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Former and Present Cropping Patterns in the Mekong Delta

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Abstract

In a previous paper, I proposed five landform units and several subunits for the Mekong delta (see Fig. 1). This paper aims to describe the former and present cropping patterns in relation to the landform, particularly the interconnected features of microlandform, water conditions, soils and the traditional methods of rice culture.

The first part of the paper describes the methods of rice growing which were predominant in the delta before the 1960s-1970s. These methods were severely affected by the uncontrolled water conditions, which differed markedly in different landform units of the untamed delta, and may be summarized in three groups, which are characterized most distinctively by three planting methods, i. e., broadcasting, double transplanting, and single transplanting.

The second part of the paper describes the present changes in the cropping pattern and the development of various rice growing methods. The most remarkable change is observed in the tide-affected floodplain (middle reach of the delta). Conventional double transplanting has been completely replaced by new methods like direct-seeding *sa chai*, and single cropping has been replaced by the year-round cultivation. Floating rice in the high floodplain (the upper reach of the delta) has also been reduced by expansion of high-yielding rice varieties. The coastal complex and the broad depression, which are affected by saltwater and sulfate acidity respectively, retain the traditional rice culture.

The remarkable change in rice culture and land use has achieved as the result of close observation of soil, microlandform and water conditions by the farmers, and through their selective adaptation to natural environments and proper technologies.

Introduction

The Mekong delta occupies about 3.9 million hectares in the South of Vietnam. It is flat and low-lying, except for minor areas of hard, rocky mountains and hills, which are exposed near the Cambodia border. The delta lies entirely within the hot monsoon climate. The rainy season runs from May to November, and more than 70 % of the annual precipitation falls during these months. Flooding occurs at the end of August and continues until the end of October. The annual average temperature is 27 °C.

The delta still has several inherent limitations such as flooding, poor drainage, salinity and acid sulfate soil. According to old farmers who have lived there, a century ago the delta was an almost inaccessible area covered by mangrove swamp forest and inhabited by a sparse population thriving on fishing and rice cultivation. By observing the landform, topography, physiography and hydrology, people have adjusted themselves to these natural

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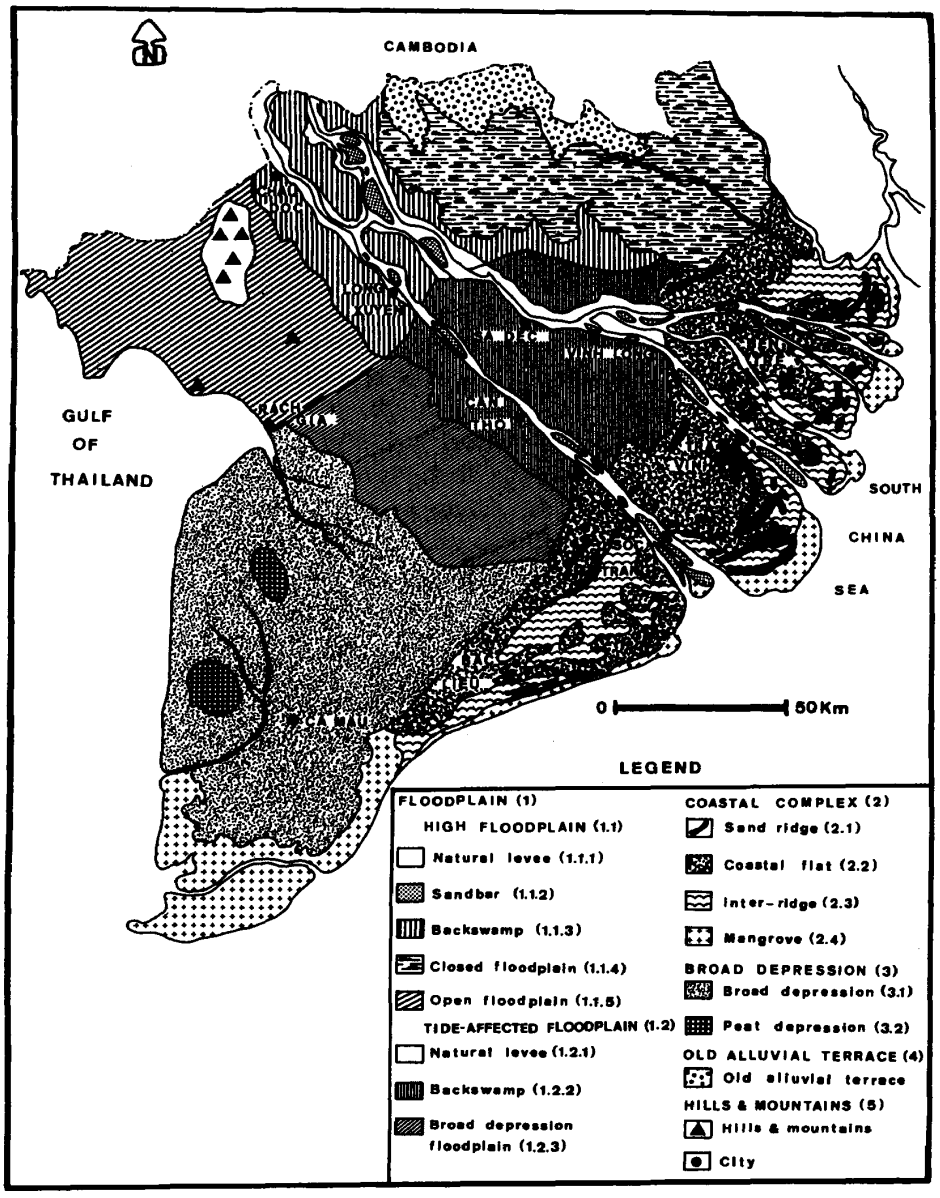

Fig. 1 Landform of the Mekong Delta

conitions. They have selected suitable cultivation methods and patterns, for their particular living environments.

I Former Cropping Patterns (Before 1967)

1. 1 Outline of Traditional Local Rice Cultivation

In the old days, most of the cultivated areas of the delta were used for local rice cultivation. Other crops were also grown in small plots located around the house compounds.

At least 1,000 local rice varieties (collected by Can Tho University) were planted in the delta, and most of them were photo-sensitive. They differed in length of growing period

Table 1 Main Groups of Local Rice Varieties in the Mekong Delta

Rice variety	Duration seed bed (days)	Growing period in days (incl. seed bed)	Time of harvest
Early varieties	30-40	130-160	Variable, main harvest generally in Oct. or Nov.
Med. varieties	40-50	160-200	Dec.-Jan.
Late varieties	50-60	200-250	Jan.-Feb.
Floating rice	none	200-240	Dec.-Jan.

Source : The Center for Rice Research, Can Tho University.

and harvesting date, and based on these characteristics, they were divided into four groups : early maturing varieties, medium maturing varieties, late maturing varieties and floating varieties (see Table 1).

Farmers divided the local rice into two types, *lua dai* (long grain rice) and *lua tron* (round grain rice). For ease of cooking and taste, they found the *lua dai* varieties to be preferable to *lua tron* varieties for daily consumption.

The early maturing rice varieties were planted mainly in the coastal complex and broad depression areas, where they could be harvested before saltwater intruded in November.

Medium maturing rice varieties were planted on the relatively high areas of the tide-affected floodplain, where it was difficult to control water, as on the natural levees of the Tien and Hau rivers and their branches.

Late maturing rice varieties were cultivated in low areas with plentiful fresh water, such as the freshwater broad depression, and the backswamps of the Tien and Hau rivers and their branches.

Floating rice was cultivated only in the high floodplain and was not seen elsewhere in the delta.

Before high-yielding rice varieties were introduced in 1967, the delta had three main cropping patterns, which were related to the three local rice planting methods : broadcasting, double transplanting and single transplanting. These cultivated areas are illustrated in Fig. 2.

Broadcasting was only practiced with floating rice varieties. Double transplanting was practiced with medium and late maturing rice varieties, while single transplanting was practiced with early rice varieties.

1.2 Floating Rice

a. Soil Preparation

The soil was still moist after the floating rice harvest in December. Some farmers then burned the remaining straw and ploughed their fields by using two water buffaloes. Thereafter, they left the field fallow during dry season from January to March. When the

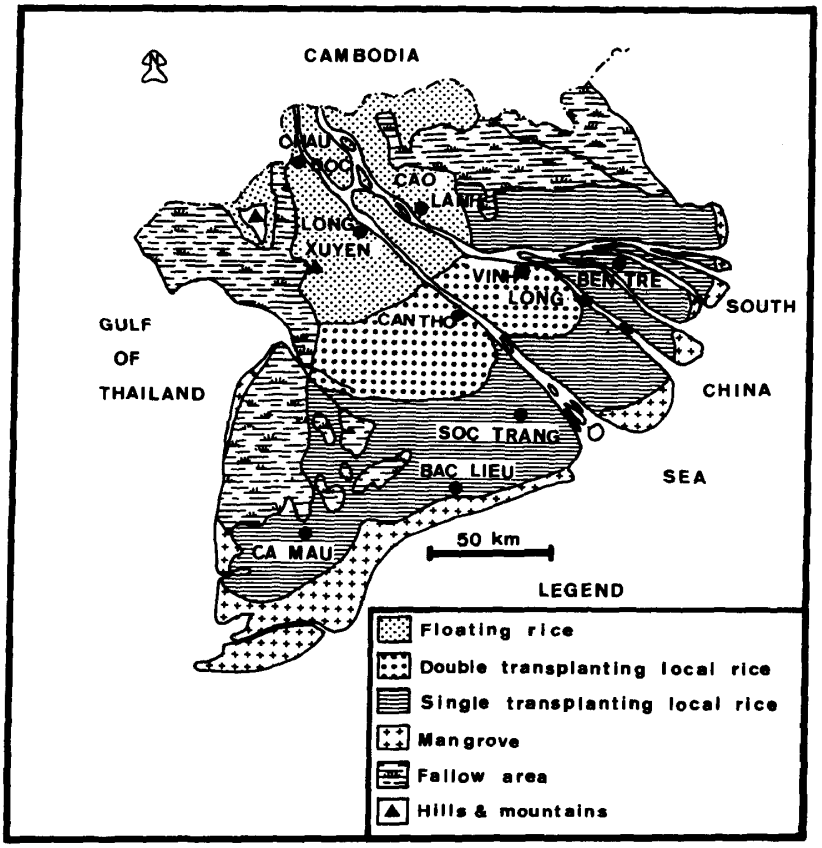

Fig. 2 Distribution of Former Cropping Patterns in the Mekong Delta (Based on [Netherlands Delta Team 1974 : 58-121] and Modified by the Author)

first rain fell in April, they began to harrow the land for broadcasting floating rice. Other farmers did not plough their fields after the rice harvest but instead planted upland crops such as mungbean and sesame in the moist soil. After these crops had been harvested, they ploughed and harrowed when the first rain fell, and immediately broadcast rice there. A schematic diagram of the floating rice-upland crop pattern and the cropping calendar are illustrated in Fig. 3.

b. Broadcasting and Harvesting Methods

Dry rice seeds (100 kg/ha) were broadcast after harrowing the soil when the first rains fell in April and made the soil soft. Buffaloes were used again to harrow the field in order to cover the seeds. This prevented dessication during the germination period of 1 to 2 weeks, when no rain fell, and it protected the seeds from birds and mice. The rice plants grew depending on rainwater until the flood came in mid-August. Inundation increased gradually, and the rice plants had a very rapid growth habit to cope with the rising water level. They sent out long culms with adventitious roots at the nodes. When the water level decreased in December, the rice plants lay flat on the ground.

Harvesting was done by sickle, which was used to cut the stalks about 20-30 cm below the panicles. The harvested ears were tied into bundles which were laid on the threshing

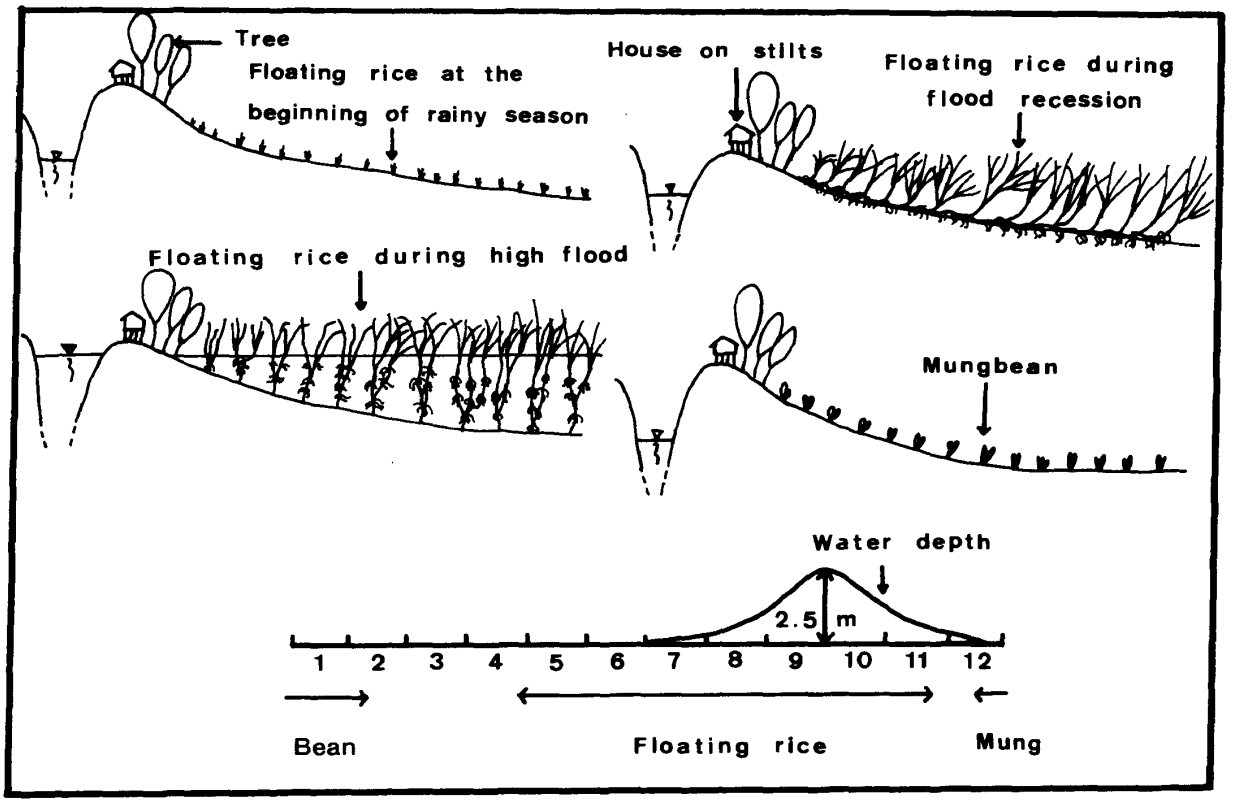

Fig. 3 Schematic Diagram of Floating Rice-Upland Crop Pattern and Cropping Calendar in Phu Chau, An Giang

floor. The threshing floor was constructed by collecting soil materials from nearby. Normally, it was located at the highest part of a field because the soil was more stable and compact there than in lower parts. Moreover, it did not take much time to raise the ground surface. Cattle were used to thresh the grain by trampling it. After winnowing, rice grains were transported to the houses by water buffalo. Good rice varieties that gave high yields were preserved in the store house at the field for the next year's cultivation. After the rice harvest, some farmers cultivated mungbean or sesame immediately. To plant these crops, farmers left the rice stubble on the field to prevent evaporation of water and did not usually plough the soil. When the soil began to dry out and small cracks appeared on the ground surface, farmers began to broadcast mungbean or sesame. Using the remaining moisture in the soil, these crops could grow without irrigation until they were harvested. Although the yield of these crops was not high, it gave additional income to the farmers.

c. Environmental Factors Responsible for Floating Rice

Environmental factors forced farmers to broadcast rice instead of transplanting. The broadcast rice area was located in the upper part of the delta, far from the sea. The influence of the tide was small. The tidal water of the Hau and Tien rivers did not reach the fields during the dry season. Precipitation during the early rainy season was low. There was no standing water to allow transplanting of rice. Flooding came to the area

normally in the beginning of August, and it rose rapidly to its maximum level in mid-September. To avoid flood damage and also to have strong and established seedlings to cope with the high flood, farmers broadcast rice as soon as possible. Another factor in the success of floating rice was the total eradication of weeds under prolonged, deep submersion from the end of August to December. This advantage is seen in the cultivation of mungbean without soil preparation or weeding.

1. 3 Traditional Double Transplanting Method

A schematic diagram of double transplanting of rice and the cropping calendar are shown in Fig. 4. The process of cultivation is described below.

a. Seedbed Preparation

A dry seedbed was prepared at the beginning of the rainy season, normally in late May. The seedbed was always sited on relatively high ground and near a canal, where irrigation was easy even without rain. The first operation of weed cutting was carried out one week before sowing rice, and the second one day before sowing. Three days before sowing, rice

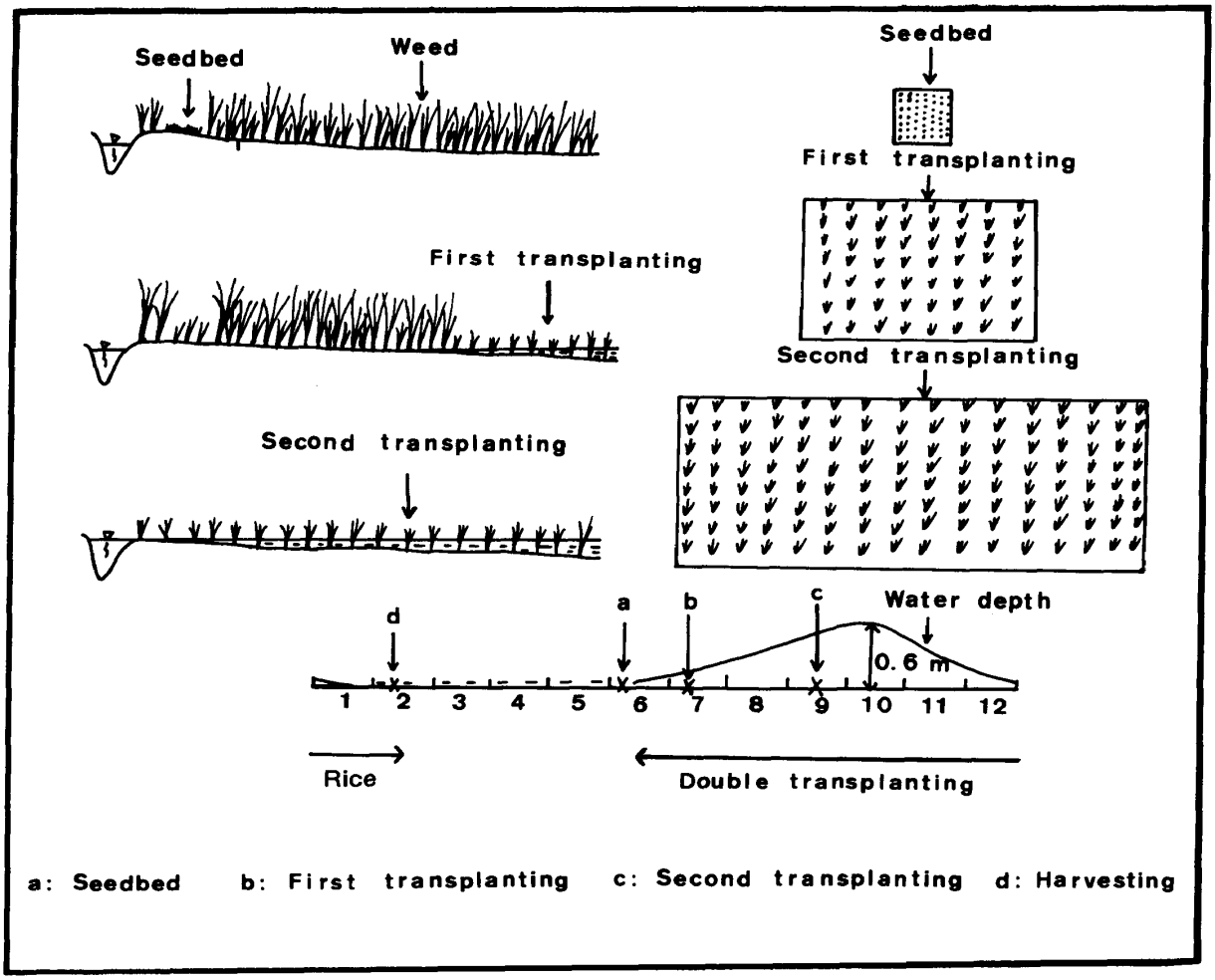

Fig. 4 Schematic Diagram of Double Transplanting of Rice and Cropping Calendar in Phu Loi, Chau Thanh, Hau Giang

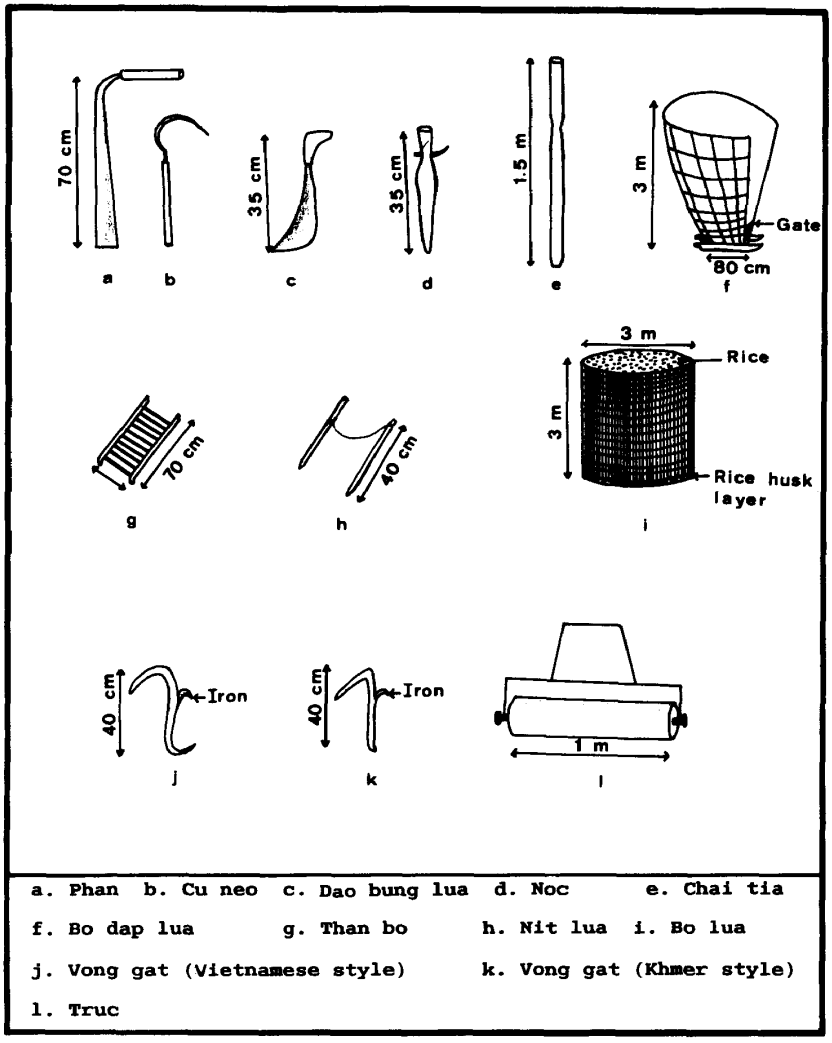

Fig. 5 Equipment for Double and Single Transplanting of Rice

seeds were soaked in water for one day, then kept in a basket covered by banana leaves for one or two days. These rice seeds were sown into round holes of 5 cm diameter and about 3 cm depth, which were made with a wooden stick called *chai tia* (see Fig. 5 : e). After sowing, the holes were covered with rice husk ash or soil mixed with organic matter. To avoid bird damage and also to protect the rice seeds from being lost in heavy rains, farmers covered the ground surface with dry weeds. The weeds were raked away after one week. The seedbed was kept moist but not waterlogged until the seedlings were 40 to 50 days old, when they were pulled up for the first transplanting. About 40 kg of rice seed is sowed in a 130 m^2 seedbed and is enough to transplant a field of 3,000 m^2 in first transplanting.

b. Weeding and First Transplanting

Weeding was begun after the making of the first seedbed. The lowest area of the field was chosen for the first transplanting, because it had more water in the early rainy season. The *phan* and the *cu neo* were used for weeding (see Fig. 5 : a,b). With these implements, one man could weed about 1,000 m^2 per day. Weeding is hard work, so it was only done

by men. All of the men of five to ten families cooperated in this task. When the field of one family was finished, they moved on to the next field. One or two days before the first transplanting, a second weeding was done to kill new shoots of weeds. Decomposed cut weeds were spread over the ground surface to suppress new weed growth. Seedling of 30 to 40 days were transplanted into the field by us of a *noc* (see Fig. 5 : d). This was the first transplanting. The area of the first transplanting was 3,000 m², which was enough to supply seedlings for the second transplanting of 1 ha.

c. Second Transplanting

The second transplanting was carried out 60 to 75 days after the first transplanting. Farmers repeated weeding two more times, 30 days and 1 to 3 days before the second transplanting. This work was again done by men. To depress the growth of new weeds, cut weeds were spread over the ground surface on the high areas, where the inundation was shallow ; but these weeds had to be cleared away in the low areas so that they did not hold down the rice when the water level rose. Transplanting was done sequentially from low areas to higher ones, following the rise of water level. A big knife called *dao bung lua* (see Fig. 5 : c) was used to take up the rice seedlings for the second transplanting. The second transplanting had to be carried out at least 15 to 30 days before the maximum inundation. The rice yield could be decreased if the transplanting was late, because some rice plants would be drowned by the high water level. In contrast, if transplanting was too early, rice plants on the high areas might have been damaged by shortage of water and been unable to compete with the vigorous growth of perennial weeds.

d. Harvesting and Storage of Rice

Harvesting time depended on rice variety. The tools used for harvesting were the sickle, the *bo dap lua,* the *than bo* and the *nit lua* (see Fig. 5 : f, g, h). Women used a sickle to cut the rice ears, which they arranged in small bundles and put on top of the stubble. The culms of rice were cut at least 50 to 60 cm long. The *nit lua* was used for holding the small rice bundles together, and the rice was threshed by hitting the bundles against the *than bo*, which was put inside the *bo dap lua.*

This threshing work was done in turns by two men. By this method, they could harvest from 1/3 to 1/4 ha per day. After threshing, rice was dried and brought home for storage in a *bo lua* (see Fig. 5 : i). The *bo lua* was made of bamboo wattle called *tan tang*, and the outside was covered by a thin layer of buffalo dung to strengthen the wattle so that it could be used for several years. Next, a layer of rice husks was laid at the bottom of the *bo lua* and this was covered with *Nypa* leaves. Rice was stored in the chamber. By this method, rice could be kept and used the whole year round.

e. Environmental Factors Responsible for Double Transplanting

Why did farmers need to apply double transplanting? And why was it only practiced in the tide-affected floodplain area? These questions have been discussed by several scientists. Thai Cong Tung [1971 : 74-94] noticed that soil rich in organic matter and nitrogen is often considered to be a reason for double transplanting. Watabe [1967] reported that

double transplanting has the effect of suppressing the excessive vegetative growth caused by the soil fertility. Fukui [1974] also summarized the various reasons for double transplanting : first, because of the high soil fertility and a moisture regime that allowed perennial weeds to survive, early planting leading to longer growth duration in the same patch of the field had to be avoided. In such circumstances, double transplanting could provide healthy seedlings for transplanting over a long time span and was more suitable than single transplanting. I agree with the ideas of the authors mentioned above, but it is desirable to look further into which factor is the major one. Based on my own experiences, I wish to add the following ideas on this matter.

The main factor responsible for double transplanting is water regime. The area concerned is located in the middle reach of the delta. Here, there are many small tributaries of the Tien and Hau rivers, and the area is always strongly influenced by the daily tides of the South China Sea. High water level occurs twice every day, and low areas such as backswamps are often submerged by 5–10 cm of water at high tide. During weeks of full and new moons, at least 80 % of the total area, excluding the natural levees, is submerged by 30–50 cm of water at high tide. Under these conditions, the ground surface of the area is often wet or moist. This creates a good environment for vigorous growth of perennial weeds, which supply large amounts of organic matter to the top soil. This organic matter is mixed with sediments from the rivers, creating very fertile soil with high nitrogen content. If single transplanting is practiced, the rice plant has a long growth period, giving rise to many tillers, decreased photosynthesis and sharply decreased rice yield.

Double transplanting is practiced to obtain older seedlings, which grow more slowly than young seedlings in the fertile soil. Many old farmers answered that single transplanting with wet type nurseries prepared in July to August always failed, because rice plants still gave too many tillers and the yield decreased sharply. In this case, I believe that the wet nursery seedlings are still not enough old.

The other factor is the instability of the water regime. The water conditions in the fields, particularly at the initial stage of the rainy season, are unstable and vary from year to year. If a wet seedbed for single transplanting is prepared directly in the fields, it will be hit by a dry spell in some years and by deep submersion in other years. To avoid the effects of the instability of the initial phase of the monsoon, farmers prepare the first seedbed as a dry nursery near a water course, from which they can obtain irrigation water with which to regulate the growth of the seedlings. Farmers observe the water conditions and wait for the proper chance for transplanting. When the lowest parts of the fields begin to submerge steadily and completely, farmers practice the first transplanting from the dry nursery to the wet nursery. Evidently, farmers are afraid of irregular droughts, which may devastate seedlings planted on high portions, and thus do not venture into full transplanting. Seedlings are kept growing in the second nursery (first transplanting place). In September, the monsoon passes into the steady rainy season, with downpours,

which causes ponding to start in the rice fields, both in high and low positions. This is the chance for the final transplanting from the second nursery to the fields. Tall seedlings are transplanted to the full extent of the rice fields under steady submersion.

High inundation is probably not a major factor in double transplanting. Although the maximum water level can rise to 50 or 70 cm during the full moon and new moon of September, this rise in only temporary (about two to three hours). This cycle is repeated two times per day. Moreover, the highest inundation normally takes place one month after the second transplanting. At this stage of growth, the rice plants can easily cope with the high water level.

1. 4 Traditional Single Transplanting Methods

Two traditional methods of single transplanting of rice were practiced in the delta. The first was distributed in the broad depression area and inter-ridge areas of the coastal complex. Late maturing local rice varieties were cultivated there. This method is also characterized by weed cutting and lack of ploughing. Wet nurseries were prepared to supply seedlings for transplanting.

The second method was distributed in tidal flat areas of the coastal complex. Dry nurseries were prepared to supply seedlings for transplanting, and the rice varieties had to be early maturing. Land was ploughed and harrowed by water buffaloes or cows instead of cutting weeds.

a. Single Transplanting in the Broad Depression

Nursery preparation: To prepare the nursery, farmers wait for the first rains. They chose a good part of the field that was not influenced by salt or acid sulfate. Wet nurseries were prepared there. First, farmers pulled up weeds by hand instead of using a *phan* to cut weeds. This work took time but it was very effective to control the vigorous growth of weeds. Second, farmers waited for the heavy rains, normally in July, which caused the ground surface to be submerged, then they began to puddle the soil by using a wooden roller, namely, a *truc* (see Fig. 5 : 1). This equipment was used to make the ground surface flat, muddy and smooth. This roller was pulled by people rather than animals. Then pre-germinated seeds were broadcast. The rate of 50 kg of rice grain is enough for transplanting 1 ha.

Weed cutting, transplanting and harvesting method : One month after nursery preparation, weed cutting was begun by use of the *phan*. The cut weeds were spread on the surface to prevent new growth of weeds. A few days before transplanting, weed cutting was done again. Then 60-day-old seedlings were transplanted over the whole field. Transplanting was done by using a *noc*. Rice grew depending on rainwater. When the rainy season was over, the water level of the field gradually receded, and the rice began to flower in November. Harvesting was the same as that of double-transplanted rice, when the water had just receded from the field.

b. Single Transplanting in the Coastal Complex

There were two methods of single transplanting in the coastal complex. The first was distributed in the inter-ridge areas. Except for the varieties planted, this method was similar to the single tansplanting in the broad depression. Early maturing rice varieties were dominant instead of late maturing rice varieties, since the latter were damaged by saltwater at the end of the growing period.

The second method was distributed on the coastal flat. When the first rains came, farmers began to plough the field by using two buffaloes. Dry nurseries were prepared in high areas, normally on the foot of a ridge. Rice seeds were sown into holes made with a wooden stick, similarly to those in nurseries for double transplanting, but the number of seeds per hole was fewer and the holes were spaced further apart. To provide enough seedlings for transplanting 1 ha, 40 to 50 kg of rice seed was needed. Nurseries are prepared at the end of July. Transplanting began in the middle of September. Two days before transplanting, two buffaloes were used to harrow the land. Then 45-to 50-day-old seedlings were transplanted by using a *noc*, from lower to higher fields depending on the water level. The rice plants grew under rainfed conditions until they were harvested at the end of December. Rice was harvested by cutting the panicle culm with a *vong gat*. There are two types of *vong gat*, one used by Khmer people and the other used by Vietnamese (see Fig. 5 : j, k).

c. Environmental Factors Responsible for Single Transplanting

Environmental factors of the broad depression forced farmers to practice single transplanting. The broad depression is nearly separate from the Mekong river system. Fresh water from the Hau river cannot reach the area. The east is blocked by the coastal complex with a system of sand ridges and mangrove forest. Although the tidal fluctuation of the South China Sea is very high, this area is not influenced. The west is bounded by the Gulf of Thailand. Saltwater intrusion comes mainly from this side. Although the tidal fluctuation in the gulf is not high, it is high enough to cause salt to impregnate the soil because the topography is low. Two months after rainy season ends, the soil often becomes salty and remains so until the beginning of the next year's rainy season.

The area also has heavier precipitation than other areas (more than 2,000 mm). The result is that water stagnates for at least 10 months of the year, and a large amount of organic matter has accumulated. Potential acid sulfate soils are also dominant very close in the area. The ripening of the soil is very weak. Under these conditions, the fields do not become dry enough for ploughing. So the best way to use the soil is to let the heavy rains flush out the salt and acidity, then to cut weeds in submerged fields by using a *phan*. Single transplanting is an adaptive strategy to the environment, since, under stagnant water conditions, double transplanting is not required, and broadcasting is not possible.

The coastal complex is quite different from the broad depression. Soil salinity and shortage of fresh water, which become severe in the dry season, are considered to be the main factors here. We need to investigate two constituent areas of the coastal complex,

namely, the coastal flats and the inter-ridges. The coastal flats have relatively high topography, and seawater does not cover the ground surface. However, it is still influenced by salt water because the subsoil texture is coarse, and saltwater intrudes into the sandy layer selectively, then rises into the topsoil by capillary movement. To cultivate rice, it takes a long time until rains wash away the salt. In addition, rainwater will be exhausted soon after the rainy season ends in late November. In these conditions, the only method available to cultivate rice is single transplanting using early maturing varieties. To limit capillary movement of salt and control the growth of weeds, land is ploughed after the harvest of rice.

In contrast to the coastal flats, the inter-ridges are very low, and seawater moves in and out freely in the dry season depending on the tides of the South China Sea. Soil salinity is only gradually flushed out by rainfall. And land can only be used for rice cultivation when the brackish water of the estuary areas is diluted by fresh water. So it is impossible to cultivate rice in the early rainy season in this area. In addition, soil becomes salty immediately after the rainy season ends. Most of this area is covered by potential acid sulfate soils. This causes farmers to refrain from drying the soil for ploughing, since drying the soil induces the emergence of acidity. Farmers preferred to keep the fields wet under grass and sedge, and prepare the fields by weed cutting with a *phan*. Furthermore, to avoid damage to rice at the end of the growing period, early maturing varieties have to be cultivated.

II Present Cropping Patterns

In my previous paper on geo-pedology, I proposed five landform units and several subunits for the Mekong delta and discussed the characteristics of each landform unit. Based on the landform map, I here investigate the present cropping patterns in each landform subunit, particularly the relationship between micro-landform, water conditions, soils and cropping patterns. Field investigation included interviews with old, experienced farmers living in each landform subunit. The interviews concentrated on such natural and social conditions as water regime, vegetations, topography, distribution of cropping patterns and cultivation methods. Present land use maps of 1 : 250,000 scale for each province were utilized as references to make contour maps of the distribution of the present main cropping patterns. Representative schematic diagrams of each cropping pattern were drawn based on observations in the field. The present main cropping patterns of the delta are as follows.

A. Cropping Patterns in the High Floodplain

1. Cropping Patterns in the Natural Levees and the Backswamps

1. 1 House-Garden and Winter-Spring Upland Crops

This pattern is distributed along the developed natural levees of the Tien and Hau rivers

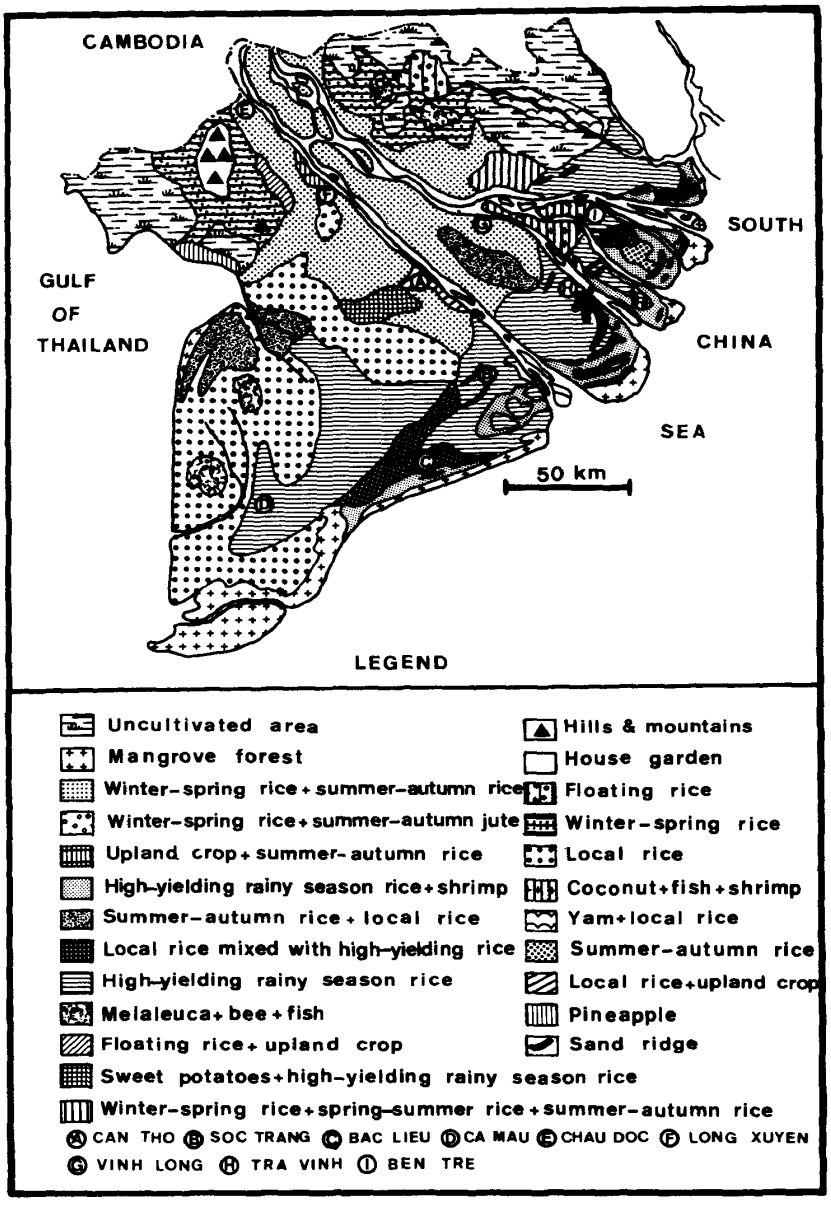

Fig. 6 Distribution of the Present Main Cropping Patterns in the Mekong Delta

(see Fig. 6). Most houses are concentrated on the big levees, because these are rarely submerged by high flood. The style of house in this area is different from other areas of the delta : houses are built on stilts approximately 0.5 to 2 m above the ground surface. Around the house compounds are gardens of fruit trees such as coconut, mango, jack-fruit and others. These trees are planted directly on the ground rather than on constructed ridges. This is because of high ground elevation here. The yield of the fruit trees is rather low, because they suffer from shortage of water during the dry season and excessive water during the wet season. Besides fruit trees, farmers also plant trees for firewood. Behind each house there is often a pigsty, hen-coop and cattle shed.

In Chau Thanh and Chau Phu districts, An Giang province, winter-spring upland crops such as soybean, mungbean, and cucumber are planted along the natural levees. These

upland crops are planted in fields, seeds being sowed directly without soil preparation. Yields are high because the soil has suitable texture and is very fertile. However, the cultivated area of these upland crops is small.

1. 2 Winter-Spring Rice + Summer-Autumn Rice

This combination is remarkable in the backswamp of the high floodplain (see Fig. 6). This area is low-lying and located in close proximity to the levees, so rainwater accumulates earlier than in other areas. Normally, two weeks after the beginning of the rainy season, enough rainwater has accumulated for rice cultivation. The water level in the field continues to increase gradually until the end of August, then it increases rapidly when river is filled with water. Maximum inundation can reach 2 m at the end of September and continues through October. The backswamp resembles a great lake surrounded by natural levees. Eventually the water level decreases, gradually at first, and rapidly after the rainy season ends in late October. Utilizing these hydrological conditions, two crops of rice culture are cultivated by the use of short-term HYVs, namely, summer-autumn rice and winter-spring rice. The interval flood period (September to October) and the later part of the dry season (from March to April) are excluded from the planting schedule. A schematic diagram of the planting calendar of winter-spring rice and summer-autumn rice

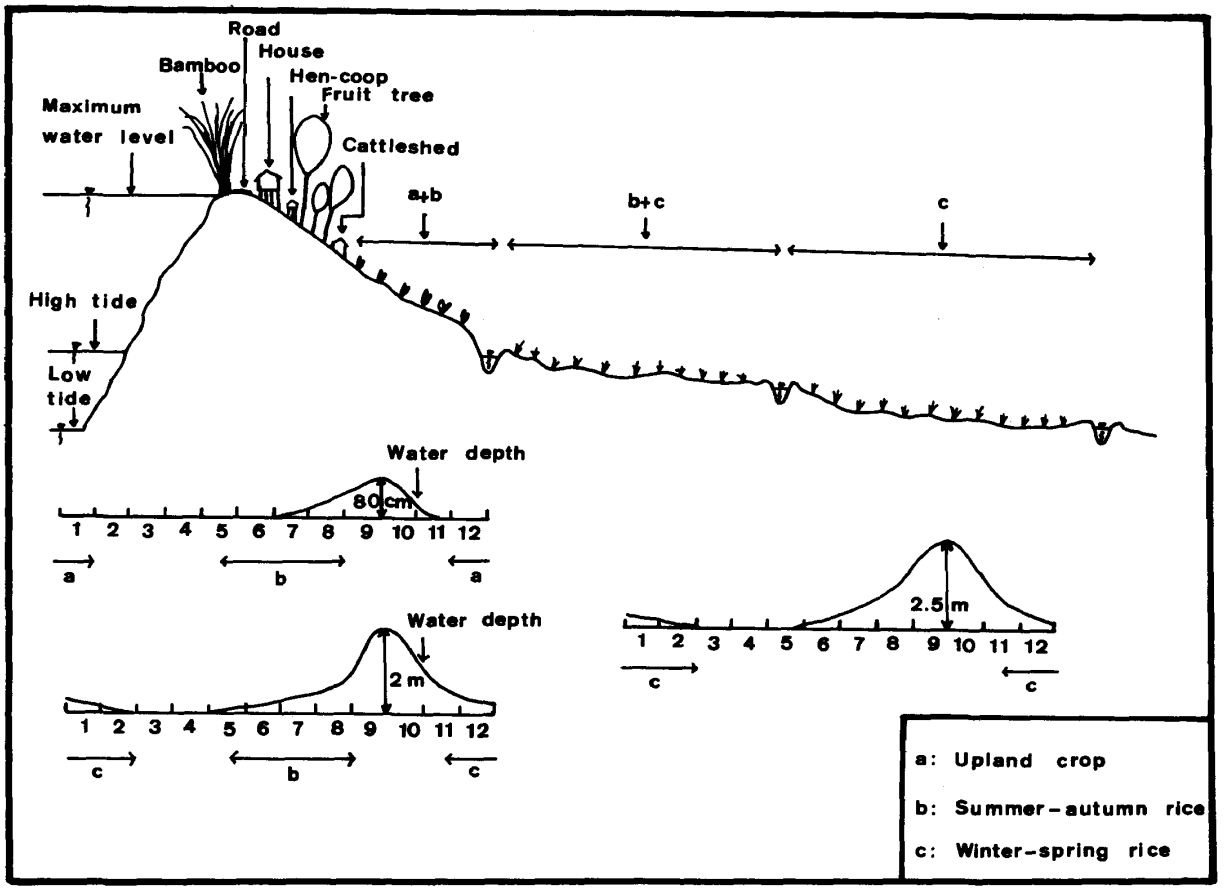

Fig. 7 Schematic Diagram of Cropping Patterns on the Natural Levee and Backswamp, and Cropping Calendar in Phu Vinh, An Giang

is illustated in Fig. 7.

Winter-spring rice cropping begins when the water level of the field recedes at the end of November. To plant this crop, farmers construct small dikes and shallow ditches around their field to drain water, then buffaloes or small tractors are used to puddle the soil. Germinated seeds are broadcast, after which the ground surface has to be kept saturated to promote seedling growth. When the seedlings grow, water has to be introduced gradually into the field by using small pumps. Fifteen days after broadcasting, the water level is kept constantly at 5 to 10 cm depth. Water control is very important, not only to help tillering of seedlings but also to control grass. To facilitate harvesting, about 10 days beforehand the farmers drain water and allow the fields to dry. Harvesting is done by using a sickle, and a thresher is used to separate rice grain from straw.

Soil is still moist after harvesting winter-spring rice. Farmers begin to plough the field and dry the soil during the dry season. When soil clods have been softened by the first rains, farmers harrow the field two or three times, and then wet rice seeds (seeds soaked in water for 24 hours but not yet germinated) of summer-autumn rice are broadcast. The timing of summer-autumn rice cropping is crucial : if the broadcasting is too late, rice will be destroyed by flood at the end of growing period ; and if it is too early, rice will be damaged by drought, because there is very little rain in the early rainy season. Moreover, there is not enough water in the canals during the early rainy season to irrigate rice. The yield of summer-autumn rice is not stable and it is often lower than that of winter-spring rice. This is because there are many limiting factors, such as abundant insects and pests, and shortage of water at the beginning of rainy season. In occasional years, flood comes to the fields too early and destroys all the rice.

1. 3 Winter-Spring Rice + Summer-Autumn Jute

This cultivation pattern is common in the backswamp, where there are moderate acid sulfate soils (see Fig. 6). The topography is low-lying, and the depth of inundation is rather high (1 m) in the flood season. Floodwater comes slowly, being impeded by a big road which runs from Can Tho to Rach Gia, which separates the area from the Hau river. Although there are some drainage canals with big flapgates, they are not enough to allow drainage or irrigation. Farmers do not want to construct many irrigation canals, because tidal water of the Hau river could not reach the canals from February to April. So, even if there were many canals, they would be of no use. Summer-autumn jute can be cultivated because it is highly resistant to drought and can also stand in deep water. It can also adapt to acid sulfate soil. A schematic diagram of the cropping pattern and cropping calendar is shown in Fig. 8.

Farmers begin to sow jute when the first rains wash away the sulfate acidity. Jute seed is sown at 5 to 10 cm depth in furrows spaced 30 to 40 cm apart. After germination, the jute plant can survive the dryness. It grows well when the heavy rain falls. Jute is harvested in August, two weeks or one month before the maximum inundation. The

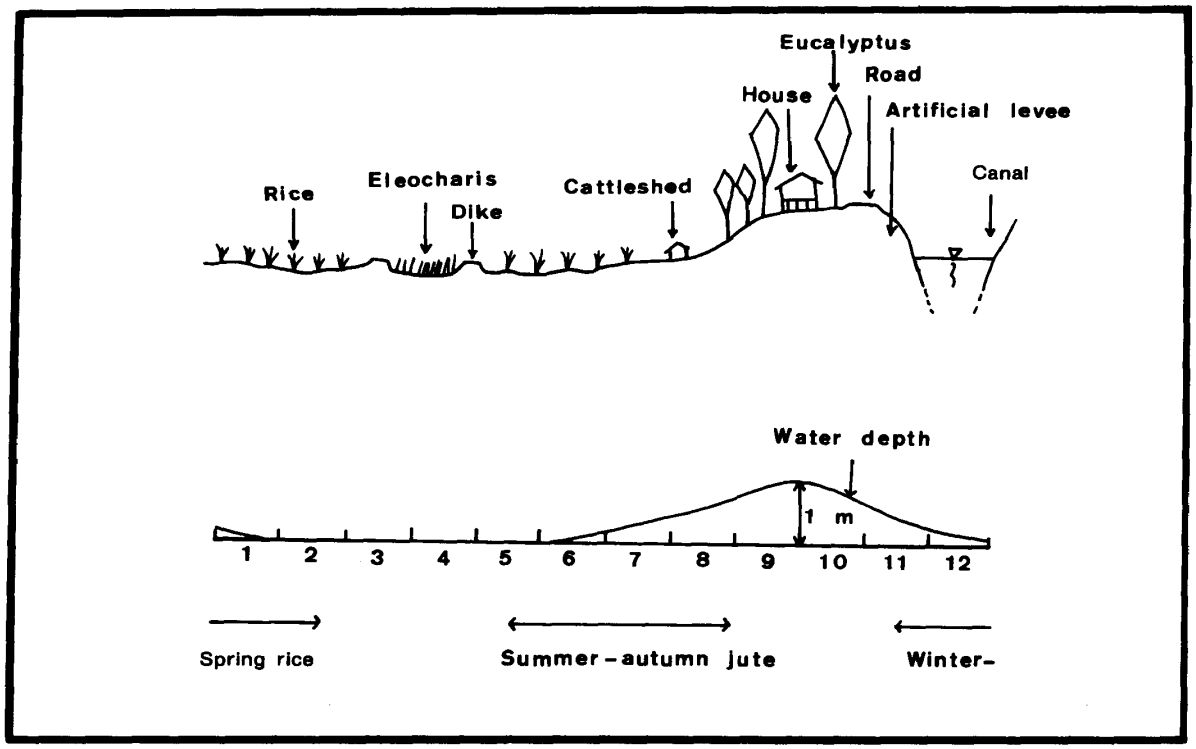

Fig. 8 Schematic Diagram of Winter-Spring Rice + Summer-Autumn Jute Pattern and Cropping Calendar in Tan Hiep, An Giang

flooding season is very convenient for transportation and peeling of jute fiber.

After harvesting jute, farmers wait until the water level recedes, then use a tractor with iron wheels to puddle the field, in which 25- to 30-day-old seedlings of winter-spring rice are transplanted. Wet seedbeds are prepared on dikes near the farmers' houses. Farmers dredge mud from the ditch bottom to cover the seedbed with a thin layer. Some farmers also practice broadcasting of rice instead of transplanting, but in this case soil preparation has to be done carefully. The cultivation method is the same as that of winter-spring rice described above.

1. 4 Winter-Spring Upland Crop + Summer-Autumn Rice

This combination is distributed in the good soil areas near natural levees (see Fig. 6). When the rainy season is over, fields dry quickly because their topography is rather high. So, upland crops such as soybean, mungbean can be planted there. This is the winter-spring upland crop.

In the early dry season when the soil is still moist, farmers use a *phan* to cut grass and the stubble of the previous rice crop, then sow mungbean seeds into round holes of 2 to 3 cm depth and 3 to 4 cm in diameter. The space between holes in a row is 20 cm and that between rows is 30 to 40 cm. The holes are covered with the ash of rice husks. To prevent water evaporation and growth of grasses, straw is used to cover the ground surface. Irrigation is done by sprinkling by hand every two days until harvest time. The yield of beans is from 1 to 2 tons/ha.

The field is left fallow after harvesting the upland crop until the first rain falls, when a tractor is used to plough the soil. When the field has enough water (normally one or two weeks after ploughing), a tractor is used to harrow the soil, then summer-autumn rice is planted. Transplating is used for summer-autumn rice rather than broadcasting, because water control is relatively difficult in these areas. Broadcasting allows grasses to grow well with high density. Eradication of grasses is very laborious and uneconomical. Seedbeds of summer-autumn rice are prepared on the dikes around the fields by wet broadcasting. When the seedlings are 25 days old, transplanting is carried out by using a *noc*. Harvesting is done by the same method as summer-autumn rice, as described above.

2. Cropping Patterns in the Open Floodplain

2. 1 Floating Rice + Upland Crop

This pattern is practiced in alluvium soil areas where the depth of inundation is high (1 to 1.5 m) (see Fig. 6). Every year during the flood season, large amounts of sediments from the Hau river are deposited on the area, forming a thick layer of alluvium topsoil. At below about 80 cm depth, brackish sediments with high sulfur contents appear which are detrimental to crops. In this environment, the traditional floating rice-upland crop pattern continues to be practiced, still employing the traditional methods of cultivation described in the first part of the paper.

2. 2 Winter-Spring Rice

Winter-spring rice is cultivated in the moderate acid sulfate soils of the open floodplain (see Fig. 6). The cultivation method and cropping calendar for this pattern are similar to those of the winter-spring rice in the backswamp, as described above (see Fig. 7). Summer-autumn rice cropping is impossible here, because the soil is still acidic at the beginning of the rainy season. If farmers wait until the soil is flushed by heavy rains, planting will be too late to prevent the rice being damaged by flood at the end of the growing period.

2. 3 Pineapple and Cashew Nut

Pineapple and cashew trees are planted on saline-acid sulfate soils, which are very high in organic matter content. This pattern is distributed in the coastal area from Rach Gia to Ha Tien (see Fig. 6). The area is very flat and low ; the southwest is bounded by the Gulf of Siam and the northeast is enclosed by a big road connecting Rach Gia and Ha Tien. It is influenced completely by the diurnal tides of the gulf. However, this tidal influence is not big because the average daily range in the gulf is only about 0.7 m. The maximum inundation reaches to about 50 cm at the end of September. In the past, this area was uncultivated and covered with *Eleocharis* and *Melaleuca*, because it has strong acid sulfate soils and is influenced by saltwater. The coastal area is dominated with mangrove trees and is not suitable for rice cultivation. Even now, only pineapple or cashew trees are planted sporadically by a special method. A schematic diagram of this pattern is shown in Fig. 9.

To plant pineapple or cashew trees, farmers have to construct polders of different

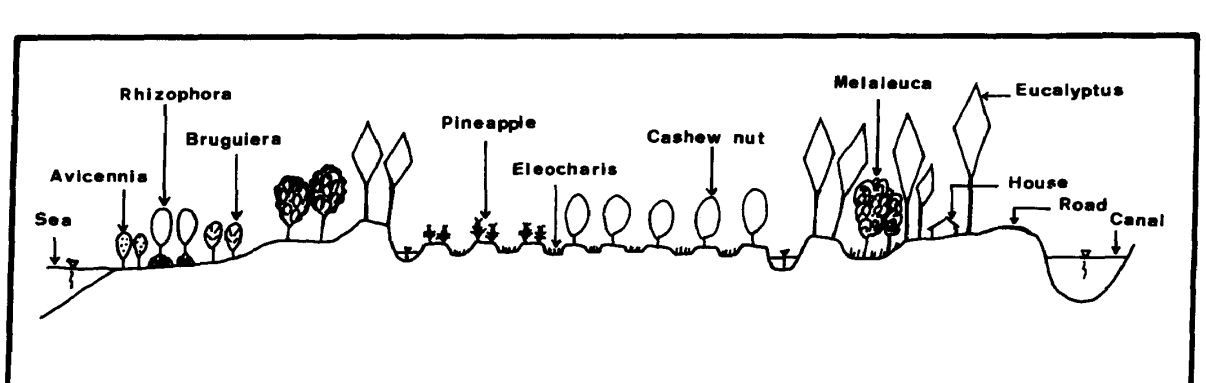

Fig. 9 Schematic Diagram of Pineapple-Cashew Pattern in the Binh Son, An Giang

sizes depending on their field (see Fig. 10 : b). Then raised beds are constructed, 5 to 6 m wide and about 60 to 70 cm higher than the original land surface. The space between two raised beds varies according to the amount of soil that has to be taken for the beds. Care must be taken during excavation not to bring pyritic and jarosite layers to the top of the beds. First the topsoil should be set aside, then jarosite or pyritic layers are deposited on the beds, and finally the original top soil is spread over the beds. It takes much time to prepare the beds, but they can be used to cultivate through one rainy season, because toxic substances are washed away quickly.

Another method, namely, *cuon chieu* ("rolling up a mat"), is also widely used for constructing raised beds (see Fig. 10 : a). This method involves piling up 30 to 40 cm of topsoil materials which do not contain pyrite and jarosite. By this method, farmers can plant pineapple immediately after constructing the raised bed. However, this method has the disadvantage compared with the first method that the plantable area is decreased because wider ditches have to be dug between raised beds in order to give sufficient topsoil materials for the bed. Pineapple is planted on these beds. The space between the rows is 60 to 70 cm, and the rows are 40 to 50 cm wide. Pineapples are planted at the beginning

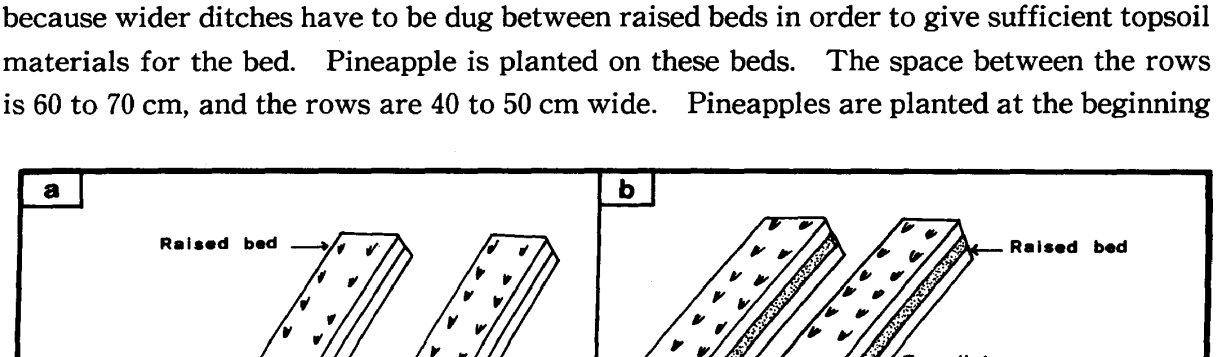

Fig. 10 Two Methods of Raised Bed Construction for Planting Pineapple or Cashew in Saline-acid Sulfate Soil (a : High Inundation Area. b : Low Inundation Area)

of the rainy season. Harvesting may take place after one and a half years and can be continued for 4 to 5 years with one planting. The yield of pineapples is usually 10 to 15 tons/ha.

Other farmers like to plant cashew trees instead of pineapple because the trees are resistant to acid sulfate soils. Cashew nuts are easier to harvest and preserve than pineapple, and the trees can be productive for many years. Cashew trees are planted on the landward side of the raised beds, the space between trees being 2 to 3 m. Nuts can be harvested three years after planting and the yield increases in subsequent years.

3. Land Use Patterns in the Closed Floodplain

3. 1 Summer-Autumn Rice + Winter-Spring Rice

This pattern is applied commonly in the closed floodplain of Dong Thap province. This area has moderate acid sulfate soils, very low-lying topography, and is located between the natural levee of the Tien river and the old alluvium terrace. It resembles a shallow lake in the flood season. Maximum inundation can reach to 2 m in September and is difficult to drain, eventhough many canals have been constructed. River water does not reach the fields during the first four months of the rainy season (April to July), and the only water in the fields is rainwater. However, the water level increases rapidly once the Tien river is filled by discharge from the upstream sources. Formerly, this was a floating rice area. Nowadays, two rice crops are grown here, summer-autumn rice and winter-spring rice. Summer-autumn rice is cultivated by using rainwater only, while winter-spring rice depends on backwater from the flood season. A schematic diagram of the pattern is illustrated in Fig. 11.

For summer-autumn rice, dry seedbeds are prepared on dikes around the field.

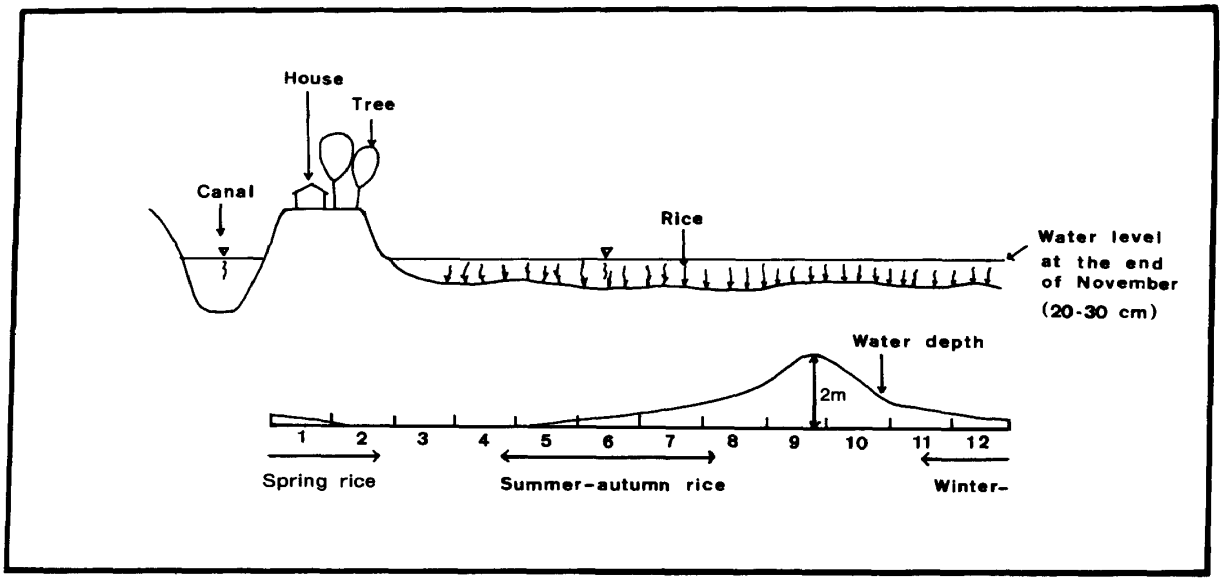

Fig. 11 Schematic Diagram of Summer-Autumn Rice + Winter-Spring Rice Pattern and Cropping Calendar in Tan Phu, Tam Nong, Dong Thap

Farmers have to wait for rains, normally at the end of April, to wash away toxicity ; then soil preparation is carried out. To make puddling of the soil easier, grass is cut by using a *phan*. Then a tractor with iron wheels is used to puddle the soil. One day after puddling, 25-day-old seedlings are transplanted. Harvesting takes place at the beginning of August. Experienced farmers always start cropping summer-autumn rice as early as possible, because a late start could mean that rice is destroyed by flood at the end of the growing period. After the harvest of summer-autumn rice, the water level rises rapidly. Fields are left fallow during the flood season.

Winter-spring rice commenced when the rainy season is over and the water level in the fields is still high (20 to 30 cm). Farmers use a tractor with iron wheels to puddle the soil. After puddling, they have to wait two or three days until the sediments are completely settled and water becomes clear. Then germinated rice seeds are broadcasted directly on the field without drainage. Rice seedlings grow through the deep water for about one to two weeks. They look very weak at the beginning of the growth period. They recover quickly as the water level recedes. This method is called *sa ngam* (broadcasting in water) and has never been seen in other areas of Vietnam. Nowadays, *sa ngam* is practiced widely in the closed floodplain. The merit of *sa ngam* is that drought at the end of rice growing period is avoided. In addition, *sa ngam* can help to keep the soil in the saturated condition. This is a best way to prevent oxidation of pyrite, which forms sulfate acidity. In some potential acid-sulfate soil areas such as Phung Hiep, Long My of Hau Giang, farmers have tried this method, but all of them failed. Experienced farmers say that *sa ngam* will not succeed if they cannot see the rice seed through the deep water layer after broadcasting. Based on a field survey, I believe that the quality and physical condition of water are the main factors that allow *sa ngam*. Water quality is related to the presence of toxic substances and its pH value. Furthermore, it needs to have a low energy water environment (water in the field has little turbulence) for settling of sediments. This will make the field water clear.

3. 2 Floating Rice

Floating rice is still cultivated in a small area with strong acid sulfate soils (see Fig. 6). The area is high compared to other areas of the closed floodplain because of its proximity to the old alluvium terrace. During the first months of the rainy season, rainwater is not enough for cultivation of high-yielding rice. But in the flood season, the water level can reach about 1.5 m, and when the rainy season is over, water also recedes very fast. Therefore, winter-spring rice is difficult to cultivate successfully. On the other hand, acid sulfate is not favorable for the cultivation of HYVs. Thus, farmers only cultivate floating rice. Here the traditional method is again employed, as discussed before.

3. 3 Yam + Local Rice

Yams are planted on acid sulfate soil with a thick humiferous topsoil of 30 to 40 cm. The area is located on both sides of the upper reach of the Vam Co Dong river. In September, the water level can rise to 1 m. When the rainy season is over, water drains through the

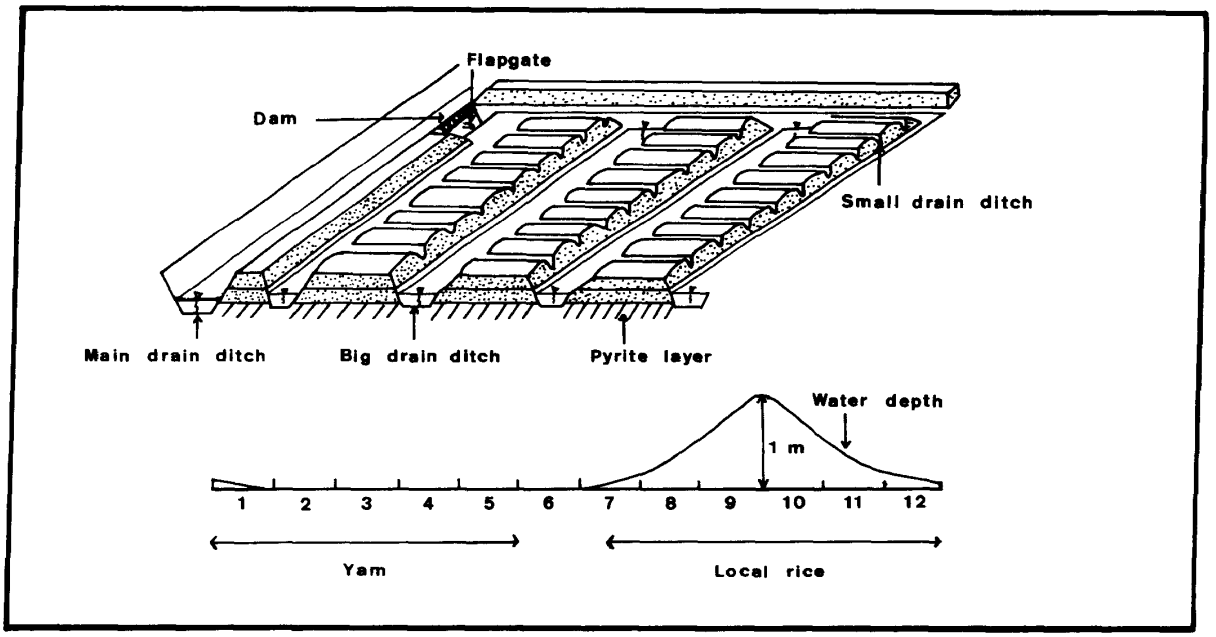

Fig. 12 The Method of Raised Bed Construction for Yam + Local Rice Pattern and Cropping Calendar in Thanh Hoa, Long An

Vam Co Dong river. Because this area is easier to drain than the other areas of the closed floodplain, acidity release from sulfate soils is so high that HYVs are not cultivable. Only yams and local rice can be planted using a special technique. The schematic diagram (Fig. 12) shows the technique to improve the soil and cropping calendar. Before the rainy season comes, farmers dig parallel small ditches which are connected to a canal. The space between two ditches, called a *lip*, is 4 to 5 m wide. On the *lips*, ridges of 30 to 40 cm height and 80 cm wide are constructed, which are perpendicular to the ditches. After constructing the *lips* and the ridges, they are left fallow throughout the whole rainy season. Toxic substances from soil on the ridges are washed away by rainwater and flood. When the flood subsides, farmers construct a small dam with a flapgate at the main drain-ditch, which is connected to the canal. The dam is used to adjust water level in the ditches in order to avoid oxidation of pyrite to form new sulfate acidity. Before planting yams, the ridges are tilled in order to improve soil structure. This work has a good effect on the roots of yams. Yam roots are planted on the ridges in January without supporting poles. Harvesting is done 5 to 6 months after planting; the yield of yams is about 15 to 20 tons/ha. Some years after planting yams, toxic substances in the soil are washed away. Farmers can transplant early maturing local rice on the *lips* instead of leaving them fallow in the flood season. Although rice yield is not high, it is a good method to augment income. Straw of local rice is used to mulch the yam *lips* to control weed growth and water evaporation in the dry season.

3. 4 Melaleuca-Bees-Fish

Besides the areas used for rice cultivation or upland crops, the closed floodplain still has

a large uncultivated area which has strong actual acidity and deep flood (see Fig. 6). Only *Melaleuca* trees adapt well to deep flood and acid sulfate soil. So they are planted there. *Melaleuca* trees are planted by transplanting or broadcasting depending on the thickness of the organic matter layer on the topsoil. If organic layer is thick, *Melaleuca* is transplanted by using wooden stick to drive a deep hole into the soil, into which the *Melaleuca* seedling is inserted. In this case, the *Melaleuca* seedling has to be one and a half or two years old (about 80 to 120 cm tall).

In the other places where the organic matter layer is negligible, weeds are cut and burnt in the dry season. Then farmers have to wait until the flood season is over. When the field water level is about 40 to 50 cm, *Melaleuca* seeds mixed with ash of rice husks are broadcast there. The seeds begin to germinate later and grow well in the submerged condition.

Flowers of *Melaleuca* are very attractive to honey bees. Therefore, honey production can also be undertaken. On the other hand, some farmers have used *Melaleuca* leaves to extract oil, which is used pharmaceutically by Vietnamese people.

In the flood season, fish from the Mekong river come and live inside the *Melaleuca* field. These fish are the main protein source for the people around the marsh.

B. Cropping Patterns in the Tide-Affected Floodplain

1. Cropping Patterns on the Natural Levee and Backswamp

1. 1 House Compounds and Fruit Tree Gardens

House compounds consist of houses, roads, pigpens, fish ponds and vegetable gardens. Commonly, such compounds are distributed along the banks of the Hau and Tien rivers and their tributaries. These are the highest areas in the plain, so they are chosen for settlement sites. Behind the compounds are fruit tree gardens. The ground here is also rather high, and it is difficult to retain water on it for rice cultivation because the soil texture is relatively coarse. Tidal water of the Hau and Tien rivers only reaches the ground surface during the full and new moons in the months of September and October. But it is high enough to maintain the ground water level near the topsoil. To retain tidal water, it is necessary to dig ditches deeper than 60 cm. This explains why all of the fruit trees in these areas are planted on raised beds separated by ditches. Many kinds of fruit trees, such as mango, jack-fruit, banana, orange and dragon eye, are planted in these gardens. A schematic diagram of a house compound and fruit tree garden is shown in Fig. 13.

To plant fruit trees, farmers have to construct dikes 4 to 6 m wide and of a length depending on their land tenure. The dikes are raised to about 0.5 to 0.8 m above the medium water level of the river in order to prevent the roots of fruit trees from being damaged by submergence, because the daily tides of the river here are very high during the rainy season. To control the water level in the ditches, a flapgate is constructed on the main dike. During high tide, water enters the ditches through the open flapgate, which is lower than the top of the dikes by about 60 to 80 cm, but is higher than the water level of

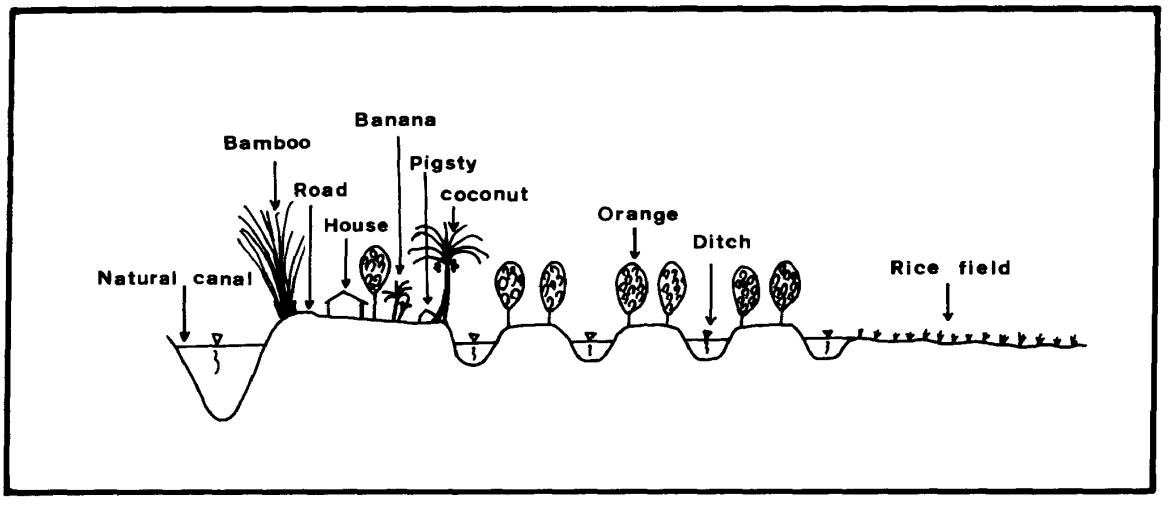

Fig. 13 Schematic Diagram of Fruit Tree Garden-house Pattern in Binh Minh, Cuu Long

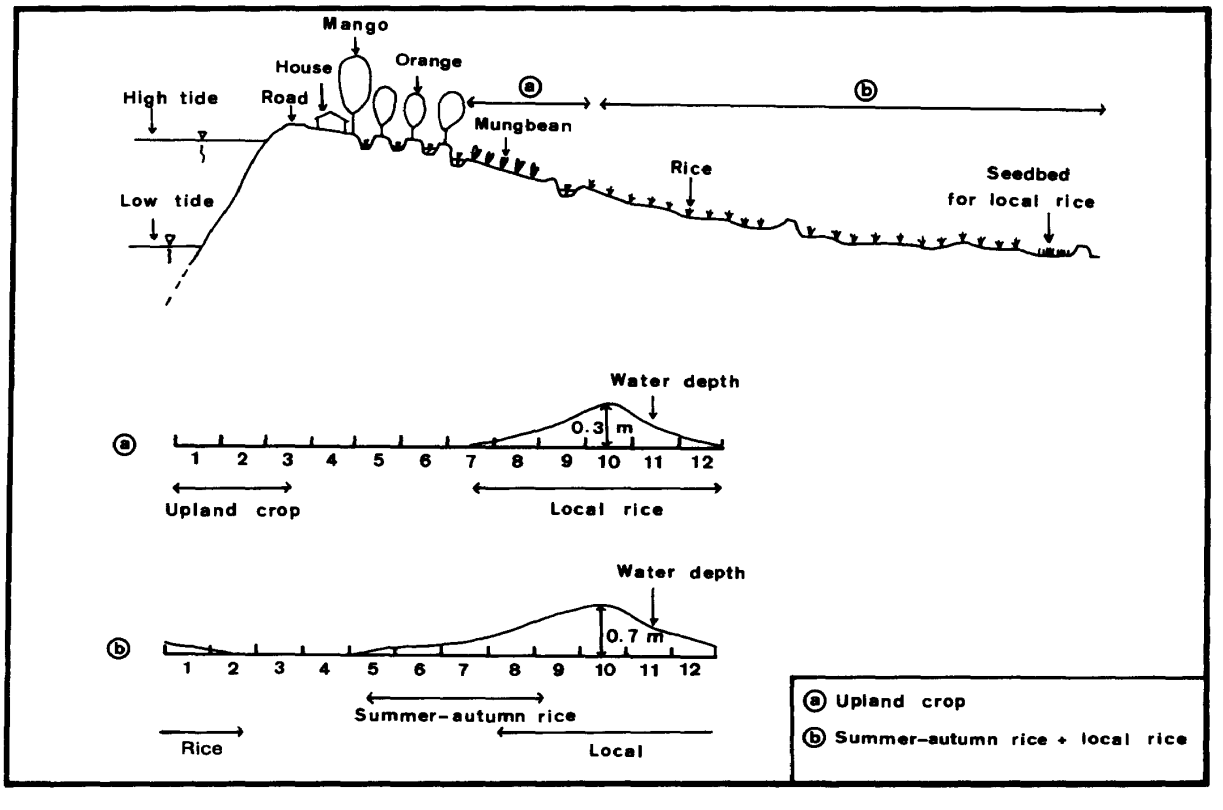

Fig. 14 Cropping Patterns on a Transect through the Natural Levee and Backswamp of the Vam Xan River (A Branch of the Hau River) in Nhon Nghia, Chau Thanh, Hau Giang

the river during low tide. Every year, mud and sediment from the bottom of the ditches are dredged up to the surface of the dikes. This work is only done in the dry season. Ditches between the dikes are used to raise shrimps or fish.

1. 2 Local Rice + Upland Crop

The local rice + upland crop pattern is found on the lower parts of the natural levees which are not used for fruit tree gardens. A schematic diagram of this pattern is shown in Fig. 14. Water control in fields is difficult because these areas are also rather high-lying, coarse in soil texture and uneven. Water can only be kept permanently in the fields in the months of September and October. Vigorous growth of weeds and water shortage at the start and end of the rainy season are considered to be the main factors which force planting of local rice. Local rice can compete with the weeds and is more resistant to dry conditions than HYVs. To plant local rice, farmers use a *phan* to cut weeds before the rains begin. Then, the soil is ploughed by tractor at the beginning of the rainy season. Wet seedbeds are prepared in the lowest part of the field, where there is sufficient water. The area of the seedbed is approximately 1/8 ha for transplanting a field of 1 ha. When rainfall becomes intense and the water level of the river rises enough to inundate the fields (normally at the end of August), farmers harrow the fields and transplant 45-to 50-day-old seedlings. Harvesting take place at the end of December. Farmers cut the grasses and rice stubble after harvesting, then plant upland crops such as corn, soybean, and mungbean. These crops are sown directly into the soil, the straw of the previous local rice crop being used to cover the ground surface.

1. 3 Summer-Autumn Rice + Winter-Spring Rice

This pattern is distributed in the backswamp areas where water is maintained permanently in the fields, such as O Mon and Thot Not district of Hau Giang province, and Tam Binh and Tra On district of Cuu Long province. The maximum inundation varies from 0.6 to 1 m in the flood season. These areas can be irrigated freely from the river during the whole year, depending on the high tide. Therefore, they have great potential for agricultural production, especially for rice cultivation. Although some areas of backswamp have strong actual and potential acid sulfate soils, their influence is not serious because plentiful fresh water is available. Experienced farmers know how to prevent pyrite oxidation by keeping the water level constantly at the upper part of the pyrite horizon. So, summer-autumn rice and winter-spring rice can be planted.

To practice this pattern, polders are constructed to control water in the field, and the polder dikes are also used for transportation. A schematic diagram of the pattern is shown in Fig. 15. Each polder has an area of about 1 to 10 hectares. On the polder, a flapgate is built about 20 cm lower than the field surface. Water can enter the field at high tide and drain easily at low tide. At the beginning of January, water in the field is drained off in order to make the field dry and harvest winter-spring rice. Farmers find time for ploughing soil earlier, then soil is dried for some months to eradicate the grasses and to improve its physical structure. When soil becomes soft with the first rains, farmers begin to puddle their fields, then they broadcast germinated rice seed. Normally, the seedling rate is 150 to 200 kg/ha. No weeding is done after the harvest summer-autumn rice. Fields are left fallow during the flood season from September to October, until

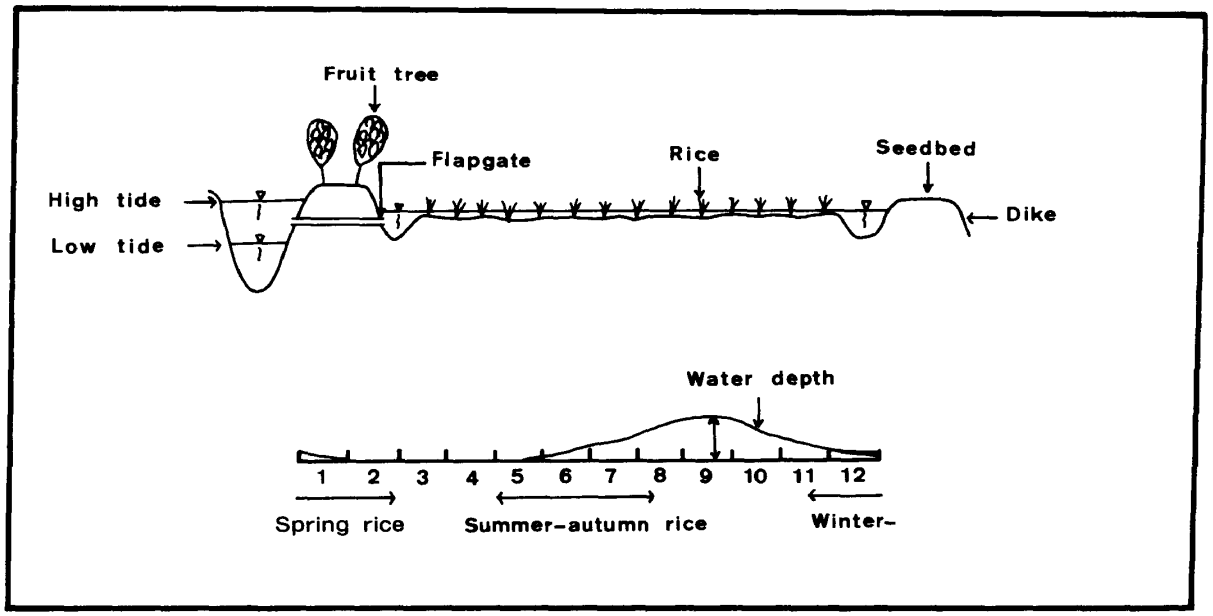

Fig. 15 Schematic Diagram of Summer-Autumn Rice + Winter-Spring Rice Pattern and Cropping Calendar in Thanh Thoi, Long Ho, Cuu Long

winter-spring rice is cultivated in November. Tractors with iron wheels are used to puddle the land. Transplanting is applied for winter-spring rice instead of broadcasting. Seedbeds are made on the dikes around the field and 25-day-old seedlings are transplanted. The yield of this crop is always higher than that of summer-autumn rice because it is seldom attacked by pests and insects. Sunlight is also more plentiful and the fertilizer response capacity of rice is also very high.

1. 4 Summer-Autumn Rice + Local Rice

This pattern can be seen in the backswamps where moderate actual and potential acid sulfate soils are present. A schematic diagram of the pattern and cropping calendar is illustrated in Fig. 14. To avoid oxidation of pyrite, fields are kept submerged. Fortunately, freshwater sources are abundant, and it reaches the field freely during weeks of full and new moons, except during the months of February, March and April. Cultivation method of summer-autumn rice is the same as mentioned above. The only notable difference is that farmers do not use the whole of their fields for cultivating summer-autumn rice. A small area is left aside for seedbeds for local rice. When the summer-autumn rice is about to flower, a wet seedbed of local rice is prepared. After harvesting summer-autumn rice, the water level in the field is about 30 to 40 cm. Farmers use a *phan* to cut the grasses and rice stubble, then they transplant 45-to 50-day-old seedlings of local rice over the whole field. One month after transplanting, the water level rises up to about 60 to 70 cm at high tide, falling to about 20 to 30 cm at low tide. This cycle is repeated twice daily. Harvesting is done at the end of February by using a sickle, and grains are separated by using the *bo dap lua* as described earlier for the double transplanting rice.

1. 5 Winter-Spring Rice + Spring-Summer Rice + Summer-Autumn Rice

This triple cropping system can be seen in Cai Lay, Chau Thanh district, Tien Giang province, where HYVs have been cultivated since 1967. A schematic diagram of this cropping pattern and cropping calendar are illustrated in Fig. 16. Fields are used nearly all the year round for planting rice. After harvesting spring-summer rice, the soil is ploughed and dried. When the first rains come, the farmers puddle the field with a tractor and broadcast germinated seed. The seedling rate of rice seed is 150 to 200 kg/ha. Irrigation is sometimes required at the start of rainy season. This summer-autumn rice has a very short growing period. After harvesting summer-autumn rice at the end of August, water depth in the fields rises to about 0.5 to 0.6 m. Fields are left fallow until the water recedes at the beginning of November. At this time, winter-spring rice is cultivated. Tractors with iron wheels are used to puddle the field when the water level is at about 5 cm. Germinated seed is broadcast there. The field has to be kept moist until the seedlings grow to 3-4 cm, then water is kept on the field permanently. Harvesting of winter-spring rice takes place when the field is totally dry. Then spring-summer rice cropping begins. The cultivation method for this crop is completely different from those of winter-spring rice and summer-autumn rice. It is called *sa chai* in the Mekong delta. The field is kept dry, neither ploughed nor puddled, but before seed is broadcast, the straw of the previous crop is spread over the rice stubble and burnt. After burning, with the stubble still standing, germinated rice seeds are broadcast on the field, then a quick surface irrigation is performed. Some farmers also broadcast dry rice seeds directly on the field, and then water is ponded for one night to promote germination. Why farmers choose *sa chai* for spring-summer rice may be explained as follows. The time for cultivating

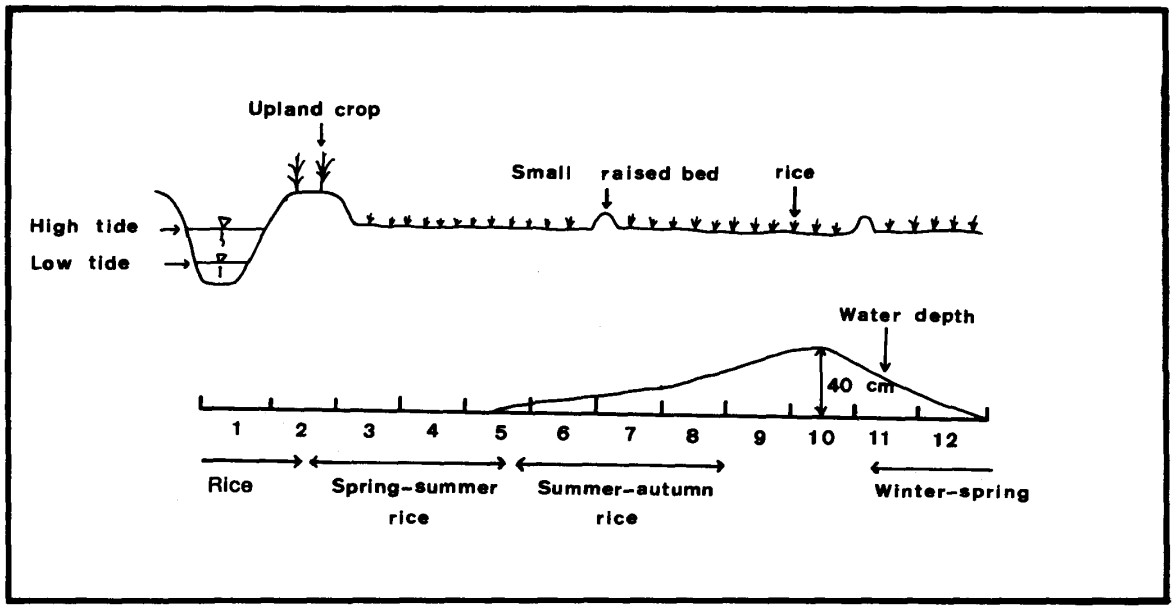

Fig. 16 Schematic Diagram of Cropping Pattern for Triple Cropping of Rice and Cropping Calendar in Hoi Cu, Cai Lay, Tien Giang

spring-summer rice is very limited, so farmers have no much time to plough the soil. Moreover, if spring-summer rice were planted by wet broadcasting, the soil would have to be puddled. This would not be practicable in the dry season because of the lack of rain, and farmers can only get water to the field at times of full or new moon by pumping it from a canal. The soil is dry and hard, there is insufficient water, and time is limited. In this situation, farmers devised an imaginative strategy : burn the ground surface to make soil even drier, then apply a quick irrigation. This technique stimulates air explosion in soil clods, immitating a classic method of splitting stone. Because the soil is not ploughed or puddled, it has to be treated by a different physical method to improve its structure. Furthermore, burning of ground surface helps to kill grasses, insects and pests from the previous crops.

The environmental factors allowing the *sa chai* method are worth investigation. The area where it is practiced is very flat and relatively high. It is located between the closed floodplain in the northwest, the natural levee of the Tien river in the south, and old sand ridges in the east. Maximum inundation at the end of September is not deep (50-60 cm). There are many natural and artificial canals connected to the Tien river, and they are influenced strongly by the semi-diurnal tide of the river. Although tidal water reaches the fields only in the months of the flood season (September and October), fresh water is present all the year round in the canals. Irrigation is done by pumping. Fresh water is in plentiful supply for rice at any time if farmers have the necessary equipment.

The soil quality of the area is good, but rice is more suitable than upland crops, because the soil texture is mainly clay. Before *sa chai* came to be practiced, ploughing and puddling had been applied for winter-spring and summer-autumn rice for many years, and a ploughpan has formed under the ploughlayer. This ploughpan is very compact, appearing like a cement sheet, and it prevents infiltration and leaching of water. This effect is reflected clearly in the long intervals between irrigation for *sa chai*, only four times per month in the dry season without any rain. Thus we may conclude that two main factors allow *sa chai*. The first is plentiful fresh water, which can be supplied to the rice at any time. The second is the high water-holding capacity of the soil.

2. Cropping Patterns in the FreshWater Broad Depression

2. 1 Local Rice

Local rice occupies about 50 % of the total area in the broad depression floodplain (see Fig. 6). This is a low area far from the Hau river. Fresh water from the Hau river reaches the area through canals, but in small volume. Maximum inundation reaches about 70 cm in October, and drainage is very difficult and slow. There are also many types of acid sulfate soils here. Only local rice varieties can be adapted to these conditions. Formerly, the double transplanting method was practiced. Now the situation has improved, and single transplanting is dominant.

For local rice cultivation, farmers first cut weeds with a *phan* in the early rainy season. Weeds are stacked, then the soil is ploughed by using two buffaloes or a tractor when it

rains. A small area of weak acidity is chosen for making a seedbed. The area of the seedbed is approximately 1/6 ha for transplanting of 1 ha. The cultivation method is the same as that used for local rice on the natural levees of tide-affected floodplain, but the varieties normally are late maturing rather than early maturing, because the late maturing varieties ripen at the same time as water recedes, which is very convenient for harvesting. When buffaloes are not available, farmers have to use a *phan* to cut grass. This is done twice. The first cutting has to be done at least one month before and the second one or two days before transplanting. Decayed grasses are spread over the ground surface to prevent new growth of grasses. Rice is harvested at the end of January.

2. 2 Sweet Potatoes + High-Yielding Rainy Season Rice

This pattern can be found in the weak acid sulfate soils that have humiferous topsoil. A schematic diagram of the pattern and cropping calendar are illustrated in Fig. 17. There are two steps in planting sweet potatoes.

Tuber planting: This is done to multiply the runners used as seedlings for planting in the field. After grass cutting and hoeing the topsoil of the dikes along the canal, good tubers of sweet potatoes are planted in the early dry season. Irrigation by hand-lifting is required every day. The area of root planting is about 1/10 ha for runner planting of 1 ha.

Runner planting: Before rain is expected, grass cutting is begun, and cut grass is spread over the ground surface to dry. After one week, the grass is burnt, then water is

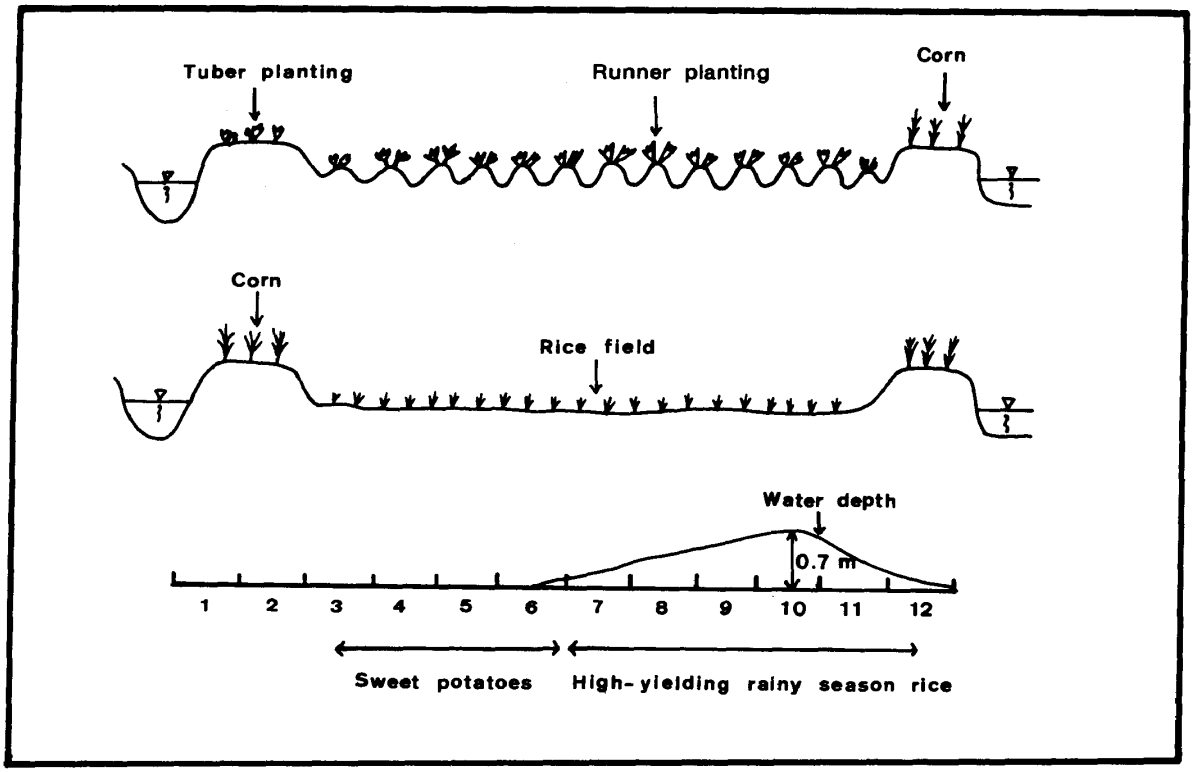

Fig. 17 Schematic Diagram of Sweet Potatoes + High-Yielding Rainy Season Rice Pattern and Cropping Calendar in Thanh Xuan, Chau Thanh, Hau Giang

pumped up for a quick surface irrigation to soften soil. Then parallel ridges of 40 to 60 cm width and 30 to 40 cm height are prepared with a spade. Ditches between ridges are about 30 to 40 cm wide. Construction of the ridges is very important work, because the yield of sweet potatoes is determined not only by soil fertility but also by the structure of the ridges. Experienced farmers say that if the structure of the ridges becomes lumpy, then the yield of sweet potatoes will decrease sharply. To overcome this, and to supply natural fertility to the sweet potatoes, farmers arrange that the topsoil layer contains more organic matter than the subsoil layer. After constructing the ridge, a small lengthwise groove of about 10 cm depth is cut on the ridge with a big knife. Runners are cut to a length of 30 to 40 cm and planted into the groove by hand. Harvesting starts about 90 days after planting. The yield is about 15 to 20 tons/ha. To increase the organic matter content of the soil, leaves of sweet potatoes are incorporated into the ditches, then covered by soil on the ridges.

Immediately, after harvesting sweet potatoes, germinated rice seed is broadcast directly on this field. Soil is not ploughed or harrowed. The yield of this rainy season rice is very high, averaging 7 tons/ha without any fertilizer. Environmental factors contributing to this success may be explained as follows. Cropping of sweet potatoes + high-yielding rainy season rice is practiced in the freshwater broad depression, Chau Thanh district, Hau Giang province, about 20 km from the Hau river. This is the area where double transplanting used to be practiced. This area is influenced by the tidal fluctuation of the Hau river (about 0.8 m). On days of full and new moons, tidal water reaches the fields through canals. Maximum inundation depth on the fields reaches as much as 60-70 cm at high tide, dropping to 20 to 30 cm at low tide in October. This water regime is quite suitable for planting rice. But farmers do not plant multiple rice crops as in other areas. This is related partly to the high yield of sweet potato on humiferous soil and partly to economic factors. The incorporation of one crop of sweet potato is more profitable than growing two rice crops.

2. 3 Summer-Autumn Rice + Winter-Spring Rice

Besides local rice and high-yielding rainy season rice, the summer-autumn rice + winter-spring rice pattern is also commonly found in the freshwater broad depression floodplain. It is concentrated mainly on areas of good soil and abundant water near canals. These areas can get fresh water from the Hau river through the canals. The cultivation method is the same as that of the winter-spring rice + summer-autumn rice pattern in the back-swamp area of the tide-affected floodplain, as described earlier.

C. Cropping Patterns in the Broad Depression Area

The broad depression area is very far and nearly isolated from the delta system. Fresh water from the Hau river does not reach the area, although canals have been dug to connect the broad depression with the Hau river. This area is influenced completely by hydrological regime of the Cua Lon, Ong Doc and Cai Lon rivers, which are independent

of the Hau river. In the dry season, all of these rivers and their branches are influenced by saltwater. Soil of the area is also salt-affected, since the area is very flat and low-lying. Acid sulfate soils are also extensive in the area. Cultivation is only practiced when heavy rains wash away salt and sulfate acidity. Fortunately, the area has the highest rainfall in the delta (more than 2,000 mm). In the Ca Mau and U Minh areas, rainfall can reach 2,900 mm. However, the distribution of rainfall is not regular. It is concentrated mostly in the middle and end of the rainy season. Previously, farmers used to follow the single transplanting method with local rice. The potential land use capacity of the area is limited compared to other areas of the delta.

1. Summer-Autumn Rice + Local Rice

Weak saline-acid sulfate soils of broad depression area are cultivated with summer-autumn rice + local rice pattern (see Fig. 6). When the first rains come, farmers begin to plough and harrow the fields. A small part of each field is set aside as a seedbed for local rice. Before broadcasting summer-autumn rice, farmer dig parallel field ditches of 20 to 30 cm width and 30 cm depth. The field ditches are connected to a larger ditch which is linked to a canal. The space, called *lip* between ditches, is 4 to 5 m wide. Dry rice seeds are broadcast directly on the *lips* and covered with soil. They will germinate when heavy rains moisten the soil. This method is called *sa kho* (dry broadcasting) in the Mekong delta, and it is rarely found in other areas of Vietnam. The schematic diagram of this

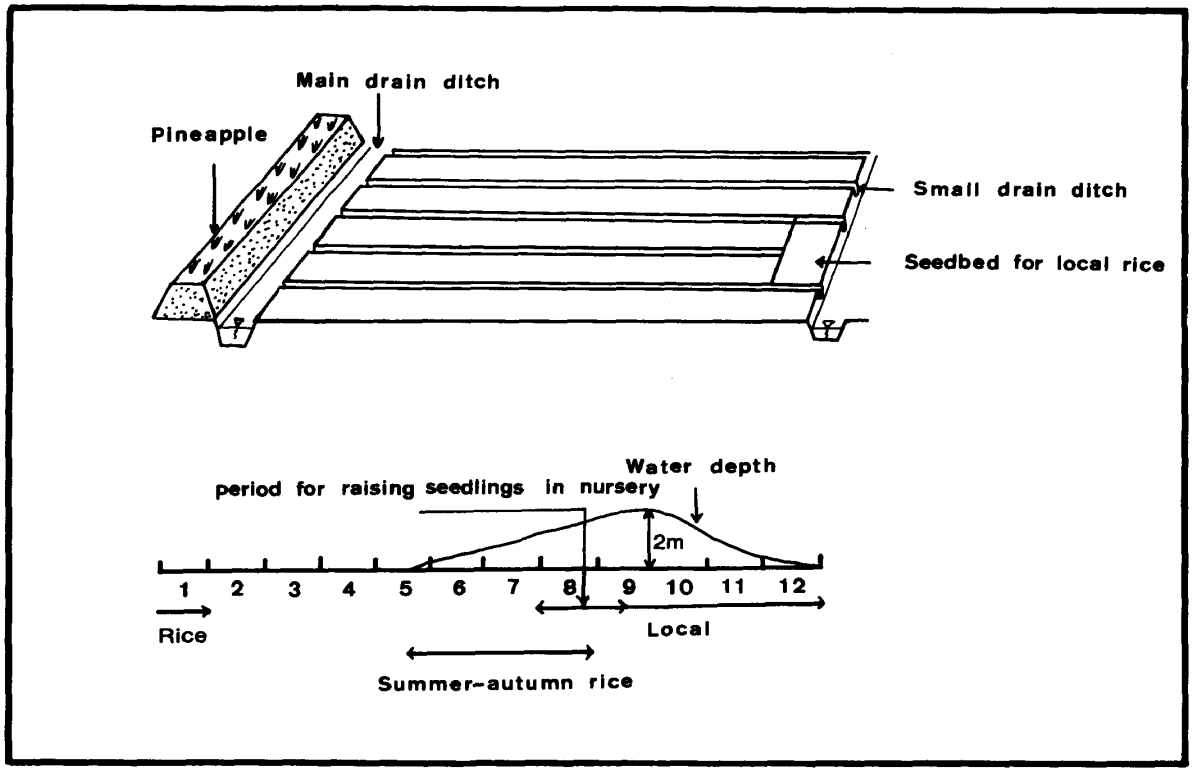

Fig. 18 Reclamation of Saline-acid Sulfate Soil by Intensive Shallow Drainage for Summer-Autumn Rice + Local Rice Pattern and Cropping Calendar in An Bien, Kien Giang

pattern and cropping calendar are showed in Fig. 18.

The *sa kho* method is commonly applied in the broad depression area because toxic substances in the soil can be washed away quickly by rains and drained off through the ditches. In addition, the broadcast seeds can survive in the soil for a period of 1 week to 1 month without any rain, and they germinate only when there is a heavy rain. In other words, the seeds select suitable moisture conditions for germination. After germination, the rice plants can tolerate dry conditions even if there is no rain for a period of 1 or 2 weeks. This is because the rice seeds are covered by a soil layer. If there is no rain, the ground surface can be dry but the soil under it is still moist.

A month before harvesting summer-autumn rice, a wet seedbed for local rice is prepared on the spot set aside for the purpose. To limit vigorous growth of weeds, farmers pull up weeds by hand instead of using a *phan* to cut them. The area of seedbed is about 1/6 ha for transplanting 1 ha. After harvesting summer-autumn rice at the end of August, field is submerged by rainwater to 20 to 30 cm in depth. Then, the ditches are filled and 40- to 50-day-old seedlings are transplanted. In those areas where saline-acid sulfate soil is negligible, farmers cultivate HYVs with long growing periods, such as IR 42, instead of the lower yielding local rice varieties.

2. Local Rice

Local rice cultivation by the traditional methods is distributed on the strong saline-acid sulfate soils, where the HYVs cannot be cultivated (see Fig. 6). Some local rice varieties such as Huyet Rong, Duoi Trau and Mong Chim have adapted to this environment. These varieties are photo-sensitive and have long growing periods. Grains are long, and the husks and milled rice of Huyet Rong are reddish brown in color. Duoi Trau and Mong Chim have yellow husks and white rice. These varieties have generally good cooking qualities and give relatively high yields (3 to 4 tons/ha). To plant these varieties, farmers dig parallel ditches and *lips* at the beginning of the rainy season, in a similar way as for summer-autumn rice, but the space between ditches is narrower (2 to 3 m). Wet seedbeds are prepared near the canals, where toxic substances are washed away quickly by the first rains. Experienced farmers can tell by observing grasses in the field to what degree the toxic substances have washed away. If young *Cyperus* or *Scirpus* grasses can grow, 40- to 50-day-old seedlings are transplanted immediately on the *lips* without filling the ditches. Farmers in this area use a *vong gat* (see Fig. 5 : j, k) to harvest rice instead of a sickle.

3. Rainy Season Rice Cropping with HYVs

Rainy season rice cropping is distributed on the weak saline-acid sulfate soils (see Fig. 6). This area is located in the middle of the broad depression, where the ground is higher than in other areas of the broad depression. Saltwater from the Gulf of Thailand enters through the Cua Lon, Ong Doc and Cai Lon rivers, but the area is far from these rivers, and the influence of saltwater is not as severe as in the lower areas of the broad depression. Rainy season rice cropping with HYVs can be planted here instead of local rice. The cultivation method of this rice is similar to that of local rice mentioned above, but it is not

necessary to construct many ditches and *lips* for washing away toxic substances. Only small raised beds of 60 cm width and 50 cm height are constructed around the field plot to retain rainwater. These raised beds are constructed by collecting topsoil from nearby.

4. Melaleuca Tree-Fish-Bees

The U Minh Thuong and U Minh Ha areas of the broad depression (see Fig. 6) have a traditional *Melaleuca*-fish-bee pattern, because soil hazards are severe, like thick peaty soils, and heavy clay subsoils with very high pyrite content. Moreover, inundation is very deep in the rainy season (more than 1 m). Only *Melaleuca* trees can grow well there. Most of the *Melaleuca* trees are natural growth. Formerly, some plots were exploited for rice and upland crops by burning the peaty layer. But this method could not succeed because after several years severe soil acidity developed due to the disappearance of the buffering peat layer. Oxidation of pyrite occurred. Now these areas belong to the government. An agroforestry system of *Melaleuca* tree-fish-bees has been adopted. Polder systems have been constructed around these areas. *Melaleuca* trees are planted inside these polders. To prevent forest fire in the dry season, many canals have been excavated to retain water. During the flood season, natural fish come and are trapped inside the polders. Honey bees are also attracted by the flowers of *Melaleuca*. They come to nest there. This agroforestry system seems to be adapted to the local natural environment. However, forest fire still occurs in the dry season because management is too slack, and the economic efficiency is thus reduced.

D. Cropping Patterns in the Coastal Complex

The coastal complex is located along the South China Sea. It can be distinguished clearly from other areas by a system of sand ridges which run parallel to the sea. Its topography varies from place to place. Cultivation depends completely on rainwater. A representa-

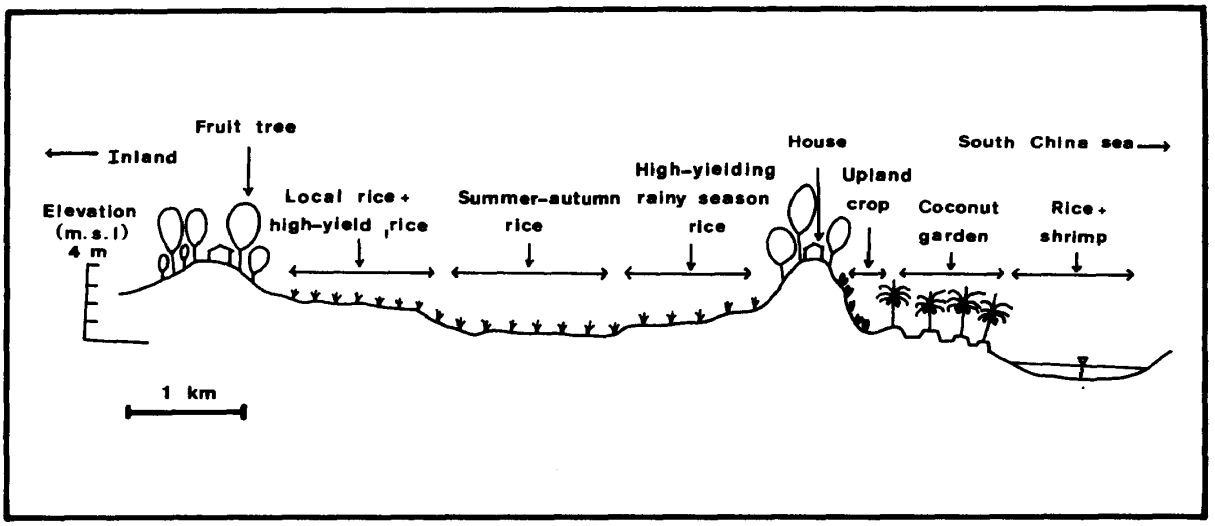

Fig. 19 Cropping Pattern on a Transect from West to East through Part of the Coastal Complex in Binh Dai, Ben Tre

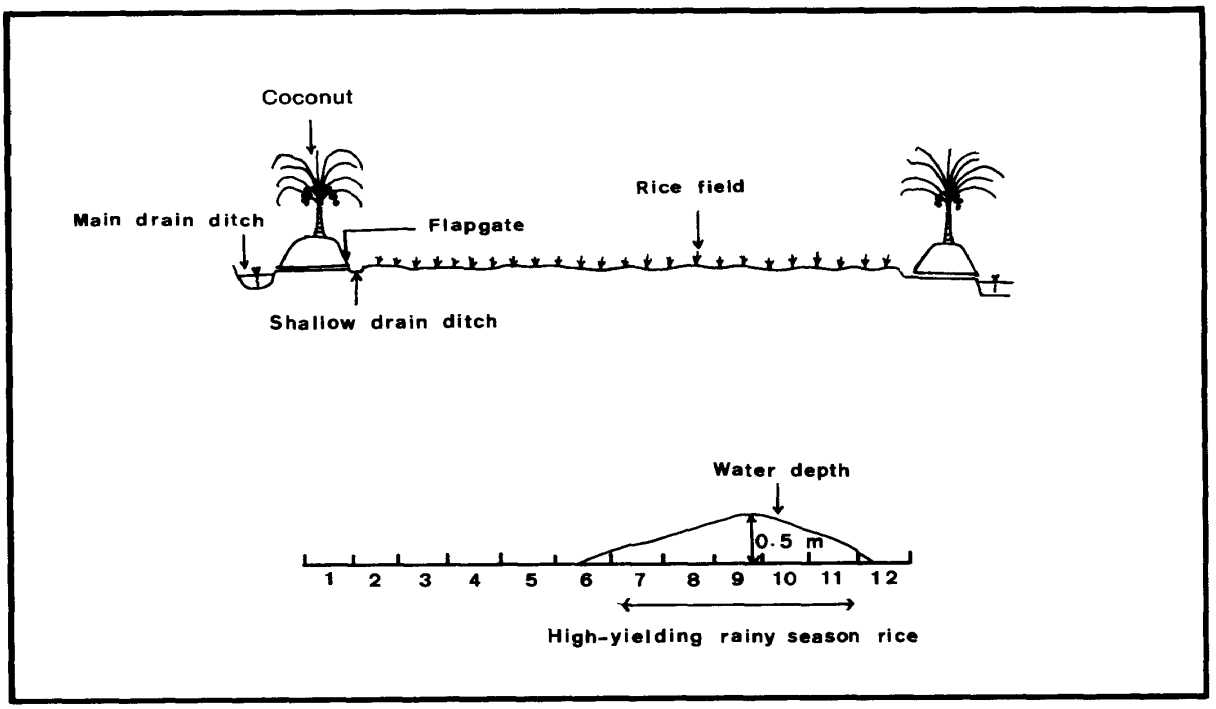

Fig. 20 Schematic Diagram of High-Yielding Rainy Season Rice and Cropping Calendar in Binh Dai, Ben Tre

tive cropping pattern of coastal complex is shown in Fig. 19. The various cropping patterns are summarized as follows.

1. Rainy Season Rice Cropping with HYVs

Rainy season rice cropping with HYVs is distributed at the foot of sand ridge areas. A schematic diagram of this cropping is shown in Fig. 20. Farmers have to plough the field when the first rains fall. A part of the field where soil salinity is negligible is chosen for a seedbed. The area of seedbed is about 1/6 ha for a transplanted area of 1 ha. One month before transplanting, farmers dig shallow ditches around the field. These ditches are connected to a canal by a flapgate which is lower than the surface of the field but higher than the water level of the canal at low tide. At both ends of the flapgate, valves are installed. At high tide, the valve on the canal side is closed by pressure of water. At low tide, both valves are opened to drain saltwater from the field to the canal. After heavy rains, salt accumulated in the topsoil of the field during the dry season is washed away through the ditches to the flapgate and the canal. Then the valves of the flapgate are closed to retain rainwater for cultivating rice. One day before transplanting, the field is harrowed, then 40- to 50-day-old seedlings are transplanted. Harvesting begins when the rainy season ends in late November. *Vong gat* or sickles are used to harvest rice, and threshing machines are used to separate rice grains from straw.

2. Local Rice Mixed with HYVs

This pattern is found in the coastal flat area. Rice cultivation depends on rainwater exclusively. Soil becomes slightly salty in the dry season, and this continues until the

beginning of the rainy season. Multiple rice cropping is impossible there. Therefore, farmers have found a way to increase yields per area by mixing local rice varieties with HYVs. By this method, farmers can harvest rice two times. The first harvest is HYVs and the second is local rice. The cultivation method is summarized as follows.

To control weeds and improve soil structure, the field is ploughed after harvesting rice, then left fallow during the dry season. Farmers have to wait until heavy rains come to wash salt away, then they harrow and puddle the soil with a tractor or buffaloes. Then mixed grains of the local rice and high-yielding rice are germinated and broadcast on the field. The ratio of the two kinds of rice seed is 300 kg of HYV to 25 kg local rice per ha. In the first harvest, when the HYV is ripe, both the HYV and local rice are cut together with a sickle, but the local rice is not damaged and continues to grow because it has not yet reached the reproductive stage. The local varieties do not bear culms yet, so when the HYVs are harvested, only the upper leaves of the local rice are cut. After harvesting the HYV, the local rice continues to grow and is harvested 4 months later. The total yield of the two harvests is nearly the same as the yield of two crops of local rice. The first harvest of HYV reaches about 4 tons/ha and the second one of local rice about 2 tons/ha.

3. Rainy Season Crop with HYV Rice + Shrimp

Littoral areas of the coastal complex are strongly affected by tidal movement, and shrimp cultivation in the dry season is combined with rainy season rice cropping. These areas are low-lying and the reduced subsoil located at 20 to 50 cm depth is very high in pyrite content. To prevent acidity release by oxidation of pyrite, experienced farmers have exploited the areas for raising shrimp during dry season by constructing polders of 5 to 10 ha. In the

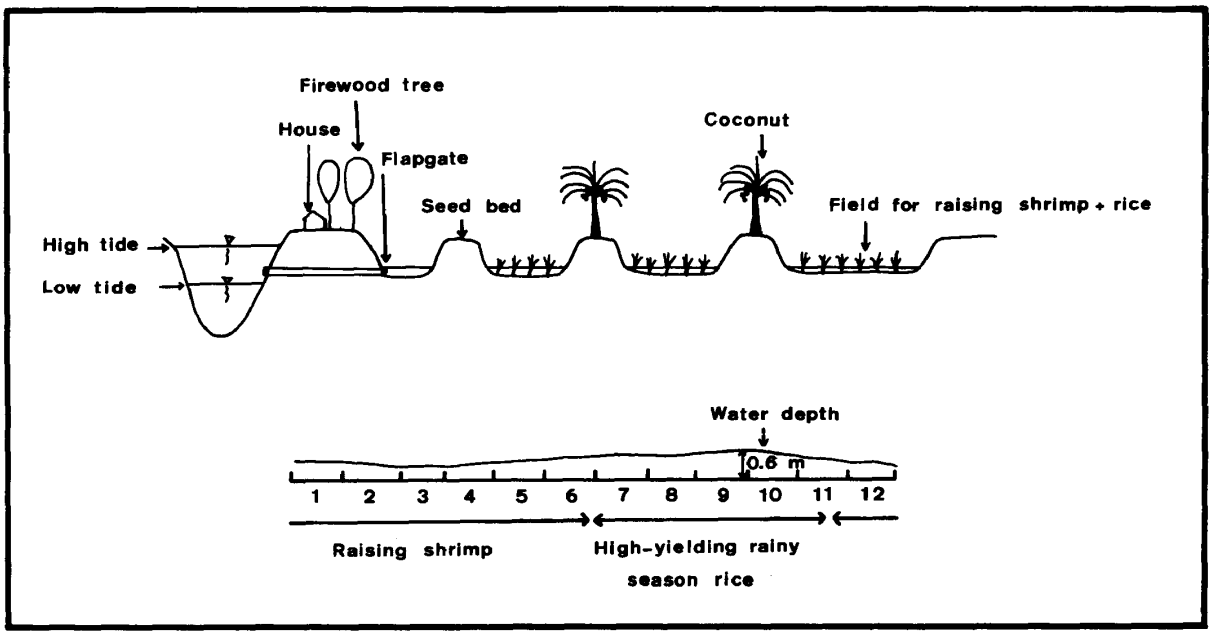

Fig. 21 Schematic Diagram of High-Yielding Rainy Season Rice + Shrimp Pattern and Cropping Calendar in Gia Rai, Minh Hai

rainy season they transplant HYV rice. The schematic diagram of this pattern is illustrated in Fig. 21. Each polder has a network of canals and ditches to control the water level, so as to enable the dual function of the polders as rice fields in the rainy season and shrimp ponds in the dry season. One or two flapgates are constructed along the waterway which opens to the estuary. At the onset of the rainy season, salinity on the soil surface is washed away into the canals, then out of the polder through the opened flapgates, which are set level with the ground surface inside the polder and higher than the water level at low tide. When soil flushing is finished, the flapgates are closed to retain rainwater for cultivating rice. Seedbeds are prepared on the dikes or polders around the field. Transplanting is begun when the seedlings are 30 to 40 days old.

During the dry season, brackish water or seawater is allowed to enter the field through the flapgates to prevent oxidation of pyrite. Fortunately, the entry of high tide also carries in shrimp fingerlings during full and new moons. Shrimp fingerlings are raised without feeding and harvested in one month. Harvesting is done by using a cylindrical bamboo fish pot placed at the entrance of the flapgates. The coarse mesh of the net allows only the mature shrimps to be caught and at the same time new shrimp fingerlings to enter. Raising shrimps is carried out throughout the dry season.

In some areas, only rainy season rice is cultivated, since the ground surface is relatively high and difficult to flood with saltwater in the dry season. However, some farmers try to lower the surface of the field by scraping the ground. The scraped mud is collected on dikes, on which upland crop or coconut tree are planted.

4. Summer-Autumn Rice after Ridge Flushing

Summer-autumn rice has recently begun to be cultivated in saline-acid sulfate soil in some districts of Ben Tre province. HYVs have been cultivated instead of local rice, which gives low yield and is often influenced by salinity at the end of growing period. Farmers make parallel beds with a spade in April. The beds are of 40 to 50 cm width and 30 to 40 cm height. Shallow ditches between the beds are about 60 to 80 cm wide. The ditches are connected to a canal. Raised bed preparation and cropping calendar are shown in Fig. 22. When it rains, toxic substances in the beds are washed away into the canal through the ditches. After several rains, the field is raked level by hand or buffalo, and germinated rice grains are broadcast in the field. Yields of 5 to 6 tons/ha have been obtained, compared to 1 to 2 tons/ha on unwashed soil.

5. Coconut Garden + Fish and Shrimp

Ben Tre province has long been famous for its coconut gardens. According to old farmers there, these coconut gardens were created a century ago and many old coconut trees have been replanted. The combination of coconut with fish and shrimp is distributed in the relatively high areas between branches of the Tien river (see Fig. 6). The land appears to consist of sand bars, but the soil texture is mainly silt. Tidal fluctuation in the rivers is very large, but water does not reach the topsoil even during high tides, except in the two months of September and October. Saltwater intrusion also occurs during the dry season.

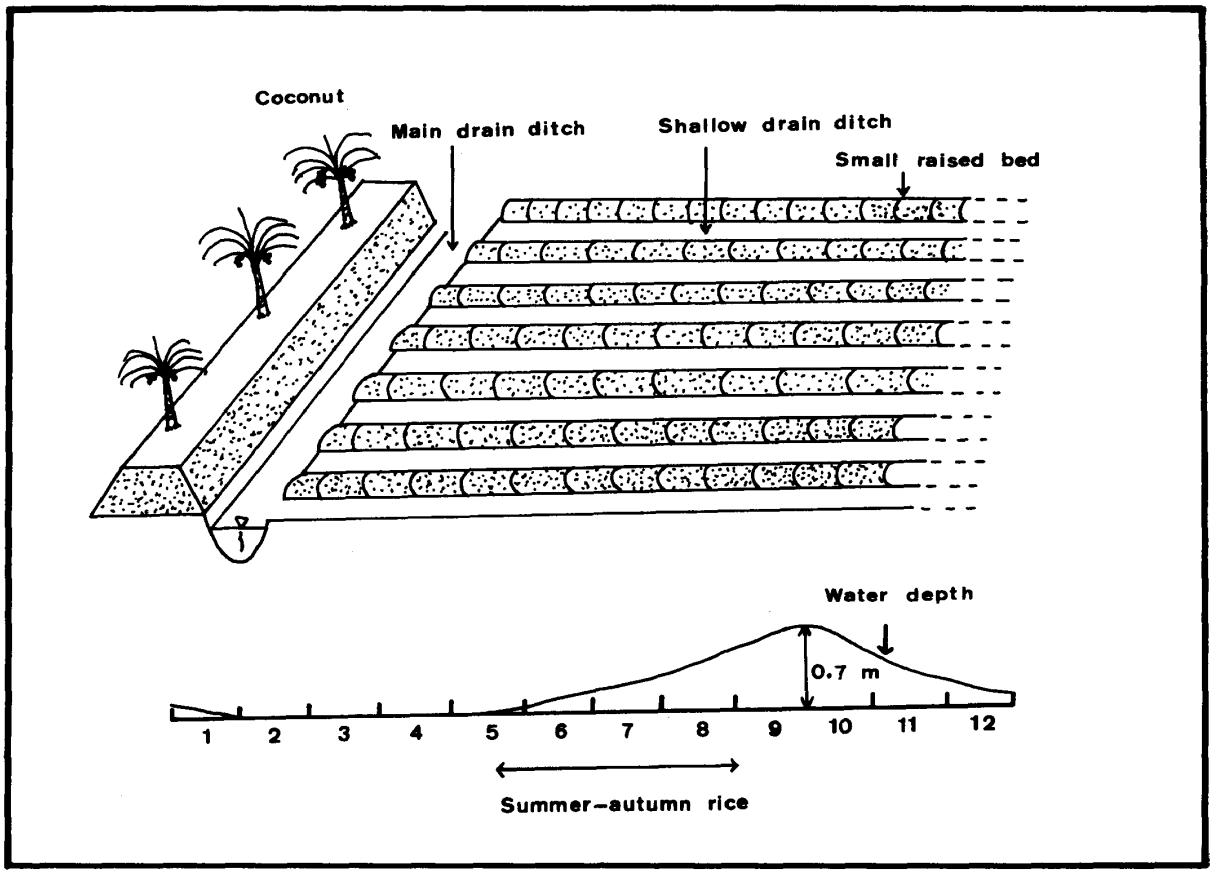

Fig. 22 Raised Bed Preparation to Wash Away Toxic Substances for Summer-Autumn Rice and Cropping Calendar in Binh Dai, Ben Tre

To retain fresh water, a system of ditches and polders with flapgates would have to be constructed. Therefore, local rice cultivation was replaced by coconut gardens. To plant coconut, farmers construct polder dikes around their gardens to prevent intrusion of saltwater and also to keep fresh water for raising fish and freshwater shrimp. To adjust the water level inside the polder, flapgates are also constructed. These flapgates open to a tidal canal or river. During the dry season, they are closed to prevent saltwater intrusion and also to retain fresh water. Irrigation in the dry season also requires a stock of fresh water. In the rainy season, excess water inside the polder is drainable through these flapgates at low tide. Within the polders, farmers have constructed parallel raised dikes of 5 to 6 m width, 50 to 60 cm height (compared with the original ground surface) separated by ditches of 1 to 1.2 m depth and 2 to 2.5 m width. A schematic diagram of this pattern is shown in Fig. 23. Coconut trees are planted in one row on the middle of dikes or two rows on the sides of dikes. The space between trees is about 5 to 6 m. Nuts are sown in nursery plots, being laid on their sides and half-covered by soil. The nuts germinate in about 70 to 90 days. Germinated nuts with three leaves can be planted immediately or one year later. To raise good coconut trees, experienced farmers often choose fruits of parent trees with desirable characters, such as many fruits, thick copra and

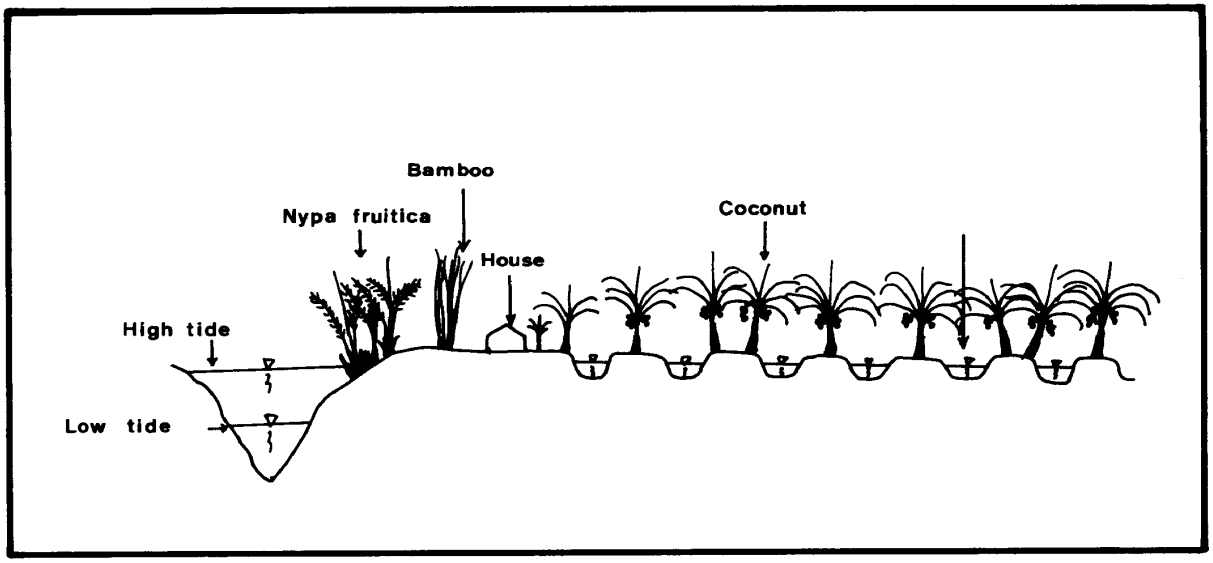

Fig. 23 Schematic Diagram of House-Coconut Garden in Tan Binh, Mo Cay, Ben Tre

thin fiber. Preferably the parent trees should be around 10 to 15 years old. Every year, mud deposited in the ditches is scraped up onto the dike surface. This operation gives a chance to catch fish and shrimp in the ditches. Each coconut tree can bear fruit in 5 to 6 years after planting. Beside the old coconut gardens, new coconut gardens have also been constructed. Most of them are concentrated in the inter-ridge areas (see Fig. 19). However, production here is adversely influenced by saltwater.

6. Upland Crop + Fruit Tree Garden on the Ridges

Most of the ridges in the coastal complex are used for settlement by people. Houses are built on the highest position of the ridges. Around the houses there are fruit and other trees such as coconut, jackfruit, mango, cashew nut, bamboo, *sao* (*Hopea odorate*), *Calophyllum inophyllum* etc. The structure of the gardens on the ridges is completely different from those in other areas. The fruit trees are planted directly in the ground without constructing dikes and ditches, because the groundwater level lies far below the topsoil during the dry season. Generally, the fruit tree gardens on the ridges are not cultivated as a major source of income for farmers but only for family consumption. Yields of fruit trees are often very low since the soil is poor and extremely dry in the dry season.

Besides the fruit gardens, most farmers have areas used for cultivating vegetables. These consist of cucumber, pumpkin, soybean, onion, water melon, *Ipomea aquatica*, etc., which are planted at the foot of ridges during the dry season. To irrigate these crops, farmers dig a pond of 2 m by 2 m in the middle of the field to collect groundwater. A pond of this size can supply enough water for irrigation of about 1,500 m^2. Usual irrigation is by sprinkling by hand. However, the groundwater is often salty in the middle of the dry season and it cannot be used for irrigation. To circumvent this problem, experienced farmers often choose short-term varieties and harvest them before the groundwater become salty. They also plant crops earlier at the end of the rainy season.

Table 2 Summary of Main Cropping Patterns and Appropriate Techniques in Relation to Landform, Soil and Water Conditions in the Mekong Delta

LANDFORM UNIT	LANDFORM SUBUNIT	MONTH: Jan. Feb. Mar. Apr. May Jun. Jul. Aug. Sep. Oct. Nov. Dec.	APPROPRIATE LANDUSE TECHNIQUE	LIMITED or SUITABLE FACTORS
High	Natural Levee		Keep soil moist by using straw	High flood but shortage of water
	Back-swamp		Polder to drain & keep water Change to other crops (jute) instead of rice	during dry season High flood and acidity
Flood-plain	Open Flood-plain		Keep soil moist by using straw Raised beds & ditches, topsoil to be spread on the beds	Alluvium soil Strong acidity Light acidity
	Closed Flood-plain		Keep soil wet to prevent oxidation of pyrite Raised beds & ditches Agroforest system. Broadcast rice when water level is still high (30-40 cm)	High flood Strong acidity Potential acidity
Tide-affected Flood-plain	Natural Levee		Construct ditches, & raised beds higher than medium tidal water of river.	Fresh water, high tide
	Back-swamp		10 ha polder with flapgate Regulate water to the depth of pyrite layer	Abundant fresh water
	Broad Depression		Raised beds Keep soil wet to prevent oxidation of pyrite	Hard drainage Potential acid sulfate soils
Broad Depression	Broad Depression		Shallow ditches & raised beds Rains wash off the salt & acid	Saline-acid sulfate soils No fresh water in dry season
	Peat Depression		Agroforest system	peaty soil
Coastal Complex	Coastal Flat		Shallow ditches to wash away salt Mixed local & high-yield rice	Brackish water
	Inter-ridge		10 ha polder with flapgate to keep soil wet to prevent oxidation of pyrite Raised beds & shallow ditches	Saltwater intrusion, acid sulfate soils
	Ridge		Dig pond to use groundwater	Shortage of fresh water

Fruit tree-house; Summer-autumn rice; Pineapple-cashew; Spring-summer rice; Floating rice; Local rice; Shrimp; High-yielding rainy season rice; Winter-spring rice; Sweet potatoes; Melaleuca-bees-fish; Leave fallow; Upland crop; Summer-autumn jute; Yam; Coconut garden-fish-shrimp

A summary of the present cropping patterns and appropriate techniques is relation to landform, soil and water conditions in the delta are given in Table 2.

III Conclusion

The study of former and present cropping patterns in the Mekong delta reflects exactly the

natural environment. Water regime and soil conditions are the most important factors which determine the selection of crop varieties, cropping seasons, combinations of crops and cultivation technologies. Landform is the key to the different water regimes and soil conditions.

The study showed that the former cropping patterns in the delta were based mainly on traditional rice cultivation. Three methods of rice growing, i. e., broadcasting, double transplanting and single transplanting, were applied on distinctive landform units such as the high floodplain, the tide-affected floodplain, and the coastal complex and the broad depression, respectively.

Today, the cropping patterns in the delta have changed almost totally. Various rice growing methods are applied. The most remarkable change is found in the tide-affected floodplain (middle reach of the delta). Fruit tree gardens have been created along the river banks, and their area is increasing year by year. The single cropping of rice by double transplanting has been replaced completely by year-round cultivation with HYVs. The year-round cultivation has resulted from favourable environmental factors such as plentiful fresh water and good soils. Fallow land and floating rice in the high floodplain (the upper reach of the delta) have also been reduced by the expansion of high-yielding rice varieties or other crops. This is due to the farmers themselves finding new cultivating methods, like *sa ngam*, and techniques to improve soil, such as construction of raised beds and polders. The coastal complex and broad depression, affected by saltwater and sulfate acidity respectively, still retain the traditional rice culture. However, high-yielding rice varieties are also cultivated by rotation technique together with local rice by improving the soil.

The success of a cultivation method is mainly dependent on the experience of farmers. By observing the topography, soil and water regime, farmers have adjusted themselves to these natural conditions. They have selected suitable cultivation methods and cropping calendars for their particular living environments. With the limitation of finance and equipment, the key to successful cultivation in the Mekong delta is to know clearly the natural conditions, such as soil and water, crop varieties, and especially the precious experiences of old farmers, which are good data sources for scientists who want to make plans for using the land.

More than 90 % of the cultivated areas have been used for rice production, while other crops still need further elaboration. To increase production in the future, water control must be given priority. Water control consists of flood protection, salinity protection, irrigation, and proper drainage systems. To this end, basic studies must be done carefully.

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