The Balanta rice farming system in Guinea-Bissau

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Abstract

Since the beginning of this century, Balanta people in Guinea-Bissau have reclaimed mangrove swamps for rice cultivation. The land is reclaimed in strips: each family has one strip of fields perpendicular to the main creek, in between the village and the creek. These form the basic drainage units. For the first few years, rice is broadcast on the newly-reclaimed land. In the third year, farmers make ridges on which the rice is transplanted. The ridges allow for leaching in the beginning of the rainy season. The size of the ridges varies with the physiographic position of the field and water availability: relatively high-lying fields have low ridges (20cm); ridges in lower-lying fields are over 1 m high.

Based on the physiographic position, soil characteristics and hydrology, a division in 6 different categories of fields has been made, each requiring its own farmers’ management.

Nowadays, decreasing rainfall, increased sedimentation and changes in the social structure make the system less resilient and external inputs are needed.

Introduction

This paper is based on research work carried out by the Rural Engineering Project Phase II, 1983-1988 (Dept. of Rural Engineering and Irrigation 1988). This bilateral project between the Governments of Guinea-Bissau and The Netherlands aimed at a better understanding of the rice production system of the local farmers, in order to develop improvements in the cultivation system to increase labour productivity. Interventions have been made in the fields of water management and soil fertility but alternative crops to replace rice have not been considered.

The project was located in Bissasséma, in the Southern coastal province of Quinara (Figure 1).

The study area

There is a prolonged dry season (November-May) and a rainy season of 5 months (June-October). Since the early "70s, the total amount of rainfall has decreased from over 2000 mm/year to an average of 1600 mm/year (1985-1987). In 1984, the lowest rainfall figure for this area has been observed (1250 mm). With decreasing rainfall, the onset and the end of the rainy season have become less reliable. August to mid-September is the wettest period: a maximum of 300 mm per 10 days has been measured during this period.

A schematic cross-section of the landscape (Figure 2) shows three major elements:
the so-called residual landscape, the estuarine terrace, and the younger estuarine deposits.

On the flat to undulating residual landscape (maximum 30 m above present mean sea level) villages are situated, surrounded by forests and savanna. The soils are mainly Oxisols, Ultisols and Inceptisols. Drainage varies significantly: under the forest vegetation well drained soils occur, while soils under savanna vegetation are poorly to moderately well drained.

Sulphidic sediments accumulated following land subsidence and sea level rise about 30,000 years ago. In this environment, mangrove (predominantly *Rhizophora*) flourished along the creeks, and barren salt flats were found on the somewhat elevated deposits. These sulphidic soils turned into acid sulfate soils during the sea level fall of 5000-3500 years ago when the estuarine terrace was formed (marine terrace of Nouak-
chott). Now the terrace is several metres above mean sea level. The soils are classified as Rhodic (Sulfic) Humaquepts (imperfectly drained) and Rhodic (Humic) Sulfaquepts (poorly drained). Nowadays, the terrace is mainly covered by grasses, some cashew and planted cassava.

The sea level fall led to erosion of part of the terrace. During the more recent sea level rise, estuarine clays have been deposited under *Rhizophora* and *Avicennia*. The sulphidic materials have been partially covered by sediments low in pyrite.

In the study area, 75 per cent of these deposits (zero to several metres above present MSL, 1-2 m below the terrace) have been reclaimed. Jarosite has developed at 25-125 cm depth but physical ripening has been limited to the upper 50-75 cm of the profile. In the well drained, usually higher lying areas, Aeric and/or Salic Sulfaquents, Sulfaquepts, Humaquepts and Tropaquents occur. In the poorly drained, lower-lying areas, Sulfic Tropaquents and Tropaquents prevail. The reclaimed lands are in use as rice fields or have been abandoned. Soils still under mangrove are Sulfaquents and Aeric (Sulfic) Hydraquents.

*The Balanta people*

At the end of the last century many Balanta people moved from the northern provinces, close to Bissau, to the southern provinces of Tombali and Quinara. They established villages on the residual landscape, continued their traditional rice cultivation system on the estuarine terrace and started reclaiming lands on the younger estuarine deposits. Rice is their staple crop and fulfills an important role in the animist Balanta society as trade ware, for labour as well as other products, and in ceremonies. Other crops include cassava, sweet potato and maize. Salt mining and wine and liquor production are among the other economic activities. Livestock (cattle) are kept for ceremonial use and as a way to keep savings.

Before the liberation war (1963-1974), in which the Balanta people played a major role, a rice surplus was produced. During the war, many people had to move and abandon their rice fields. Since then rice production has never reached its pre-war level. The society has changed and many young people have left the villages. Although the male village elders still decide on social and agricultural affairs, it is not possible anymore to organize the working groups of young men during the dry season and during land preparation time.

**Land reclamation**

The Balanta people in Quinara started land reclamation about 80 years ago. In the mangrove area, dikes of 1 m high and 3 m wide were constructed to exclude the tidal water from the lands to be reclaimed. The height of the dikes is about 10 cm above the highest flood level. The construction of the dike is communal village work. One year after reclamation, the dying mangrove is removed. The land is divided amongst the farmers, in strips, 15-30 m wide, perpendicular to the main creek, in between the village and the creek. Consequently, each farmer has a variety of higher as well as lower-lying rice fields, which are called bolanhas.

The second year after reclamation, rice is broadcast on the cleared lands. In the third year, farmers start land preparation with their local spade (arado). Horizontal
layers of about 8 cm thick are turned upside down to make ridges and furrows perpendicular to the slope. This work can be done only after the soil has been saturated. The ridges vary in height from 20 cm in the high-lying fields to over 60 cm in the low-lying fields. The latter are prepared first as they are saturated earlier.

The size of the fields within a strip depends on the slope. Sloping strips require smaller fields than flat strips to obtain an optimal water level where all ridges are equally inundated with rainwater. The water level is regulated by opening the bunds between the fields and, finally, by opening the outer dike to the creek.

Fields are not fertilized but, during land preparation, last years' ridge is turned over to become a furrow. The rice stubble ends up at the bottom of last years' furrow, which becomes the new ridge.

Local varieties of rice are sown in seed beds which are prepared on the upland. In the same way as on the rice fields, ridges are made after the first 200 mm of rainfall. They may be fertilized with farmyard manure. The seedlings remain in the seed beds for 3-10 weeks. Transplanting can be done as soon as all fields are prepared, after 650-750 mm of rainfall. Before transplanting the whole field, farmers plant about 10 hills to check whether the seedlings survive. First, the high-lying fields are transplanted, as they will fall dry soon after the rains have stopped. Rice is transplanted on top of the ridges. Most farmers do not remove weeds. Harvest takes place 115-135 days after sowing.

In the period of 1985-1987 a mean yield of 1100 kg paddy/rice field was recorded. A maximum of 3750 kg/ha was recorded in the zero plot of a fertilizer trial.

Per family (5.1 persons), about 2.5 ha is planted each year, which requires about 225 working days from land preparation to threshing. Some 85 per cent of the crop is kept for home consumption and seed. The remainder is used for trade and ceremonies.

Characterization of the different rice fields

During 3 rainy seasons (1985-87), soil characteristics, hydrology, crop-performance and farmers' practises have been monitored along 4 transects in the study area. In between the rainy seasons, soil characteristics have been monitored. Two of the 4 transects represented traditional drainage units, originally being the fields of one family.

Six categories of fields could be distinguished. The major distinction is made between high-lying fields and low-lying fields. High-lying fields are characterized by low ridges (< 20 cm). Land preparation, transplanting and harvesting are carried out early, and early-maturing varieties are used. These high-lying fields are subdivided as follows:
1) Fields with favourable soil properties;
2) Fields neighbouring the terrace;
3) Fields with salinity problems;
4) Fields with limited drainage.

Low-lying fields (part of the present or former drainage system) have higher ridges. Land preparation is done immediately after the rainy season or at the onset of the
rainy season. Late-maturing varieties are transplanted after the water level has reached its peak. These low-lying fields are subdivided into:
5) Fields with sufficient drainage;
6) Fields with limited drainage.

1) **High-lying fields with favourable soil characteristics**
These fields have favourable soil characteristics (Table 1) so crop yields are determined by total rainfall, rainfall distribution and the farmers' practices. Farmers use these fields almost every year.

During the dry season salinity and acidity increase in the topsoil due to redistribution of salts and acids in the upper 60 cm of the profile. Oxidation does not contribute to the acidity (van den Elshout 1987). When the rainy season starts, the ridges are leached. When bunds in between fields are opened, the leaching water can be flushed to low-lying fields and to the creeks.

Rice is transplanted as early as possible, because water availability at the end of the rainy season is the most limiting factor. Fields fall dry at the end of October or, in somewhat wetter years, by mid November. Fields which have been transplanted late always yield less than the mean yield for fields in this category. In fields where the water availability is limited, irregular crop stands are observed.

2) **Fields neighbouring the terrace**
These fields, although close to the villages, are not used very often. When fields are not used, the ridges slump which reduces the possibility of leaching. These soils have relatively low pH values, caused by seepage from the terrace. Seepage also brings Fe and Al into the rice fields, making these fields unsuitable for early transplanting. As these fields are also the first ones to fall dry after the rains have stopped, the growing season is too short for rice under the present hydrology regime.

3) **High-lying fields suffering from salinity**
Fields suffering from salinity are located close to the tidal creeks. During the dry sea-

<table>
<thead>
<tr>
<th>Table 1a pH (1:2.5) and EC (1:2.5) of the ridges (0–20 cm) and the standing water (not diluted) in the fields of category 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>pH</strong></td>
</tr>
<tr>
<td>Soil, dry season</td>
</tr>
<tr>
<td>Soil, planting time</td>
</tr>
<tr>
<td>Soil, rainy season</td>
</tr>
<tr>
<td>Standing water</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 1b Some field and yield characteristics of the fields of category 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean height of the ridges (cm)</td>
</tr>
<tr>
<td>Mean max. water level on top of the ridges (cm)</td>
</tr>
<tr>
<td>Mean paddy yield (kg ha⁻¹), 32 observations</td>
</tr>
<tr>
<td>Min. and max. paddy yield measured (kg ha⁻¹)</td>
</tr>
</tbody>
</table>
Table 2a pH (1:2.5) and EC (1:2.5) of the ridges (0–20 cm) and the standing water (not diluted) in the fields of category 2

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (mS cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil, dry season</td>
<td>3.5–4.0</td>
<td>2.5–4</td>
</tr>
<tr>
<td>Soil, planting time</td>
<td>4.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Soil, rainy season</td>
<td>3.5–5.0</td>
<td>2–4</td>
</tr>
<tr>
<td>Standing water</td>
<td>3.5–5.0</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

Table 2b Some field and yield characteristics of the fields of category 2

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Mean height of the ridges (cm)</td>
<td>10</td>
</tr>
<tr>
<td>Mean max. water level on top of the ridges (cm)</td>
<td>15</td>
</tr>
<tr>
<td>Paddy yield (kg ha⁻¹), observation</td>
<td>950</td>
</tr>
</tbody>
</table>

season, evaporation of the saline groundwater increases the salinity of the topsoil. This can be reduced at the beginning of the rainy season to a lower but still critical level. During the rainy season, the tidal creeks remain brackish up to 10 km inland. The highest spring tides occur in August and September and, although farmers check the outer dikes very often during this period, only proper maintenance can prevent the dike from breaking. Crops have often been destroyed by saline water intrusion.

The construction of dams to prevent saline water intrusion into the creeks has not proved successful. In the study area, one large creek has been closed by a sluice; this resulted in a drastic lowering of the watertable (1.2 m) and oxidation of the subsoil so that all the fields had to be abandoned (van den Elshout 1987).

As the salinity is increasing rapidly with decreasing water level in the field, the need for early transplanting is greater than in the fields of category 1. Acidity in the topsoil is not a problem, as these fields are reclaimed from levees and raised tidal flats under *Avicennia* that have no pyrite in the topsoil. Only very few fields of this category are in use.

Table 3a pH (1:2.5) and EC (1:2.5) of the ridges (0–20 cm) and the standing water (not diluted) in the fields of category 3

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (mS cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil, dry season</td>
<td>4.0–5.0</td>
<td>3.5–16.0</td>
</tr>
<tr>
<td>Soil, planting time</td>
<td>5.5</td>
<td>3.2</td>
</tr>
<tr>
<td>Soil, rainy season</td>
<td>4.5–6.5</td>
<td>1.5–3.0</td>
</tr>
<tr>
<td>Standing water</td>
<td>4.0–7.5</td>
<td>1.5–16.0</td>
</tr>
</tbody>
</table>

Table 3b Some field and yield characteristics of the fields of category 3

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<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Mean height of the ridges</td>
<td>12</td>
</tr>
<tr>
<td>Mean max. water level on top of the ridges (cm)</td>
<td>20</td>
</tr>
<tr>
<td>Mean paddy yield (kg ha⁻¹), 7 observations</td>
<td>340</td>
</tr>
<tr>
<td>Min. and max. paddy yield measured (kg ha⁻¹)</td>
<td>0–1650</td>
</tr>
</tbody>
</table>
4) **High-lying fields with limited drainage**

The physiographic position of these fields is comparable to the fields of category 1 but, due to the very limited drainage possibilities of the surrounding low-lying fields, fields of category 4 have too high water levels and limited possibilities for flushing. Salinity is not a problem but pH values are low. With the decreasing water level at the end of the rainy season, the pH decreases rapidly.

Farmers who plant in good time before the peak water level in the fields, may obtain good yields. When rice is planted after the peak water level (end of October), the growing period becomes too short (fields fall dry mid December). Many of these fields are flooded too deeply to consider rice cultivation.

5) **Low-lying fields with sufficient drainage**

Low fields with sufficient drainage give the highest yields in the study area. Ridges are high, which increases possible rooting depth, the availability of nutrients, and the possibilities for leaching. Because fields in the depression can drain towards a creek, the fields are flushed as well. During the dry season, saline water can be taken in through the outer dike so that the farmers can work the soil during the dry season. This is an advantage since the construction of high ridges is time-consuming and labour is scarce. Unfortunately, the surface area of the category is small.

Van den Elshout (1987) showed that the intake of saline water has no influence on the salinity of the fields in the following growing season. According to the farmers, saline water kills weeds very efficiently.

Water is available in very large quantities and fields remain wet until January. Hence salinity and acidity do not pose problems; apparently sufficient dilution takes place. As the present rice varieties do not grow fast enough to follow the increasing water level at the beginning of the rainy season, rice is transplanted at the end of September, after the peak water level. Harvesting takes place in December-January.

6) **Low-lying fields with limited drainage**

Intrinsically, the possibilities of these fields should be similar to the former category:

<table>
<thead>
<tr>
<th>pH</th>
<th>EC (mS cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil, dry season</td>
<td>3.8–4.5</td>
</tr>
<tr>
<td>Soil, planting time</td>
<td>4.5</td>
</tr>
<tr>
<td>Soil, rainy season</td>
<td>3.5–5.4</td>
</tr>
<tr>
<td>Standing water</td>
<td>4.0–5.0</td>
</tr>
</tbody>
</table>

**Table 4b Some field and yield characteristics of the fields of category 4**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean height of the ridges (cm)</td>
<td>10</td>
</tr>
<tr>
<td>Mean max. water level on top of the ridges (cm)</td>
<td>31</td>
</tr>
<tr>
<td>Mean paddy yield (kg ha⁻¹), 7 observations</td>
<td>1010</td>
</tr>
<tr>
<td>Min. and max. paddy yield measured (kg ha⁻¹)</td>
<td>450–2180</td>
</tr>
</tbody>
</table>
ridges are high and water is plentiful. However, drainage possibilities are limited due to the low drainage capacity of the creek.

The water level in the fields increases faster than in the fields of category 5 and, although the ridges are leached, there are no possibilities for draining acidity and salinity. The salinity and acidity originate from the fields in the depression as well as from the surrounding high-lying fields. Farmers transplant when the water level in the fields is decreasing. At the same time, pH decreases rapidly and EC increases, resulting in poor crop performance.

The future of the system

Farmers make optimal use of the natural resources of the area. The rice farming system has flexibility that has enabled it to continue for 5 generations. However, rainfall has now decreased and labour availability is less, due to migration in the dry season, so

Table 6a pH (1:2.5) and EC (1:2.5) of the ridges (0-20 cm) and the standing water (not diluted) in the fields of category 6

<table>
<thead>
<tr>
<th></th>
<th>pH</th>
<th>EC (mS cm⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil, dry season</td>
<td>3.5-4.0</td>
<td>&lt; 8.0</td>
</tr>
<tr>
<td>Soil, rainy season</td>
<td>4.0-4.5</td>
<td>1.0-3.5</td>
</tr>
<tr>
<td>Standing water</td>
<td>3.5-4.0</td>
<td>1.0-5.0</td>
</tr>
</tbody>
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Table 6b Some field and yield characteristics of the fields of category 6

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<thead>
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</tr>
</thead>
<tbody>
<tr>
<td>Mean height of the ridges (cm)</td>
<td>24</td>
</tr>
<tr>
<td>Mean max. water level on top of the ridges (cm)</td>
<td>35</td>
</tr>
<tr>
<td>Mean paddy yield (kg ha⁻¹), 7 observations</td>
<td>350</td>
</tr>
<tr>
<td>Min. and max. paddy yield measured (kg ha⁻¹)</td>
<td>270-1020</td>
</tr>
</tbody>
</table>
the resilience of the system is less. Traditional ceremonies are held less frequently, and only in years when there has been a reasonable rice yield, as in 1986.

To maintain the pillar on which the Balanta society is built – the rice cultivation system – external inputs will be needed. Experiments with interventions of the project showed that the construction of small drainage structures, which do allow saline water intake, can help farmers with their water management. The construction should not induce lowering of the groundwater table, and water management units should be adjusted to the present organizational structures. Sedimentation should be avoided and, therefore, drainage devices should be built as far upstream as possible.

Fertilizer trials showed that the application of 30 kg N and 30 kg P₂O₅ in fields with mean yields of 1000 kg paddy ha⁻¹ could increase the yield by about 500 kg paddy ha⁻¹ (Ukkerman and van Gent 1989). The use of fertilizers can be decided by the individual farmer, provided that fertilizers are available when they are needed.

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Volume V: Soils, 50 p. and 4 maps
Volume VII: Bibliography
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Farmers’ experiences in using acid sulphate soils: Some examples from tidal swampland of southern Kalimantan, Indonesia

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Abstract

Millions of hectares of tidal swamplands in Indonesia have been opened-up by two ethnic population groups, the Banjarese in southern Kalimantan and the Buginese in Sumatra. They are very skillful at reclaiming coastal swamps with acid sulphate soils for the cultivation of rice as well as other crops such as coconut, citrus and rambutan. Farmers’ management in utilizing coastal swamp soils is greatly influenced by socio-economic and micro-ecological conditions. The latter vary according to natural land, water and vegetation. The Banjarese farmers apply escape mechanisms in their cropping system, starting from their water management system, the land preparation and subsequent transplantation sequence as well as in the choice of the varieties grown and, eventually, the switch to crops other than rice. Their indigenous knowledge is very valuable for, and applicable in land evaluation, land use planning and land development projects.

Introduction

Tidal swamplands are among the major natural resources of Indonesia. These vast lands occur mostly along the coasts of Sumatra, Kalimantan and Irian Jaya. In their natural state, they are rich in plant and animal life. Also, they offer tremendous potential for food production as well as space for the rapidly expanding population of Indonesia. Prospects for swampland development are great, indeed, but so are the problems. Soil constraints severely limit agricultural development.

Soils in the tidal swamps are mainly of marine/estuarine alluvial origin and peats (Driessen and Sudjadi 1984). Soils developed in alluvium include both actual and potential acid sulphate soils while most of the peats in Indonesia are underlain by pyritic sediments. These potentially acid conditions severely restrict agricultural productivity and development options. There are some 1.5 to 2 million ha of these acid sulphate soils in Indonesia (NEDECO/Euroconsult/BIEC 1984).

Reclamation of tidal swampland in southern Kalimantan has been carried out over some hundred years already by the Banjarese population who live mainly along the coast and, further inland, on the river floodplains of the area. Only in the 1920s, large scale reclamation started, especially near Banjarmasin (Figure 1). Some 40 years later, by 1965, almost 65,000 ha of tidal swampland had been reclaimed by the Banjar-
ese in South Kalimantan, mainly along the banks of the Barito river (Schophuys 1969; Idak 1982).

It is estimated that, in total, the Banjarese in Kalimantan have opened-up approximately 1 million ha of swampland (BARIF 1985) but because they switch to crops other than rice or have abandoned the older lands, the remaining Banjarese riceland is presently only about 165 000 ha in southern Kalimantan (Collier et al. 1984). In comparison, lands reclaimed in the framework of the Indonesian government’s transmigration projects covered in total approximately 33 000 ha in the period 1969 to 1974, 242 000 ha between 1974 and 1979, and 396 000 ha between 1979 and 1984. Out of the latter total, some 96 500 ha are in South and Central Kalimantan provinces. These lands are earmarked for transmigrants from Java and Bali.

Farmers’ techniques of, and approaches to, local and traditional cultivation are usually micro-topographically oriented (Watson and Willis 1985). This traditional approach incorporates the interaction of crop varieties, soil and water management, and socio-economic factors. There are many examples of successful management of tidal swampland in general, and of acid sulphate soils in particular, using local and traditional techniques. The following discussion puts into perspective the strategies and practices of Banjarese farmers in utilizing tidal swamplands for crop cultivation and in coping with the specific soil constraints of sulphate acidity and related toxicities. Most of the information was gathered by interviewing the farmers during extensive soil surveys in the Pulau Petak area of southern Kalimantan.

Tidal swampland of Indonesia with special reference to Pulau Petak in Southern Kalimantan

**Climate**

Southern Kalimantan has a humid tropical climate. Annual rainfall is between 2100 and 3200 mm with seven to nine wet months (rainfall > 100 mm). During the wet season (October/November through May/June), monthly rainfall averages 250 mm, while from July through September it is about 100 mm/month. Daily temperatures ranges between 25 and 35°C with a slight seasonal variation, and relative humidity varies between 75 and 90 per cent.

**Hydrology**

Kselik (1990) has subdivided the study area into four tidal land classes (Figure 1). This classification is based on the tidal flooding regime as well as on the drainage characteristics. Type A comprises the areas between mean low tide and mean high neap tides, which are under the influence of daily flooding and drainage. Type B covers the areas between mean high neap tides and mean spring tides. These areas are flooded during spring tides only but they are subjected to daily drainage. Type C is land above spring tides but, still, under the influence of the tide. There is no tidal flooding in these areas but they are permanently drained. Type D land is beyond the influence of tide; there is no tidal flooding and limited drainage. The watertable in this areas drops only during the dry season.

Pulau Petak has an extensive and very intricate system of drainage canals that has been dug by the Banjarese farmers on their own initiative, as well as by government agencies that became involved in the 1970’s and 80’s.
Physiography and topography
Pulau Petak comprises five major physiographic units: alluvio-marine plains which occupy the largest area, river levees, coastal ridges, old river beds and peat domes (Janssen et al. 1990). The river levees are found along the Barito and Kapuas Murung/Pulau Petak rivers and along old river beds. The peat domes, which at one time covered large areas, are hardly found nowadays. Reportedly, they were between 2 and 3 m thick (Van Wijk 1951). Where peat is still present, in the centre of Pulau Petak (see Figure 2), it is less than 1.5 m thick.

Over the whole area, slopes are generally less than 1 per cent but river levees and coastal ridges, both belonging to active systems as well as from former rivers or coastlines, form subdued local relief with height differences of up to 1 m.

Soils
There are two major soil types in the area (Hendro Prasetyo et al. 1990): The soils of the alluvio-marine plains and the old river beds have a brown layer, 20-60 cm, overlying a gray layer which is generally pyritic (up to 8 per cent FeS2). These soils are rich in organic matter (5-14 per cent), poorly drained, half to nearly ripe and most of them are mottled. The pH is between 3 and 4. A peaty thin layer (10-20 cm) overlies most of these soils. In terms of Soil Taxonomy (Soil Survey Staff 1987), they
are classified as Sulfaquents (the potential acid sulphate soils) and Sulfaquepts (the actual acid sulphate soils) (Sutrisno et al. 1990).

The soils of the levees and coastal ridges have similar texture but they are better drained, strongly mottled, nearly ripe to ripe. Their organic matter content is between 4 and 6.5 per cent and pyrite content is low ($\text{FeS}_2 < 1.5$ per cent). Soil reaction is slightly acid to neutral ($\text{pH} 5-6$). Gray pyritic subsoil occurs at greater depth ($> 125 \text{ cm}$). In Soil Taxonomy, these soils are classified as Tropaquepts mainly.

Scattered over the island and in the remaining peat domes, peat soils occur (Figure 2).

The art of tidal swamp cultivation; some examples from Banjarese farmers

With abundant fresh water available, especially during the wet season, tidal swamps seem an ideal setting for wetland rice cultivation. This has been recognized by the Banjarese farmers in Kalimantan and the Buginese farmers in Sumatra. For centuries,
the Banjarese have been opening-up and cultivating tidal swamplands in Kalimantan. It is believed that the Buginese, who in fact originate from Sulawesi, have learned from the Banjarese during their contacts in South and East Kalimantan. Both the Banjarese and the Buginese are very skilful at reclaiming the tidal swamps for the production of rice as well as other crops such as coconut, orange, rambutan, mango and cloves (Schophuys 1969, Noorsyamsi and Hidayat 1974, Damanik 1990).

In Kalimantan, some 1 million ha of tidal swampland and in Sumatra some 0.9-1 million ha have been reclaimed by these two peoples (BARIF 1985). In Kalimantan, however, not more than 500,000 ha of these lands are presently being cultivated and only about one-third of this area is used for rice (Collier et al. 1984). In addition, some 96,500 ha of swamplands has been reclaimed in the framework of government-sponsored transmigration projects, involving the settlement of Javanese and Balinese farmers.

**Choosing the land**

Opening new land starts with a scrutiny of the vegetation on the banks of rivers and creeks. Dense foliage is taken by the farmers as an indicator of generally favourable soil conditions. Obviously, the slightly higher-lying, better-drained, non-potentially acid soils of the river levees and coastal ridges are preferred. Not only are the physical conditions better for settlement and for cultivation but, also, the adjacent natural water courses provide easy access. For the latter reason, of course, much spontaneous settlement and cultivation has taken place along the main canals, i.e. the Tamban, Serapat and Talaran canals, that were constructed by the government since the 1920s (Figure 1).

Nipa palm (*Nipa fruticans*) is an indicator of brackish or saline water whereas sago palm (*Metroxylon spp.*) indicates fresh water conditions. The Buginese generally avoid saline or brackish areas, the Banjarese, however, accept both areas as long as the nipa growth is not too dense, as that would reflect unripe soil conditions. The Banjarese avoid peats more than 1 m, but they do like to reclaim the land surrounding such peat domes as the good-quality water flowing from these domes is preferred for irrigation.

**Land reclamation and rice cultivation**

After clearing trees and shrubs from the selected site by slashing and burning, small drainage ditches are dug, called 'handils', some 0.5-1 m depth and 2-3 m wide. Their size depends on the magnitude of the tidal movement: close to the sea the handils are smaller than inland. Usually, they are dug perpendicular to the river or canal.

The Banjarese work in groups of seven to ten to dig the handils. The name handil originates from the Dutch word 'aandeel', meaning a share or part of the work (Idak 1982). The person chosen as the group leader (kepala handil) has the right to the land at the head of the handil. Usually his name is used for that of the handil. For each family, a plot of 15 × 30 depa (1 depa = 1.7 m) is marked out (Idak 1982). In larger areas, the parcels could be up to 30 × 30 depa (Collier et al. 1984). The user rights of the selected sites are awarded by the village head (kepala kampung). A family that wants more land is allowed to extend the handil further inland. People settling later may do the same (handils thus may extend up to 2-3 km inland) or they compensate those who opened up the land.
Secondary drainage ditches are built perpendicular to the handils. Near the sea, in tidal land class A, intervals between these ditches are generally 10 depa. Their depth is approximately 0.5 m and their width 0.3 m. In contrast, secondary ditches are not made in areas belonging to land class C. Instead, tabat (small weirs made of clay or ironwood) are built here, at the head of the handil, to conserve water during the cultivation cycle. The tabats are usually constructed in February when rainfall begins to decrease.

Land preparation for rice cultivation is very simple. It consists of slashing and cutting the weeds or peeling the land with a tajak, a scythe-like tool with a short handle. The cut vegetation is left in the field for 10-15 days and is then gathered into heaps which are turned over every week or so. Upon complete decomposition, this compost is spread over the land prior to planting. The land is neither plowed nor harrowed (Noorsyamsi and Hidayat 1974). The compost not only serves as a source of nutrients, but it also helps to keep the underlying soil, including any sulphidic material in a relatively reduced state (Arifin 1989).

Tidal rice is usually sown at the beginning of the wet season, in October or November, on rather dry seedbeds and the seeds are covered with ash. The seeding rate is approximately 5 kg seed for a 150 m² seedbed that, after two transplantings, will serve 1 ha. After 30-40 days, the seedlings are transplanted to the lowest parts of the rice field. This is repeated after 40 days into larger areas which still cover only about one-third of the total area to be planted. Final transplanting depends on the water level in the main field. On type A land, the planting should be ready by February, whereas type B or C lands are planted from March through April. Traditional, tall, photoperiodic varieties are used that take some 9 to 10 months till maturity. The crop is harvested in August-September by cutting the panicles with a knife. The yields range widely from 1 to 4 tons/ha. The higher yields are obtained on non-acidified soils (Muhrizal Sarwani, unpublished farmers' interview data). Rats are a main pest adversely affecting rice yields.

Adaptation of Banjarese cropping systems to soil changes
After some 3-5 years of cultivation, the rice yields start to decrease. The yield decline is caused by a number of factors, including acidification which is promoted by drainage and by the gradual disappearance of the peat layer. The Banjarese then gradually switch to other crops. In general, the conversion from rice-based cropping systems into coconut-based cropping systems is gradual and starts with the arrangement, in rows, of individual heaps of dug-out soil material 75 \times 75 \times 75 cm, called tembokan (Figure 3). On top, a small heap 30 \times 30 \times 30 cm of topsoil material is placed (the

![Figure 3 Cross-section of a tembokan (Arifin 1989)](image-url)
tukungan) in which coconut or other seedlings are planted. Each year, new topsoil is added to the tembokan which, eventually, forms a long raised-bed, or sorjan. Acid formed in the sorjans is flushed away by tidal floods or by percolating rainwater. Throughout the years of building the sorjans, rice is cultivated in the in-between basins. Eventually, if these basins become too deep for cultivation, they may be used for fish.

Farmers are keenly aware of the higher economic returns of tree crops as compared to rice cultivation (KEPAS 1985). Earning extra income is very important with respect to a possible pilgrimage to Mecca which, within the Banjaranese society, is a well established aspiration. Especially on type A lands having strong tidal influence, even if the rice yields are not decreasing, the farmers initiate tukungan across their paddy fields in order to grow coconut, orange, mango, clove and coffee. The same holds true for the higher lying areas (type B lands).

Acidified areas beyond the influence of the tides (land type C) are used for the cultivation of such acid-tolerant crops as pineapple, rambutan and ketapi (*Sandoricum koetjape*) on raised beds. Observations near the Talaran canal in the northern part of Pulau Petak showed that these crops perform very well even at soil pH between 3 and 4. Very often, the pH of the water standing on these soils is as low as 2.5.

Not all the rice land is converted, however, and commonly about three quarters of the land in Pulau Petak is left idle. Especially if subsidence and stagnating water play a role in yield decreases, the land may be abandoned altogether.

Discussion and conclusions

The Banjaranese farmers have long recognized that water management, together with the use of acid- or salt-tolerant crops or crop varieties, is the key to successful management of tidal swampland in general and acid sulphate soils in particular. The handil drainage system allows limited oxidation of pyrite while toxic elements produced can be leached by the tides or rainwater. The size of the handils is adapted to either the occurrence of pyrite at shallow depths, where the handils are shallow but wide; or to the amplitude of the tidal fluctuation, if the rise and fall is great the handils are narrow and deep.

Also, the drainage intensity is adapted to the physical conditions. In the low-lying areas with daily tidal flooding, type A lands where pyrite generally occurs within 50 cm from the surface, drainage ditches are approximately 10 depa (17 m) apart. Here, flushing of acids formed in the topsoil during the dry season is enhanced by the use of brackish tidal water. On type C lands which, in Pulau Petak, contain both potential and actual acid sulphate soils, the farmers use rainwater to leach acids and toxic elements by opening the tabats two months prior to transplanting. If rainfall is insufficient, it is supplemented with the water from the remaining peat domes which is of good quality (Klepper et al. 1990). Konsten et al. (1990) found that, during the wet season, the pH of the surface water in type C lands increases gradually while the salinity of the water decreases.

Raw salt is sometimes applied to the rice fields at the beginning of the rainy season. Applications of 100-200 kg/ha are given when farmers feel that rice yields are declining. The practice is then repeated every 2 to 3 years. Raw salt replaces Al from the adsorption complex (Van Mensvoort et al. 1991) and it also alleviates iron toxicity problems.
in the same way as leaching with brackish water (Muhrizal Sarwani, unpublished data).

The method of land preparation is also noteworthy. By applying the ajak only, the farmers practise minimum tillage. Neither plowing nor harrowing is done. In other words, the pyrite in the subsoil is not disturbed and any peat is kept as such. At the same time, green manuring is being practised as the decomposed organic matter eventually is spread over the fields. Ottow et al. (1991) have pointed to the additional beneficial effect of organic matter in alleviating iron toxicity. The system of triple transplanting seems a typical local adaptation to acid sulphate conditions and related toxicities (Sevenhuysen et al. 1989). The use of old seedling rice plants to alleviate primary iron toxicity has been recommended in a number of studies (Noorsyamsi and Hidayat 1974; Van Breemen and Moorman 1978; Prade et al. 1988).

The surface peat layers play a key role in the cultivation of the acid sulphate soils in southern Kalimantan. Not only are they a source of nutrients but, also, they regulate loss of water due to evaporation in the dry season and they maintain reduced conditions in the soil underneath, preventing the oxidation of pyrite.

We conclude that the Banjarese farmers apply escape mechanisms in their cropping systems; starting from their water management system, the land preparation and subsequent transplantation sequence as well as in the choice of the varieties grown and, eventually, the switch to crops other than rice. Their practices are adjusted to the microtopography, hydrology and soil. Local custom calls for group participation in reclamation works, while economic and changing ecological conditions determine the decisions of individual farmers to change to crops other than rice. Tidal swamp cultivation by the Banjarese has proven to be a sustainable and equitable system (KEPAS 1985) though at low level of productivity. Research as well as development projects on acid sulphate soils, and tidal swampland in general, can benefit from integration of the knowledge and experience of local farmers (Watson and Willis 1985; Noorsyamsi and Sarwani 1989). This interaction could also facilitate acceptance of new technology by the local farmers.

References


