened in 1975, the pesirah was given 2 ha of cleared land which is intended for coconut after rice. In 1976 he was given 0.5 ha, and in 1977 he received 7.8 ha with 20 cm of peat in which he plants rice.

The pesirah has developed a profitable rice-based cropping system that is suited for these swampy lands and peat soils. He is able to expand his holdings by using contract laborers or local residents who sharecrop. Because he plants rice and banana the first couple of years and then adds coconut, he is able to intensify his operation and increase his return per hectare. He is also able to choose the best cropping system for each location, depending primarily on the depth of the peat. Table 3 summarizes the pesirah's operation in 1980.

Besides the rapid development of swampland by the Buginese and the pesirah's intensive/extensive system, there are other settlements which illuminate the possibilities in these coastal wetlands. The village of Purwosari on the 25-km long canal (Anjir Tamban) across the Barito River from Banjarmasin is an important example of a government-sponsored transmigrant project. It shows how to develop a site at low cost, using migrants to do most of the work. It can be considered a possible alternative model for marginal-land development.

In 1937, the Dutch initiated this project using only man power to open the forest, dig the secondary canals, prepare the site, and construct the houses for the transmigrants. The now-prosperous operations are based on a combination of rice growing and coconut production. The reasons for the prosperity are the cropping systems, more flexible regulations than in more recent transmigration projects, and the length of time the transmigrants have been in the project. Besides being quite successful, the project costs the government little.

The Purwosari transmigration project is an interesting model because of its obvious success and its difference from the present program. The most important differences are that the transmigrants cleared the land, lived in dormitories, dug the secondary canals, and built their houses. They received only food, materials, and perhaps government guidance. Because the peat swamp soils are very fragile, land opening by hand is much better than doing it with large equipment.

The farmers on the right side of the canal adopted the Banjarese cropping system of rice for 4 years, intercropping rice and coconut for 4 years, and then having only coconut. Their income is much better than if they had only rice fields. In their coconut gardens, they also plant coffee trees, banana, and cassava.

The better farmers also were able to purchase land from the migrants who were unable to withstand rigorous pioneer life.

The unique feature of Tamban Lupak, a village on the Barito River, is its two annual rice crops. The farmers plant seed in two seedbeds at the same time — one has local varieties, the other, high-yielding (IR) varieties. The IR variety is transplanted from the first seedbed to the rice field and harvested after several months. Later the farmers harvest the local variety from the same field as the IR variety. Below is a schedule of their operations:

October
Prepare fields by cutting weeds.

November
Plant seed (local and IR) in two seedbeds.

December
Transplant IR to rice: field. Transplant local variety to second bed.

January/February/March
Transplant local variety two times to seedbed.

April/May
Harvest IR variety in the field. Transplant local variety to the field.

June/July
Harvest local variety in the field.

The farmers estimated their yield in 1980 was 3 t/ha IR variety and 3.80 t/ha local varieties. They estimated that only one-third of the transmigrants in Tamban Lupak use this two-rice-per-year cropping system and most of those who do are in nonpeat areas.

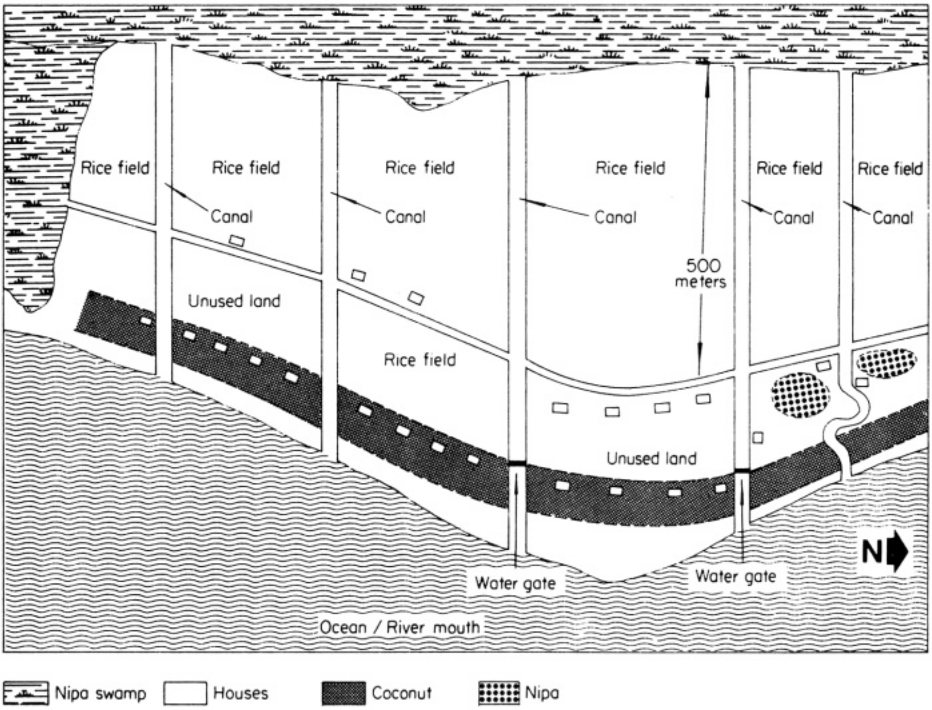
Another noteworthy area is along the seacoast from Kuala Jelai (border between West and Central Kalimantan) to the Arut River. Here the Mendawai people have developed a functional blend of agricultural and fishing systems. They have cleared the nipa swamp along the coast to produce deepwater rice, and to develop the beach ridge for coconut, and to fish in the sea and swamp. Figure 3 represents their area development.

Several points need to be stressed. There are few pests, and rats are not a problem. A few times there has been some brown planthopper infestation. Only in dry years are there rather severe weed infestations. During the first 2 years after opening this nipa swamp, the yields increased but then stabilized at 1.8 t/ha. Farmers estimated their highest yield to be 2.5 t/ha.

After the rice harvest, the Mendawai farmers turn to fishing in the Ocean to supplement their incomes. From October until April, if the weather is good, they fish everyday from 5:00 a.m. to 9:00 a.m. They catch shrimp and many varieties of fish. If they have a large catch, they take it to Pangkalan Pun. If the catch is small, they dry the fish.

The Mendawai farmers also cut nipa leaves and sell them. Once a month, they spend an average of 2 days collecting nipa fronds.

A study of Banjarese migrant operations in Lupak Dalam illustrates the cultivation activities in the wetlands of Central Kalimantan. The following description is true of a farmer who plants rice once a year using a local variety with



3. Orang Mendawai village of Tanjung Puteri (near Pangkalanbun), Central Kalimantan, showing canals, rice fields, and coconut small holdings.

a 9-month growing season in his 2-ha field. There are ridges with coconut, other tree crops, and vegetables.

First seedbed. The farmer plants in October or November using 10 kg seed/ha. He works 4 days (3 hours/day) in a seedbed for 2 ha. Labor use is 6 hours/ha with no cash costs. The seedlings remain in the first seedbed near the farmer's house for 45 days and are then transplanted to the second seedbed in the rice field.

Second seedbed. The second seedbed is actually part of the farmer's ricefield. The seedlings are transplanted to this seedbed in late November or December and grow for 2 months. Because this seedbed is part of the ricefield and occupies from 8 to 16 borong (a borong is 0.028 ha; 8 borongs = 0.2 ha) for a 2-ha rice operation, the field must be prepared in the same manner as the field for the final transplanting. For a 4 borong/ha seedbed, the farmer:

- cuts the weeds with a small scythe, 14 hours (7-hours work/day);
- cleans the field of weeds, 14 hours;
- transplants from the first seedbed to the second seedbed, 28 hours (men and women); and
- weeds twice, 28 hours (men and women).

Prepare the field. To clear the field of weeds that have grown since the last harvest, the farmer cuts them below the water level with a small scythe. One man clears a 1 borong area of weeds in 6 hours. Cutting weeds is done only by men. The field is then flooded to prevent weed regrowth.

Bale the weeds. The farmer wraps the weeds in bales so they will rot, and turns the bales twice weekly. The farmer (7 hours/day) and wife (1 1/2 hours/day) work together. A 1-ha field requires 82 hours from the man and 6 hours from the woman.

Chop and spread weeds. The farmer chops the weeds that have rotted and spreads them over the field as a green manure. It takes him 8 days to cover the entire field.

Transplant from second seedbed to field. In February, the farmer pulls most of the seedlings but leaves enough so that the second seedbed remains part of the ricefield. He can handle 2 borongs/day. He uses family labor in this way: to transplant, he uses 4 men and 1 woman for 8 days (6 hours) to pull and plant a 1-ha field that has a 4-borong seedbed. This is a total of 40 workdays or 240 workhours of transplanting per hectare.

Weeding. The farmer weeds his field twice. Each weeding takes 3 days (8 hours/day), or a total of 48 workhours/ha.

Apply rat poison. Spreading rat poison in the field takes 4 hours/ha. Rat poison is applied three times and consumes 12 hours of labor.

Harvest. The farmer harvests his rice crop in June or July. Depending on the number of family members and the size of the rice operation, he may hire laborers to help. Harvesters use the hand-held rice knife. One person can harvest 1 borong/day. The labor use is 35 workdays or 210 workhours/ha.

Thresh and clean the rice. The farmer can thresh about 100 kg/hour. It takes him 3 or 4 hours to clean the rice of chaff. If the yield is 70 kg/borong (2.5 t/ha), then it takes him 25 hours for threshing and 33 hours to clean rice from 1 ha.

Dry the grain. The farmer and his wife can dry 1 t of rice in 2 days. This is 40 workhours (8 hours/day, depending on the weather) per crop.

RESEARCH PRIORITIES IN THE COASTAL WETLANDS

We have primarily analyzed the role of rice-based cropping systems in coastal wetlands management. As a result we believe that the following are the most important issues for further research.

Cropping systems analysis. Rice-based and coconut-based cropping systems should be analyzed to determine which system will provide the highest returns in specific environments: deep peat areas, along canals more than 3 or 4 km from the river, potential acid sulfate areas, nipa swamp areas, secondary forest areas, areas with water control difficulties, and areas where drainage is a problem.

Transmigration project evaluation. Each transmigration project should be evaluated to determine needed canal system improvements, to select improved varieties, and to suggest extensions of food support in projects that have low yields.

Rice-yield monitoring. Rice yields should be monitored for local residents, spontaneous migrants, and transmigrants, to determine under what conditions yields increase, decrease, or stabilize over time.

Peat depth analysis. The relation between peat depth and the income levels of the transmigrants, spontaneous migrants, and local residents should be analyzed to determine proper cropping systems for various peat depths. In addition, there should be an examination of the effect on farmers' operations of peat shrinkage and disappearance.

Comparison of land opening methods. The methods for opening the swamp forest for agriculture should be compared to aid in the design of a low-cost approach that employs transmigrants in canal construction, forest clearing, and house construction.

Irrigation systems study. Irrigation systems constructed by the government and the local/spontaneous migrants should be studied to determine if they are capable of irrigating wetlands in the dry season or if they should be considered only as drainage canals.

Land-use inventory. Present and potential land use in the coastal wetlands should be inventoried to determine what areas should remain in swamp forest, and what areas have potential for government-sponsored transmigration projects and for spontaneous migration.

Spontaneous migration. Spontaneous migration from Java to Kalimantan should be studied to determine how spontaneous migration can be promoted at low cost to the government.

Environmental impact of canals. The impact on the environment of the major canals in South and Central Kalimantan needs to be evaluated to determine how canals encourage spontaneous development of a large area for agriculture. That should be combined with an investigation of the possibility of more canals connecting the major rivers of Kalimantan, and a determination of the economic, social, and environmental impact of opening vast areas of the coastal wetlands to agriculture.

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AGROECONOMIC PROFILE OF AN OLD TRANSMIGRATION AREA IN THE TIDAL SWAMP ENVIRONMENT

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The agroeconomic profile method was developed to rapidly identify the dominant characteristics of a target area research site so that the information gathered could be used to plan field trials. By first understanding the biological and social conditions, and using that information in planning the research program, more rapid progress will be made toward developing technologies to meet the farmers' needs.

This report describes the agricultural and socioeconomic conditions in Purwosari I village, Tamban Subdistrict, Barito Kuala District, South Kalimantan Province, Indonesia. Information reported was collected by an agronomist and an economist during a 2-day site visit, and provided an overview of the agricultural and socioeconomic conditions in the village. Recommendations for high-payoff research are based on information obtained during the field visit and consultation with scientists from several disciplines.

Before visiting the village, the team listed general information needed to understand the farming system practiced in the area. Then, villagers judged to be knowledgeable about local conditions were interviewed: village officials, extension staff, market agents, input dealers, and farmers. In addition, the team collected statistical data from village records, and visited several farms.

ENVIRONMENT

Tamban is about 20 km southwest of Banjarmasin on the Barito River along the Tamban primary canal. The topography is flat and the elevation about 0.5 m above sea level. The area has direct tidal influence; the water level fluctuates from 0.3 to 0.8 m as the tide rises and falls daily.

The soil in the area is humic clay. Peat depth varies with distance from the primary canal — the farther from the canal the deeper the peat layer. Peat depth has been reduced by good drainage and by burning. Farmers report that near the canal the peat layer is now about 5 cm deep and is underlain by about 10 cm of topsoil. The pH is about 3.5 in new land with deep peat layers, and 4.5-5 in old

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Table 1. Average monthly rainfall for 197881 in Tamban, South Kalimantan, Indonesia.

Month	Rainfall (mm)	Month	Rainfall (mm)	Month	Rainfall (mm)
Jan	331	May	232	Sep	75
Feb	364	Jun	132	Oct	100
Mar	309	Jul	47	Nov	143
Apr	232	Aug	27	Dec	310

land that has been cultivated 15-20 years.

The 4-year rainfall pattern (1978-81) is shown in Table 1, Generally, flooding is not a problem, although in some years drought at the end of the cropping season (July-September) has been severe. In years when the dry season is exceptionally long and rainfall abnormally low, salinity becomes a problem in land near the primary canal.

HISTORY

Before 1938, Tamban was secondary and primary forest with no permanent population. Settlers came from East Java under a transmigration program sponsored by the Dutch Government. The first immigrants came in 1937, followed by others in 1938,1939, and 1941. Those pioneer families were provided transportation from Java to Banjarmasin, simple hand tools, cooking ware, 10 boards for building a house, a 6-month food supply, 0.1 ha for a garden, and 1.5 ha of forest land to clear and develop for agriculture.

Construction of the primary canal (Anjir Tamban) running perpendicular to the Barito River was started by the Dutch in 1941. Only 2 km had been completed when World War II broke out and construction halted. Work resumed after the War. Fourteen kilometers were completed by 1952, and the last 25 km extending to the Kapuas River were completed in 1956-57. Numerous secondary canals flowing into Anjir Tamban have been constructed by the resident farmers to drain the land far from the primary canal.

Initially, original settlers reported that the best area for food crop production was the primary forest land. In contrast, the peat was 1 m or deeper where palm and aquatic weeds had grown. To make this land productive farmers drained the fields and burned off the peat for 5 successive years.

Tamban residents believe the transmigration project has been successful. Having left Java where opportunities were limited, the transmigrants developed a productive farming system that generates a substantial income. Further evidence of the project's success is that few of the original settlers have returned to Java, although some initial settlers moved to Banjarmasin or to nearby towns.

POPULATION, EMPLOYMENT, AND WAGES

In 1981 Purwosari I had 2,992 inhabitants and a population density of 3.3 persons/ha. The average household size is 4.6 persons. Of the total population, 45% are 14 years old or younger.

Table 2. Typical wage rates in Purwosari I, South Kalimantan, Indonesia, 1981.

Activity	Rate
Clearing 1 borong (area of .028 ha)	
Light	$1.12
Heavy	$1.60
Transplanting 1 borong	$1.12
Weeding/8 h	$1.92
Harvesting [a]	14% crop share

[a] When labor is scarce, farmers sometimes pay 17% of the crop.

Population has increased at around 5.5% annually in the past 10 years. A substantial portion of this increase is due to immigration (averaging 60 families/ year during the past 5 years) with less than 10 families emmigrating annually.

Of the total resident households (614), about 84% are headed by farmers, 11% by government officials, and 3% by businessmen. Off-farm jobs in rice production include land preparation, transplanting, weeding, and harvesting. Child labor is used only for weeding; female labor for weeding, transplanting, and harvesting rice; and male labor for all operations. In coconut production, male labor is hired for building the beds on which coconut seedlings are planted. Farmers report that in recent years hiring labor has become more difficult because new transmigrants quickly acquire their own farmland. Consequently, exchange labor is more commonly used than hired labor.

Nonfarm work in the village includes fishing, carpentry, marketing, and lumbering. These seldom are primary activities, but they supplement agricultural income. Purwosari I residents generally do not go outside the village in search of off-farm agricultural jobs. But about 30 men frequently find nonfarm work at the sawmills in Banjarmasin where they earn $4.80/day ($1.00 = Rp. 625). About 20 work as carpenters in Banjarmasin.

Each year about 300-400 laborers (men and women) come from up to 80 km away to harvest the rice crop in the Purwosari area. In recent years the number of migrant laborers has decreased.

Wage rates paid to hired agricultural laborers are shown in Table 2. While these wage rates are per unit area, workers reported they can earn US$3.25/day. That is relatively high compared to the daily wage rate of $0.80-$1.10 in Java.

Nominal wages have increased rapidly. For example, the transplanting wage was $0.55/borong (1 borong = 0.028 ha) in 1977-78 and $1.10 in 1980 .Even taking into consideration the effect of inflation (20% a year), real wages have increased by 10-15% during each of the past 2 years.

LAND USE AND AVAILABILITY

A total area of 907 ha is administered by the village. About 813 ha (90%) is classified as direct tidal area, 77 ha (8%) as home garden, 10 ha as rainfed upland (1%), and 7 ha (1%) as urban land.

Almost all agricultural output comes from the direct tidal swamps. About 63% of this land is planted to mature coconut, 25% to monoculture rice, and 12% to rice intercropped with coconut.

The pattern of land use is continually evolving. Land is typically planted first to monoculture rice, gradually shifted to rice intercropped with coconut, and finally converted to monoculture coconut. The cycle takes about 15 years. There is no virgin land within the village. That means that the rice area will decline as the coconut area increases.

Because all original transmigrant families were given 1.5 ha cropland, access to land has remained relatively equitable. Average holding per farming household is 1.6 ha, excluding land outside the village that is farmed by villagers. The typical farmer owns 1-2 ha, divided into 2-3 parcels, 2-6 km from his house. The largest holding in the village is 12 ha. Generally, the larger the holding, the greater the amount of land the farmer plants to coconut.

About 75% of the farming households are owner operators, 10% are share-tenants, and 15% landless. Almost all families own their home lots. The share-tenants and the landless are new transmigrants who have not yet acquired enough money to purchase land. Only rice land is rented out under a share arrangement, with 1/3 of the crop going to the farmer and 2/3 to the owner. Typically, the share-tenant provides all inputs.

Fragmentation does not appear a serious problem today, but Islamic inheritance law requires that land be equally divided among all children. Consequently, average farm size and parcels per farm household are expected to decline over time.

Farmers report that new land (cultivated less than 5 years) is still bought and sold for about $8/borong or $280/ha. Old rice land (cultivated more than 5 years) is less frequently available, but would sell for $1,120/ha. Although old land with mature bearing coconut is seldom sold, its estimated market value is ± $5,600/ha.

Most new transmigrants purchase new land outside the village where it is more readily available. About 15% of the farmers cultivate fields beyond the boundaries of Purwosari I.

CROPPING PATTERN AND CROP CALENDAR

Before the transmigrants arrived, the land was in secondary and primary forest. The farmers cleared the land, burned the forest and peat, dug drainage ditches, and planted rice. After about 10 years, the pioneers began to plant coconut in the rice fields — a technology adapted from the local Banjar farmers who lived downriver.

The current cropping pattern is based on the historical pattern followed by the pioneers. The primary long-term objective of the farmers is to establish a coconut plantation, but in the short-term family food needs must be met by producing rice.

New land is claimed from secondary growth by cutting the trees and burning them. Stumps are removed in successive years. If the peat layer is too deep, canals are dug to drain the soil and the peat is burned off to the desired depth.

On land that has been cleared, grass is cut in early December, then rolled into piles. After 2 weeks, the compost is turned and 10-15 days later is spread over the field. That is the extent of land preparation.

Farmers follow a triple-transplanting system because water control is poor in most fields. This system facilitates the production of tall seedlings that will survive flooding at depths greater than 30 cm by March or April.

Early in October a seedbed — elevated enough to protect the seedlings from flooding — is prepared at the edge of the field and 5 kg/ha of a local rice variety is sown. The seedlings are first transplanted into a larger seedbed, 40 days after sowing (DS) at a plant spacing of 50 cm × 50 cm. Then, in mid-January (about 80 DS), the seedlings are transplanted a second time into strips in the main field equivalent to one-third the area to be planted. From the end of March to early April (140 DS) when the seedlings are 60 cm tall — their roots and top leaves are pruned, and the seedlings are transplanted into the main field (4 seedlings/hill at 30 cm × 30 cm spacing). The water level is maximum at final transplanting and the crop matures as the water level falls. The photoperiod-sensitive varieties used mature in 10 months and are ready to harvest by August-September.

In successive years, the farmers construct in their rice fields 1-m^2 beds spaced 8 m × 9 m, with a drainage ditch 60 cm deep cut along the edge. At the beginning of the rainy season in October, they plant a 1-year-old coconut seedling atop each bed. The coconut seedling density is 120 trees/ha. As the trees mature, the farmers enlarge the beds in successive dry seasons until eventually all trees are connected in a raised bed running the length of the field. Rice is normally grown between the coconut beds 6-15 years (depending on plant spacing) before the shading effect reduces rice yield enough to make rice culture uneconomical.

Farmers plant cassava on the coconut beds in June and July until the coconut trees are 5 years old, at which time shading severely restricts cassava growth. Farmers also plant vegetables (long bean, pepper, greens) and fruit trees (banana, jambu, breadfruit, citrus) on the beds between the coconut trees to meet family consumption requirements. Legumes are not grown because they do not yield well on the low pH soils.

CROP MANAGEMENT

All rice varieties grown in Purwosari are of traditional origin. The three most commonly planted rice cultivars are photoperiod-sensitive Pandak, Tilang, and Karang Dukuh. All have 10-month duration and a mature height of 1.3 m, but differ in productivity and eating quality. Pandak, a new rainfed introduction, gives the greatest number of tillers, the most grains per panicle, and grows well in shade. Although Tilang and Karang Dukuh give lower yields, they are preferred for their superior eating quality which is comparable to that of Rojolele in Central Java. Some farmers also plant Lemo, Ketan Hitam (glutinous), Pajar Putih, and Pajar Kuning. Seeds are either saved from the previous crop or obtained from a neighboring farmer.

Timely land preparation and seedling production are key crop management factors. If the final transplanting is postponed, yield losses are severe as the crop matures later than crops in neighboring fields and suffers severe rat and bird damage and, possibly, drought.

Farmers seldom apply inorganic fertilizer or insecticides to the rice crop, but returning the cut grasses or weeds during land preparation provides some organic nutrients.

In the tidal swamp environment with abundant water, weeds are not a major problem. If weeding is required at all, it is done only once per crop about 40 days after the third transplanting.

Rice yields are difficult to estimate because they vary with peat depth and the spacing and age of coconut trees intercropped in the rice fields. Also, the rice area in an intercropped field can be determined accurately only by direct measurement A rough estimate is that rice yields average 2 t/ha in monoculture and 1 t/ha in intercropped fields. Rice yields decline as the shading effect of the coconut trees increases. If the coconut trees are spaced at 15 m, rice can be grown even between mature trees, but if coconut trees are spaced 10 m apart, rice yields fall considerably after 5-6 years and farmers generally stop growing rice.

Local farmers classify coconut trees as producing either yellow or green nuts. About 50% of the farmers plant each type and do not distinguish between types based on yield. Within each classification, there appear to be differences in growth rate and height.

Farmers apply no inorganic fertilizer to the coconut trees. In fields with intercropped rice and coconut, the trees are treated with compost — organic materials removed from the rice fields — in the dry season.

Coconuts planted on beds 3-4 m wide begin producing fruit in 5 years, but on beds less than 2 m wide they bear in 8 years, yielding 4–5 nuts every 20 days. Maximum production of 6-7 nuts every 20 days is obtained from trees 15-40 years old. Old plantations are renovated by planting coconut seedlings next to 50-year-old trees. The old trees are removed after 5 years when the new seedlings begin to bear.

All other crops grown in the village are of local origin. Inorganic fertilizers and insecticides are seldom applied. Because these crops are grown for household needs, no attempt has been made to estimate yields.

LIVESTOCK AND FARMING EQUIPMENT

All rice production activities are done by human labor. Previous efforts to introduce carabaos failed because pasture or feed was not available and the soil could not support the animals' weight. Furthermore, farmers felt it required too much effort to maintain an animal that would be used only once a year for plowing.

Farmers used a machete to cut grass and a hand hoe for plowing. Weeding is done by hand pulling, and harvesting with a finger knife (*ani-ani*). Harvested rice is threshed by foot. Some farmers winnow the rice with a homemade box winnower. There is one rice huller in the village where most families have their rice cleaned. Hand pounding disappeared at least 5 years ago.

The main livestock raised by village residents are goats, ducks, and chickens, primarily for family consumption.

WATER CONTROL

Since 1957, when the primary canal was completed, farmer groups have constructed many secondary canals to drain the inland areas. Individual farmers have built small tertiary canals.

But in most farmers' fields, the water level depends on the tidal influence on water level in the Barito River. On about 15% of the land (fields nearest the primary canal) farmers have built effective drainage systems to control water. Sluice gates can be closed when the tide is out and the water level manipulated as needed.

Some land farther inland is slightly higher and is influenced less by the tidal fluctuations. Although less subjected to deep flooding, these areas are also more vulnerable to drought.

SUPPORT SERVICES

Extension

Purwosari is served by one full-time rice extension agent (PPL) who covers 2 villages, 2 general extension agents (PPM) serving 19 villages in 1 subdistrict, and 1 extension specialist (PPS) working throughout the district.

The primary role of the extension service is to support the government's rice intensification effort (BIMAS). The BIMAS program was first opened to residents in 1974 when 50 ha were enrolled. By 1979 participation had grown to 90 ha. Inputs, however, arrived too late in 1980, so no farmers enrolled in the program that year. Farmers who chose to participate received loans for 50 kg urea/ha, 35 kg triple superphosphate/ha, 1/2 liter insecticide, and 1/2 kg rat poison. In addition to these inputs valued at about 532, participants receive the equivalent of $32 in cash. Interest of 1% a month was charged and the loan was repaid after harvest.

Informal credit is available from neighbors and relatives without interest. In addition, many residents participate in informal savings groups.

Fertilizers and insecticides are sold through the government supply cooperative (KUD). BIMAS members' requirements are met first. Remaining inputs are sold to nonmembers at slightly higher prices. For example, urea is sold to members for $0.11/kg, to nonmembers at $0.14/kg. There are no private input dealers in the village.

Markets

Marketing channels in the village are all private. There is no public agency to purchase surplus rice from the farmers. Farmers can sell their produce and buy consumer goods at a weekly market. There are six resident middlemen who purchase rice and coconuts for resale in Banjarmasin. Farmers generally sell to the middlemen because the Banjarmasin price is only about 1% above the price the middlemen pay the farmers.

Prices for farm products vary considerably over the year. In 1980-81 paddy commanded a price of only $0.14/kg after harvest (October) but rose to $0.28/kg in June-July. During the same period the price of coconut ranged from $0.06 to $0.12/nut and was probably influenced by the world market price for copra.

Surpluses of rice, cassava, and other food crops grown primarily for home consumption may be sold in the weekly market if supply exceeds family needs. A household of 5-7 persons consumes 1.5 t of paddy annually.

Community infrastructure

The waterways are the principal means of transportation. River taxis that continually ply the canal charge $0.40 to travel to Banjarmasin. Taxis are always available because the primary canal connects the Barito and Kapuas Rivers.

The village has five lower primary schools, one junior high school, and a health clinic served by a nurse. There is no public electrification, but several groups of families have their own generators.

PREVIOUS RESEARCH

While no formal research has been conducted in this village in recent years, the extension service has done demonstration trials. In the 1979 wet season, a variety demonstration was conducted in farmers' fields. In the area with good water control, 1 ha was sown to IR38 and 1 ha to Asahan, an Indonesian modem variety. Both were fertilized with 50 kg urea/ha and 35 kg triple superphosphate/ha. All recommended practices were followed, including complete land preparation by hoe, seedling transplanting at 30 DS, and insect control. Yields averaged 4.2 t/ha for IR38 and 3.8 t/ha for Asahan. Complete water control was possible because the fields were near the primary canal. The farmers, however, found the system required too much labor and planted a local variety the next year. In the 1980 wet season the extension service established a fertilizer trial on local varieties.

CONSTRAINTS

There are several reasons farmers are unlikely to adopt modem varieties and the intensive management system associated with their production. Short modern varieties can be grown only in the 15% of the area that has good water control. In the new land, rice yields remain low for at least 5 years until drainage is established. The establishment of adequate drainage is dependent on neighboring farmers because maximum benefit can be achieved only through a coordinated area-wide effort. Although the farmers could extend the existing drainage system and expand the potential area, they are unlikely to because they use rice primarily as a transition crop until coconut is established. Capital improvements with a short benefit period would have little appeal.

Traditional rice production requires perhaps one-half to two-thirds as much labor per crop as the intensive system associated with modern varieties. On lowland farms in Java where farm size averages 0.5 ha, about 85% of the labor is hired when modem varieties are grown. Because farm size is relatively large in

Purwosari I, the farmer would have to hire a considerable amount of high priced labor to adopt the intensive system. Given that the price of paddy at harvest is relatively low in this area ($0.l4/kg compared to the official support price of $0.18), the cost of hired labor would considerably reduce profits, even if yields were double that of the traditional variety.

Farmers also feel that the modern system demands a large labor input at fixed times to complete land preparation and transplanting. The traditional system permits these activities to be extended over a longer period, thereby enabling the farmer to use more of his own labor.

The local varieties grown by most farmers have superior eating quality. From our experience in Java, we expect the taste of modern varieties to be less acceptable to the farmer, and to sell for 15-20% less in the local market. The farmer who grew IR38 in 1980 reported its eating quality equal to that of Pandak, so the price discount may be less than suggested.

Although the early-maturing modem varieties permit farmers to grow two rice crops a year, growing a second crop may be less attractive than it first appears. For farmers who are employed in nonfarm jobs when they are not growing rice, we have to consider the income they would lose by giving up the nonfarm jobs to grow a second rice crop. Simple budget analysis of the traditional vs the modern two-crop system may overestimate the relative profitability of the modern technology.

Single fields initially planted to early-maturing modern varieties may be badly damaged by birds and rats before the main crop local variety matures. Damage by these pests is reduced when harvest is relatively synchronized as is the case for farmers planting local varieties.

Because the present rice production system appears to be meeting family consumption needs (1.5 t/family per year) and coconut is the preferred cash crop earning an income of $1,717/ha per year there seems to be little incentive for Purwosari farmers to adopt an intensive rice production system.

TECHNOLOGICAL NEEDS IN PURWOSARI I

Technology must be compatible with the physical environment and the socioeconomic situation in a target area before it will be adopted. Environmental constraints in the study area include peat soils, low pH, moderately deep water, daily fluctuations in the water level, occasional drought and salinity, and minimal water control. Socioeconomic determinants include a relative abundance of land as indicated by the large average farm size, labor shortage as indicated by the low population density and high daily wage rate, and the existence of nonrice income opportunities that give high returns to labor (coconut production). These environmental and socioeconomic determinants are responsible for the farming system that has evolved in Purwosari. Any new technology to increase agricultural production in the area must consider these factors.

The modern rice technology that the extension service has attempted to introduce in the village is designed for the factor endowment of Java. Semidwarf varieties and granular fertilizers require good water control, which is absent in Purwosari I. Complete land preparation, planting in rows and weeding of semidwarf seedlings all require a high labor input. This labor-intensive system is appropriate in Java where wages are low and land is scarce because the economic objective is to optimize output per unit land. This technology is not appropriate in Purwosari because labor is more expensive and land in greater supply. Therefore the economic objective is to optimize output per unit labor.

To meet farmers' needs in areas similar to Purwosari, the modem rice technology must be modified significantly. The goal should be to find ways to make marginal improvements in yield and output per labor day, not by replacing the traditional system but by building into it productivity-oriented improvements.

Management practices

The management practices needed to increase productivity are essentially the same no matter what the level of water control. All are aimed at reducing the labor costs. They include traditional minimum tillage, weed control through scattered planting of tall seedlings plus herbicide or row transplanting plus the use of a rotary weeder, and the use of urea briquets to reduce the number of fertilizer applications required. Ratooning the second rice crop is appropriate because it yields in 60 days and reduces the probability of drought damage late in the dry season in fields far from the primary canal and saline water infiltration close to the canal.

Varieties

Varieties suited for the Purwosari I area, whether water control is good or poor, should share some common characteristics such as early seedling vigor, good ratooning ability, and moderate to tall plant height. They should also have tolerance for shade because rice is commonly intercropped with coconut.

Areas with good water control. Varieties suitable for areas with good water control should have these characteristics:

- early seedling vigor so seedlings will be taller and easier to transplant into unplowed fields 30-60 DS,
- intermediate plant height (100-130 cm) for better weed control and to permit harvesting with a finger knife,
- medium maturity (150 DS) so that transplanting time is less critical and farmers could extend transplanting over several weeks to reduce the need to hire labor,
- tolerance for moderately low pH (4.5), and
- good ratooning ability.

Areas with poor water control. Varieties suitable for areas where water control is poor usually are triple transplanted. They should have these characteristics:

- early seedling vigor so seedlings will be taller and easier to transplant at the first transplanting (40 DS),
- moderately long duration (175-220 DS) so the third transplanting can be accomplished 30 days before flowering,

- moderate plant height (130 cm) so that seedlings will be at least 60 cm tall at the third transplanting,
- tolerance for low pH (3.0-4.0), and
- good ratooning ability.

Trials for system components

High payoff research to evaluate the potential of the improved systems suggested should include trials on the

- response of local varieties to urea briquet,
- timing of briquet placement,
- rate of urea briquet application,
- effect on yield of traditional vs complete land preparation,
- effect on yield of single, double, and triple transplanting,
- yields from ratoon crops, and
- yield response to shading.

The results of these trials and evaluation of previous research on these topics would provide valuable information on the potential of introducing a less labor-intensive rice production system using modern varieties. Economic analysis of the data would show the benefit cost of each component and its attractiveness to the local farmers.

Socioeconomic studies

Socioeconomic research should focus on monitoring labor use and production costs for the traditional farming system, including nonrice and nonagricultural activities. Crop cuts should be taken to estimate rice yields. Weekly monitoring of a small sample of farmers is necessary to comprehend the existing farming system and income generated. Because the system is complex, single visit interviews will not provide accurate information. Data from research should be used to evaluate the profitability of the traditional system and to identify labor constraints that could be overcome through the introduction of technology such as rotary weeders and power tillers. Labor-reducing technologies may make a significant contribution in the Purwosari environment because labor is a major production constraint.

Experimental data should be evaluated in terms of the marginal benefit cost of each treatment compared with farmers' practice. This analysis is needed to determine the financial attractiveness of the new technology for farmers.

RECOMMENDATIONS

COLLABORATIVE SCREENING OF RICE BREEDING MATERIALS FOR SALINE SOILS AND PEAT SOILS OF TIDAL SWAMP AREAS

The common breeding objectives for tidal swamp rice are tolerances for submergence, acid sulfate soil, salinity, peat soil, and some pests and diseases (blast, bacterial blight, Helminthosporium). The collaborative project aims to identify materials for use in the hybridization program, perform special screening tests where there are adequate facilities, and exchange information.

A program to identify tolerant materials that can be used for breeding is proposed. The collaborative project to identify parent materials for hybridization should be initiated, with each country assuming responsibility for conducting specific screening tests.

Each collaborating country will extend assistance in the field screening:

- Bangladesh: submergence tolerance;
- Indonesia: salinity tolerance, acid sulfate soil tolerance, peat soil tolerance;
- Thailand: submergence tolerance, acid sulfate soil tolerance;
- India: to be determined;
- Vietnam: to be determined; and
- IRRI: greenhouse screening, hybridization, and rapid generation advance.

The coordinator for the screening program is Dr. G. S. Khush. The collaborators are A. Hamid (Bangladesh), C. Prechachart (Thailand), Z. Harahap (Indonesia), and F. Andrade (Ecuador).

Cooperators are requested to report to the coordinator the results of testing that are related to this program (International Rice Salinity and Alkalinity Tolerance Observational Nursery [IRSATON], other International Rice Testing Program [IRTP] nurseries, and international collaborative tests of rice for problem soils).

COLLABORATIVE RESEARCH ON FERTILIZER MANAGEMENT

The problems in the coastal wetland areas concern acid sulfate, peat, and saline soils; and deep water. The first two problem areas were considered highest priority and a collaborative research program was agreed upon.

Acid sulfate soils

A uniform set of 10 rice varieties will be tested by all collaborators. Other national and local varieties may be added to the basic set of 10 if the researcher desires.

There will be at least three replications of fertilizer treatments to include no added P, rock phosphate, and trisuperphosphate. Lands to be used for experiments are those opened and presently used for agriculture. Soils will be described according to standard procedures.

Peat soils

The following treatments will be used in common on peat soils: no added fertilizer; NPK; N; NP; PK; NK; NPK + Ca, Mg, Cu, Zn, S, Mo; NPK + all minus Ca; NPK + all minus Mo; NPK + all minus Mg; NPK + all minus Cu; NPK + all minus Zn; and NPK + all minus S. Other details will be included in a procedures manual. Lands to be used for experiments are those opened and presently used for agriculture. Soils will be described according to standard procedures.

WATER MANAGEMENT AND RECLAMATION

Priority should be given to water management on nonacid marine and saline tidal soils and to acid sulfate soils because they represent the largest rice-producing areas and contain high levels of toxic substances in the soil and water.

Nonacid marine and saline tidal soils

For the nonacid marine and saline tidal soil areas, construction of low dikes and shallow drains and development of appropriate varieties (early maturing or salinity tolerant) to cope with adverse water effects at the critical grain filling period are proposed.

Acid sulfate soils

For acid sulfate soils, research should consider the effect of incorporation of weeds on nitrogen balance, and iron and aluminum concentrations. Where raised beds have been constructed for growing upland crops, characterization and long-term monitoring of the chemistry and hydrology should be done. A study should be done on the feasibility of constructing an irrigation system, separate from the tidal canals, that would be used for drainage of toxic compounds.

COLLABORATIVE TESTING OF THE INTERNATIONAL RICE DEEP WATER OBSERVATIONAL NURSERY (IRDWON): TIDAL SWAMP SCREENING SET

Leading local and improved varieties from tidal swamp rice areas might provide materials for hybridization, for further evaluation, and possibly for local introduction. Before hybridization programs are initiated to improve tidal swamp rice varieties, the best potential parents need to be identified through a rigorous screening process. Apparently the best approach is to plant varieties and lines under severe direct tidal conditions to identify the outstanding varieties.

A screening set for tidal swamp rice is proposed.

A tentative list of 62 entries was presented and additional entries were nominated by Bangladesh (2), Indonesia (5), and Thailand (5). These countries will send IRRI 200 g of each additional entry. For each entry, 3-4 rows will be transplanted using local practices.

Scoring will be based on percentage survival, number of tillers at different stages, color and vigor of the plant, toxicity symptoms, and number of panicles at maturity.

Characterization of the site according to soil type will be needed (acid sulfate, peat soil, saline soil, etc.)

The screening sets should be received by collaborators on the following schedule: Indonesia, October; Thailand, July; Sri Lanka, September; Bangladesh, June; and Ecuador, April. Indonesia should receive five screening sets, and Bangladesh, Ecuador, and Sri Lanka each should receive two sets.

The most popular varieties and promising experimental lines from countries growing tidal swamp rice should be included in an international screening test. This would form part of the IRDWON, with collaborating countries providing seeds of their most promising lines or varieties.

DEVELOPMENT OF METHODS FOR SCREENING BREEDING MATERIALS TOLERANT OF SUBMERGENCE AFTER TRANSPLANTING

Many successful tidal land rice varieties perform poorly in tests for submergence tolerance. Tidal rice experiment stations therefore may need to rely on their own natural facilities to test for tolerance for tidal submergence. The relevance of extreme tolerance for prolonged submergence was discussed in relation to tidal submergence situations. A divergence of opinion was noted.

Common check varieties

To aid in the interpretation of contradictory results from the various tidal submergence procedures, the use of common check varieties should be promoted. A uniform set of varieties for tidal submergence testing should be made available.

Advanced hybrid line

To obtain accurate information based on research data, an advanced hybrid line with strong submergence tolerance should be made available as a common check in tests under tidal submergence of higher than normal amplitude.

OTHER RESEARCH PRIORITIES FOR TIDAL SWAMP RICE

There is insufficient information to establish whether the incidence of pests and diseases in tidal swamp areas is similar to that in deepwater areas. It is likely that methods and procedures used to study pests and diseases under deepwater conditions will be applicable to tidal swamp conditions, but this needs to be examined. A Southeast Asia project organized by IRRI/Thailand will survey the incidence and prevalence of pests and diseases of deepwater rice. A survey of pests and diseases in tidal swamp rice was recently completed in South Kalimantan.

Rat damage is one of the most serious constraints to rice production in many tidal swamp and deepwater areas of Southeast Asia. Specific control measures have been developed in some countries, but their broad applicability has not been determined. The problem of rat control is largely organizational and requires government intervention and support.

A great deal of discussion was devoted to the prevalence of weeds and their significance in rice culture. In some regions, tidal swamps used for rice are abandoned in favor of coconut because of higher net returns. Much of the weed control discussion was concentrated on

- the identification of troublesome weeds,
- the use of weed residues as a soil nutrient amendment, and
- the use of manual labor and herbicides in weed control and management.

Ratooning of photoperiod-sensitive rice cultivars has not been successful. Short season and photoperiod-sensitive types, however, lend themselves to ratooning. The supply of plant nutrients, especially N, may significantly affect ratooning, and the incidence of pests and diseases may be a serious constraint as well.

Seedling age, number of seedlings to be transplanted, number of transplantings, and plant spacing were discussed, but appeared to be of national rather than regional interest.

It was agreed that studies to identify and characterize cropping patterns and farming systems in tidal swamps should go beyond rice-based systems and include perennial crops and animal enterprises. Techniques and procedures in the collection of secondary information and on-farm surveys as outlined by Dr. Richard Bernsten will be useful in base line studies.

Growing two crops of rice a year using improved photoperiod-insensitive cultivars is possible, but farmer adoption has been slow.

The examination of alternative secondary crops and how they fit into the cropping pattern in relation to land and water management was discussed. It was agreed that multidisciplinary teams studying cropping and farming systems should include agronomists, agricultural economists, sociologists, anthropologists, and animal scientists wherever applicable.

At present, manual labor and simple tools are primarily used in tidal swamp rice culture. The discussion group believes that implements used in some countries might have utility in other countries where tidal swamp rice culture is practiced. During critical labor periods, mechanized equipment might have application if it: is of the appropriate size and design.

Many projects in national programs have included social scientists as members of interdisciplinary teams. The group sees merit in the conduct of on-site research by biological scientists with surveys and input by social scientists.

Social scientists outside the agricultural research organizations frequently generate information that might be beneficial to biological scientists. Their studies sometimes correspond to the region of interest to biological scientists, but more often they do not. The collaborative roles and contributions of the biological and social scientists have not always been clearly delineated and defined.

Plant growth is reduced and crop yields are often low at the extremities of water channels where water flow is restricted. It is assumed that at such places, there are conditions that lead to toxicity.

Rice sterility under certain tidal swamp conditions is physiological, especially on peat soils where drainage and crop production lead to degradation of the peat, and is associated with particular soil chemical conditions.

Pests and diseases

National tidal swamp rice programs should give high priority to determining the incidence and prevalence of pests and diseases in the tidal swamps. Recommended categories of pests and diseases are most important, occasional, potential, and migrant.

Researchers (plant pathologists and entomologists) should avail themselves of the methodologies and procedures used for the study of pests and diseases under deepwater conditions. Information is available from Dr. H. D. Catling, IRRI/Thailand, G. P. O. Box 2354, Bangkok.

National tidal swamp rice programs should join forces with rat control research agencies to implement control measures as a national policy with financial and logistical support from ministries of agriculture. Additional information on control can be obtained from the Rodent Control Center, University of the Philippines at Los Baños, College, Laguna, Philippines.

Crop management

On a regional basis rice agronomists should solicit the collaboration of weed scientists who can provide assistance in weed control studies in the tidal swamps using herbicides and other measures, particularly management practices related to land preparation.

Rice agronomists should collaborate with rice breeders to obtain information on varietal response to ratooning. In particular, the effects of cultural practices should be examined and the prevalence of pests and diseases should be monitored.

Cropping and farming systems

Rice agronomists should bring to the attention of the Southeast Asia Cropping Systems Working Group the need for additional studies on cropping and farming systems in the tidal swamps, and provide appropriate collaboration and assistance for increasing food production and stabilized farming.

Appropriate tools for tidal swamp rice culture

National programs and IRRI should inventory simple hand tools and examine other implements that might improve cultural practices in the tidal swamps.

National programs should continue or implement pilot research on the use of small tractors and appropriate equipment for land preparation.

Socioeconomic issues

Rice agronomists should promote the collaboration of social scientists and those from other disciplines, especially where credits, returns, labor allocations, attitudes of farmers, transfer of technology, etc. are involved. Members of the multidisciplinary team should be partners from the time of discussing research priorities and developing plans of organization and operation, through interpretation and transfer of technology.

Other research aspects

The sterility of wetland rice on deep peat should be studied by a multidisciplinary team, including plant physiologists, plant pathologists, hydrologists, and soil scientists.

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