PROBLEMS AND PERSPECTIVES OF AGRICULTURE ON ALLUVIAL SOILS OF INDONESIA *

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RINGKASAN

Sedjak permulaan adanja manusia dataran² aluvial selalu memegang peranan penting didalam kehidupan manusia. Hal ini disebabkan mudahnja didatangi untuk berburu dan kemudian karena ketjotjokan sebagai tempat tinggal dan untuk bertjotjok tanam.

Dalam banjak kedjadian tanah² aluvial mempunjai produktivitas rendah. Faktor² jang menjebabkan keadaan ini ialah bahaja bandjir, air tanah jang terlalu dangkal, drainasi dachil jang buruk, masalah kegaraman tanah dan air, pembentukan lapisan gambut jang terlalu tebal, bahaja timbulnja "cat clay", keadaan fisik tanah jang menjulitkan pengolahan tanah, terkena pasang-surut laut.

Di Indonesia tanah² aluvial bersama dengan tanah² organik jang berasosiasi mentjapai luas 44,6 djuta hektar. Ini adalah 23,5% dari luas daratan Indonesia. Mengingat hal ini, maka tanah² tersebut harus memegang peranan penting dalam pengembangan dan pembangunan pertanian di Indonesia.

Suatu klasifikasi tentang tanah² aluvial harus dapat memperlihatkan perbedaan² jang azasi jang ada diantara tanah² itu. Perbedaan-perbedaan itu, jang menentukan kesuburan dan kemampuannja, adalah akibat dari kelainan proses pembentukan geologinja. Oleh karena tanah² aluvial adalah tanah² muda, maka fisiografi merupakan landasan jang sesuai untuk menjusun rangka klasifikasinja. Dalam tulisan ini dikemukakan pula kemungkinan klasifikasinja menurut sistim klasifikasi "7th Approximation".

Masalah utama terdapat dalam bidang hidrologi. Karena itu penekanan harus diletakkan pada pengelolaan air. Tudjuan dari pengelolaan air ialah pengaturan pemberian dan pengurangan air, baik untuk memenuhi kebutuhan tanaman akan air dan aerasi maupun untuk mempertahankan keadaan fisik tanah jang baik, penguasaan kegaraman tanah dan air, pengendalian bandjir, reklamasi wilajah² bandjir, gambut, cat clay dan pasang-surut. Uraian ini djuga menjadjikan tjontoh², bahwa sebelum pengelolaan air dapat dilaksanakan dengan baik pemasukan teknologi madju dalam bertjotjok tanam seperti bibit unggul dan pemupukan tidak banjak artinja.

SUMMARY

Since the early days of the existence of man alluvial plains play an ever important role in human life. First as an easily accessible hunting ground and later on as a convenient place to settle and to work the soil to raise crops.

In many cases the productivity of alluvial soils is low. Several adverse factors that depress the yield of crops are floods, too shallow ground water, poor internal drainage, soil and water salinity, the formation of excessively thick peat layers, the development of injurious cat clay, soil physical condition which counteracts the development of a good tilth, the influence of tidal movements.

44.6 million hectares, or 23.5% of the total land area of Indonesia, are covered by alluvial soils and the associated organic soils. So alluvial plain soils should significantly contribute to Indonesia's efforts in boosting its agricultural production.

A classification of alluvial soils should show the principle differences among them. Since these soils are young their differences in fertility and capability are closely related to the geological forces that govern their existence. Therefore physiography is an appropriate basis for the classification of these soils. It has been attempted also to apply soil classification according to the 7th Approximation.

The major problems are linked with the hydrology of the area. Consequently, a strong emphasis should be given on water management. This includes irrigation and drainage, salinity control, flood control or regulation, and reclamation of peat land, cat clay soils and tidal areas. Several examples are presented to show that the introduction of better plant varieties and fertilization mean little unless a proper water management has been established first.

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Since the early days of the existence of man alluvial plains play an ever important role in human life. First as an easily accessible hunting ground and later on as a convenient place to settle and to work the soil to raise crops. Many prehistorical and historical evidences point to this. In addition to their accessibility the soils of alluvial plains are fertile, at least more so than their surrounding upland soils.

The famous remains of the Meganthropus and Pithecanthropus were found in what was once the flood plain of the Solo River in Central Java and that of the Brantas River in East Java (high and low terraces, fluvial and estuarine deposits). The history of Indonesia, for example, bears many evidences of the prominence of alluvial plains as centers of political powers and cultural developments. The kingdoms of Çrivijaya in the coastal alluvial plains of Riau and Jambi (Sumatra), Tarumanegara in the alluvial plain between the rivers Tjitarum and Tjiliwung (West Java), Majapahit in the deltaic plain of the Brantas River (East Java), and Kutai in the lower stream area of the Mahakam River (East Kalimantan), are just a few to mention.

It is true that the productivity of alluvial soils is in many cases low. This is due to several adverse factors that depress the yield of crops. When man was still primitive in his needs, and population was still sparse, there was no necessity for big yields and diversified products. However low the productivity of the soil was it had been able to sustain a population.

With the development of modern thoughts and the tremendous population pressure existing these days it becomes compulsory to draw more and more plant nutrients from the soil to support bigger and still bigger yields of many kinds of crops. Every harmful or suppressing factor should be corrected, and every inadequacy in one or more of the productivity factor(s) has to be filled.

Indonesia has considerable areas of alluvial plains, inland along big rivers and in large depressions as well as along the coast. It has been estimated that 44.6 million hectares, or 23.5%, of the Country's land area are covered by alluvial soils and their associated organic soils (MULJADI and ARSJAD, 1967). Of these 37.5% is in Sumatra, 30.1% in West Irian, 24.9% in Kalimantan, and 4.6% in Java. The rest, namely 2.9%, are scattered among the islands of Sulawesi, Nusa Tenggara and Maluku. It becomes clear that alluvial plains should contribute a significant share to Indonesia's efforts in boosting its agricultural production.

Many problems concerning the utilization of these soils, however, are still not fully understood yet. The ways that will lead to the solution of the problems are far more from being established. This paper is attempted to show the various problems that may be encountered in utilizing alluvial soils, and what the possibilities are if they can be developed properly. Since agricultural development is in fact an integral part of community development, more so in developing countries, social and economical considerations are of equally importance as technical computations. The author lacks the capacity to elaborate on the social and economical aspects of the case. Therefore only the physical matter and the technical implications will be discussed.

About The Term „Alluvial"

There are two different usages of the word "alluvial". The first meaning of it is physiographic. It pertains to alluvium, which is a general term for all detrital deposits resulting from the operations of modern rivers, including the sediments laid down in river beds, flood plains, lakes, fans at the foot of mountain slopes, and estuaries. The subaqueous deposits of seas and lakes are not intended to be included. Permanent submergence is not a criterion (AMERICAN GEOLOGICAL INSTITUTE, 1962). The second meaning indicates a soil of the order azonal originated from materials deposited from flowing or still water. The term refers not directly to "soils from alluvium" but to young soils in flood plains and deltas actively in process of construction and which have no developed characteristics beyond those inherited from the alluvium itself (USDA SOIL SURVEY STAFF, 1951; JACKS, TAVERNIER and BOALCH, 1960). In the soil classification developed by the Soil Research Institute of Indonesia alluvial soils are restricted to fine textured azonal soils. The coarse textured soils are included in the great soil group regosol, regardless of whether they were of alluvial origin.

In this paper the physiographic meaning is employed. In fact, the term "alluvial soils" had been discarded from the latest proposed system of soil classification (USDA SOIL SURVEY STAFF, 1960, 1964, 1967). In addition, alluvial soils have only one feature in common, namely their physiographic position. Therefore alluvial soils are often classified by characteristics to their physiographic position (BURINGH, 1968). Morphometric characteristics among alluvial soils are quite different due to distinct forming factors. Hence grouping them under one common name may introduce confusing or conflicting ideas about their capability.

Thus with the term "alluvial soils" is merely meant "soils that are generally found in alluvial plains and alluvial basins". In the case of Indonesia it comprises all kinds of soils formerly called alluvial soils, hydromorphic alluvial soils, automorphic gleied alluvial soils (stagnoglei and pseudoglei soils), low humic glei soils, humic glei soils, organosols, saline alluvial soils, calcareous alluvial soils, cat clay soils, and a part of the regosols having clearly established evidences of being formed as alluvial deposits.

Characteristics Of Alluvial Soils

It has been said that differences among alluvial soils were the result of varied constructional forces. These factors can be separated into three groups: the source of the materials that built up the plain, the transportation characteristics, and the environmental condition under which sedimentation has taken place. The first factor determines the initial chemical and mineralogical make up, and the physical properties of the sediment. The second factor modifies or alters the original characteristics by various ways, as the mechanical differentiation of the particle size and shape distribution, selective and partial solution and grinding of the composing particles thereby altering their shapes (roundness and sphericity) and reducing their sizes, mixing materials from different sources or mixing transported materials with bedding materials, and brings about a change in the ratio of light to heavy minerals by the process of elutriation. Depending upon the duration and pattern of transportation, and upon the chemical composition of the transporting water, other more intensive alterations might as well take place such as oxidation (coupled or not with reduction), carbonation, hydrolysis, hydration, ion exchange, and mineral particle exhange between the transported and bedding material. The third factor pertains to elevation, relief position (or energy environment), average level of ground water and its seasonal fluctuation, macro and micro climatic condition, initial surface drainage pattern and its development (integration, density and uniformity), marine influences in the form of deposition in sea water and the subsequent subsurface encroachment of sea water and/or tidal action through estuaries, and vegetative cover.

The characteristics exhibited by alluvial soils determine the capability of these soils for agriculture, sometimes by sedimentological inference. The shape distribution of the particles related to the distance and mode of travel, for example, may to a certain extent imply the readiness of the material to change under the physical and chemical action of water. The site quality where sedimentation is taking place, or had taken place, contains a prominent part of the problems of managing alluvial soils. One of them is the hydrology, including that governs salinity and acid clay formation in coastal plains and acid peat development in backswamps.

Classification Of Alluvial Soils.

Alluvial soils are immature or incipient soils. Therefore the criteria for classification and agricultural evaluation should include"non-soil" elements. The following grouping seems to be sufficient to depict on a reconnaissance basis the problems encountered in alluvial soils.

I. Inland alluvial

1. River plains

   a. Flood plain soils: flat relief or frequently it acquires an elongated basin-like shape bordered at one side by its upland and by the natural levee of the river at the other; seasonally flooded if not protected; especially in the basin-like plains the periodic inundations become more serious by the additional ponded rain water; ground water table is usually moderately deep but it may become shallower when the river bed got sufficiently aggraded as to make the river influent.

   b. Soils of high and low terraces: step-like relief; well drained especially the higher laying parts; free from floods except the low terraces which are occasionally flooded during extremely wet weather condition.

2. Depressions

   They were former lake bottoms or sedimentation basins receiving runoff from their surrounding highland. Lake bottom soils (lacustrine soils) are originated from subaqueous sediments (mud clays), while basin soils are deposited subaerially. In a very wet climate the shallow depressions were usually converted into swamps or marshes. Here the sediment laid down on the bottom will eventually develop into palustrine soils. An upper layer rich in organic matter may formed in lacustrine and palustrine soils accompanied by hydromorphic or automorphic gleiing. The formation of a muck or peat superficial layer is a frequent feature of palustrine muds. The thickness of this histic layer ranges from a few centimeters to several meters. Internal drainage is better in basin soils because of a rather coarser texture or a somewhat better aggregation, although some have a shallow ground water table if the bottom of the basin is close to the general ground water level of the area.

3. Alluvial fans

   These are essentially talus deposits carried down the mountain slopes by accelerated runoff or during limited periods of heavy discharge of small streams. The relief is gently sloping to strongly sloping depending on the texture and the degree of particle aggregation of the material. The drainage is good to somewhat excessive. In Indonesia most of these soils are composed of volcanic ash which are found on the lower reaches of mountain slopes and at the foot of those slopes.

II. Coastal alluvial

1. Coastal plains

   a. Periodically saline soils: initially formed from materials sedimented in sea water and become exposed due to regression of the sea and/or the general uplift of the land mass; during a second sedimentation cycle the sediments were laid down in brackish swampy environment; after the completion of these periods a third sedimentation cycle begins where deposition takes place subaerially in a non-saline environment; capillary upwards movement of soil moisture during dry seasons from a shallow and saline ground water makes the uppermost soil layer still discernibly saline; the salinity of the soil increases with depth; dilution occurs in the wet season and during heavy rains, but salinity recurs in the dry season; the soils are mostly heavy with a great swelling and shrinking capacity; flood incidences are frequent and occur regularly in the wet season; if the floods carry enough load the aggradation continues, the ground level gradually increases with the consequence of reduced wetness, and finally the land becomes freed from regularly occurring floods.

b. Non-saline soils: these are actually the landwards continuation of the periodically saline soils; the subaerial sediments are thicker and further inland the sediments were laid down on former beach material; the ground water level is deeper and the existence of fresh ground water in the beach area results in the depression of the level of saline ground water, or it may push back the advancement of the subsurface sea water encroachment; floods are still a disastrous problem; the farther inland the more they resemble river flood plain soils.

2. Deltas and deltaic plains

Although deltas are directly affected by stream action, as a matter of fact they are an extension of stream-bed deposition, there is one important difference from solely fluvial formations, that is the deposition beneath the surface of the water. In coastal regions the sedimentation had taken place in sea water. It tends to extend upstreams, finally becoming subaerial and merging with the true fluvial deposits (in this respect it is similar to coastal plains). The enlargement of deltas and deltaic plains is the result of an outward progress. The delta landform is determined solely by the topset beds. Marine deltas are fluvial deposits resting upon fluviomarine sediments (LUEDER, 1959). Seasonal floods from rivers, and swampy or marshy tracts are common features. These are the result of the low energy environment in deltas. As the deltas expand laterally, they ultimately coalesce to form a deltaic plain. Such plains are usually extremely broad, flat, and complex. The water table is permanently high. A confined ground water having a piezometric surface very close beneath the soil surface is not uncommon. The aquifer is constituted of somewhat coarser particles than the overlying material, or sometimes it consists of a mucky mud, and it is situated at a shallow depth. This confined ground water is found in the higher or older parts of the delta. Here the water is generally non-saline. In the younger parts and at the vicinity of estuaries the fresh ground water is replaced by a ground water which is brackish or strongly saline. There are two different soils, viz. soils that are proper to natural levees of rivers and soils which are proper to backswamps. The levee soils are fairly well drained and at least the topsoil is at a rather high stage of oxidation. On the other hand, the interfluve soils are permanently saturated or submerged most time of the year, and consist of a very unripen silty clay (mud) in a very high state of gleization. Upon desiccation a very thin and strongly oxidized superficial layer quickly develops.

3. Estuarine plains

They often are part of deltas. The pattern of sedimentation in estuarines and deltas are similar, exept that in the former the environment is brackish as a result of the mixing of fresh and saline water by tidal action. An estuarine delta is formed if the mouth of a stream has been submerged. They are exceedingly variable in morphology; the deposits may be submerged or semisubmerged bars and islands, tidal marshes, which may proceed to the formation of subaerial deltaic fill. As a consequence the drainage pattern is very complicated consisting of many crooked creeks and brooks. Estuarine plains can be divided into two parts, that is a part which is directly affected by sea water and the other which is not affected. The first part is covered by non-acid alluvial soils with or without a histic epipedon, and periodic saline alluvial soils. The upper part of the profile of the non-acid soils is oxidized while the lower part is reduced. The periodic saline soils are somewhat similar to the former but the reduction is less intense and it gradually decreases with depth until it reaches the zone of ground water level fluctuation where a partial oxidation exists. It seems that the movement of saline ground water is great enough to contain sufficient oxygen. The non-acid soils are saturated or inundated throughout the year, or for most part of it. The salinity of the periodic saline soils is governed by the movement of the tides. The second part consists of potential cat clay soils and cat clay soils, with or without a histic epipedon, and histosols in various degrees of decomposition from real peat to muck. The peat may have a dome-shaped appearance like raised bog or highmoor. In this case the peat layer has a thickness of several meters at the crest. The other peats have the features of lowmoors and their thickness is much more limited; they seldom reach a thickness of more than one meter. Besides these soils, there are also soils that were developed on natural levees of estuaries. The underlying mineral horizon of the histosols is strongly gleied and possesses a mud-like consistency. Also the lower part of the profile of the cat clay and potential cat clay soils is gleied, but it is more ripen.

Considering the Comprehensive System of Soil Classification (1960, 1964, 1967), and what has been proposed by BURINGH (1968) for alluvial and organic soils of the tropics and subtropics, the different soils found in Indonesia in the physiographic units stated above may be classified tentatively as follows. The flood plain and basin soils may well be included in the Great Group of Tropofluvents. Many of them have the characteristics of Vertic Tropofluvents. This is particularly true for the basin soils. The soil of the river terraces seem to fit into the Troporthents (Andic, Vertic, and sometimes Lithic), or Ustipsamments (Typic), or Arents. Hydraquents may represent the lake bottom soils, the palustrine soils without an organic top layer, and the interfluve soils of estuarine plains. The alluvial fan soils consist of soils that resemble Durandepts or Vitrandepts. In coastal plains the periodic saline soils are closest to the Ustifluvents (Aquic Vertic). The non-saline soils may go into the Tropofluvents, or Vertic Ustifluvents. The levee soils of the deltas and deltaic plains may fit into the Tropaquepts (Typic).

The soils with a histic epipedon of 50 cm or more are called Histosols. The name Histic Tropaquepts may be used to include all soils which have a histic epipedon of less than 50 cm thick. These are the soils of the backswamps of deltas and deltaic plains, a part the soils of estuarine plains, and the palustrine soils with a histic epipedon. The periodic saline soil of estuarine plains are different than the soils under the same name which are found in coastal plains. The periodic salinity of the former is due to the direct effect of sea water coming in with high tides. Thus they become saline (or more saline) when wet. The soil of the coastal plain builds up salinity during the dry season. The Classification System has no provision yet to accommodate the cat clay and the potential cat clay soils.

Agricultural Perspectives Of Alluvial Soils

Since the major problem is hydrology with its various aspects, the emphasis should be laid on water management. The principal aim of water management is six-fold.

First it is to supply enough water at the right time and at the right place to satisfy the requirement of crops. Supplemental irrigation is also needed to keep the soil physical condition in a suitable state for the development of a good tilth. To this kind of program it should be given top priority in areas where the climate has a pronounced dry season. In addition to water shortage during the dry season, such kind of climate favors the development of Vertic subgroups, which possess several unfavorable characteristics for the growth of plants (swelling, cracking, slacking, high wilting point, great K fixing capacity). The author has studied the relative merit of each factor that affect the yield of sawah rice (lowland rice) in similar areas, viz. the southern coastal plain of Central Java. It is composed of non-saline alluvial soils, saline alluvial soils, and hydromorphic alluvial soils; in several parts of it there are also poorly drained automorphic soils (pseudoglei and stagnoglei soils according to German classification). The yield factors studied were variety, drainage, irrigation, fertilization, soil tillage, and season (wet or dry). The results strongly suggest the preponderance of water and water management over the other factors. There is no use, for instance, to introduce better varieties — even with increased fertilization — unless water control is adequate. At least a 35% yield increase can be secured with good water management only (NOTOHADIPRAWIRO, 1969).

The second consideration in water management is the control of soil salinity. In many coastal regions the soil and water become saline during the dry season. One method to control salinity is by constructing a series of alternating broad furrows and elongated broad hills (Indonesian term : surdjan). The hills, which are about eight meters wide and 50 to 100 cm high from the bottom of the furrows, are used for upland crops such as corn, cassave, sweet potatoes, beans, and other vegetables, which are sensitive to salt. The furrows (four to eight meters wide) are acting like bottom land to be managed for rain fed sawah rice. Rice plants are moderately resistant against salt injury. The measured electrical conductivity (EC) has shown that the upper 60 cm of the top of the hills were practically free from harmful amounts of salt (EC less than 2 mmhos). The bottom part on the other hand was strongly saline from the surface down to 90 cm with an EC of between 4.5 and 7 mmhos. This degree of salinity seems still be fairly tolerated by local rice varieties, but it was already injurious for upland crops. Furthermore, the ponded rain water was having a dilution effect upon the saline bottom soil. This method has been practiced since long by the indigenous farmers of Java, although it has been intended to make the most efficient use of the available water in the dry season, which is very limited. In the rainy season the furrows furnish the hills with drainage. Thus the surdjan system is useful to reduce the risk of crop failure caused by excessive water, and it provides a means to distribute soil salinity wisely. Consequently, it tends to overcome a too long fallow period in the wet as well as in the dry season, and to enable to multiply the kind of crops that might be grown (NOTOHADIPRAWIRO et al., 1970).

Leaching of course is still the best solution towards desalinization. Here again a well planned water management system is imperative. From a limited number of observations it can be seen that a high to very high salinity will reduce sawah rice yields as much as 30% compared with yields from soils having a low to medium salinity. With good soil management, in conjunction with the use of better varieties, the yield may be boosted to above 360% over that growing on low to medium saline soils under traditional cultivation practices. With those improved managements yields of close to five tons/ha are not difficult to obtain (NOTOHADIPRAWIRO et al., 1970).

Automatic gates built at the mouth of streams carrying sea water into their upstream courses tend to hamper the encroachment of saline water into arable lands. In one area a good functioning gate was able to reduce river water salinity from 37 mmhos at a point just before the gate to 1.2 mmhos at a point just behind the gate when it closes automatically in the dry season. The movement of the gate is regulated by the water pressure difference at opposite sides of the gate. When the discharge of the rivers drops low in the dry season the hydraulic pressure of the sea water becomes sufficient to close the gate. Earthen dikes constructed along the sea shore may impede the overflow of sea water and its subsequent contamination of ponded water on rice fields. Behind an intact portion of such a dike the EC of water on the rice fields was 1.4 mmhos, while behind a deteriorated portion, about one kilometer apart from the former, the EC was as high as 8.8 mmhos (NOTOHADIPRAWIRO et al., in preparation).

The third point is flood control. The importance of this is obvious and needs no further explanation. If we consider the formation of alluvial plains, floods are a natural phenomena in these areas. As a matter of fact without the occurrence of floods there would be no alluvial plains. But after the plains were inhabited and the soils were worked, floods shoulds be kept out from the area. To this end appropriate structures have to be erected. One serious drawback of such a scheme is that the land be constantly low, hence it is continually susceptible to floods. The safety of the land then depends entirely on the flood control devices. The alternative solution is to tolerate floods under controlled conditons. The land will gradually aggrade to eventually reach a safe level.

Thus the fourth point is the reclamation of flood plains. This should be carefully planned as it will have a strong social impact and economic implications. In Indonesia there are still vast low lying lands of swamps and marshes, and lands which are continuously flooded during high discharges. Most of them are still idle. Any land reclamation scheme should be carried out as early as possible, if the land has the feasibility to be developed, making it ready for settlement. This is to avoid any social and economic consequences as it will have if it is carried out after settlement. Planning land aggradation by flood regulations is not always workable, however, because of it is depending on how much load the runoff generally contains, and how the colloidal behavior of the suspended matter is in connection with the physico-chemical environment of the area in which sedimentation should take place. If the runoff is too dilute, the first alternative is the only choise open.

The fifth aspect is land drainage. At the present time tile drainage of individual farms is in Indonesia economically not feasible. Besides, many areas need an overall plan of drainage treating them as parts of a catchment area. Data on the beneficial effect of drainage in Indonesia are very meager. The results of a few observations for rice in Kalimantan under a primitive management can be summarized as follows. Rain fed sawah rice in South Kalimantan produces on the average 2 tons/ha of dry unhusked grains. This type of sawah is practiced on dry lands where rain water can be ponded. Thus to some extent drainage is in hand of the farmer. The yield of rice on periodically inundated depressions of lacustrine origin is on the average 1.6 tons/ha. The rice is planted when the inundating water has subsided (at the beginning of the dry season) and harvested before the wet season comes in. Frequently the harvest cannot be brought in due to an early start of the rains and floods. In tidal swamp areas of South Kalimantan a poor drainage drops the yield of rice from a range of 1.1 to 1.8 tons/ha to a range of 0.6 to 0.7 tons/ha. A poor drainage leads to the development of a very acid water on the fields, and it enhances the severeness of rat pest. The diurnal movement of the tides affected the yield of tidal swamp rice. The more rapid the movement is the more higher will be the yields, provided that all other yield affecting factors were similar. With better tidal movement the yields may range from 2.4 to 4.4 tons/ha dry unhusked grains (SUNARJO et al., 1969).

The system of tidal rice cultivation utilizes the mechanical force exerted by tidal waves and currents to lift water onto the rice fields at high tides, and to drain it back at low tides. The same channel has two functions, i.e. as an irrigation channel during one part of the day, and as a drainage channel during the remaining part of that day. If the water in the swamps that has to be drained is harmfully acid, the saline or bases rich estuarine water coming in with the high tide has a beneficial effect. When the water of the swamps is not acid a salt laden high tide water may harm the rice crop. The yield of rice in the latter case may reach only one-third of the average yield of unaffected fields. Because of this dual purpose of the channels, a special construction is desired. The Gadjah Mada design employing socalled "tidal basins" at the end of each secondary channel was created by prof. Sunarjo and Mr. Pragnjono Mardjikun of the Technical Faculty. It was successfully tried out in the laboratory, and at the moment it is still being tested on a full scale model in the field, one at Barambai in South Kalimantan and another at Tamban Baru in Central Kalimantan. So far the results have been promising. The excessive water which is very acid, that cannot be drained away in one tidal period, can be temporarily stored in the tidal basins before it can be taken out by consecutive tides into the big estuaries. Here the acid water is finally dumped into the sea, or it undergoes a neutralizing process in the fresh water carried by the rivers before it may flow back again into the channels during high tides.

The back and forth movement of the water on the fields and in the channels is also advantageous from the point of view of keeping the oxygen level in the soil as well as in the water at a sufficient height. The O_2 and CO_2 content of the water of various channels at different points are presented in Table No. 1.

Table 1. Contents of O_2 and CO_2 of channel water at the Test Farm of Barambai, South Kalimantan

Water	O_2, ppm		CO_2, ppm	
	Average	Range	Average	Range
Water coming in with high tide	4.3	3.5 — 5.1	7.7	4.4 — 11.0
Water flowing out at low tide	2.9	2.0 — 3.8	36.0	11.0 — 64.6

TEAM TEST FARM, 1970.

The maintenance of the channels is therefore of primary importance. There has been a case where a negligence among the farmers to maintain their self-designed channels has caused a tremendous decrease of rice yield in only one year span from 2.3 tons/ha to 0.8 ton/ha (SUNARJO et al., 1969). An illustrative example of the relationship between the fluency of water refreshment and the yield of tidal swamp rice is given in Table No. 2 The data are self-explanatory.

Table 2. The influence of the distance between rice fields and big estuarine rivers upon the yield of tidal swamp rice

Distance of rice field from a big estuarine river (km)	Yield of rice, fresh weight of unhusked grains (tons/ha)
6	1.0
4	1.2
2	1.9
1.5	2.4
0.7	2.6

Cross-tabulated from data of Central Kalimantan of SUNARJO et al., (1969) The sixth aspect of water management is dealing with the danger of cat clay. In organic matter rich soils originated from marine deposits a high content of sulphur compounds can be expected. In an intense anaerobic condition the compounds are gradually reduced forming sulphides, particularly pyrite and H_2S. Upon microbiological oxidation they change into sulphuric acid, after elemental sulphur has been liberated by inorganic oxidation. If the reaction of the environment in which elemental S has been liberated was slightly acid to neutral, $Fe(OH)_3$ will also formed by hydrolysis of pyrite, eventually leading to the formation of the mineral jarosite. When the initial reaction was acid the resulting soil reaction becomes very strongly acid, while in the former case the pH will not go down beneath 4 due to the partial neutralizing effect of the $Fe(OH)_3$. Also the presence of lime and other salts, or easily weatherable minerals, or base-forming cations, have a neutralizing effect (LEMBAGA PENELITIAN TANAH, BOGOR, 1971; BURINGH, 1968).

Drainage speeds up the subsidence of the peat layer and that of the underlying unripen mud layer in histosols.
From reconnaissance studies made in West Kalimantan an impression has been obtained that unless the peat layer has a thickness of not much more than one meter agriculture will not be successful. Data on rice yields in South and Central Kalimantan show similar tendencies (SUNARJO et al., 1969). The provision of an effective drainage complemented with periodic deep cultivation greatly helps initiating the natural process of ripening. On the other hand, drainage which has been carried out without due consideration reduces the value of its primary aims. The bly will happen may, in the long run, nullify or by partial or unequal decomposition and desiuneven subsidence of the soil brought about about the undesirable side effect that probaccation is one of the undesirable side effects. This phenomenon will create micro-relief in an otherwise smooth surface. The second unwanted happening is the formation of cat clay. Liming and flushing in conjunction with deep drainage, or alternatively keeping the subsoil saturated with water by shallow drainage, may eventually correct the tendency of certain alluvial soils to develop cat clay upon reclamation.

Technical archives of the Faculty of Agriculture, Gadjah Mada University, as well as that of the Provincial Agricultural Extension Service of Central Java, are holding convincing data about the need for phosphate fertilizers of most coastal alluvial soils of Central Java. This is more so for the Vertic subgroups of all alluvial soils and the Typic subgroup of Ustifluvents. Of course nitrogen is the nutrient primary needed in most tropical soils, except for those having an adequate organic matter content with a normal or rather low C/N ratio. With a well balanced N-P fertilization using proper varieties (high yielding and highly responsive), and supplemented by a good water management system, yields of sawah rice in the order of five tons/ha are easily obtained.

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