THE WAGENINGEN RICE PROJECT IN SURINAM

A STUDY ON THE DEVELOPMENT OF A MECHANIZED RICE FARMING PROJECT IN THE WET TROPICS

STELLINGEN

1. Het grootlandbouwbedrijf is in Suriname, binnen zekere grenzen, zowel uit economische als sociale overwegingen gewenst.

   WEST AFRICA – Plantations for Prosperity. 2198:505–506 (1959)

2. Het vestigen van blanke landbouwkolonies in tropische gebieden met een vrijwel uitsluitend gekleurde bevolking, schept dikwijls grotere problemen dan het oplost.

   EAST AFRICAN TRADE AND INDUSTRY – Bold agricultural scheme to settle 20.000 white farmers. 73:44–45 (1960)

3. De korte looptijd van de E.C.A.-aankoopvergunningen heeft bij het Wageningen-project geleid tot ondoelmatige bestedingen.

4. Het noteren van dagregenvallen – na meting om 7 of 8 uur 's morgens – op de datum van meting, kan een foutenbron zijn.

5. De kleigronden van de Surinaamse jonge kustvlakte vertonen een grote overeenkomst met de knipgronden in Nederland.

   SMET, L. A. H. DE – Enkele opmerkingen over kalkarme zeeklei afzettingen. Boor en Spade, 8:169–173 (1954)

   VEENENBOS, J. S. – Gedanken zum Knick-problem. Z. Pfl Ernähr. Düng. Bodenk., 68(113): 141–158 (1955)

6. Van een monocultuur worden te veel de nadelen en te weinig de voordelen gezien.

7. Ook in de *gemechaniseerde* rijstcultuur is inzicht in de factoren die de groei van het gewas bepalen van groter belang dan een bijzondere kundigheid in het hanteren van landbouwmachines.

8. Het schadelijk optreden van waterslakken (*Pomacea lineata* [Spix]) bij rechtstreekse uitzaai van padi, is een van de factoren, die mechanisatie van de bevolkingsrijstbouw in Suriname tegenhouden.

9. De sociaal-economische aanvaardbaarheid van het Wageningen-project hangt af van de waarde welke men toekent aan de indirecte en imponderabele voordelen.

   SCHICKELE, R. – General introduction. International Seminar on Land Development for Agricultural Uses, Wageningen, Stencil: 14 p. (1958)

10. In alle onderontwikkelde, rijstproducerende landen moet bij de onderzoekprogramma's rekening worden gehouden met de mogelijkheid, dat de rijstbouw er in toenemende mate zal worden gemechaniseerd.

    WICKIZER, V. D. – Some aspects of agricultural development in the tropics. Trop. Agr. (Trinidad), 37:163–175 (1960).

Proefschrift Th. P. M. de Wit
Wageningen 1960

THE WAGENINGEN RICE PROJECT IN SURINAM

A STUDY ON THE DEVELOPMENT OF A MECHANIZED RICE FARMING PROJECT IN THE WET TROPICS

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD VAN
DOCTOR IN DE LANDBOUWKUNDE
OP GEZAG VAN DE RECTOR MAGNIFICUS,
IR W. F. EIJSVOOGEL,
HOOGLERAAR IN DE HYDRAULICA, DE BEVLOEIING,
DE WEG- EN WATERBOUWKUNDE EN DE
BOSBOUWARCHITECTUUR,
TE VERDEDIGEN TEGEN DE BEDENKINGEN
VAN EEN COMMISSIE UIT DE SENAAT
DER LANDBOUWHOGESCHOOL TE WAGENINGEN
OP VRIJDAG 9 DECEMBER 1960 TE 16 UUR

DOOR

TH. P. M. DE WIT

MOUTON & CO - 'S-GRAVENHAGE

Dit proefschrift met stellingen van

THEODORUS PETRUS MARIA DE WIT,

landbouwkundig ingenieur, geboren te Oude-Tonge, 10 juni 1924, is goedgekeurd door de promotor, IR J. H. L. JOOSTEN, hoogleraar in de tropische landhuishoudkunde.

De Rector Magnificus der Landbouwhogeschool,
W. F. EIJSVOOGEL

Wageningen, 14 november 1960

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CONTENTS

Photographs

By courtesy of the "Stichting voor Ontwikkeling van Machinale Landbouw in Suriname", photographed by P. ter Laag: Nos. 1, 4, 10, 11, 13 – 17, 22, 29, 34 – 36, 50 – 52, 63, 64. Do., by unknown phothographers: Nos. 19, 20, 26, 33, 55.

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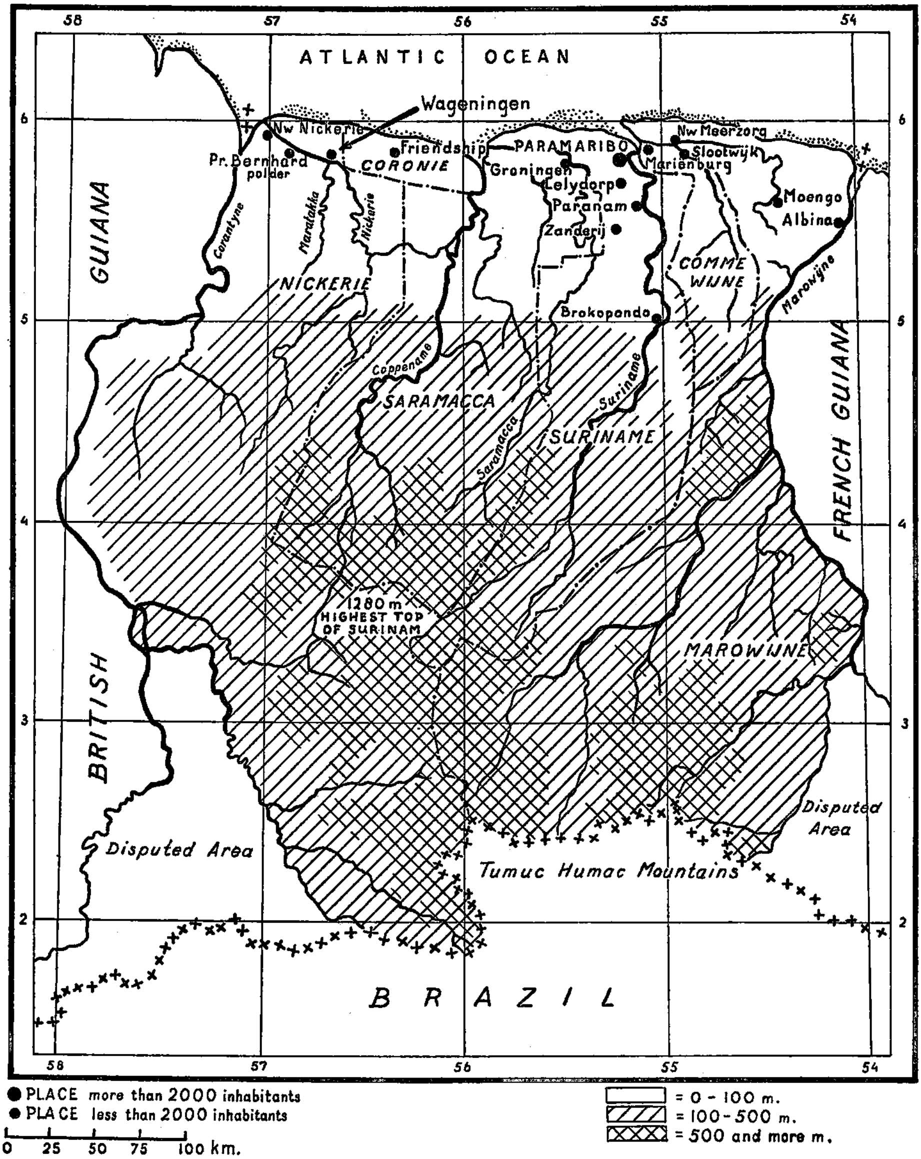


Fig. 1. *Surinam.*

GENERAL INTRODUCTION

The Wageningen project area is located to the west of the coastal plain of Surinam between the northern bank of the Nickerie river and the Atlantic Ocean.
Since 1949 a polder of about 6,000 hectares has been brought into cultivation and equipped with the necessary dwellings and farm buildings. Next to it was built the Wageningen settlement with some 200 dwellings, a rice-mill, a power-station, a central pumping-station and various other installations and facilities required for the operation of the estate and for residents' services.
The project is financed by the Netherlands Government. In order to implement the plan, in 1949 the Netherlands and Surinam governments jointly set up a Foundation named: STICHTING VOOR DE ONTWIKKELING VAN MACHINALE LANDBOUW IN SURINAME (translated: Foundation for the Development of Mechanized Agriculture in Surinam, and abbreviated SML). In the text is usually referred to this Foundation as the "STICHTING".
By the beginning of 1958 the project was completed and the total capital then invested amounted to 32 million Surinam guilders.[1])
In ten years the project has grown up to be one of the largest undertakings in Surinam, employing some 900 persons, with an annual production in 1958 valued at 3 million Surinam guilders.

The Wageningen Rice Project is an estate which is being developed with modern resources in a tropical coastal swamp and in which rice is being produced by the latest labour-extensive but capital-intensive methods.
Many problems arising in the development of this project may also occur, possibly in a slightly different form, in the development of mechanized rice growing in other tropical and sub-tropical areas.

Rice is one of the most important crops in the world since it is the staple food of about half the world's population and rice growing is the chief means of subsistence for a quarter. Most of this rice cultivation is an impoverished smallholders' agriculture. In South-East Asia in particular, where about 90% of the world's rice acreage is situated, any attempt of improving the living standards of the rice-growing population meets with almost insuperable difficulties, as a result of over-population and the absence of alternative sources of subsistence.

[1] 1 Surinam guilder (Sf) = 2 Dutch guilders (Nf).

In the tropical and sub-tropical regions of Africa and South America, rice is cultivated on a relatively limited scale, but here too it is chiefly grown on dwarf farm units barely capable of meeting the food requirements of the farmer and his family. Apart from the capital required, the prospects of an extension and improvement of rice cultivation seem to be brighter in these regions than in Asia, as they still have a large area of unoccupied land potentially suitable for agriculture.

At the present day world-wide interest is shown in assistence to the under-developed tropical and sub-tropical regions to which the said rice areas belong. These under-developed countries are all preponderantly agrarian and, in the more densely populated areas, rice is mostly the principal subsistence crop. Hence one of the main items on the development programmes in the countries concerns the improvement of rice farming. With this object in view various steps are being taken, such as:

1. Institutional improvements. Introduction of price regulations, co-operatives, people's credit banks. Measures against corruption, usury, concentration of land ownership, non-bonafide speculators, etc.
2. Agricultural measures aimed at increasing rice production per hectare and productivity of farm labour.
3. Development of new areas for rice.
4. Emigration and transmigration, to populate new and to relieve over-populated areas.
5. Industrialization, in which particular emphasis should be placed on the development of rural industries.
6. Demographic measures aimed at limiting the increase in population.

The problems which the Wageningen project is designed to solve lie in the sphere of improving production methods and of development of new acreage for rice, referred to under points 2 and 3 above.

Experience so far gained in the Wageningen project in category 2 relates to some principal elements of rice growing which are also in great need of improvement elsewhere in the tropics.

These elements are:

— efficient construction of irrigation and drainage systems;
— selection of better rice varieties;
— improvements in cultivation such as tillage methods, fertilizer application and weed and pest control;
— proper storage and processing of the rice and provision of appropriate marketing and transport facilities.

In the Wageningen project great attention is also being paid to agricultural practices which aim at increasing productivity per working day, obviously in the first place by mechanization which here means the use of 25–100 h.p. tractors with corresponding agricultural implements, and of combine-harvesters. It is true that at present this kind of full mechanization is not altogether a suitable method in the overpopulated rice areas of South-East Asia. There is already too great a labour capacity on the land and there are no alternative uses for the labour which would be released by mechanization. But it can hardly be assumed that this situation will last indefinitely. In our opinion with increasing prosperity mechanization must sooner or later become important for rice-growing in South-East Asia as well. In other tropical and sub-tropical rice areas the conditions are such that machines are already beginning to appear in every quarter.

The Wageningen project is also an example of the development of new acreage referred to under 3, since under it an uninhabited tropical swamp region is being transformed into a modern rice polder.
Elsewhere in the tropics there are still extensive areas of a similar kind which can be brought into cultivation. At the moment various reclamation schemes in which conditions are similar to those of the Wageningen project are actually being carried out or considered. The reason why many of these projects are especially directed towards wet rice cultivation lies in its specific possibilities on swampy and heavy soils. Moreover in the tropics rice usually gives a higher yield per hectare than other grain crops and wet rice cultivation has a greater tolerance to such factors as rainfall, salt content of water and soil, soil structure, etc. In various instances mechanized cultivation has been envisaged as it enables large areas to be utilized more quickly, especially in case of a low agrarian population and because it results in a greater production per farmer or per worker and may thus provide higher incomes for them.
On the Wageningen project the aim was originally to develop a group of medium-sized independent commercial farms, but owing to the specific problems in this region it has become a large fully-mechanized rice-growing estate. This estate can provide a high level of productivity per worker, making it possible to use every kind of modern know-how in order to obtain high yields per hectare, and offering the best guarantees that the capital and the other production factors are used efficiently.

It is hoped that the present study which attempts a discussion of the problems which presented themselves during the development of the Wageningen project, will contribute towards a better understanding of the aspects of the development of mechanized wet rice cultivation in the tropics in general.

PART I

REALIZATION OF THE PROJECT

HISTORY
ENVIRONMENTAL CONDITIONS
CONSTRUCTION

CHAPTER I

EARLY HISTORY

The decision to develop the Wageningen project was taken on a number of facts and considerations which will be broadly outlined in this chapter. The plantation agriculture to which Surinam owed its former prosperity declined greatly in importance during the 19th century, especially as it was no longer able to compete with other parts of the world. Every year the mother country had to expend considerable amounts in subsidies for the needy colony of Surinam.

In considering improvements for this situation it was always evident that although there was abundant land available there were not sufficient workers to utilize it.

During the plantation era slaves were imported from Africa. After the abolition of slavery in 1862, efforts were made to meet the labour shortage by immigration of Javanese and Hindustanis.

It was found, however, that Hindustani immigrants in particular preferred to settle as independent smallholders after the expiry of their working contract with the plantation; thus after the plantation agriculture a settlers agriculture grew up in Surinam.

Owing to the unattractive prospects private capital took very little interest in Surinam, so that the view became current that if Surinam agriculture only had more capital its greatest difficulties would be solved.

Because large-scale agriculture had not succeeded and one could expect little from the peasant agriculture in the way of a rapid increase in production, the idea arose of establishing a class of independent medium sized farms with the help of Dutch farmers. Such a class of agriculture would bring with it its own capital and labour (e.g. the family), and the "great natural wealth" of the available land of Surinam would be put to good use.

There was also a call for greater government support for the establishment of farms. With the rapid rise of mechanization in agriculture a new element entered the discussion.

In the report of the SURINAME STUDIE SYNDICAAT in 1919, already was referred to proposals made by advocates of a mass colonization by Dutch farmers, and also of the forming of medium sized farms with government support. The same report states that the rice fields seemed very suited for mechanical soil cultivation (KASTELIJN, ET AL. 1919).

It was in 1920 that proper experiments were first carried out in Surinam on mechanized tillage for the cultivation of rice. About 50 ha of rice land were made ready for sowing with Cleveland crawler tractors.
The experiments, which were paid for by Messrs C. KERSTEN & CO., were carried out under the superintendence of H. VAN WAVEREN who was said to have gained experience with agricultural machinery in Russia.
In that year LIEMS, a government agriculturist, wrote as follows in his annual report (DEPT. VAN LANDB. IN SUR.): "But an entirely different state of affairs would arise if the question of mechanized tillage were to be solved. In that case the capitalist would also be able to take an interest in rice growing which would therefore be managed by more advanced agriculturists who could apply more intensive methods such as fertilization, selection, etc., and thereby successfully compete on the world market, both now (author's note: with the high rice prices during and after the first world war) and later on."
LEYS, an other agriculturist of the government, observed in his 1921 report (DEPT. VAN LANDB. IN SUR.):
"The curious case arises that propaganda for animal and mechanical traction has to be carried on simultaneously... Now there is no question of being able to omit the period of animal draught here and using mechanical traction exclusively; on the contrary, in this land of smallholdings the ox, or rather the team of oxen, will still have to be of great importance but the Department was of the opinion that the value of tractors should also be investigated and tested, and will continue with this in the years to come."

By order of the Dutch Government, in 1922 PYTTERSEN carried out an investigation into the viability of modern farms in Surinam. He came to the conclusion that Surinam was very suitable for the establishment of a large, private agricultural industry.
Important favourable aspects which he noted were: abundant cheap fertile soil which could go for many years without fertilization and could easily be made suitable for agriculture; a climate suitable for the growth of crops owing to the adequate rainfall; good irrigation and drainage facilities; no floods or hurricanes; cheap water transport on the estate; the accessibility of the potential areas for small ocean-going vessels via the rivers; a favourable situation with regard to the world market; cheap inland transport connections by the rivers running parallel to the sea.
Having regard to the principal disadvantage of Surinam, i.e., the need of good and not too expensive labour, PYTTERSEN considered mechanization of agriculture necessary. In connection with the distribution of work and spreading of the risk, the farms should aim at more than one crop. He advised to choose open lands rather than forest land because the former would cost less to develop and would also be more immediately suitable for mechanical soil cultivation.
PYTTERSEN paid much attention to the mechanization of sugar cane and rice crops and thought there would be very good possibilities for them.

On page 30 of his report he writes:
"In Surinam it is practically impossible to carry on rice cultivation on a large scale with the exclusive use of 'live power' (i.e. man and animal). During the war, mechanized rice farming has been considerably developed in North America and it has been shown that under favourable conditions a large percentage of live power can be dispensed with. The demands made by this kind of farming are such that there can be no question of cheap production in that area. However, the situation is different in Surinam where exceptionally favourable factors are encountered. Nevertheless, practice will have to show whether the use of machine labour will indeed result in a cheap rice product. It is certain that rice cultivation in Surinam, as shown by the native smallholdings is very successful. The Nickerie area in particular is extremely suitable for this crop."
The writer of the report consulted H. N. VAN DIJK and K. VAN DER VEER. The former experimented with cable ploughs for mechanized tillage of the sugar cane estates in Java. VAN DER VEER was an expert on rice cultivation in Java. PYTTERSEN agreed with VAN DIJK that the best method of mechanical tillage for rice would be with the use of cable ploughs, the cable carriages with the motor being transported via the waterways on pontoons. It is true that VAN DER VEER (according to PYTTERSEN) had also seen crawler tractors working without cables in rice fields in the U.S.A., under such conditions, so that he thought it possible that this method could be employed in Surinam as well.
In any case mechanized tillage was not expected to present any great difficulties. The problem of mechanical harvesting was considered more difficult by PYTTERSEN. If the binders could not be hauled through the fields by tractors, it would be necessary to convert these harvesting machines so as to adapt them to cable traction. Moreover, the rice varieties grown in Surinam were too subject to lodging. Selection of varieties with stiff straw was, however, thought possible.
PYTTERSEN also observed that the control of grassy weeds in the crop was still an unsolved problem.
PYTTERSEN advised the Dutch Government to take the following steps:
— to study the accessibility of the Corantijn river for ocean-going vessels;
— to make a rough survey of the Nickerie area;
— to investigate the use of dredging machines for the mechanized establishment of the polders;
— to test mechanized soil cultivation for sugar cane and rice (with reference to an offer of the H. N. VAN DIJK INGENIEURSBUREAU);
— to carry out field-tests with a large number of specified crops;
— to investigate other regions for their suitability for agriculture.

As a result of PYTTERSEN's report (1922) some years afterwards the Dutch Government entrusted H. N. VAN DIJK with the task of establishing an experimental farm for mechanized rice cultivation in the Nickerie-district of Surinam. In 1933 the MECHANISCH RIJSTBEDRIJF N.V. INGENIEURSBUREAU H. N. VAN DIJK started its operations with a *f* 150.000 subsidy.

In taking this step the aim of the Dutch Government was:
1. A systematic investigation to see whether mechanized medium-sized rice farms were possible in Surinam, more especially in the Nickerie district. (The settlement of Dutch farming families had hereby already been borne in mind.)
2. To raise the level of rice cultivation of the local smallholders by extension work on cultivation and processing, and by providing pure seed of rice varieties suitable for export.
The first machines tested by VAN DIJK were two McLaren cable installations, one Benz and one Cletrac tractor, various ploughs, harrows, seeders and mowers.
In 1936 VAN DIJK (1940) reported that the experimental period had been completed and that work could begin on extending the polder.
He estimated that the cost price of paddy would be 1.8 cents/kg, with a production of 3,000 kg/ha, and a farm size of 90 ha.
However, FERNANDES commented on this subject in the 1936–37 annual report of the DEPT. VAN LANDB. ECON. ZAKEN: that most results of VAN DIJK's practical experiments showed less favourable figures than the above calculations. In succeeding years VAN DIJK's farm gradually developed into a commercial enterprise consisting of a rice mill and a farm machinery import business (Allis Chalmers).
In this way (though in a different manner than had been envisaged) the INGENIEURSBUREAU H. N. VAN DIJK was the main incentive to the initial development of mechanized rice growing in the Nickerie-district.

In 1938 at the request of the Dutch Government, H. C. P. DE VOS went to Surinam to advise on the improvement of the hydraulic situation. His report lists the hydraulic problems of Surinam.
In his opinion areas suitable for empoldering were Nanni (10,000 ha), Coessewijne (54,000 ha), Saramakka (30,000 ha), Para (12,000 ha), Surnau (2,000 ha), and Cottica (30,000 ha). In these areas irrigation water would be available and at the same time they could be drained by natural means. According to DE VOS other large areas along the Nickerie and the Maratakka were suitable for irrigation, but it was not expected that any natural drainage would be possible there.

After the Second World War mechanization progressed surprisingly in native rice growing, especially in the Nickerie district. In 1941 NARPAT was the first Hindustani farmer to have his 24 ha sawahs mechanically tilled (by VAN DIJK). In 1945 NARPAT himself bought a wheeled tractor with implements and even a combine. In 1947 the same farmer successfully prepared land for sowing under wet conditions with an iron-wheeled tractor by the puddling method, which consisted of repeated passes with a disk harrow over the wet weedy land until a bed of mud was obtained. Partly as a result of this, and thanks to the coincidence of very high rice prices, there was a rapid increase in the number of wheeled tractors owned by farmers in the

district. In those years Allis Chalmers wheeled tractors were chiefly bought owing to the workshop service and advice given by the VAN DIJK firm (RELYVELD, 1954).
Table 1 shows the rapid growth of smallholder mechanization.

TABLE 1 *Development of mechanized tillage in native rice growing in the Nickerie district* (RELYVELD, 1954)

	1943	1947	1952
Total area planted (ha)	3,538	5,600	6,620
Area tilled by hand (ha)	1,757	1,360	577
Do. by draught animals	1,757	4,000	2,150
Do. by machinery	24	240	3,893
Draught animals owned (number)	982	1,600	2,013
Tractors owned (number)	6	20	128

Dutch interest in Surinam proved to be on the increase after the war, especially because of the difficulties in Indonesia.
During the war years 1939–1945, the "NIEUW-NICKERIE" and L.O.S. (LANDBOUW ONTWIKKELING SURINAME) associations were created in the Netherlands, the members of which aimed at emigrating to Surinam for the purpose of colonization on a basis of mechanized agriculture.
In 1946, in connection with the activities of these groups, the Dutch Government sent W. C. VAN DER MEER and L. J. DIJKHUIS to Surinam to report on the possibility of settling Dutch farmers (VAN DER MEER, DIJKHUIS, 1947). The principal conclusions of these Dutch agricultural experts were:
1. mechanized rice growing without transplanting is technically possible (demonstrated by the VAN DIJK experimental farm in Nickerie);
2. the minimum farm size would have to be 100 ha;
3. on the basis of the 1946 export prices the profitability of rice growing is satisfactory;
4. citrus, cocoa and coconuts are suitable subsidiary crops;
5. the virgin areas in the Nickerie district are most suitable for colonization;
6. emigration of Dutch farmers to Surinam is possible and deserves consideration in view of the land shortage in the Netherlands;
7. for creating the settlement a semi-governmental institution should be brought into being, financed by government funds;
8. the native population should also "be given an opportunity of making use of these lands on the same conditions as the Dutch farmers".

Consequent upon the positive advice of DIJKHUIS and VAN DER MEER, in 1948 the Dutch Government decided to send a new commission of three experts on tropical agriculture, viz., W. F. EIJSVOOGEL, hydraulic engineer, J. A. VAN BEUKERING, agronomist, and J. M. VERHOOG, pedologist.
The principal conclusions of this commission were as follows:
1. the region between the Nickerie river and the Atlantic ocean to the

west of the Koffiemakka creek is a suitable area for the establishment of large rice polders;[1]

2. an experimental farm should be laid out before the main project is begun;
3. as a first step to a large-scale reclamation of 20–50,000 ha, a 5,000 ha polder should be constructed, parcelled out in farms of 72 ha, based on a crop rotation of 1/6 leys and 5/6 arable, with rice in the rainy period and maize and soya in the dry period of the year;
4. rice should be the principal crop, but other crops and leys were considered essential for the conservation of the humus, as a safeguard against one-sided exhaustion of the soil, and to provide a solid economic basis for the farms.

In their report the commission also gave a rough plan for the construction of the experimental polder and of the large 5,000 ha polder (EIJSVOOGEL, ET AL., 1948).
The Dutch Government submitted this report to an advisory board under the direction of the then Director-General of Agriculture in the Netherlands, C. STAF. This advisory board considered the plan to be favourable and advised the government to entrust its execution to a foundation to be created for the purpose (STAF, 1948). The government then decided to construct a 5,000 ha polder, preceded by the construction of an experimental polder of about 200 ha. The experimental polder (called the Prins Bernhard Polder in commemoration of a visit by H.R.H. PRINCE BERNHARD in 1950) was constructed and developed with money from the WELVAARTSFONDS (Development Fund) and it was largely completed by 1950.

On 27th July 1949 the STICHTING VOOR DE ONTWIKKELING VAN MACHINALE LANDBOUW IN SURINAME was established at The Hague by representatives of the Netherlands Government and the Surinam Administration.
The aim of this Foundation is defined as follows in article 2 of the articles of association: "The aim of the Foundation is to empolder, reclaim, prepare for cultivation, provide houses on, develop and encourage the development of land in Surinam, and everything related thereto or resulting therefrom in the widest sense. The Foundation is a non-profit making organization."

[1] This North-Nickerie region had some very favourable characteristics for the large-scale construction of rice polders:
- The lands were flat and partly only overgrown with herbaceous vegetation; the soil consisted of a uniform heavy clay suitable for rice growing.
- The lands were unoccupied and there were no rights of ownership by private persons.
- The region was sufficiently large for future extensions to several times the size of the projected 5,000 ha plan.
- Irrigation water could be drawn from the Nickerie river.
- Along the lower tidal course of the Nickerie river part of the lands could be drained naturally at ebb-tide.
- Ocean-going vessels of up to 5,000 tons could sail some way up the Nickerie river.

One of the most obvious unfavourable characteristics of the region was the complete absence in the immediate neighbourhood of sand and stone for civil engineering works.

This brief historical account shows that gradually, in the course of about 30 years, an idea developed that finally achieved concrete form in the Wageningen project.

The Wageningen project has been given various names in the course of the years during which it has been in execution.
In accordance with the wording of their instructions the EIJSVOOGEL commission refers to a plan for the settlement of Dutch farmers in Surinam. But the title of their report is very general and reads: "Report concerning the possibilities of agricultural development in the western half of the coastal plain of Surinam". The STAF commission employed the title: "Plan of mechanized agriculture in Surinam". Later the following names were used: Eijsvoogel plan, Nickerie project and North Nickerie project, but since 1953 the title "WAGENINGEN PROJECT" has emerged and since then has become generally accepted. Thus the scheme is named after its central settlement which has been given the symbolic name of Wageningen in honour of the Agricultural University at Wageningen, the Netherlands.

We think that the social and economic objectives on the basis of which the execution of the Wageningen scheme was considered acceptable, are best formulated in the report of the STAF commission (1948). The previous reports usually gave a somewhat biased account of the interest involved, e.g. the VAN DER MEER-DIJKHUIS commission (1947) stressed the colonization by Dutch farmers, and the EIJSVOOGEL commission (1948) mainly discussed the technical possibilities of carrying it out.
The STAF commission reported that the profitability of the project was acceptable. In their considerations on this matter they made allowance for the fact that a part of the investments, especially the establishment of irrigation and drainage works, would have to be borne by the government; but these investments would have their own benefits resulting from the levying of direct and indirect taxes. The STAF commission concluded *that the principal benefits of the scheme should be viewed in the light of the agricultural development of Surinam.* The commission considered this in itself a sufficient motive for recommending the execution of the scheme. The commission noted the following additional reasons:
1. Improvement of the provision and production of food within the borders of the Netherlands and her overseas territories.
2. Creation of a livelihood for an, albeit limited, number of Dutch farmers. (Moreover, the professional ability of the Dutch farmer should not be overlooked in connection with the project.)
3. The stimulating influence on the agriculture of the whole of Surinam, that will result from the presence of a community of energetic farmers.

When the project was elaborated in 1950–51, the question of the most desirable extent of the scheme emerged as an important problem. Should it be subsequently found that the initial design was too small, supplementary patching up would be required, and this would be less effective and cost relatively more money. Moreover, there was a chance that owing to the narrow limits of the plan the maximum effect would not be reached, so that too small an initial investment might be the cause of failure. On the other hand, uncertainties and risks were mentioned which necessitated prudence in investments. After due consideration a minimum project of 15,000 ha was planned (À CAMPO, 1951), of which 5,000 ha were constructed in the first instance. After the construction of these 5,000 ha it was however, for reasons to be discussed later, again decided to provisionally limit the extent to 6,000 ha.

CHAPTER II

POPULATION AND ECONOMIC STRUCTURE OF SURINAM

Surinam is situated to the north of South America at lat. 2–6° N., between French Guiana and British Guiana. Excluding disputed areas, it has a territory of 1,430,000 sq.km.
The population, which in 1950 was estimated at 220,000, lives almost entirely in a narrow coastal strip. This population is characterized by a great diversity of races. In 1950 the percentage composition was estimated as follows (PLANBUREAU, 1951):

37% Creoles[1]	(in 1925 — 42%)
30% Indians	(in 1925 — 23%)
17% Javanese	(in 1925 — 16%)
10% Maroons	
1–2% aboriginal Indians	
1–2% Chinese	
2–3% Europeans	

Of the whole population some 40%, of which 69% are Creoles, live in Paramaribo, the only city in the country (VOX GUYANAE, 1959). The agrarian population in the rural districts consists mainly of Indians (Hindustanis) and Javanese, both races having fairly well separated residential areas. As a result of low incomes, both of plantation workers and independent peasant farmers, there has long been a migration – particularly of Creoles – from the country to the city of Paramaribo.
The usual language of communication of the different population groups is the srenang (Negro pidgin English) of the Creoles. The official language is Dutch. The Javanese and Hindustanis perpetuate their own languages.

The great racial differences in the population reflect the country's variegated history. About the middle of the 17th century the British established the first permanent settlement in Surinam. In 1667 they were expelled by a Zealand fleet under ABRAHAM CRIJNSSEN, after which the colony became a Dutch possession. CORNELIS VAN AERSSEN VAN SOMMELSDIJK, governor of Surinam from 1683 to 1688, acquired special merit for the country's initial development, because under his leadership was begun the construction of plantation polders on the fertile clay soils along the coast (BRONS, 1952).

[1] Principally descendants of the Negro slaves.

Labour was required for these plantations. The indigenous Indians were fairly small in number, nor were they very suitable for this work. Hence the plantations were entirely dependent on the supply of Negro slaves from Africa. It is estimated by VAN LIER (1949) that in all 300,000 to 350,000 Negro slaves were brought to Surinam.

The most important products were sugar, coffee and cotton, to which cocoa was later added. In the 18th century the colony reached a high level of prosperity. At that time possibly over 100,000 ha were in cultivation.

In the 19th century there was a gradual decline because of increasing competition from agriculture in other parts of the world. The slave labour system no longer worked so well: there were many slave rebellions and large groups of slaves fled into the interior. (The descendants of these runaway slaves are the Maroons of today.) The plantation estates received their death-blow with the abolition of slavery in 1862. As a result the freed Negroes were no longer willing, even for payment, to carry on with the detested work in the plantations.

Many attempts were made to meet the labour shortage by immigration. Between 1850 and 1870 there was an influx of 500 Madeirans and about 2,500 Chinese. Afterwards, from 1870 to 1913, there were about 34,000 immigrants from India, of which number about one-third returned to their own country, and from 1870 to 1939 about 33,000 Javanese, of whom about a quarter afterwards returned. (PANDAY, 1959).

These immigrants were usually not very keen on plantation work. After their five-year work contract had been completed, the government promoted their permanent settlement in Surinam by issuing plots of agricultural land in settlement areas, and by payment of premiums. Large-scale agriculture gradually broke up to an increasing extent, but on the other hand a peasant agriculture began to develop in the 20th century as a result of the Asiatic immigrants setting up themselves as small independent farmers. Especially the Hindustani group is very active and their prosperity is increasing

TABLE 2 *Approximate estimates of the national production of Surinam* (PLANBUREAU, 1951)
In millions of Surinam guilders

	1938	1947	Index in 1947 (1938=100)
Mining	4.7	18.1	385
Agriculture	5.8	15.9	274
Industry	6.0	13.5	225
Trading Profits on Imports	1.6	7.6	475
Building Industry	3.0	4.5	150
Forestry	0.4	3.3	825
Stock Raising, Fishing	0.8	1.8	225
Miscellaneous	3.2	3.7	115
Total	25.5	68.4	268

rapidly. On the other hand the Javanese as a group continue at a low subsistence level.

Until recently economic statistics of Surinam were scarce, and moreover the figures given were not very reliable. In 1951 the PLANBUREAU SURINAME published the first approximate estimates of the national production of Surinam (Table 2), after figures of the CENTRAAL BUREAU VOOR DE STATISTIEK in the Netherlands which were computed by the method of STONE.
The 1947 cost-of-living index was 250 (compared to 100 in 1938). Hence the actual growth seems to have been small.
The budget of the Surinam Government is greatly dependent on the proceeds of a single mining product, viz. bauxite. The dominating position of bauxite in the economy of Surinam can be clearly seen from the export statistics (Table 3).

TABLE 3 *Exports from Surinam* (CENTRALE BANK, 1958; PLANBUREAU, 1951)
In millions of Surinam guilders

	1929	1938	1947	1948	1949	1950	1955	1956	1957
Bauxite	2.70	3.83	17.76	21.90	25.35	25.61	39.82	45.54	52.02
Wood	0.23	0.07	2.13	1.20	2.37	2.50	4.47	5.67	5.86
Rice	0.04	0.44	1.91	0.45	3.23	1.18	2.80	3.43	2.72
Balata	1.01	0.31	1.17	0.73	0.51	0.55	0.58	0.59	0.38
Fruits	0.02	0.01	1.00	1.20	1.49	1.07	0.36	0.82	0.75
Coffee	1.85	0.47	0.24	0.26	0.47	0.44	0.80	0.60	0.69
Sugar	1.36	0.55	—	—	—	—	—	0.18	0.35
Other items.	0.74	0.93	0.30	1.70	0.80	0.05	0.85	1.04	1.00
	7.95	6.61	24.51	27.44	34.22	31.40	49.68	57.87	63.77

Total imports in 1929 were 8.64 million Surinam guilders, in 1950, Sf 39.3 million, of which Sf 5.7 million were for foodstuffs, in 1957, Sf 73.1 million, of which foodstuffs and drinks accounted for Sf 10.1 million (CENTRALE BANK, 1958; PLANBUREAU, 1951). The balance of trade thus shows considerably greater imports than exports in the agricultural sector, a phenomenon which is connected with the low standard of development of agriculture.

Despite its important mining industry, Surinam is primarily an agricultural country because half the population finds a livelihood in agriculture.
The planted areas and the yields of the different crops are shown in Table 4. Of these, coffee, cocoa, citrus fruits and sugar cane are grown primarily in plantation agriculture (large-scale agriculture) and rice in peasant agriculture (small-scale agriculture). Farm sizes in agriculture are divided into the following percentage classes of numbers: about 50% < 2 ha, about 25% 2–4 ha, about 20% 4–20 ha, and about 2½% > 20 ha (VOX GUYANAE, 1959).
Livestock farming is of little importance in Surinam. In 1949 the following numbers of livestock were estimated: cattle 43,000, pigs 6,500, sheep and

TABLE 4 *Planted areas and yields of agricultural crops in Surinam* (DEPARTEMENT VAN LANDBOUW, 1949, 1956)

Crop	1949 Area	1956	
		Area	Yield
Rice	17.600 ha	25.000 ha[1]	71.200 tons (paddy)
Coconuts	2.500 ha	2.100 ha	9.500.000 nuts
Coffee.	2.300 ha	2.200 ha	270 tons
Citrus	2.000 ha	1.600 ha	56.000.000 fruits
Bananas	1.400 ha	1.000 ha	520.000 bunches
Sugar cane. . . .	1.300 ha	1.600 ha	100.000 tons (cane)
Cocoa.	500 ha	1.600 ha	135 tons
Sundries	1.400 ha	2.100 ha	
	29.000 ha	37.200 ha	
Grassland approx.	4.000 ha	4.000 ha	

[1] Including Wageningen Project and Prins Bernhard-polder 4.500 ha.

goats 5,200. Cattle raising is very difficult owing to unfavourable climatic conditions. Thanks to the recent efforts of the government, the fisheries show a favourable development. In 1956 total production was estimated at 3,300 tons fresh weight (chiefly coastal fishing). The export of shrimps is developing gradually (DEPARTEMENT VAN LANDBOUW, 1949, 1956).

Government activity in agriculture has greatly increased, especially since the war. Since 1949 the Department of Agriculture consists of the following sections: the Agricultural Experiment Station (since 1903), the Agricultural Service (with the subsections Education, Extension, Land Improvement and Mechanization), the Livestock Service, the Veterinary Service, the Fishery Service, the Service for Marketing, and the Administration. In 1958 the Department had about 25 university-trained staffmembers and about 50 with secondary education (RELYVELD, 1958; PENDERS, 1958).

As regards development projects in general the following may be observed. In addition to the Wageningen project three large schemes are being carried out or have been completed in Surinam:

— In 1947 the Dutch Government made available a fund of Nf 40,000,000 for the improvement of welfare in Surinam (WELVAARTSFONDS).

— In 1955, approximately when the Welfare Fund terminated, work began on a ten-year development plan costing a total of Sf 250,000,000, of which 1/3 was made available by the Netherlands as a grant, 1/3 as an interest-free loan, and 1/3 contributed by Surinam itself (TIENJARENPLAN).

— In 1958 an agreement was signed with ALCOA, under which this company will, firstly finance the construction of a dam with power equipment on the Surinam river, and, secondly, build an aluminium factory in Surinam (BROKOPONDO PLAN).

CHAPTER III

CLIMATE

1. General characteristics

Surinam has a tropical rainy climate. On the coast the rainfall is less than inland and the coastal rainfall also decreases from east to west. Proceeding in a westerly direction, the coastal rainfall gradually increases again in British Guiana. According to Köppen's classification we can class the climate of the coastal plain in the west as a tropical monsoon forest climate (Am), and of the rest of Surinam as a tropical rain forest climate (Af) (BRAAK, 1935; BEACHELL and BROWN, c. 1949).

Taking the rainfall as the basis four seasons are distinguished which are for the Nickerie-district approximately as follows:

the long rainy season – from the beginning of April to mid-August (about 4½ months);

the long dry season – from mid-August to mid-December (about 4 months);

the short rainy spell – from mid-December to the beginning of February (about 1½ months);

the short dry spell – from the beginning of February to the beginning of April (about 2 months).

The long rainy season and long dry season occur every year although the times of the rains and the dry spells vary considerably from year to year. The short rainy spell and the short dry spell can be easily inferred from the mean rainfall figures but they are irregular and cannot be clearly distinguished every year.

The long rainy season occurs owing to the approach of the equatorial air-pressure minimum in the summer months. The long dry season can be explained by the greater distance of this air-pressure minimum, and the change of direction of the N.E. trade wind to the east, as a result of which more land air blows over Surinam. The cause of the short rainy spell is unknown (BRAAK, 1935).

2. Wind

The wind which blows over Surinam is the N.E. trade. The wind direction is fairly constant between N. and E.; the wind force is slight. Over a period of 30 years a wind of force 8 (Beaufort scale) has only been recorded once in Paramaribo and a wind of force 6 only five times. On the coast the land and sea winds have a considerable influence.

Wind measurements are available for Coronie and Paramaribo. It was not

until 1958 that an automatic recording anemometer (Lambrecht type) was set up at Wageningen on plot 1 of the polder. Having regard to the situation of Wageningen vis-à-vis the coast the wind characteristics at Wageningen may be taken as being intermediate between the above two stations.
BRAAK (1935) computed the wind measurements for Paramaribo over the periods 1911–15 and 1919–33, and for Coronie over the period 1926–33. These are daily measurements at 8 a.m. and 2 and 6 p.m. At night the wind force is considerably less than during the day. Table 5 shows the mean figures for wind force and wind direction for Paramaribo and Coronie. Since it lies more inland, Paramaribo has a much smaller wind force. The wind force has an annual and a diurnal pattern. Both at sea and on land the maximum wind force occurs from January to April. Under the influence of the land and sea winds, the diurnal pattern shows a reinforcement of the wind at 2 p.m., while unlike in Paramaribo the wind force in Coronie at 6 p.m. is also higher than at 8 a.m.; this is no doubt also due to the stronger sea winds occurring in Coronie. The mean wind direction is most northerly in January-March and most easterly in August-September; it is noticeable that Coronie only has very slight variations owing to the levelling influence of land and sea winds which are more highly developed in August-September.
The great effect of the sea winds in Coronie is also shown by the great mean diurnal amplitude of the wind direction which is about 60° for Coronie in July, whereas it is only 30° for Paramaribo. According to BRAAK (1935) this is to be explained as follows:
the wind blowing from the land to the sea (from the south) during the night and morning combines with the N.E. trade to give a wind vector which is steeply deflected to the east, whereas at mid-day the sea wind (from the north) causes a wind vector turning to the north.

Some advantages of the wind characteristics for the Wageningen project are mentioned by KRAS (1953):
— the regular, light wind is pleasantly cooling during the day;
— owing to the regularity of the wind the houses can be built accordingly for ventilation;
— owing to the low wind force light structures are sufficient;
— high coastal defence dikes in the north are unnecessary as there are no storm floods;
— Wageningen can have sea communications with Paramaribo by means of small vessels;
— the low wind force causes little lodging of the crops.
The following factors however, are also important:
— owing to the constant wind direction, various buildings especially the sheds for agricultural implements, need only be given rain-proof side-walls on the windward side;
— the slight wind in the early morning hours makes it possible to achieve a large effective working width with power dusters used for insect control;

TABLE 5 *Wind direction (North...East) and wind strength (Beaufort scale) in Surinam* (BRAAK, 1935)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean
Coronie (1926–1933)													
Mean wind strength . . . . 8 a.m.	2.4	2.8	2.9	2.7	2.1	1.9	1.8	2.2	2.4	2.0	2.2	2.0	2.3
Mean wind strength . . . . 2 p.m.	3.8	4.0	4.2	3.9	3.2	3.0	2.8	3.1	3.3	3.4	3.1	3.3	3.4
Mean wind strength . . . . 6 p.m.	3.3	3.5	3.7	3.5	2.9	2.8	2.6	3.1	3.1	3.1	2.9	2.9	3.1
Resultant wind direction . . . . 8 a.m.	70°	68°	70°	74°	95°	117°	122°	106°	104°	108°	98°	89°	90°
Resultant wind direction . . . . 2 p.m.	53°	51°	51°	53°	55°	50°	44°	48°	47°	44°	50°	55°	50°
Resultant wind direction . . . . 6 p.m.	53°	57°	55°	59°	62°	59°	56°	57°	57°	58°	57°	61°	58°
Paramaribo (1911–1915, 1919–1933)													
Mean wind strength . . . . 8 a.m.	1.0	1.1	1.2	1.2	1.1	1.0	1.1	1.4	1.7	1.6	1.4	1.0	1.2
Mean wind strength . . . . 2 p.m.	2.1	2.4	2.3	2.2	1.7	1.4	1.3	1.4	1.6	1.7	1.6	1.6	1.8
Mean wind strength . . . . 6 p.m.	1.4	1.6	1.6	1.4	1.1	0.9	0.9	1.1	1.2	1.2	1.1	1.1	1.2
Resultant wind direction . . . . 8 a.m.	81°	71°	72°	79°	87°	101°	102°	105°	104°	103°	96°	89°	91°
Resultant wind direction . . . . 2 p.m.	60°	58°	58°	61°	61°	64°	70°	75°	76°	65°	65°	64°	65°
Resultant wind direction . . . . 6 p.m.	64°	61°	65°	71°	61°	68°	72°	69°	71°	70°	68°	68°	67°

to this end it is desirable that the fields lie somewhat at right angles to the prevailing direction of the wind;
— the slight wind restricts damage caused by waves washing out rice-seedlings on flooded fields; in this respect it is also better that the fields lie at right angles to the direction of the wind.

3. Temperature

The temperature in Surinam is of a uniform pattern. It is also virtually the same for the whole coastal plain. The influence of the sun's altitude is only noticeable by a slight annual fluctuation. Table 6 gives some temperature data from the Nieuw-Nickerie station.

TABLE 6 *Air temperatures at the Nieuw-Nickerie station*
Means of the period 1924–1953 (OSTENDORF, 1954)

Mean annual temperature	27.3° C
highest monthly mean temperature (in September)	28.3° C
lowest monthly mean temperature (in January)	26.4° C
Mean daily maximum temperature	30.1° C
highest mean daily maximum temperature (in September)	31.7° C
lowest mean daily maximum temperature (in January)	28.8° C
Mean daily minimum temperature	23.7° C
highest mean daily minimum temperature (in May)	24.0° C
lowest mean daily minimum temperature (in January)	23.2° C
Absolute maximum temperature	35.7° C
Absolute minimum temperature	17.4° C

The temperature amplitudes are smaller on the coast than further inland, this being due to the levelling influence of the land and sea winds. The mean daily amplitudes are 6.4°C. for Nieuw-Nickerie and 8.2° for Paramaribo.

4. Air humidity

Table 7 is a summary of the relative air humidity at Paramaribo.
The annual fluctuation follows the pattern of the wet and dry seasons.

5. Sunshine

The mean sunshine percentages of the Nw.-Nickerie Station were calculated by BRAAK (1935), OSTENDORF (1956) and KRAS (1953). Table 8 shows KRAS's figures. The hours of sunshine were counted from 7 a.m. to 5 p.m., so that the calculation of the percentage was based on ten day-time hours.
The mean annual percentage of sunshine is 57%, both for Nickerie and Paramaribo. The correlation between rain and sunshine is often poor owing to the occurrence of cloudy weather without rain. The latter type of weather occurs fairly frequently in Surinam, and is the reason for the low sunshine percentage. In Table 8 the means of the available sunshine percentages for Coronie are also given compared with the means of the same years for

TABLE 7 *Relative air humidity at Paramaribo*
Means of the period 1924–1933 (BRAAK, 1935)

	8 a.m.	2 p.m.	6 p.m.	Mean	Mean monthly min.
January	93	71	83	82	52
February	90	67	80	79	53
March	89	68	79	79	50
April	88	69	81	79	53
May	91	76	86	85	56
June	92	78	88	86	55
July	92	73	87	84	54
August	90	66	84	80	48
September	88	62	81	77	44
October	87	62	80	76	43
November	88	65	81	78	41
December	93	73	85	84	54
Year	90	69	83	81	50

TABLE 8 *Sunshine per month in hours and percentages at Nieuw-Nickerie and Coronie*
(measured with Jordan sunshine recorders from 7 a.m. to 5 p.m.)

Months	Nieuw-Nickerie Over the period 1922–1952 (KRAS, 1953)				Over the period 1926–1940 (excl. 1939)	
	max. hours	min. hours	mean hours	mean %	Nickerie (mean %)	Coronie (mean %)
January	232	90	143	46	45	53
February	207	88	150	53	53	62
March	218	114	169	54	56	62
April	220	114	160	53	51	56
May	188	107	143	46	44	49
June	194	111	151	50	51	56
July	215	157	182	59	57	66
August	247	157	209	67	68	77
September	255	182	226	76	75	84
October	256	147	218	70	69	84
November	244	171	190	63	62	78
December	183	103	144	46	47	56
Year			2085	57	57	65

Nw.-Nickerie. It appears that there is more sunshine in Coronie. This phenomenon was also found by BRAAK (1935). Comparison of a longer period of observation is desirable in order to determine the quantitative differences between the above stations. The Coronie observation station is nearer to the coast than the Nw.-Nickerie station, at least if we consider the broad Corantyne estuary at Nickerie as being inside the coastline. If the areas close to the coast are indeed considerably sunnier this might be of some agricultural importance, since with a suitable choice of rice-varieties there is, according to BEST (1959), a marked positive correlation between hours of sunshine during the growing period and the assimilation and hence the yield of rice. The greater amount of sunshine at Coronie is found to be distributed over the whole year and is most in evidence from October to December. It is possible that the northern part of the present polder also gets more sun than the southern part. It would therefore be desirable to set up sunshine recorders in both areas.

As for the annual pattern of sunshine, in connection with the scheme of cultivation used at Wageningen, the main-crop rice (April/May–August/September) gets a greater average amount of sunshine than the second-crop rice (November–March).

6. Evaporation

Evaporation depends mainly on the sunshine, air movement (wind), and relative humidity. It is necessary to distinguish between:
a. the evaporation from an open water surface; b. the evapotranspiration; c. the evaporation from the bare ground-surface.

Knowledge of the evaporation from an open water surface and of the evapotranspiration is important for drying up the land for reclamation, and for determining the irrigation water requirements of the rice fields.

No reliable observations have been made in Surinam on the evaporation from open water and evapotranspiration. The NEDERLANDSE HEIDE MAATSCHAPPIJ (written communication, 1959) estimated that the mean evaporation/day from a water surface was as follows for the Nw.-Nickerie station: Jan. 4.9 mm, Feb. 5.7 mm, March 6.1 mm, April 5.9 mm, May 5.0 mm, June 4.1 mm, July 4.1 mm, Aug. 4.5 mm, Sept. 5.1 mm, Oct. 5.2 mm, Nov. 4.4 mm, Dec. 4.5 mm. The low evaporation is a drawback for reclamation, but an advantage for irrigation.

7. Rainfall

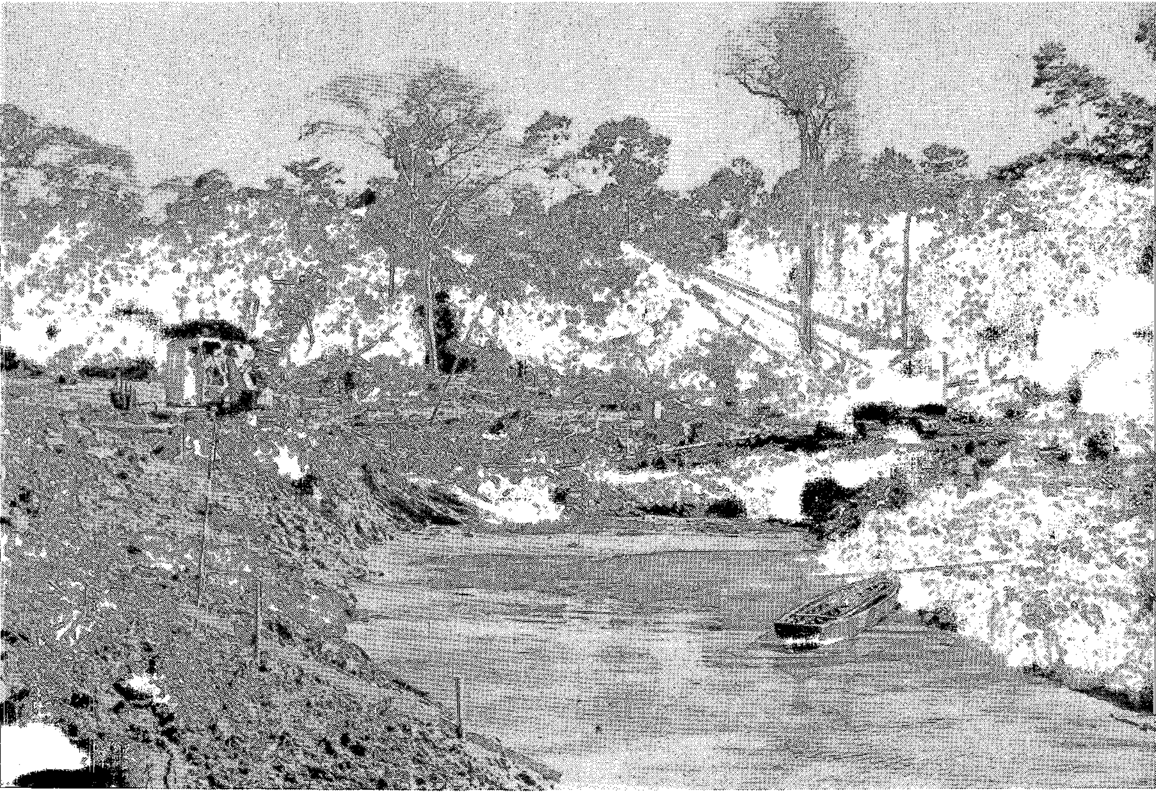
Rainfall is one of the most important environmental factors in the Wageningen project.

The rainfall characteristics are decisive for:
— the choice of crop,
— the dimensions of the irrigation and drainage system,
— the method of reclamation,
— the methods of cultivation, and,
— the choice of machinery.

The situation of the rain stations in and near the Wageningen project is shown in Fig. 2.

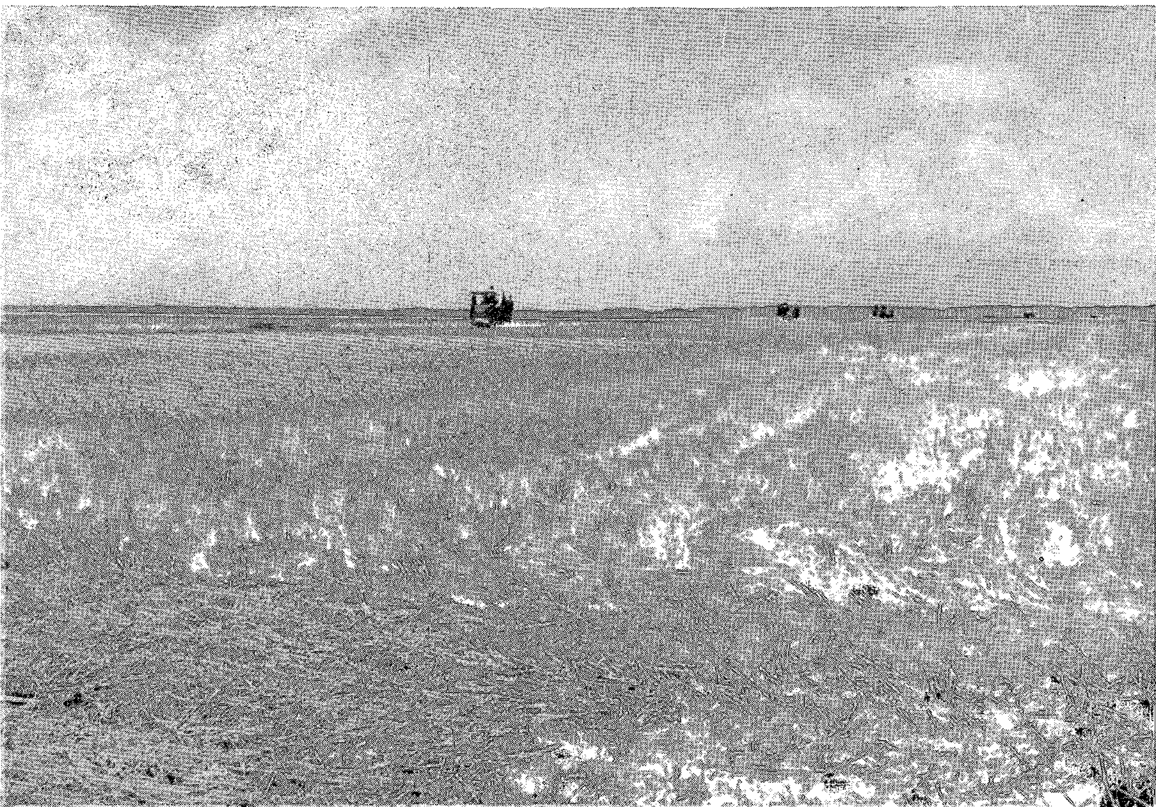
Annual rainfall

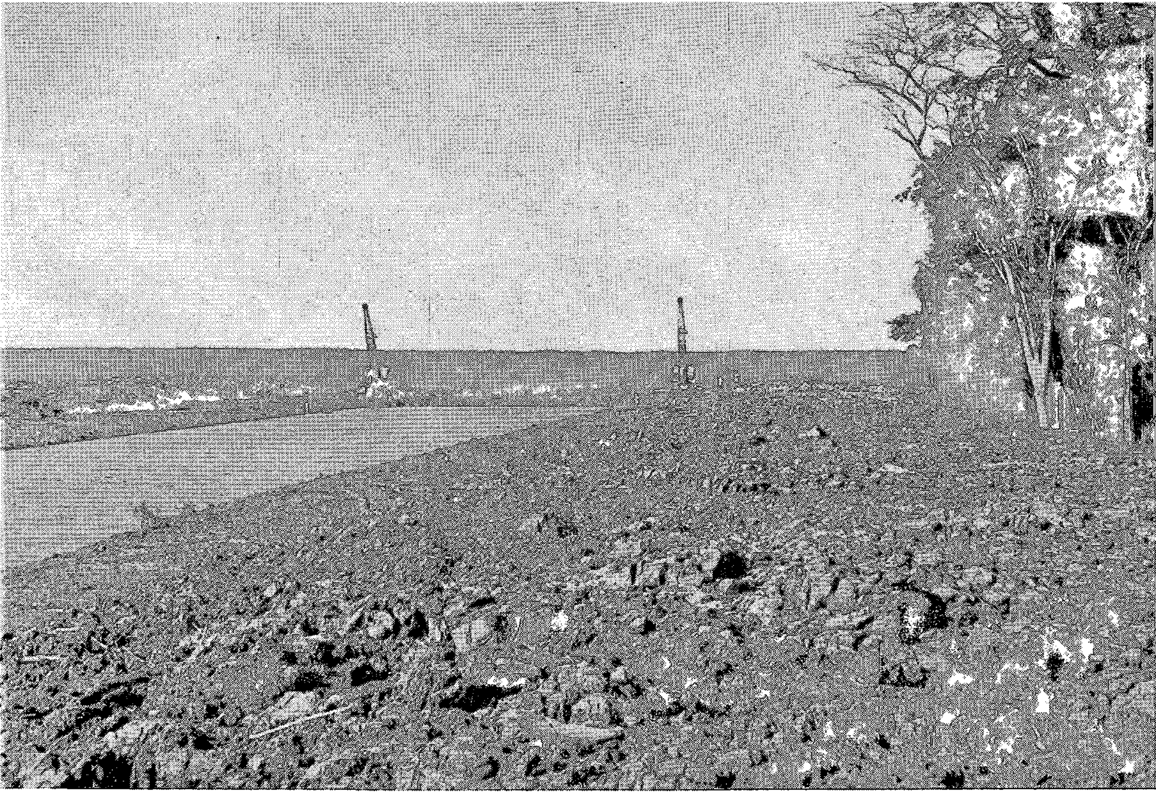
The multi-annual mean of the Nw.-Nickerie station is 1,934 mm, with a



1. *Canal excavation in forest.*

2. *Rice fields being harvested.*





3. *Canal excavation in open herbaceous swamp.*

4. *Subsidence of talus in main drainage canal, shortly after excavation.*

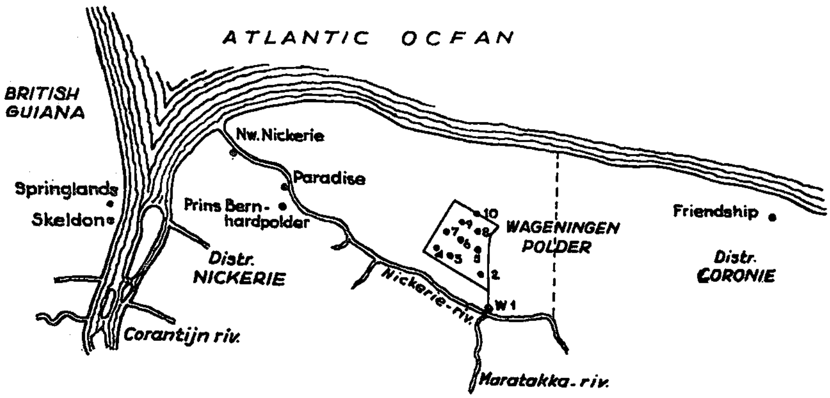


Fig. 2. *The rain stations in the Wageningen area.*
Scale c. 1:10⁶.

minimum of 1,090 mm and a maximum of 2,560 mm (DE SURINAAMSE LANDBOUW, 1950; KRAS, 1953).
Table 9, which gives the annual rainfall figures for various regions of Surinam and British Guiana, seems to show that the Wageningen project lies in the area with the lowest annual rainfall.

TABLE 9 *The mean annual rainfall in Surinam and British Guiana* (DE SURINAAMSE LANDBOUW, 1958; BEACHELL AND BROWN, c. 1949)

Moengo	(1919–1955)	2424 mm
Paramaribo	(1899–1956)	2292 mm
Coronie (Friendship)	(1907–1954)	1684 mm
Nw.-Nickerie	(1924–1955)	1934 mm
Corantyne-Berbice	(c. 1925–1948)	1941 mm
Berbice-Mahaica	(c. 1925–1948)	2381 mm
Mahaica-Demerara	(c. 1925–1948)	2489 mm
Demerara-Essequibo	(c. 1925–1948)	3053 mm
Essequibo-Pomeroon	(c. 1925–1948)	2210 mm

These figures however, appear to be at variance with the rainfall figures hitherto collected in the short period of observation at Wageningen (see Tables 10 and 11), which indicate a higher rainfall than the surrounding Surinam stations. The explanation of this, except for chance deviations, is to be sought in the increase in rainfall from the coast inland. According to observations made elsewhere in Surinam this increase in rainfall is found to occur within a few kilometers behind the coastline. In our comparisons of rainfall figures in Table 9 and 10, it is probable that we are right in this transition area. If this reasoning is correct, a modified and more systematic arrangement of rain stations is desirable, both in Surinam and British Guiana, in order to obtain a better insight of the rainfall in these areas and to create a more reliable basis for making comparisons between them. According to the Paramaribo Agricultural Experiment Station which likewise supports our opinion, the reason for this rainfall phenomenon is that the land is more heated by the sun than the sea, so that there is more ascent precipitation over the land in the dry seasons. Then, owing to the N.E. trade wind which is reinforced by the sea wind during the day, on an average less rain will fall not only over the sea but on a narrow coastal strip as well. Our impression is that even in the Wageningen polder itself the influence of the coastline on the rainfall is still noticeable, although this is not sufficiently demonstrated by the small number of observations hitherto made (Table 10).

TABLE 10 *Annual rainfall in mm over the years 1952 to 1959 measured at the ten stations of the Wageningen project area, compared with the rainfall at Coronie, Nickerie, Prins Bernhard Polder and Paradise*

	1952	1953	1954	1955	1956	1957	1958	1959
Coronie (Friendship)	1335	1729		1760	2225	1054	1385	
Nickerie	1925	1927	2457	2532	2390	1295	1800	
Prins Bernhard polder	1812	1971	2465	2558	2126	1255	1829	1471
Paradise	1859	2058	2328	2513	2568	1574[1]	1991	
Rainfall stations at Wageningen								
W 1	1939	2180	2614	2699	2694	1644	1784	2012
W 2				2623	2512	1796	1914	2154
W 3				2496	2570	1768	2044	1790
W 4					2499	1672	1741	1692
W 5					2384	1674	1929	1928
W 6						1708	2004	1797
W 7					2272	1484	1952	1537
W 8						1577	1925	1647
W 9					2189	1505	1870	1628
W 10							1951	1495

[1] No figures for January 1957; the corresponding rainfall of the Prins Bernhard polder was counted.

During the years 1956 and 1959, when rainfall in the northern part of the polder was lower, mechanized rice farming was substantially facilitated there.

Monthly rainfall

The mean monthly rainfall illustrates the trend of the wet and dry seasons. Table 11 shows the mean monthly rainfall figures for Paramaribo, Nw.-Nickerie and Coronie, and also the means of the same stations, from 1955 to 1958, for comparison with the Wageningen stations W 1 (village), W 2 and W 3.

The lighter rainfall of the Nw.-Nickerie station compared with Paramaribo is found to occur mainly during the period from February to May inclusive. The mean rainfall distribution at the Nw.-Nickerie station is therefore more

TABLE 11 *Mean rainfall in mm per month*

Months	Multi-annual mean (periods see Table 9)			Means from 1955 to 1958					
	Paramaribo	Nieuw-Nickerie	Coronie (Friendship)	W 1	W 2	W 3	Nieuw-Nickerie	Coronie	Paramaribo
January	215	195	189	157	180	172	173	148	142
February	161	109	101	98	104	109	88	115	138
March	192	112	135	165	157	178	99	106	207
April	228	172	152	167	180	172	223	174	231
May	313	249	210	279	318	324	234	202	347
June	302	318	231	314	290	286	287	231	250
July	232	265	214	309	337	326	234	188	195
August	161	149	123	179	176	201	181	77	134
September	79	59	48	149	96	113	93	48	86
October	78	56	45	78	86	73	72	40	87
November	120	77	69	74	76	76	47	80	75
December	211	173	167	236	211	191	270	192	199
Year	2292	1934	1684	2205	2211	2221	2004	1606	2096

favourable for rice cultivation than that of Paramaribo, since, owing to a more marked short dry season as compared with Paramaribo, Nickerie presents fewer difficulties for mechanized tillage. The lighter rainfall in the Coronie area compared with Nw.-Nickerie may be not very advantageous in this respect because this lesser rainfall mainly occurs in the long rainy season when the rice crop is growing.

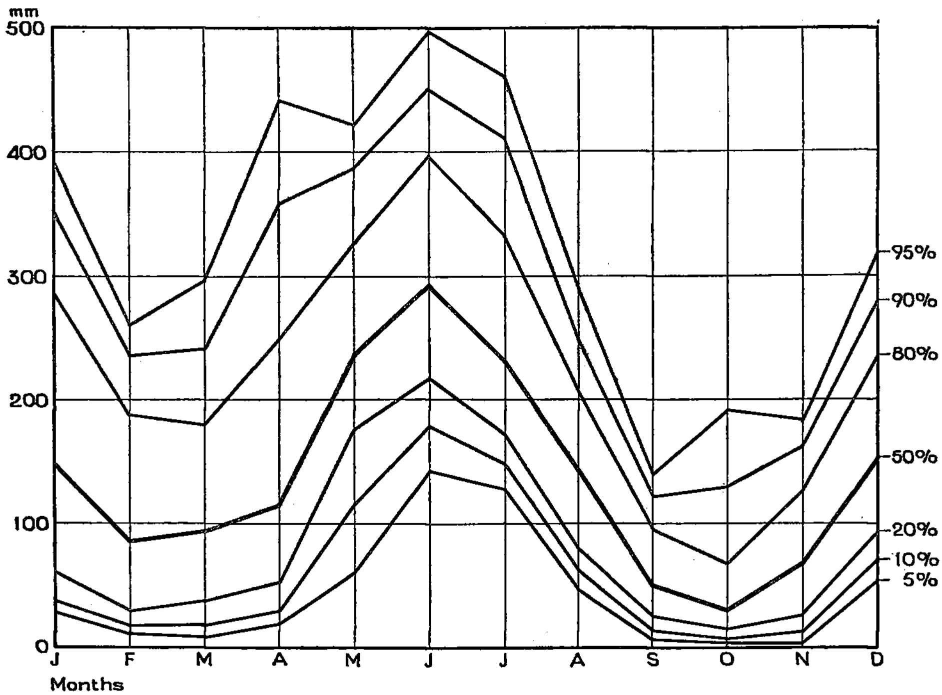


Fig. 3. *Frequency of monthly rainfall at Nieuw-Nickerie as a % chance of less rainfall.* Period 1907–1952 (KRAS, 1953).

Figure 3 gives the frequency distribution of the monthly rainfall at the Nw.-Nickerie station (KRAS, 1953). This figure in particular shows the unreliability of the short dry season compared with the long dry season.

Long-term rainfall periodicity

KRAS (1953) and OSTENDORF (1953) found a periodicity of about 7 years in the annual rainfall. KRAS determined progressive means of the rainfall at the Nw.-Nickerie station for the period from September to March. For a period of 6 years the values varied from 700 to 800 mm, for 7 years from 350 to 825 mm and for 8 years from 650 to 950 mm.

Hence a minimum did actually occur once every 7 years. These minima

occurred in 1911–12, 1918–19, 1925–26, 1932–33, 1939–40, and 1946–47. It was also found that an extra-light rainfall occurred every 14 years, viz. in 1911–12, 1925–26 and 1939–40. On the strength of these findings a long dry period was forecasted for 1953–54. Such a dry spell would have been quite important for the reclamation work envisaged at the time at Wageningen and some preparatives were taken in connection herewith. But the forecast was wrong; the season in question proved even wetter than average.
OSTENDORF'S analysis of the rainfall at Paramaribo shows that a 7-year and perhaps a 14-year period occurs at this station too, but he found that this period may be occasionally disturbed by other influences.

Daily rainfall

From the agricultural point of view, the following aspects are important in the daily rainfall:

a. the daily pattern (for agricultural operations);
b. the frequency of heavy showers (for drainage);
c. the distribution of showers over a certain surface area (for drainage).

The daily rainfall pattern is to be explained by the occurrence of ascent precipitation during or immediately after the maximum heating of the land by the sun.
BRAAK (1953) computed the mean hourly rainfall totals for the months over the period 1922–23 from the pluviograph set up at Paramaribo. The results are shown in Fig. 4. No other data are available for the daily rainfall pattern in Surinam. In January and February the daily rainfall (according to fig. 4) is found to be fairly well distributed over the 24 hours. In the other months a maximum occurs which is still fairly slight in March and April, but highly developed in the remaining months, especially in the long dry season. A

TABLE 12 *Chances of excess in daily rainfalls for the Nw.-Nickerie station, calculated over the period 1923–1952* (KRAS, 1953)

Months	Excess:			
	3 times per year	once per year	once per 5 years	once per 10 years
January	30 mm	40 mm	80 mm	100 mm
February	20 mm	40 mm	60 mm	70 mm
March	20 mm	30 mm	60 mm	80 mm
April	20 mm	40 mm	70 mm	90 mm
May	30 mm	40 mm	80 mm	110 mm
June	40 mm	60 mm	90 mm	110 mm
July	30 mm	50 mm	80 mm	100 mm
August	20 mm	30 mm	60 mm	70 mm
September	10 mm	20 mm	40 mm	50 mm
October	10 mm	20 mm	50 mm	70 mm
November	10 mm	30 mm	60 mm	70 mm
December	20 mm	40 mm	70 mm	80 mm

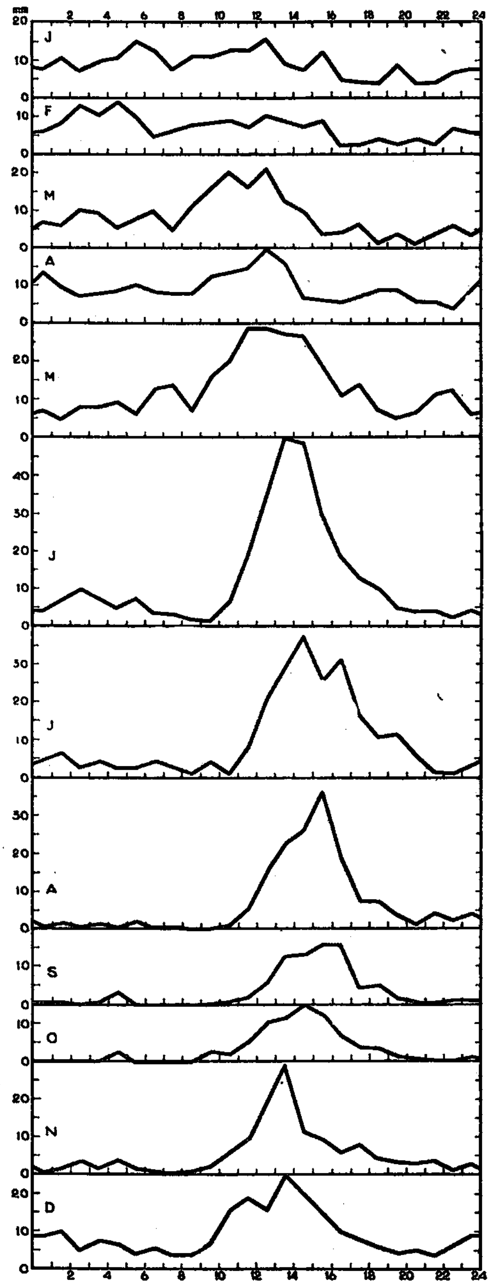


Fig. 4. *The daily pattern of rainfall in means of monthly totals per hour at Paramaribo.* Period 1922–1933 (BRAAK, 1935).

striking feature is the gradual movement of this maximum from c. 11 a.m. in March to c. 12 noon in April, 1 p.m. in May, 2 p.m. in June, 3 p.m. in July, 4 p.m. in August and September, and back again to 2–3 p.m. in October and 1–2 p.m. in November and December.

For determining the drainage provisions required it is necessary to estimate the probability that the rainfall for one or more days will exceed set values. The rainfall figures of the Nw.-Nickerie station were used for this purpose for the Wageningen project. Table 12 shows some approximate figures of the one-day rainfall chances, calculated by KRAS (1953), for the months of the year.

For the special purpose of obtaining an idea of the distribution of showers over an area, we have had analysed the available rainfall figures of the months February, March and April for 10 stations at Wageningen (which are all in use for a short period only). This analysis was carried out by the NEDERLANDSE HEIDEMAATSCHAPPIJ (1959) according to a method described *inter alia* by BEGEMAN (1931). The results are shown in Table 13.

TABLE 13 *Analysis of frequencies of daily rainfalls for 7 rain stations (and partly for 3 others) in the Wageningen polder over a 3-year period (1956–57–58) for the purpose of calculating the reduction coefficient for shower distribution* (NED. HEIDE MIJ., 1959)

The figures in brackets are relatively more doubtful

	Mean frequency of daily rainfall (in mm)			Frequency of mean daily rainfall (in mm)			% reduction		
	excess			excess					
	once per year	once per 2 years	once per 3 years	once per year	once per 2 years	once per 3 years	once per year	once per 2 years	once per 3 years
February . . .	22	28	31	17	(21)	(23)	23	(25)	(26)
March	36	54	64	34	50	(62)	6	7	(3)
April.	30	37	41	27	31	(32)	10	16	(22)

In this connection it should be emphasized that the figures have only a limited indicative value owing to the short period of observation. This is also at once apparent if we compare the results with those of Table 12. This reservation is all the more necessary as several inaccuracies were found in the observation material at hand.

CHAPTER IV

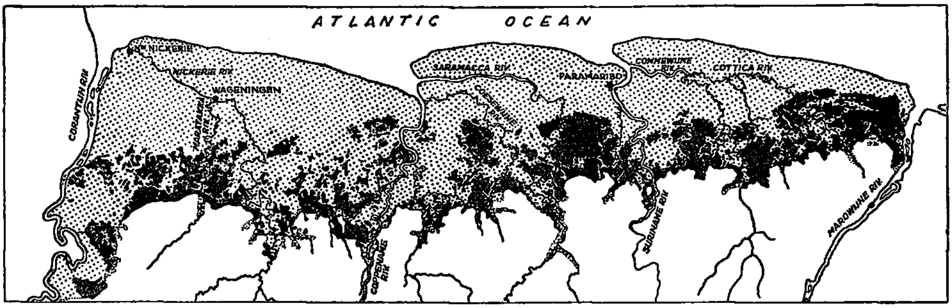
SOIL AND ORIGINAL VEGETATION

1. Soil formation

According to VAN DER EIJK and HENDRIKS (1953), in Surinam one can distinguish from south to north: the highland area (c. 123,000 sq.km), the old coastal plain or the Coropina formation (c. 4 to 5,000 sq.km), and the recent coastal plain or the Demarara formation (c. 16,000 sq.km) (Fig. 5). As far as is known the highland area consists of poor, deeply weathered, residual soils which are not very suited for agriculture. This highland area is practically uninhabited and has still been only roughly surveyed.[1] Apart from some small plots planted with food crops by Maroons and Indians, there is no agriculture.
The old coastal plain which lies in scattered complexes between the highland area and the recent coastal plain, consists mainly of sandy sediments. This formation is very cut up by deposits of the recent coastal plain in the old erosion depressions. The altitude varies from 1 to about 7 m above Surinam Survey Datum[2] (VAN DER EIJK, 1954; VAN DER VOORDE, 1957).
Recent investigations by HENDRIKS (1956) and DIRVEN justify the expectation that at least a part of the old coastal plain soils offers prospects for livestock farming (grassland) and perennial crops. However, at the moment agriculture on these soils is still of no importance whatever.

The recent coastal plain belongs geologically to the Demarara formation (alluvium). Especially along the rivers the Demarara formation penetrates deeply into the Coropina formation as far as the highland. The width of the recent coastal plain increases irregularly from east to west from 10–20 km to 60–80 km (Fig. 5). The soils of the recent coastal plain consist mainly of recent marine-fluvial heavy clays, lying on an average about 1 m below Surinam Level, and which in a natural condition are overgrown with herbaceous vegetation and forest. Because of the flat situation and the absence of drainage these lands are mostly under water (swamps).
Two landscapes can be distinguished in the recent coastal plain, viz. the ridge landscape, and the clay or Nickerie landscape. The ridges occur principally in East-Surinam. They are sand ridges running more or less parallel to the coast; they range from a few metres to some tens of metres wide, to several kilometres long, sometimes grouped in the form of a bundle or a fan, and lie

[1] At the moment a systematic survey is being undertaken under the Ten Year Plan.
[2] The zero level of this Datum is about 2 m above average sea level. (An other Surinam Survey Datum exists with a 10 m lower zero level.)



recent coastal plain (demerara formation)
old coastal plain (coropina formation)
older formations

Fig. 5. *Map of the coastal plain of Surinam.*
Drawn by Centr. Bur. for Aerial Surveys at Paramaribo (HENDRIKS, 1956).

0—2 m above the clay (VAN DER EIJK, VAN DER VOORDE). According to VAN DER VOORDE the sand ridges were formed by the action of waves and wind on the coast line. The Nickerie landscape, in which the Wageningen project is also located, is characterized by the following elements (VAN DER EIJK):

1. Extensive level clay swamps;
2. Strips of flood forest on the sea side;
3. Flat brackish lagoons (pans) immediately to the rear of the flood forest;
4. Somewhat higher banks along the rivers which are overgrown with fairly dense forest.

The recent coastal plain arose by accretion in a shallow sea after the fall of the peneplain and the old coastal plain, and after a rise in the sea level. The clay sediments are chiefly derived from the Amazon whence they are carried by the ocean currents (CHOUBERT, 1949; VAN DER VOORDE, 1957).
After the mud banks had become sufficiently high, a pioneer vegetation arose and a tidal swamp was formed which finally turned into the brackish and salt-water swamps of today.
In the Wageningen region the clay is 20–30 m thick. Indications of marine formation were found in the presence of sea shells in the soil and in the high Mg and Na content in the adsorption complex.
The clay is very heavy and contains practically no lime. Because of the anaerobic condition resulting from permanent inundation, the soil is covered with a layer of half decomposed organic material called pegasse which varies in depth from 0–40 cm (measured in the drained condition). Relatively few studies have been made of the subsoil. The clay is of uniform composition to at least a metre in depth. On excavating the canals at Wageningen, layers of dark earth with the remains of timber were frequently found at a depth of a few metres. After drying out on the dams, soil of this kind showed a rash of yellow iron sulphate and a very low pH ("katteklei"). It is noteworthy

that sometimes shell deposits with high pH's occurred at only a few centimetres distance from the "katteklei" layer in the profile.[1]

An important aspect of the soil formation of the recent coastal plain, with which the "katteklei" formations are also connected, is formed by the exceptionally low lime content. Until recently the general opinion was that marine clay is deposited in the first instance when rich in lime, and that lime impoverishment is caused by a leaching later on by organic acids arising from the vegetation growing on it (DE SMET, 1954; VAN DER SPEK, 1950; VEENENBOS, 1955; VAN WIJK, 1951).
Recent investigations, including some in the Netherlands, have shown, however, that direct lime-deficient deposition may occur (MÜLLER, 1955; DE SMET; VEENENBOS). According to VERHOOG (EIJSVOOGEL ET AL., 1948) and VAN AMSON (written comm.), this is also the case with the clay of the coastal plain of Surinam. In our opinion the fact that there is no significant difference in the lime content of the clay soil with increasing distance from the coast (i.e. with increasing age of the deposition), and the fact that no variation in the lime content has been found in the profile, also points to direct lime-deficient deposits.
On the analogy of lime-deficient deposits elsewhere, we imagine that the Surinam deposits were formed as follows. During sedimentation below sea level there was little lime deposition. This view is supported by NOTA's observation (1958) that the submarine sediments along the coast of the Guianas have low lime contents (less than 2%). Apart from the possibility that in places sea water may already have low Ca-contents[2], this can be explained by the coastwise dilution of the sea water by a great deal of river water which was partly deficient in bases and even acid.
There was also sedimentation in the presence of vegetation, an environment which we might term a tidal swamp.
The layer with remains of timber and other organic material which was found a few metres deep in the profile of the Wageningen polder indicates that the sea water levels during the formation of the soil were occasionally lower. Thus the soil at a depth of a few metres in the profile may also have been sedimented in the presence of vegetation. The lack of lime deposition in the clay during sedimentation in the tidal swamp can therefore also be explained by the dilution of the sea water with large quantities of rainwater or acidic swamp water.

2. Profile structure and topography

The investigation carried out in order to determine the choice of a site for the

[1] Similar *katteklei* phenomena occur in the sugar-cane plantations in British Guiana. As a result, the sugar-cane grows very poorly on some of the dams along the canals.

[2] For the Netherlands the following composition of sea water has been given: 2.67% $NaCl$, 0.32% $MgCl_2$, 0.20% $MgSO_4$, 0.16% $CaSO_4$, 0.13% KCl, 0.04% $NaBr$ (DOMINGO, 1946).

Wageningen scheme consisted of a soil reconnaissance, a topographic survey and vegetation mapping with the help of aerial photographs.

The soil reconnaissance was carried out by VERHOOG (EIJSVOOGEL ET AL., 1948). In 1948 and 1950 he followed the route of several cleared tracks in the Wageningen region. Samples were taken and submitted to analysis.

Considerable uniformity was found and this was confirmed by a study of the aerial photographs. Taking into account the general character of this type of land, it was assumed that no substantial acreages having widely differing properties would be found within the area to be empoldered. Since it also appeared that the soil properties agreed with those of other coastal clay soils in Surinam, it was not considered necessary to map the polder area in detail.

In its natural position, i.e. before reclamation, the average soil profile, according to DOST, is constructed as follows (LANDBOUWPROEFSTATION, 1956):

about 0– 40 cm (above the clay): more or less decomposed organic material viz. the pegasse.
0– 10 cm: humous clay.
10– 30 cm: reduced zone, viz. grey clay with a little mottling.
30–100 cm: rust-brown to yellow-brown mottled, grey clay.
>100 cm: uniform dark grey, salty clay.

In the early years little attention was paid to the pegasse and no chemical analyses were made of it. In the field reconnaissance usually only the depth of the layer has been observed, this being in fact the most important fluctuating feature of the pegasse with regard to reclamation and cultivation.

The thickness of the pegasse in the area selected mostly varied from 0 to 40 cm (measured in the drained condition). Only on a relatively inconsiderable area the layer was thicker than 40 cm. It was found that the pegasse on the older, poorly drained, forest lands more to the south, was somewhat thicker than in the northern grassy swamps.

In places the pegasse was practically absent in the grassy swamp owing to repeated fires. Moreover, the central *Pterocarpus*-forest complex exhibited thicker pegasse, this being principally due to the somewhat lower elevation of this area. Silted-up creeks and small depressions were scattered over the polder area, all with more pegasse development.

Generally speaking the great mass of the pegasse was of a coarse and fibrous structure; under grassy swamp vegetation it was densely matted by the root system; under forest it had a looser structure. From the top downwards the pegasse gradually changed from recently withered plant material to a more decomposed peaty material, but this transition was disturbed by the roots of the living vegetation. The transition to the clay was fairly abrupt with a small layer of black friable earth a few centimetres thick.

The observation of the depth of the pegasse in the initial site reconnaissance, was important in connection with the choice of site as in the coastal plain of Surinam, and especially in British Guiana, there are areas with very thick pegasse layers extending to more than a metre in depth. The difficulties

caused by these peaty soils in reclamation and rice cultivation make them less attractive at the moment as long as other soils are available.
In Malacca also similar reasons led to soils with little peat being preferred (COULTER, 1956).

The extent of the mottling of the clay was an index of the drainage condition and hence of the elevation of the land. For example during construction of the estate the river bank ridges exhibited a relatively higher degree of mottling. When empoldered and brought into cultivation the profile changed somewhat. Part of the pegasse is then found in the topsoil. As a result of tillage the humous clay layer reaches a thickness of about 20 cm. According to DOST (LANDBOUWPROEFSTATION, 1956) the reduced 10–30 cm zone disappears, within a year of empoldering; this clay then has the same mottling as the layer beneath it.

Since there are no great differences in the nature of the clay soil the factors of topography and original vegetation assume greater interest. The topography of the area was found to be completely related to the soil formation. The topographic survey was carried out by CALOR and KRAAN in 1950 and 1951 along the tracks shown in Fig. 6, in which the level of the clay soil, viz. excluding the pegasse, was measured at 100 m intervals.

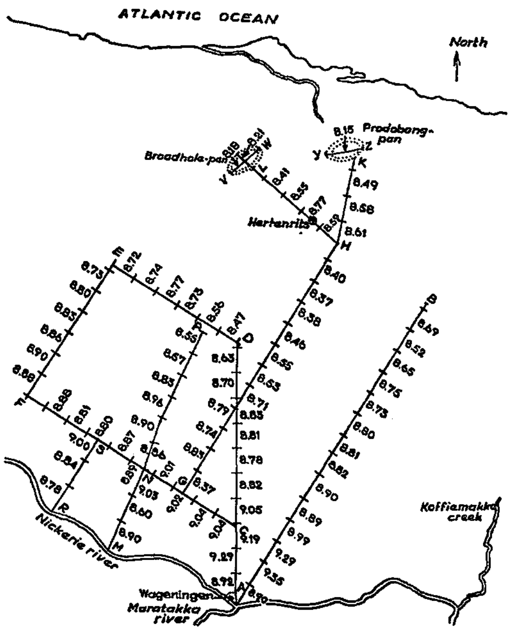


Fig. 6. *Topographic reconnaissance; survey lines with means of 10 height measurements per 100* m.
In metres + "Nickerie-survey datum". (The zero level of this Datum is about 8 m below average sea level.)

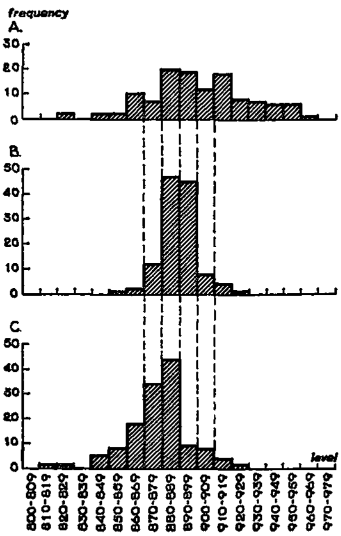


Fig. 7. *Frequency distribution of height measurements per 100 m in survey lines referred to in fig. 6.*
A. 1st 3 km strip to the north of the river.
B. 2nd do.
C. 3rd do.
In metres + "Nickerie-survey datum".

The figure shows the averages of 10 measurements, i.e. about every km of the lines surveyed. A strip of about 3 km along the river has a somewhat uneven topography with differences in height of up to 1 m at short intervals of some hundreds of metres. These differences were caused by the presence of old river banks. On the aerial photograph (Fig. 8), five banks can be vaguely distinguished by their denser forest growth.

Further to the north the land is flat, at first with a slight drop of 5–10 cm/km towards the north, but about half-way to the coast there is no further distinct slope.

In order to give an impression of the topography of the land, the altitude frequency distributions of the survey lines running from the river were summed for the first, second and third 3-km sections respectively.

The graphs (Fig. 7) show the influence of the banks in the first sections.

Summing up, the following pattern emerges:

1. A somewhat uneven terrain with various old banks near the river. The creeks draining into the river reach their largest dimensions in this area.
2. A central area with slight differences in altitude. The outliers of the river and ocean creeks are small and mostly filled with accumulated organic matter and silt.
3. Again a somewhat uneven terrain near the coast, caused by ocean creeks kept open by ebb and flood flow, and lagoon depressions (pans) which are gradually filling up as a result of marine silt and vegetation.

3. **Original vegetation**

Introduction

The nature of the original vegetation is important: for the method of reclamation and the reclamation costs, for an indication of the soil characteristics (elevation, salt content and acidity) and for its direct influence on the soil.
The influence of the vegetation on the soil in the recent coastal plain of Surinam, has especially occurred by the differing type and thickness of the pegasse which is formed by this vegetation. During reclamation, pegasse which was not burned, was mixed with the top clay layer and thus became a part of the topsoil.
When the project was laid out from 1952 to 1956, and as the areas became accessible as a result of the excavation of canals and ditches, a detailed vegetation map was made for each 12-ha field before this vegetation was removed mechanically. From this a vegetation map of the whole polder was compiled of which Fig. 9 gives a simplified picture. When one compares the aerial photographs (Fig. 8), made in 1947–49 with the field map (Fig. 9), it can be concluded that they show substantial agreement. The principal point of difference is the central *panta* forest which is scarcely visible in the aerial photographs. This is to be explained as follows:
— *Panta* forest is scarcely visible on aerial photographs because the *panta* (*Tabebouia insignis* group) is an insignificant tree from a few metres up to a maximum of 10 m in height, its main feature being in this respect its low amount of foliage and almost complete lack of crown. Moreover, the *panta* frequently occurs as a fairly open shrub forest. In the early years of the project, the *panta* forest, which owing to its tough wood is difficult to clear was an unexpected source of trouble. This again shows the need for supplementing aerial photography with adequate field interpretation.
— When the polder lands progressively became better drained as a result of the excavation of the canals, the conditions for forest growth became more favourable. The central forest area had to be drained for a fairly long period before it was reclaimed, so that here the forest could still develop vigorously.

The natural vegetation of the recent coastal plain of Surinam was studied by LINDEMAN and a description published in a monograph in 1953.
Comparison shows that the natural vegetation of the Wageningen polder is no exception to the entire pattern of the Surinam coastal plain. The principal vegetation types which occur in the Wageningen area (see Fig. 8 and 9) are: mangroves on the coast and along the banks of the river estuaries; herbaceous swamps and forest swamps further from the coast; marsh forest, on the bank ridges and the better-drained parts along the rivers.
The following description of the original vegetation is a combination of LINDEMAN's data and our own observations.

Mangroves

a. Along the lower rivers. As soon as the wave action at the mouth of the Nickerie river becomes insignificant the *mangro (Rhizophora mangle* L.*)* grows on the slope of the bank, in places alternating with *akira (Laguncularia racemosa* L.*)*, both occurring as bushy forest. On the bank ridge itself and behind it we find the *parwa (Avicennia nitida* Jacq.*)*, with fairly vigorous trees.

Further up river where the water is polyhaline (10,000 to 17,000 mg Cl/litre) *brantimakka (Machaerium lunatum* L.*)*, a thorny impenetrable shrub plant, also occurs.

Still further upstream the *parwa* decreases, the *akira* gradually disappears, and it is usually not until the water is fresh or at most oligohaline (100–1,000 mg Cl/litre), that *moko-moko (Montrichardia arborescens* Schott*)* appears at the water's edge, and occurs in dense groups of vegetation. The *parwa* is replaced by mixed forest but, like the *mangro* it does not at first disappear altogether.

The *brantimakka* still occurs in considerable numbers further up river. In the mixed forest we find a.o. wild *cacao (Bombax aquaticum* Schum.*)*, *bébé (Pterocarpus officinalis* Jacq.*)* and *mora (Mora excelsa* Benth.*)*. In this gradual transitional area lies the line of the bank of the Wageningen project.

b. Coastal mangroves. On the Atlantic coast north of Wageningen *parwa* forest occurs in a strip in places several kilometres wide. Surinam has a muddy coast. As a result of the movement of mud banks, accretion and erosion occur alternately.

Parwa seedlings have even been found on the mud flat in front of the accreting coast. *Parwa* is the principal pioneer plant, after which come *akira* and *Spartina brasiliensis* Raddi, the latter however crowded out by the trees. In immediate proximity to the sea *parwa* occurs as bushy forest, and further inland full-grown *parwa* occurs. Scattered *parwa* patches are met with quite far into the swamp behind the *parwa* coastal strip. The *sapakara* fern *(Acrostichum aureum* L.*)*, a plant of considerable size, also grows in the *parwa* area. On an eroding coast, the *parwa* forest is gradually destroyed. The *parwa* forest is also affected on the inland side by swamp fires.

Herbaceous swamps

There is some diversity in the plant communities in these swamps. Little is known of their stability. From the *parwa* strip going further from the coast we find the following vegetation types in the Wageningen area:

a. *Eleocharis mutata* R. and S. A short triangular rush which in places forms entire fields behind the *parwa*. This *E. mutata* can grow in a very salty environment; owing to evaporation the swamp water just behind the coast may be about twice as salt as sea water (sea water contains about 19,000 mg Cl/litre). In a less salty environment it is overgrown by other plants. According to LINDEMAN, *E. mutata* has a highly acidifying effect and turns the swamp water dark brown. This area of vegetation lies outside the present polder but will probably come within the northern extensions.

b. Brackish swamps with *long grassie (Typha angustifolia* L.*)* and *bies bisie (Cyperus articulatus* L.*)* which occur separately or together, with few associate species. This vegetation grew on a large part of the 6th and 7th series of the polder. The *Typha* swamp occurred especially in a lower part which had a very soft soil.

c. Slightly brackish to fresh water swamps with a vegetation in two layers: at the top, up to a few metres high: *Cyperus giganteus* Vahl, *Scleria* sp., *Montrichardia arborescens*, *Fuirena* sp., *Jussieua* sp., etc. and below: *Cyperus articulatus*, ferns *(Blechnum indicum* Burm., *Dryopteris* sp.), short grasses *(Leersia hexandra* Sw., *Luziola spruceana* Benth. ex Doell.), etc. This mixed herbaceous vegetation occurred in alternating combinations on the other areas of the polder then covered with grass swamp (Fig. 9).

In places there were fairly homogeneous swamps of *C. giganteus* and of *Typha* or ferns.

LINDEMAN (1953) described a fourth grass swamp type with *Rhynchospora corymbosa* L. as well as numerous ferns which was not found in the Wageningen area and probably occurs only in the old oligotrophic swamps with thick pegasse layers. The *maurisie* palm *(Mauritia flexuosa* L.f.) was also typical for this swamp.

Swamp forest

The herbaceous vegetation in the swamp alternated with areas of low forest.

In the central part of the Wageningen polder there was a fairly uniform area of about 500 ha with *bébé (Pterocarpus officinalis* Jacq.). This area was characterized by a soft clay which caused difficulties in reclamation. *Bébé* forms a fairly dense forest of quite straight trees, of moderate size. The stem is very markedly spread out at the foot in curiously shaped plank buttresses. The root system forms a horizontal layer which lies on the clay and does not penetrate into it.

To the south of the *bébé, panta (Tabebouia insignis* group*)* formed large areas, sometimes in the form of a dense low forest but mostly fairly open and passing over into scattered stands in the grass swamp. Unlike the *bébé*, the root system of the *panta* penetrates somewhat deeper into the clay. The trees remain small and have a relatively broad base. The wood is hard and tough and is used for spade handles, for example.

In the first and second series of the polder there was about 1,000 ha of fairly homogeneous *koffiemama* forest *(Erythrina glauca* Willd.*)*. This is a moderately high freshwater forest which moreover can tolerate some salt. The uniformity is assisted by the deep shade of the large crowns and by the ready reproduction. Propagation is by seed and vegetatively since the trees, which topple over easily, throw out shoots in many places forming a row of new trees. The *koffiemama* wood is soft and after dying it rots away quickly. The bark is very thorny.

In places the *koffiemama* was mixed with *mirahoedoe (Triplaris surinamensis* Cham.). Below the trees there was a fair amount of undergrowth such as ferns, *paloeloe (Ravenala guyanensis* (L.C.Rich.) Benth. and *Heliconia psittacorum* L.f.*)*, and *moko-moko*.

The thornbush *brantimakka (Machaerium lunatum* L.*)* formed a special type of vegetation which occurred in the polder in dispersed places of pure stands (total area about 30 ha). In the swamp land to the east of the present polder there are hundreds of hectares of *brantimakka* which makes this land less suitable for reclamation. The liana-type network of the *brantimakka* is difficult to clear; it has to be entirely rolled up with bulldozers.

Marshland forest

By marshland is meant areas which regularly dry up in seasons of drought. Parts of the lands between the southern boundary of the polder and the Nickerie river come under this category. The area has a number of old river banks of clay (up to about 1 m above the plain), the highest parts of which are mostly dry. Some of this area has natural drainage into the river.

The forest vegetation is very mixed and fairly heavy. The most common tree is the *mirahoedoe*. In addition there are found the *maripa* palm *(Maximiliana maripa* Mart.), the *pina* palm *(Euterpe oleracea* Mart.*)*, *baboen (Virola surinamensis* Rol.), *mora, bébé*, wild *cacao*, *bolletrie (Manilkara bidentata* A.DC.*)*, locust *(Hymenaea courbaril* L.*)*, wild *papaya (Cecropia peltata* L.*)*, etc. Very conspicuous is the massive *kankantrie (Ceiba pentandra* (L.) Gaertn.*)* with a wide crown extending above the rest of the forest.

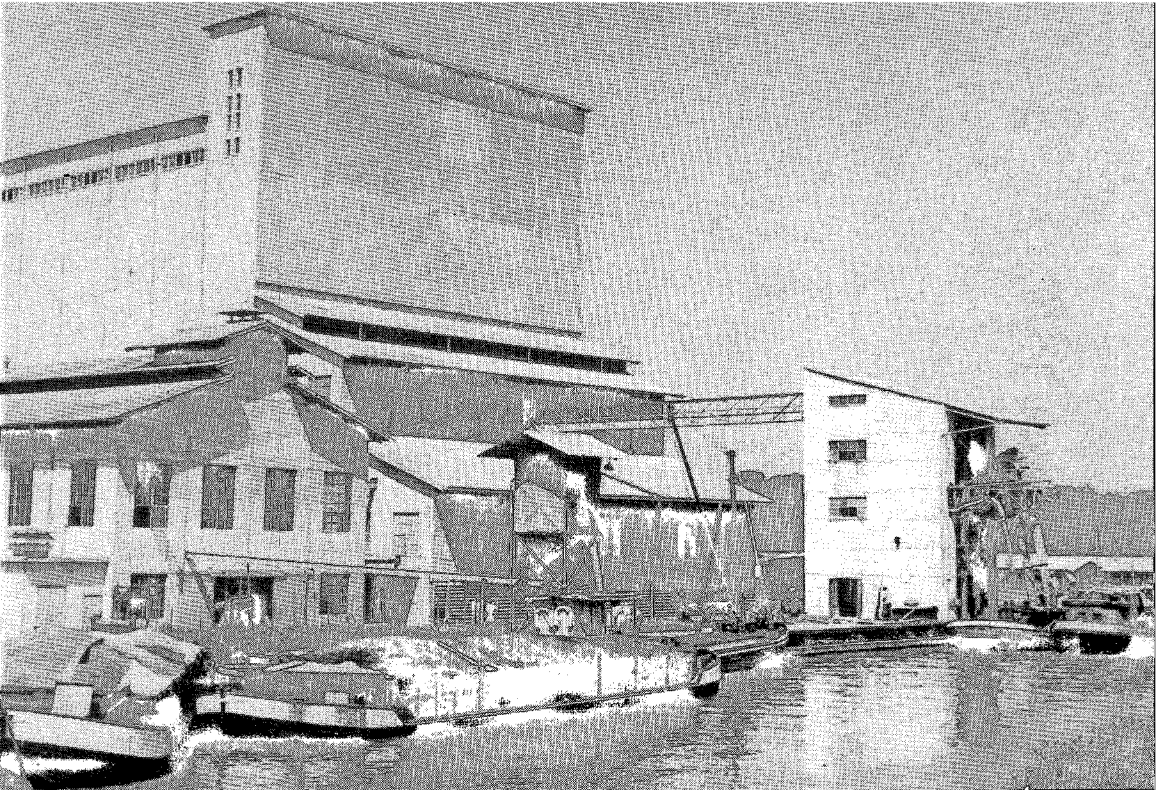
The causes of the vegetation pattern

The vegetation pattern of forest and grass and of the various plant species in the swamp is partly fortuitous and partly due to the habitat.

Lindeman (1953) could find no differences in forest boundaries in the Nickerie area between aerial photographs made in 1939 and 1948. He rightly supposes that tree growth requires special conditions which occur only once in so many years and then only locally. These conditions for change will occur, for example, in extremely dry years in which on the one hand new tree seedlings can develop on drying ground, and on the other hand large swamp fires may occur as a result of which existing forests disappear.

The salt content of water and soil is an important habitat factor.

We can find with a certain regularity the sequence of the pioneer plant *parwa* by *salt* water with *E. mutata* close behind it, and further away from the coast via the *brackish* area with *C. articulatus* and *T. angustifolia* the *fresher* swamp with *C. giganteus, moko-moko*, ferns and forest areas of *bébé, panta, koffiemama* and *mirahoedoe*. It is likely that with an



5. *Rice processing plant; from l. to r. mill, silo with driers in front, and precleaning station withe levators; in the foreground, inner harbour with lighters loaded with bulk paddy.*

6. *Main irrigation canal with speedboat- and lighter-traffic.*

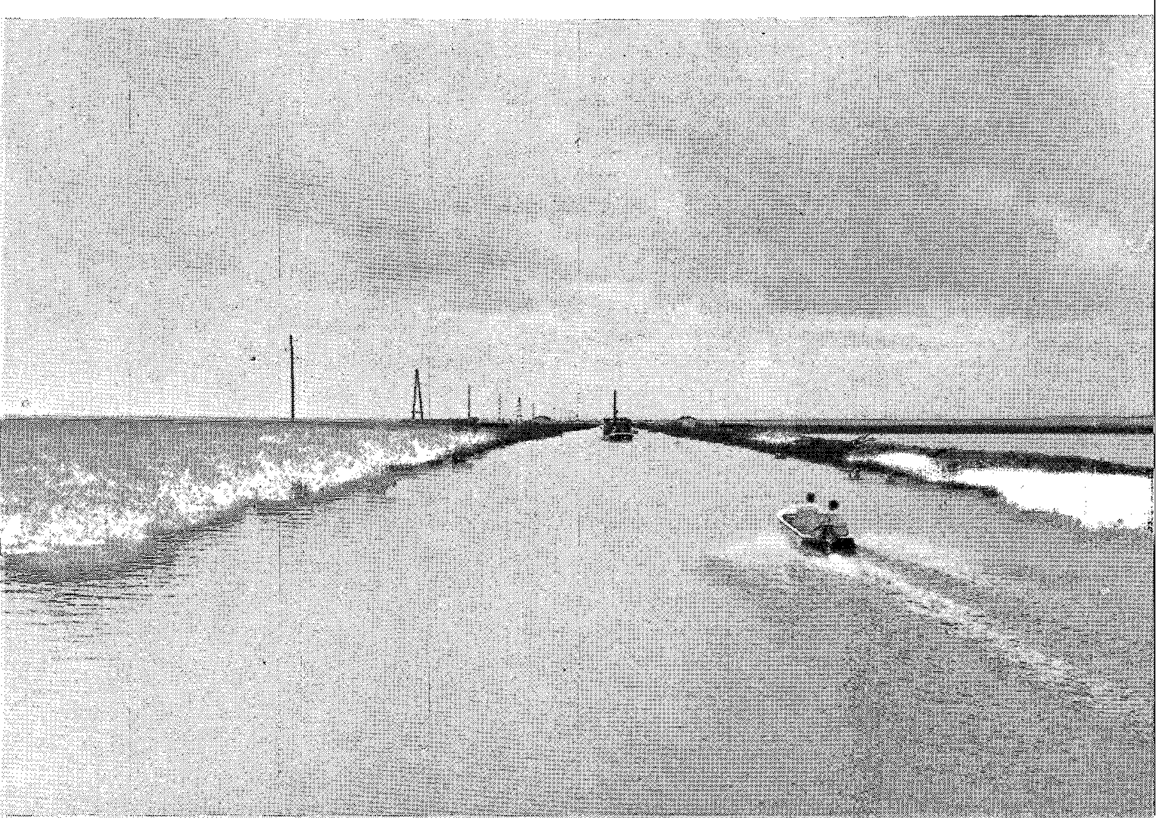


Fig. 8. *Aerial photograph of the Nickerie area by KLM 1947-'49, with outline of present polder.*

Scale appr. 1 : 200,000

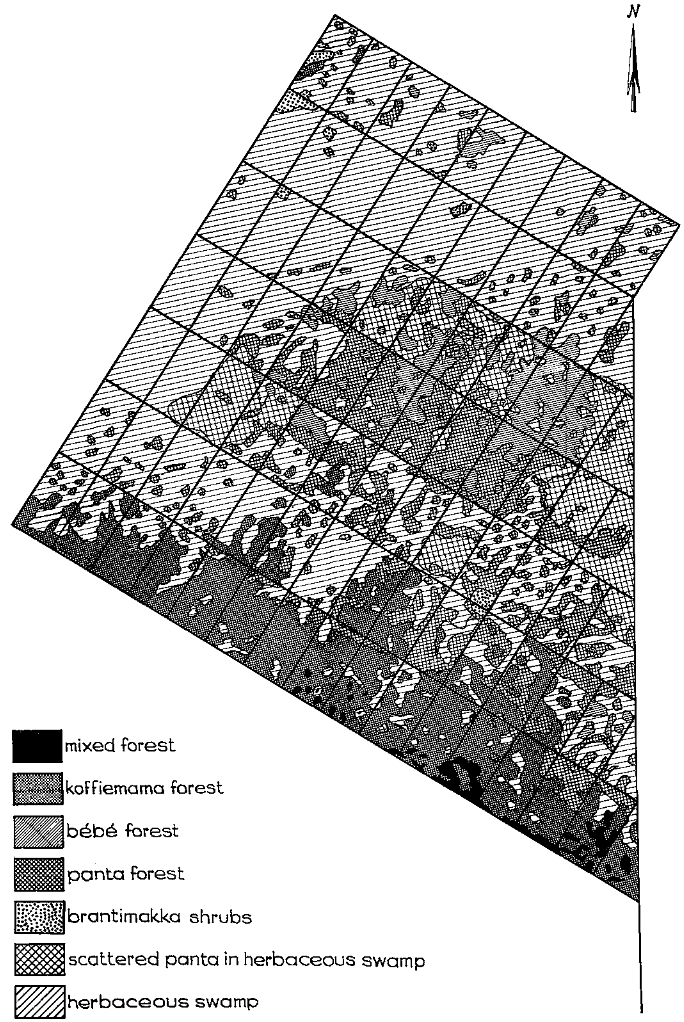
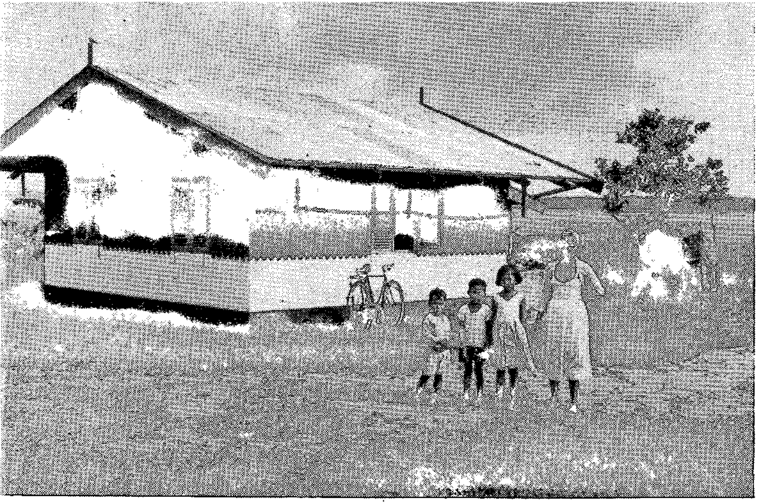
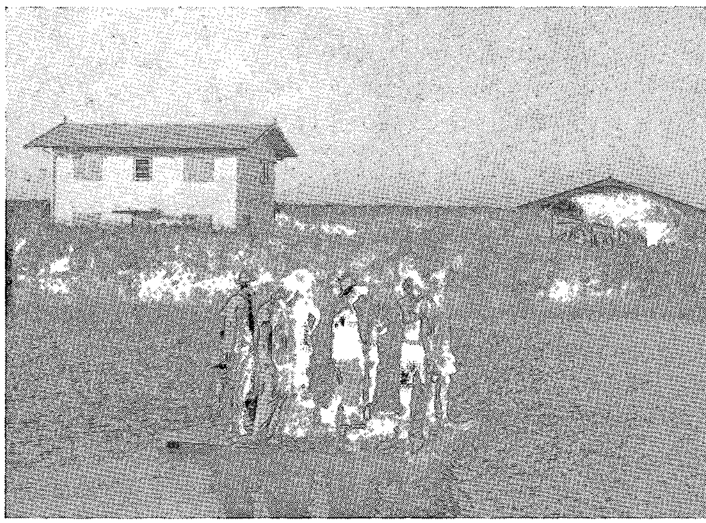


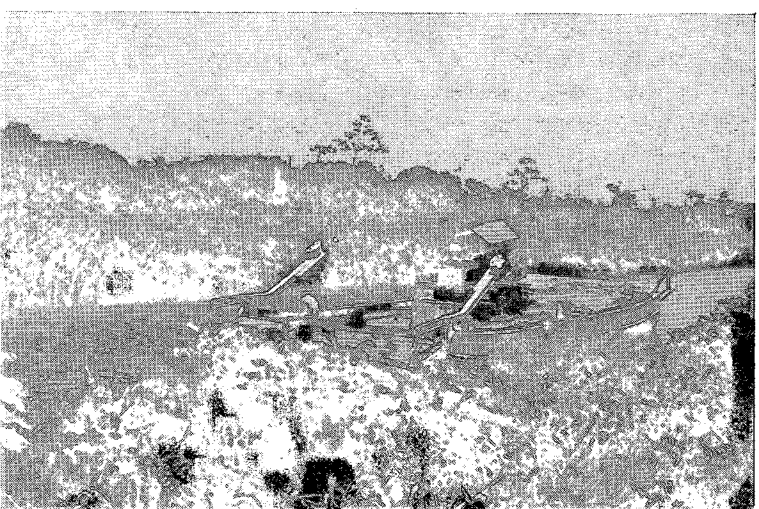
Fig. 9. *Map of the original vegetation of the project.*



7. *Labourer's house with Javanese family.*

8. *Ferry floating on steel drums used for crossing irrigation canal. On background farmhouse.*





9. *Pontoon for transport of machinery.*

accreting coast the vegetation, at one particular site will change in a similar sequence. Hence the vegetation is a rough guide to the presence of salt water or salt soil.
A second environmental factor is the influence of the water table and thus of the level of the land. In the north of the polder *parwa* in open swamp indicated beds thrown up by Indians in former times. A dense mixed forest also occurred here on an old Indian dwelling terp of about 6 ha. In the west a fine line on the aerial photograph can be observed (Fig. 8). This shows a bush vegetation on a narrow shell ridge. In the south by the river the broad strip of forest shows that this land lies somewhat higher (and/or is better drained). In this riverbank forest small open grass swamps occur in places which again may indicate a lower elevation, for example between the old river bank-ridges. In contrast to this the *bébé* forest in the central plain corresponds to a somewhat lower elevation of the clay soil, which agrees with the observations of LINDEMAN (1953), that *bébé* forest has a certain preference for low lands.
A third factor is the thickness of the pegasse. With increasing thickness there is a change in the vegetation. The *Rynchospora* grass swamp is an example of this. It usually leads to increased fern growth as well.

The chemical composition of the clay in the Wageningen polder is very homogeneous so that it does not result in any differences in vegetation.
In the chemical soil analyses no systematic differences were found for the polder area when sampling was carried out according to vegetation types (BEDRIJFSLABORATORIUM, 1953; KONINKLIJK INSTITUUT V. D. TROPEN, 1955; LANDBOUWPROEFSTATION, 1953). However, the pegasse was not included in these experiments.

Fires are the main reason why extensive grass swamps are situated immediately behind the coast. According to LINDEMAN (1953) and GONGGRIJP (1948) these fires are probably entirely anthropogenous.
The forest and swamp fires may reach vast dimensions. Large areas are then under a smoke cloud for days, while flakes of ash from the foliage are carried by the wind for miles outside the area of the fire. It may be assumed that these fires have led to a certain chemical depletion of the soil both by removal of ash by the wind and solution of ash salts in the swamp water.
When the Wageningen polder was brought under cultivation the forest areas were found to give more difficulty because of over-rank growth of the rice crop as compared to the grass swamp areas. This difference is due to the relatively greater N content (thicker pegasse) of the forest ground compared to the grass swamp resulting from enrichment by the tree leguminosae and the accumulation thereof consequent on the absence of fires.
Whether the chief factor is at present the occurrence or absence of fires or the presence or absence of leguminosae is a matter of which we are ignorant.

4. Results of soil analyses

The chemical analyses all relate to the clay soil before reclamation. The pegasse layer lying on the clay was invariably ignored. The investigation was made with samples of 0–20, 30–50, 50–70 or 60–80 cm depth, and also of 0–24, 24–48 and 48–72 cm, or of 0–10, 10–30 and deeper than 30 cm, or of 0–10 and 25–35 cm. For the purpose of compiling a survey of the various soil investigations in Table 14, the analysis figures were schematically divided as far as possible, into the profile depths 0–25, 25–50 and 50–75 cm. The analyses were made by the Agricultural Chemistry Laboratory, Wageningen, the Agricultural Experiment Station, Paramaribo, the Farm Laboratory, Oosterbeek, and the Royal Tropical Institute, Amsterdam. In all more than 150 samples from scattered sampling sites were analysed.

The mechanical composition of the clay is uniform. No differences were found depending on the distance from the river or sea.
In a X-ray investigation (KONINKLIJK INSTITUUT VOOR DE TROPEN, 1955), about 50% of illite was identified in the < 2 μ fraction. The other minerals were 25% quartz, 10% kaolinite and 15% of an unknown illite-type mineral. Mineralogical investigation of the deeper layers (LABORATORIUM VOOR GRONDMECHANICA, 1951) also showed a preponderance of the clay mineral illite to a depth of about 13.5 m.
According to the laboratory reports the content of P_2O_5 extractable with 2% citric acid, is low in the topsoil and moderate in the subsoil. The total P_2O_5 content (in 25% HCl extract) showed great variations in the analysis figures, viz. from 16.3 to 135 mg/100 g dry soil. According to the KONINKLIJK INSTITUUT VOOR DE TROPEN (1955) most of this P_2O_5 is bound to Fe and Al, which, like Mn, are present in the soil in large quantities in an easily extractable form.
The potassium contents increase somewhat with the depth in the profile; according to the LANDBOUWPROEFSTATION at Paramaribo (1952, 1953, 1956) the level can be considered satisfactory for rice growing.
The analytical data for chloride and sulphate contents were incomplete and generally very divergent and hence unsuitable for inclusion in the table.

All soils contain a fair amount of Na chlorides deeper in the profile. The following chloride contents (mg/100 g dry soil) were found in one investigation (EIJSVOOGEL et al., 1948):
0–20 cm average 20 of 11 samples varying from 4 to 41,
30–50 cm average 46 of 6 samples varying from 18 to 67,
50–70 cm 89 in 1 sample.
In another investigation (LANDBOUWPROEFSTATION, 1952) the following chloride contents were found:
0–10 cm average 39 of 6 samples varying from 26 to 59,
25–35 cm average 54 of 6 samples varying from 34 to 87.
Towards the coast, the swamp water and the topsoil too become brackish to salt. The pans south of the parwa forest are in communication with the sea; the water in them can be very salt during dry weather, but in the rainy season it is brackish to fresh. In WIGGERS' soil survey (1956) for example, in the area west of the polder the Cl content (in mg/100 g dry soil), varied in the topsoil from 34 to 230, and in the swamp water samples in the north (about 7 km from the sea) from 69 to 135 mg Cl/litre. The desalting of the topsoil after empoldering is a rapid process, especially in the case of rice growing in which great quantities of irrigation water are used. Therefore the initial salt content of the clay does not substantially affect the productivity of the rice crop.

The sulphate contents found in the analyses vary from 0 to 400 mg (per 100 g dry soil) in about 50 determinations. The analysis-figures vary somewhat erratically between those values and their seems to be no clear connection

TABLE 14 *Summary of some results of soil analyses*
(Compiled from reports by: BEDRIJFSLABORATORIUM, Oosterbeek, 1953; EIJSVOOGEL et al., 1948; KONINKLIJK INSTITUUT V. D. TROPEN, Amsterdam, 1955; LANDBOUWPROEFSTATION, Paramaribo, 1952, 1953)

	0–25 cm			25–50 cm			50–75 cm		
	mean	scatter	number	mean	scatter	number	mean	scatter	number
Organic matter (%)	5	2.0–9.5	34	1	0.7–1.6	12	1	0.4–0.8	12
C/N		10–17	12		7–11	12		5–10	12
Mechanical composition (%):									
$< 2\mu$	65	47–79	45	65	45–74	35	61	42–74	29
2–20μ	28	15–36	30	31	21–40	23	34	26–44	17
20–200μ	4	0–16	30	3	0–11	23	5	0–19	77
$> 200\mu$	0	–	45	0	–	35	0	–	29
N-total (mg/100 g dry soil)	187	103–303	12	58	46–87	12	45	36–52	12
P_2O_5–2% citr. (mg/100 g dry soil)	6	1–14	37	6	4–14	24	12	7–15	12
K_2O–0,1 n. HCl (mg/100 g dry soil)	21	9–35	32	29	19–40	24	35	29–41	12
Cations (m.e./100 g dry soil):									
total adsorption capacity	37	33–44	20	32	30–34	14	34	31–37	12
H^+	7	5–11	6	2	2–3	6			
Ca^{++}	10	6–14	20	8	6–10	14	9	8–10	12
Mg^{++}	16	14–18	8	16	15–16	2			
K^+	1	0–1	20	1	–	14	1	1–2	12
Na^+	1	1–2	8	2	–	2			
$CaCO_3$ (%)	0.0	–	12	0.1	0.1–0.2	12	0.1	–	12
pH–H_2O		4.8–6.8	44		4.6–7.7	34		5.0–8.3	30
pH–KCl		4.1–5.4	28		4.0–6.0	18		4.9–6.5	18

with the depth in the profile. The Soil Science Laboratory of the KONINKLIJK INSTITUUT VOOR DE TROPEN (1955) thought the sulphate figures strikingly high. However, no disadvantageous effects of this have been observed so far with wet rice cultivation.

The topsoil is slightly acid; in the subsoil the pH increases and becomes neutral to slightly basic. The lime-free sedimentation of the clay, the occurrence of a swamp vegetation, and the fluctuating sea level have created a situation which may lead to the formation of "katteklei" by aeration. "Katteklei" is formed by oxidation of sulphides present in the soil to sulphuric acid which will not be bound by absence of free lime (VAN DER SPEK, 1950).

The phenomenon of "katteklei" formation is found on marine clay swamp soils throughout the world, both in the temperate zones and the tropics (DOUGALL, 1950; CONFERENCE REPORT GUIANA, 1955; VAN DER SPEK, 1950; VAN WIJK, 1951; ILACO (VAN DER MEER) 1957).

In the soil survey in the Wageningen project area particular attention was paid to this question. As "dry" crops were envisaged in the cropping pattern, the intensive drainage and dry tillage would increase aeration and might therefore engrave the danger of "katteklei"-formation.

In addition to the already mentioned dark-coloured layers of earth occurring at a depth of a few metres, which developed into "katteklei" after excavation, low pH's (< 3) were found only sporadically in the topsoil of the polder, as a result of thick layers of organic material or of organic material sealed off by clay. The sampling points showing acid soils in the Wageningen area were mostly small dried-up creeks and also beds raised by Amerindians in earlier times. The total surface of these acid soils however was practically negligible.

The soil mechanics investigation in connection with the construction of canals and the structure of buildings was carried out by the Soil Mechanics Laboratory, Delft (LABORATORIUM VOOR GRONDMECHANICA, 1951). A discussion of this is outside the scope of this study.

It will merely be observed that the soil has a marked clayey character so that tali and dams can easily flow out, while during droughts shrinkage cracks will appear. In rainy weather the clay will become impassable, and at the wind/water line of the canals soil will crumble away. These unfavourable properties had to be strictly taken into account when profiling the canals and roads.

CHAPTER V

TYPE OF FARMING

The type of farming to be chosen for the Wageningen project was dependent on several factors which can be classed according to: the object of the scheme, the natural environment and the economic conditions.

Object of the Scheme

The main object of the Wageningen scheme is to make a contribution towards the development of Surinam agriculture. Originally it was thought to achieve this aim by the establishment of independent farms leased to Dutch farmers, which meant that the net farming results had to guarantee a good living by Western standards.

In the basic plan therefore was suggested to create a mixed type of agriculture with a farm-size of 72 ha, with 1/6 of the area in ley and 5/6 under paddy in the main rainy season, followed by such dry crops as soybeans and maize in the less rainy period of the year. This plan however was not put into practice, as the highly fluctuating rainfall, the properties of the heavy clay soil and other factors which will be discussed on p. 56–57 did not permit the economic integration of cattle (grassland) and of dry crops in a mechanized agricultural undertaking. On the other hand, wet rice-growing fully came up to expectation. The mechanization of this crop in particular proved a great technical success. Owing to the absence of alternative possibilities, agriculture on the Wageningen project developed into a mechanized monoculture of rice.

It was also found that the return of a 72 ha rice farm was insufficient to provide a reasonable living for a Dutch farmer, while considerable enlargement of the units leased would require too high investments from the farmers. Various other financial and social considerations, which will not be discussed here, finally led to the abandonment of the entire scheme of issuing agricultural land to Dutch farmers. For the time being the entire developed area of 6,000 ha is run by the STICHTING as one estate. This decision was however made at a time (in 1956) when part of the polder had already been laid out according to the original plan.

The natural environmental factors

The results obtained in peasant rice-growing demonstrate beyond doubt, that the recent coastal plain forms a good environment for the growth of paddy.

In 1953, the last year before the Wageningen project came into production, the rice area in Surinam was about 20,000 ha. This rice was grown almost entirely on Indian and Javanese smallholdings. The yields on these peasant farms were generally quite uniform and in most years about 3,000 kg/ha. Although the smallholders applied no control measures there were few calamities caused by pests or diseases. Bad harvests practically only occurred in extremely dry years as most of the peasant paddies were entirely or partially dependent on rain. In Table 15 some yield figures are given for the whole of Surinam and for the Nickerie district separately.

TABLE 15 *Areas and yields of peasant rice farming*[1] *for all Surinam and the Nickerie district separately, for 1945–53*
(ABRAHAMSE, 1959)

	Area (in ha)		Yield (in 100 kg paddy/ha)	
	Surinam	Nickerie	Surinam	Nickerie
1945	14631	4450	22.8	30.9
1946	16925	5150	30.4	31.6
1947	17891	5600	21.9	25.0
1948	18257	5232	32.0	32.1
1949	17617	5335	28.5	30.9
1950	17710	5709	28.3	30.8
1951	18665	5942	30.7	31.2
1952	19573	6444	27.5	24.6
1953	19939	6498	28.7	30.1
1954	21575	6845	30.0	33.6
1955	19555	6128	29.7	32.7
1956	20244	6400	29.0	31.5
1957	20699	6569	18.1	28.7
1958	22999	6991	27.3	32.0

[1] Viz. excluding rice farming on estates: the Prins Bernhard polder (from 1950–'58: 120 ha to 640 ha resp.) and the Wageningen project (from 1954–'58: 450 ha to 7,400 ha resp.).

Thus the choice of rice as main crop for the Wageningen project had the considerable advantage that already had been gained extensive and moreover favourable experience with that crop under similar natural conditions.
As regards the climatological conditions for rice-growing rainfall is obviously most important. However, whilst in peasant rice farming the occurrence of low rainfall in certain years is the main drawback, under the specific conditions of the project with maximal mechanization aimed at, it appears that irregular high rainfall in the so called dry seasons may cause most difficulties. Droughts are only disadvantageous for the project in so far they might effect the flow of the Nickerie-river which is the source of the irrigation water pumped in.
The characteristics of the four annual seasons: the main rainy and main dry

season, the small rainy and small dry season are in particular important. It appears that the alternation and length of these rainy and dry periods provides a more or less suitable condition for the rice cropping pattern and the agricultural operations, as it is possible to project growing periods in rainy seasons and tillage and specially harvesting in dry seasons.
The main dry season (September-November) has a fairly settled dry weather and is therefore the appropriate period for mechanized harvesting. Hence the main crop should grow in the preceding main rainy season (April–August). In this connection it is an advantage that the length of the main rainy season (4½ months) coincides rather favourably with the growing period of the new rice varieties (about 140 days) which have meanwhile been selected for mechanized cultivation. As an inevitable drawback, however, results that seedbed preparation for the main crop then has to be carried out during the uncertain small dry season in February and March and the beginning of the main rainy season.
During the main dry season a second rice crop may be sown which develops during the short rainy season and matures and can be harvested during the short dry season. This latter harvesting involves more risks however than the one during the main dry season, as the chance of rain is much greater.

The soil characteristics are also favourable for rice (see GRIST, 1959), viz. a heavy impermeable clay, with a pH of 5–6, a reasonable content of organic matter and a good supply of bases.
The disadvantages of a heavy clay soil for dry crops in a rainy climate are actually advantages for a paddy crop. After suitable tillage, the stiff, hard clay swells under water, and becomes a loose, light mud which forms a suitable environment for the rice roots, while the impermeability reduces the loss of water so that the required level can be maintained with relatively little irrigation water.

The intensity and distribution of rain make necessary both irrigation and drainage.
The level and impermeable soil makes drainage through the soil virtually impossible so that surface run-off is the only practical method. In the case of mechanized rice growing, rapid removal of surplus water is a basic requirement for tillage and harvesting. Moreover during the sowing and growing periods it should be possible for the level of water on the paddy to be rapidly and effectively adjusted (see p. 226). This makes irrigation definitely necessary during the main rainy season as well. Moreover, irrigation is useful and necessary because then:
— the sowing time is independent of the irregular onset of the rainy season;
— a greater harvest spread is possible: the sowing can already take place in the short dry season, and the last fields can still be flooded in the main dry season;
— the risk of extremely dry years can be obviated;
— a second rice crop can be grown in the between-season.
The lands chosen for the project can be flooded with fresh water from the

Nickerie river with the help of a pumping station. The lower course of the Nickerie river, like the Coppename, Coesewijne and Saramakka rivers, is deflected towards the west as a result of the direction of accretion by the Gulf Stream, so that in part it runs parallel with the coast. From the point of view of utilizing fresh river water this is an advantage.
The flow rates of the Nickerie river were estimated to be sufficient although actually still too few observations have been made to provide a complete survey. In April-May 1954 RINGMA found a mean flow of 83 cu.m/sec.
These measurements were made during (and after) a long rainy period.
Normally the water in the Nickerie river has a clear tea colour (swamp water) and contains practically no silt. According to the admittedly scarce measurements, the salinity of the river, going upstream, becomes low enough at the mouth of the Maratakka tributary for the water to be used for irrigation purposes.
According to the EIJSVOOGEL report (1948) drainage by pumping and by gravity would have to be based on the removal of 70 mm of precipitation a day. Originally this was not considered necessary for the rice crop, but only for the discharge of peak rainfall in the between-season for the benefit of the dry crops planned in this report. In other words the dry crops were considered so important that even the drainage capacity was based on them. Later on this proved a fortunate circumstance as the paddy crop also makes very high demands on the discharge of water in a mechanized undertaking.

Thus as far as the natural factors are concerned conditions for rice-growing prove to be generally favourable in the project-area.
But the situation is vastly different with the grassland and dry crops planned according to the basic project, of which the latter were intended to be the second crop (from October to March) in rotation with paddy (from April to September).
The idea to incorporate grassland farming and cattle raising in the plan appears to be somewhat irrealistic. Owing to the very low yields compared with other regions cattle raising in the humid tropics at sea level still is a great problem throughout the world.
Under the conditions of the Wageningen project there were the following additional drawbacks:
— the soil and rainfall are definitely unfavourable for grassland;
— cattle raising in Surinam is still in its infancy, and until about 1950 no important relevant research had been carried out;
— the project would depend on exporting its meat and dairy products.
When the project was first put into practice the STICHTING took two important steps in connection with the cattle raising incorporated in the basic plan:
— the grassland investigation in Surinam was begun by obtaining the services of the grassland expert J. G. P. DIRVEN;
— an experimental farm for cattle and pigs was established in the Wageningen project area.

The results of this research afterwards confirmed that for the time being cattle raising offered no prospects. In view of the high costs involved, the experimental farm was reduced after a few years to a small production farm for local supplies of meat and milk. The grassland and cattle fodder investigations were, however, continued by DIRVEN at Paramaribo in co-operation with the Surinam Government.

In the period 1950–56 crops such as soya, maize, sorghum, groundnuts and mung beans were tested on an extensive scale by J. G. J. VAN DER MEULEN (1955) within the framework of the research for the Wageningen project. Before this time there was practically no experience with these crops on the heavy clay soil in the coastal plain of Surinam. During the mentioned period W. A. DE LINT tried to grow these crops on a practical scale in the Prins Bernhard Polder. Under the guidance of the author, also about 150 ha of dry crops were sown in the 1953–54 between-season at Wageningen. Our main conclusion of all these investigations is that the heavy clay soil, together with the nature of the rainfall, forms an unsuitable environment for the cultivation of dry annual crops in rotation with paddy.

In view of the apparent disadvantages of a rice monoculture for the project, extensive investigations were again started in 1957 by E. J. FORTANIER to re-examine the possibilities of crops other than rice. This time however not only in rotation with rice but also as independent crops. It is not impossible that the mechanized cultivation of some dry annual crops will succeed in the end on a small scale and with the aid of an intensive ridge- or bed-system combined with sprinkler irrigation and similar measures, but in our opinion, this is really no longer in keeping with the idea of the undertaking as planned,. while there are justifiable doubts about its profitability.

Moreover, cultivation on beds militates against wet rice growing in the wet season, so that the rotation principle would have to be dropped.

The cultivation of semi-perennial crops as bananas and sugar cane offer more possibilities on these heavy soils, principally because the longer growing period and the greater yield capacity of these crops may give a sufficient return from the costly tillage and laying out of beds. This is even more true of perennial tree crops. All these crops appear less suitable however, as they require too much hand labour. In fact their cultivation is altogether outside the scope of the project and would mean new plans and investments.

Economic conditions

The farming system of the project was greatly determined by the facets discussed thus far: the object to establish Dutch farms of medium size and the possibilities which the natural conditions would allow. Still this farming system had to satisfy also the economic conditions.

A prerequisite of the system should of course be that the rendability would be maximal within the technical possibilities. It was thought at the outset that a mechanized cultivation of rice for export would comply favourably in this respect.

Calculations at that time showed a sufficient margin between costs and receipts (to meet the living standard of the Dutch farmers).

The economic conditions in general are related to the economic structure of Surinam and the prices on the world market.
Aspects of the economic structure are: the home market for agricultural produce, the infra-structure, labour-force, and level of costs.
The marketing possibilities in Surinam are extremely limited so that the Wageningen project was dependent on export for its produce. Also internal trade and transport facilities are poorly developed which meant that the project had to make appropriate provisions and that a staple-product would be preferable. The labour-force is small in Surinam and the level of wages comparatively high. This made the choice of a crop which could be fully mechanized a necessity.
When the basic plan was drawn up in 1949 the possibilities of selling rice in the Netherlands and on the world market were particularly favourable.
Also in the market analyses made in connection with the Wageningen project in 1951–52 the opinion was expressed that the rice shortage prevailing on the world market would continue for a time and that the prospects for rice prices were good.
But in 1953, at about the same time as the project first came into production, there was an unexpected sharp drop in price which lasted until 1956. The prices finally stabilized themselves at a level 20–30 % below that of 1949.
As further on the expectations of other crops did not materialize and the scheme became solely a big rice producer this development had of course a considerable unfavourable influence on the financial results of the operations of the scheme.

CHAPTER VI

THE MARKETING POSSIBILITIES OF RICE

This chapter is included, because it may be of general interest to discuss in greater detail the rice-marketing situation at the time of the planning of the Wageningen project and the market development afterwards, as an example of miscalculation which is possible when future prices and markets are predicted.

The rice situation in Surinam and the Netherlands

Surinam was never considered as a market for the rice of the project. Since 1930 it had had rice surpluses which were exported. The Surinam Government's regulations relating to the rice trade were, however, important to the project. Their object was to protect both the rice producer and the home consumer and to promote rice exports (GOUVERNEMENTSBLAD VAN SURINAME, 1950–58).

The regulations controlled prices at home and made exports contingent on licences. In 1950 the fixed minimum price for paddy at which the rice farmer could sell to the government was 9 S cents/kg. The maximum home consumer price for milled rice was 20[5] S cents/kg.

In the period from 1950 to 1954, about 20% of the Surinam rice production was exported at high world-market prices (see Table 16), and the rest had to be sold at the artificially low price ruling on the home market. If the Wageningen project had to sell its rice on the basis of the regulations then in force a large part of its production would have to be sold in Surinam. This would be illogical, as the project was actually intended for the production of good export grades. Native cultivators were not yet in a position to produce good rice qualities, their production being one of the basic problems in selling Surinam's smallholders-rice surpluses.

The Surinam Government therefore decided (on February 10th, 1951) to make an exception for the scheme and to grant it an export licence for 90% of its production, with the proviso that home rice supplies were to be guaranteed. As a result of the latter reservation in 1957, when a severe drought caused a partial failure of the rice crop in Surinam, the Wageningen project supplied about 30% of its production to the Surinam Government. In 1958 the home prices in Surinam for consumer rice could be freed, partly owing to a further steep fall in world market prices in the interim.

After the Second World War the possibilities of exporting Surinam rice to the

TABLE 16 *Production and export of rice in Surinam* (ABRAHAMSE, 1959)

Year	Production	Export		
	in 1000 kg paddy (=unhulled rice)	in 1000 kg rice (=milled)	(F.o.b.?-) value in Sf 1000	Mean price Sf cents/kg
1945	33,400	156	39	25
1946	51,500	2043	514	25
1947	39,400	2531[1]	1153	46
1948	58,400	1184[2]	267	23
1949	50,200	9697	3229	33
1950	50,400	4245	1176	28
1951	57,700	3658	925	25
1952	54,100	8733	2553	29
1953	57,600	7444	2743	37
1954	66,700	6417	1864	29
1955	64,500	11891	2795	24
1956	71,200	14674	3427	23
1957	55,100	11250	2727	24
1958	85,000			

[1] Excluding export of unhulled rice 3881 tons.
[2] Excluding export of unhulled rice 1231 tons.

Netherlands appeared favourable, specially as S.E. Asia had more or less ceased to be a supplier of rice.
Before the war the Netherlands imported annually about 170,000 tons of rice (various grades, mostly cargo), principally from S.E. Asia, of which about 103,000 tons were re-exported after processing, about 16,000 tons were used for cattle fodder, and the rest for human consumption (DEPARTEMENT ECON. ZAKEN NED., 1951). This amount would be sufficient to cancel out the Surinam export surplus for many years.
It is therefore obvious that both Surinam and the STICHTING which planned the Wageningen project, were interested in a Dutch import guarantee. Soon after the STICHTING was established, the Dutch Government promised that the Wageningen scheme would be able to sell its rice production in the Netherlands, but no further agreement was worked out. Owing to the abolition of the central state purchases of rice about 1950, this question became more difficult because the Dutch rice millers (who were also the importers) had to be consulted. This consultation did indeed take place, but as a result of the steep rise in rice prices in the meantime and the great demand on the world market, selling no longer constituted any problem, and from the STICHTING's point of view interest in an agreement declined. Moreover Dutch importers were only ready to buy cargo rice (semi-processed) so as to provide work for their own rice-mills, and in the meantime the STICHTING had decided to establish fully equipped milling installations in Surinam, with a view to spreading the risks.

Marketing prospects of rice about 1950

At the time the Wageningen project was drawn up, rice prices on the world market seemed to offer very favourable prospects. Towards the end of the forties, the world market pattern was still dominated by the scarcity of foodstuffs as a result of the Second World War. About 1949 prices of agricultural produce were all on the high side, notwithstanding the fact that in most countries free price formation was hampered by import and export quota systems and fixed home prices.

Great shortages existed, especially of rice and vegetable oils and fats. Some 94% of the pre-war annual world production of rice of 150 million tons (unhulled) was produced in S.E. Asia. A drop in production occurred in this area as a result of the war and the subsequent political unrest.

In the rest of the world rice production increased slightly. Table 17 shows the pattern of production estimates up to 1949.

TABLE 17 *Area (in millions of ha) and production (in millions of tons) of rice (unhulled) in the world, according to estimates made by the FAO in 1949*

	World		Asia		Rest	
	area	production	area	production	area	production
1934–'35—1938–'39 (mean)	83.7	147.4	80.1	141.3	3.6	6.1
1946–'47.	83.9	140.0	78.0	130.8	5.9	9.2
1947–'48.	85.3	142.1	79.5	132.7	5.8	9.4
1948–'49.	86.1	144.5	80.2	135.1	5.9	9.4

Allowing for a 1–2% p.a. increase in population in the rice-consuming areas, the production figures in Table 17 indicate a serious rice shortage.

At its first meeting in Bangkok in 1949 the International Rice Commission set up under the FAO after the war, placed expansion of production as the main item on the agenda. The enormous increase in price was a reflection of the shortages. The f.o.b. export prices (taken from FAO chart No. 266) (ANONYM., 1949) of Rangoon Small Mills Special (Burma) and Bangkok White Rice No. 1 (Siam) were $50 and $80/ton respectively in 1920, remained fairly stable until 1930, after which both fell sharply to a minimum of $15/ton, and in 1935 began to rise again very slowly to about $20/ton. In 1945 the price was about $80, in 1946 $90, in 1947 $130–140, and in 1948 $150/ton.

Only a small percentage of the rice produced comes on to the world market, i.e. before the war about 8.5 million tons, or 9% (conversion rate as adopted by GRIST (1959): 100 tons paddy equals 66 tons rice). In 1949 the total exports, 3.5 million tons, were still very low compared with before the war. After the war there was a notable change in direction of the movement of rice exports. In 1949 Asia, which earlier had a net balance of exports to the West, imported rice from America and Africa (NED. ECON. INST., 1952b).

In 1951, on the instructions of the PLANBUREAU SURINAME, the NEDERLANDS ECONOMISCH INSTITUUT (N.E.I.) at Rotterdam carried out a study on the marketing possibilities of Surinam rice. Basing their investigation on the production and export data, this Institute tried to predict the probable development of the rice supply and demand factors up to 1965. No definite final conclusions were drawn in the actual N.E.I. report, dated February 1952. In the conclusion on p. 16 it was stated that in view of the unstable political conditions in Asia, and the fact that little and only poor statistical material was available for Asia, a forecast of rice prices up to 1965 would have to be extremely vague. It was also stated that the Asian rice shortage would probably tend to increase and that this shortage could not be completely compensated by the anticipated increase in rice production outside Asia.

Finally the report says: "From a survey of the world rice situation from today up until 1965, it can be stated that the marketing prospects of Surinam rice are good, provided it is not priced too high".

It is rather surprising, however, that the N.E.I. in its "Summary report on the market analyses of Surinam export products etc." dated April 1952, came to a much more positive conclusion, the actual words being as follows: "The only conclusion to be drawn with sufficient certainty is that as a result of the investigation into demand the price level of rice will rise up to 1965".

For the sake of completeness we have quoted both views. We must however assume that the last conclusion was the final formulation of the N.E.I. It is surprisingly positive when one considers the number of times the words "vague", "approximate", "unreliable", etc. are used in the report. In our opinion it represents more the general world feeling of the time, without well-founded statistical material.

Also the Directorate-General of Foreign Agrarian Relations of the "DEPARTEMENT VAN ECON. ZAKEN" in the Netherlands, concluded in a note in 1951 that the marketing prospects Surinam rice were favourable with regard to the strong statistical position of rice on the world market. According to this authority the high price of rice was admittedly a drawback as this would have a bad effect on its use for cattle fodder. (Which is of course a rather limited point of view.) Moreover, reports from India were said to indicate that owing to high prices rice was being replaced by other foodstuffs for human consumption.

Having regard to ocean freight rates the Directorate-General thought it desirable that attention should be paid in the first place to selling in the Carribbean area. This idea is however based on an obvious mistake. Actually despite the short distance, freight rates to the Caribbean are as high as or higher than those to Europe.

Thus about 1949–51, at the time it was decided to construct the Wageningen project, and when the necessary funds were voted, the prospects for rice prices in the future were considered favourable. This strengthened the forecast that the project would prove profitable. Moreover, the project would contribute towards reducing the world rice shortage in the trade volume and in particular would cater for Dutch requirements (at that time Holland had still not forgotten its low allocation), all of which emphasized the desirability of carrying out the project.

Besides rice, analyses were made into the marketing possibilities of soya (NED. ECON. INST., 1951, 1952a). In this case also it was concluded that market prospects were very good. This favourable picture was probably one reason why the designers of the basic project included soya in the farming plan, although there was practically no experience with this crop in Surinam.

The world rice market since 1950

Since 1950 both world rice production and the world rice market have differed from the forecasts.

Tables 18, 19, 20 illustrate the trend in the area grown, production, exports and prices. The most important conclusions are:

— production increased more rapidly than was expected;

— supply and demand balanced each other at a lower world turnover level than before the war;

— in contrast to the predicted rise, there was a sharp drop in price.

Concerning the wrong forecast of the increase in production, it may be observed that the compilers of the market analyses may not have realized sufficiently well that the bulk of world rice is produced by some 150 million small peasants who farm on a subsistence basis in a predominantly self-sufficient economy. The potential increase in rice production of these countless millions in combination is enormous. How and when increase in production will take place and surpluses will become available for international trade is difficult to predict. It is certain that their food-production is little affected by supply and demand on the world market and that the laws of demand, prices and production do not apply in the same manner as may be expected in Western economies.

A second factor which made it difficult to carry out market analyses was the poor quality of the statistical data. If we refer to some FAO Commodity Reports since 1949, it can be seen that the same figures were not always given for the world rice production for certain years, but that these figures kept on rising as though to indicate that subsequent data had been received on areas grown with rice. One result of this was that in the 1951 memorandum of the DEPT. VAN ECON. ZAKEN (in the Netherlands) world production was assumed to be 10 million tons lower than that estimated by the NED. ECON. INSTITUUT (N.B. world exports of rice in 1949 were only 3.5 million tons). As stated above, about 95% of all the world's rice is produced in Asia. The statistics for these countries are inaccurate and certainly allow a margin of some millions of tons. The biggest Asian rice producer is Communist China with 30–40% of the world production. Even before the Second World War the production estimates of this country were very approximate, but since

TABLE 18 *Area of rice grown, and world production and exports, excluding Communist countries*
(FAO, 1949–1959 and USDA, 1959)

	World (excl. communist countries)		Asia (excl. communist countries)	
	area in million ha	prod. in million tons paddy	area in million ha	prod. in million tons paddy
From 1934–'35 to 1938–'39 mean	63.8	98.8	60.3	93.1
1948–'49	72.4	103.0	66.2	94.3
1949–'50	74.7	108.1	68.1	97.0
1950–'51	75.5	103.4	68.7	91.8
1951–'52	75.6	103.9	68.9	92.6
1952–'53	76.0	110.4	69.0	98.2
1953–'54	79.3	122.0	71.8	109.0
1954–'55	78.3	116.1	70.6	102.4
1955–'56	79.4	124.2	71.6	110.2
1956–'57	81.2	129.6	73.4	114.9
1957–'58	80.2	120.6	72.3	106.2
1958–'59	81.9	127.5	74.1	113.4

TABLE 19 *World rice exports*
(FAO, 1949–1959 and USDA, 1959)

	in millions of tons of hulled rice	
	World	Asia
1934–'38 mean	8.7	8.3
1947	2.6	1.8
1948	3.5	2.7
1949	3.5	2.8
1950	4.3	3.1
1951	5.2	3.8
1952	5.0	3.4
1953	4.4	3.0
1954	4.6	3.5
1955[1]	5.1	3.9
1956[1]	6.1	4.1
1957[1]	5.9	4.4

[1] Preliminary.

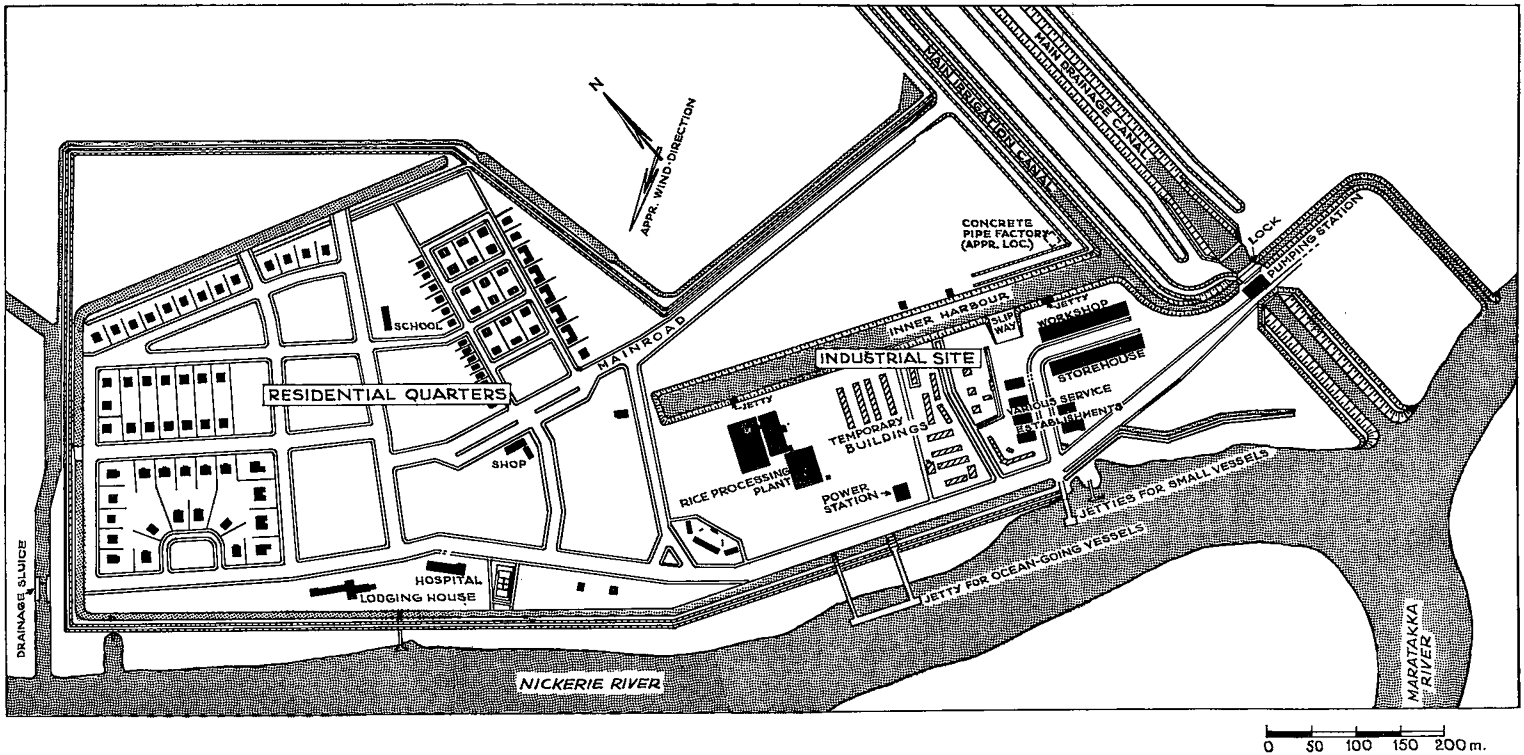


Fig. 10. *The Wageningen settlement in 1955.*

10. *Forest, six months after poisoning with Na-arsenite.*

11. *Flattening herbaceous growth with the brushcutter.*

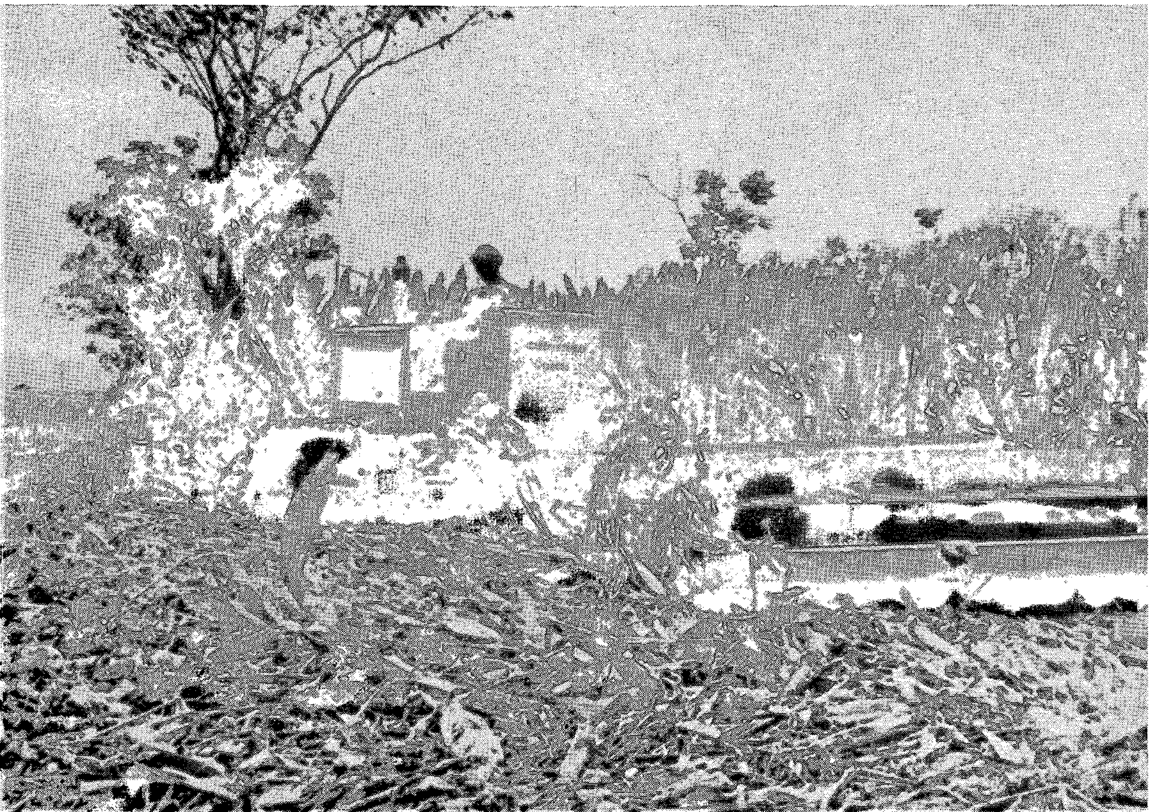


TABLE 20 *Approximate*[1] *export prices of rice and wheat in U.S.$*
(FAO, 1949–1959 and COMMONW. ECON. COMM., 1958, 1959)

Period	Thai White Rice 5% brokens f.o.b. Bangkok[2]	Burma Small Mills Special (mostly Ngatsein) 42% brokens f.o.b. Rangoon[3]		Canadian wheat No. 1 f.o.b. Port Arthur
	free market	free market	contract market	
Pre-war mean[4]	...	30	...	35
1947	...	130	...	100
1948	185	150	...	90
1949	...	...	...	80
1950	...	...	130	80
1951	...	...	130	80
1952	...	225	130	85
1953	220	190	165	75
1954	175	140	...	70
1955	150	130	...	65
1956	130	110	100	65
1957	140	...	100	65
1958	140	110	100	60
1959	135	...	95	

... not available.

1 Complete statistics of mean export prices are not available.

2 Hard, translucent, long-grained quality. It is comparable with export quality of the Wageningen project: Wageningen Select (max. 5% brokens). An important difference is that the latter is only processed to the cargo stage.

3 Semiglutinous, short- to medium-grained quality.

4 The period over which the mean is determined was not stated in the FAO publication (1949). Presumably it is a five-year mean.

the Communists came into power we have no certain information at all. Since 1954 the FAO estimates of world production of rice, exclude the mainland of China and other Communist countries for want of reliable data. Before the Second World War, China's production was estimated at 50 million tons on 20 million ha. However, for the year 1957–58 we find an estimate of 85 million tons on 34 million ha (COMMONW. ECON. COMM., 1958). Has there actually been such a vast increase in production?

In any case, since about 1950 China has become an exporting instead of an importing country. In 1956 these exports were at least 900,000 tons (COMMONW. ECON. COMM., 1958). Thus, Communist China alone can radically disturb any market forecasts for rice.

A third factor constitute the changes in trade volume. The turnover of rice on the world market before the war was about 9 million tons, but after the war supply and demand seemed to have balanced each other at the much lower level of 5–6 million tons (Table 19).

One reason for this is, that there has been a shift from rice to wheat in the rice-importing countries of S.E. Asia. In 1949, S.E. Asian countries with a food shortage imported 6.7 million tons of wheat and 2.8 million tons of rice. Before the war the proportions were exactly opposite, viz.: an average of 6.4 million tons of rice and 0.8 million tons of other cereals (FAO, 1949–1959). Although this shift is only a small percentage of the total S.E. Asian consumption it has a great influence on world market turnovers. This shift primarily occurred as a result of the relative cheapness of wheat compared to rice (see Table 20), after the war, and the favourable conditions of payment for wheat offered by the U.S.A., this being due to the large surplus stocks of wheat as well as the growing realization of the political importance of aid to underdeveloped areas. Also, the shortage of suitable means of payment in the S.E. Asian rice-importing countries (Indonesia ,India, Pakistan) had a restrictive effect on rice trade. The shift was directed by the governments concerned who entered into contracts for wheat and rice quota imports.

As can be seen from Table 20, rice prices on the world market continued to rise until 1952. There was then a formidable drop in price, until in 1956 the price level was 20–30% below that of 1948. From 1956 to 1959 the prices became stabilized at this low level.
In the Surinam rice exports (see Table 16) there were large fluctuations in price from 1945 to 1950, mainly caused by differences in quality in the relatively small annual amounts. After 1950 the price trend follows world market prices better. The price drops were, however, camouflaged by a simultaneous improvement in quality as a result of the gradually increasing participation of the Wageningen project in the exports.

With regard to the future we will first quote the FAO Commodity Report: Rice No. 9 of September 1958: "However, the strong consumer preference among rice eaters, which limits the substitution of other cereals, and the steady expansion in world rice consumption constitute important long-term elements of strength in the market situation".
Yet, more recently, FAO stated in its report: "Major Developments in the World Agricultural Commodity Situation (33rd Session of the Committee on Commodity Problems, 1960)," on p. 22:
"The longer-term outlook is more obscure. On the one hand, paddy is still greatly dependent on uncertain rains. When bad crop years occur, as they are bound to occasionally, world supplies may be inadequate to meet the sudden upsurge of demand. On the other hand, world rice production shows a marked upward trend, and has been growing at a faster rate than population. Since the expansion has been concentrated in food deficit countries the larger supplies have been easily absorbed, but the increase in output has been accompanied by a persistent decline in rice imports in Asia. Although demand has been well maintained in other regions, in the longer-run reduction in Asian requirements must be a source of concern for exporting countries which are planning to increase production for export."

CHAPTER VII

THE LAY-OUT AND CONSTRUCTION OF THE PROJECT

Introductory remarks

A 6,000 ha polder was constructed and a settlement by the river, i.e. the village of Wageningen.

The construction of the polder (Fig. 12) comprised:

a. The excavation of two canal systems, one for drainage and one for irrigation. These canal systems divided the polder into parcels of a gross area of 80 ha. These parcels were each subdivided into six fields separated by ditches and dams, the fields being adapted for individual connection to the irrigation and drainage-canal system.

b. The building of houses for farmers and workers, and sheds for housing the agricultural machinery.

c. The drainage, forest clearance, reclamation ploughing and levelling of the land to make it suitable for rice cultivation. We shall not, however, discuss these reclamation operations in this chapter, but separately in the next.

The layout of the settlement (see Fig. 10) comprised the estate installations, the staff accommodations and various social provisions. The estate buildings were allocated a site near the inland harbour and the river jetties. The residential quarters were separate from this, also as regards the prevailing direction of the wind.

The most important estate installations were the rice processing plant, the pumping station for irrigating and draining the polder, the power station, the repair and building workshops, and the warehouses.

The rice processing plant consists of a concrete silo for storing 13,500 tons of paddy, a dryer, a rice mill, a storage shed, and installations for landing paddy from lighters and for loading rice products into ocean-going vessels.

The power station originally had a capacity of 1,500 h.p. (two diesel engines). In 1957 this was extended by an 800 h.p. steam turbine with free exhaust (capable of increase to 1,000 h.p. with condensation), adapted to the use of rice chaff as fuel.

In its present size the village of Wageningen has about 200 houses. In addition nearly 200 houses are scattered over the polder.

As the project was constructed in an uninhabited area without road connections to the outside world, various facilities had to be provided to take care of the population, now numbering over 2,000. Schools, recreation centres and a clinic were built. Both the polder and the village were supplied with electricity generated by the power station of the scheme. The village was also provided with piped water and an automatic telephone system. Shops were built and various sports fields laid out. A cattle farm was also found necessary for the production of meat and fresh milk.

The excavation of the canals as well as the building of hydraulic structures, estate buildings and houses, was mostly carried out by a firm of contractors. The construction operations were split up into a series of separate works, for which agreements were made with the contractor according to the work schedule.

The contract was generally on the basis of cost plus fixed fee, with an extra premium percentage of the savings if the work was done at lower cost than the previously agreed estimates.

The heavy excavation equipment, tractors and combines were bought by the S.M.L. via the E.C.A. (MARSHALL AID). The digging of the field ditches, the forest clearance and the further preparation of the ground for cultivation were carried out under the direct supervision of the STICHTING.

1. History of the planning

Since the Dutch government's decision in 1949 to construct a polder for mechanized rice cultivation in Surinam, various plans were proposed for carrying it out. In order to understand the way in which the present 6,000 ha polder came into being, a brief discussion of these plans is desirable.

When the STICHTING was set up for carrying out the project in 1949, the construction was envisaged of a 5,000 ha polder, on the basis of the advice of the EIJSVOOGEL Commission.

The STICHTING began its work by elaborating the draft plan of this commission. This work did not merely comprise the designing of a 5,000 ha polder, but it was also considered necessary, in anticipation of the future requirements, to formulate an avant-projet for the development of the whole coastal area under consideration. This general plan comprised an area of more than 50,000 ha, in which the initial 5,000 ha had to be incorporated as an organic part.

One of the most important conclusions at which the STICHTING arrived in 1950 after a thorough study of the plan was that a 5,000 ha project would be too small and that it should be enlarged to 15,000 ha. The following motives were adduced for this larger plan:

— from an hydraulic point of view it was only considered feasible to build adequate works on a larger scale and at higher cost than a 5,000 ha plan would allow;

— a considerable reduction of the necessarily high research, overhead, and initial costs per net hectare would result as these costs would increase little for a larger scheme;

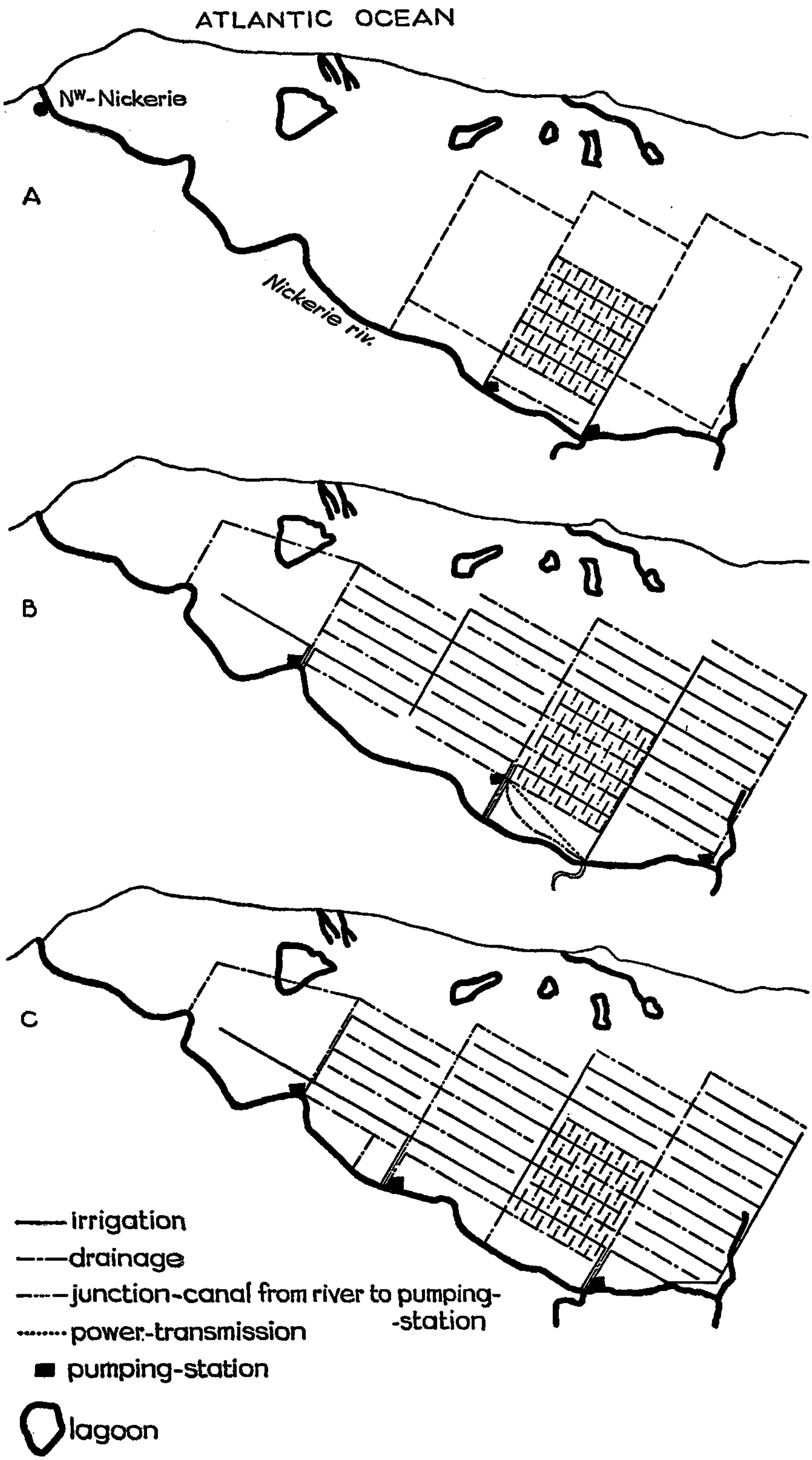
— the possibility of forming a larger community of Dutch farmers, this being considered desirable for social reasons.

The capital needed for the 15,000 ha plan, was estimated at Sf 33,500,000 (TERVOOREN, 1955). A proposal on this matter was submitted to the Dutch

government. In 1951 the latter agreed in principle that in various sections of the plan a future extension to 15,000 ha could be taken into account, but that for the time being only a 5,000 ha polder would be actually constructed. In Fig. 11 various provisional designs of development plans of the North-Nickerie area are reproduced. Referring to this figure, design A presents the diagrammatical plan of the EIJSVOOGEL Commission in 1949 of a 5,000 ha polder, with possible extensions shown by broken lines. The preliminary drafts B, C, D and E were drawn up by the STICHTING in 1950 (HENS, 1950, 1951).
Of these, design E was selected as being the most satisfactory solution. The hatchings in this draft indicate the areas which would be drained by the three pumping stations planned. From this plan the part drawn in detail, the first polder, was completed in 1955. In 1955–57 two more strips were added in the north, which increased the total area to 6,000 ha. (The actual layout as presented in Fig. 12 thus practically conforms to the planned design Fig. 11-E.) Finally, design F of Fig. 11 was drawn up in 1956 by the STICHTING in co-operation with the Dutch Land Improvement Service (CULTUURTECHNISCHE DIENST), when the present polder was already nearly complete. It is a revised plan for the possible extension of the 6,000 ha polder by a second polder of 9,000 ha to arrive at the planned 15,000 ha.

The following arguments were put forward for the choice of the first empolderings (within the total area of design E):
1. As the point of intake of irrigation water and consequently the location of the pumping station, a place on the Nickerie river was chosen opposite the mouth of the Maratakka tributary, since, according to the observations available only at this point the river water became sufficiently low in salt-content. A second advantage of this location was that the mouth of the tributary formed a suitable natural basin as turningpoint for ocean-going vessels.
2. North of the projected intake were extensive level lands with little forest, suitable for reclamation. (The heavily wooded 2–3 km strip along the river was left outside the first polder-area.)
3. It was expected that tidal movement in the river section in question would still be sufficient, as to drain a part of the polder naturally at low-tides. The land further downstream was, of course, more favourable in this respect, but this advantage did not outweigh the difficulties connected with it. (High costs of a long supply channel for irrigation water; more forest vegetation.)

The pumping station was one section of the project built at a capacity for a larger area than 5 or 6,000 ha. The capacity of this station namely was based on the drainage of an area of 8,700 ha, being that part of the considered area of the 15,000 ha plan which was estimated to need artificial drainage.
The area chosen for the 15,000 ha plan in 1950 originally comprised the polders No. 1 and 2 shown in Fig. 11 E, with southern extensions to the river.


ATLANTIC OCEAN
N^W-Nickerie
A
Nickerie riv.
B
C
irrigation
drainage
junction-canal from river to pumping-station
power-transmission
pumping-station
lagoon

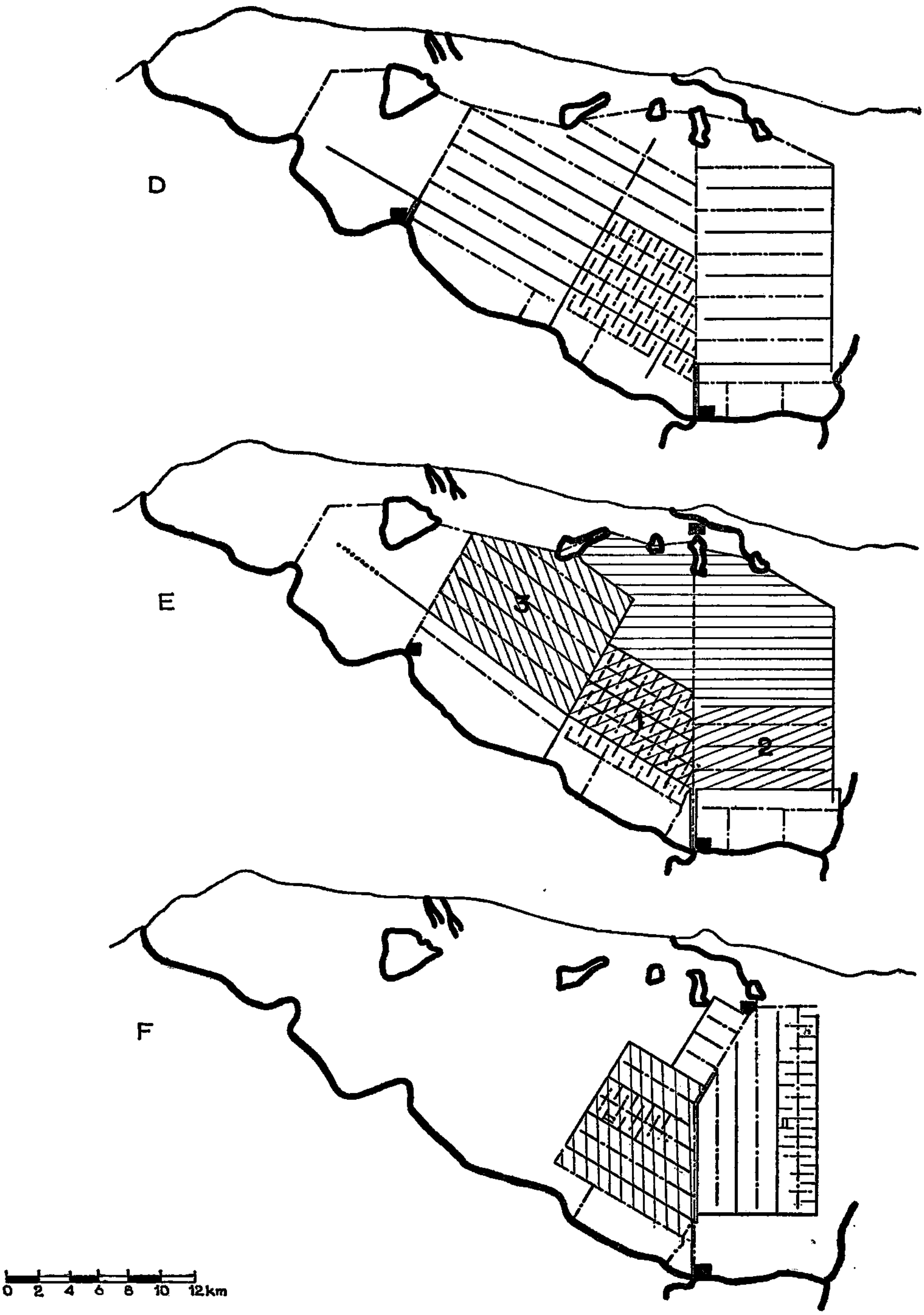


Fig. 11. *Provisional designs for a general plan of development of the North-Nickerie area.*

It was expected that the entire strip along the river with a surface of 6,300 ha could be drained naturally into the river. Hence this was an important advantage of the bank strips which would outweigh the higher reclamation costs resulting from dense forest growth.
However, some years later it was found that in this riparine area were a number of old bank ridges which were responsible for differences in level of about 1 metre. The levelling of the ridges would have been costly. Moreover, continued observations showed that the possibilities of natural drainage were less favourable than had been estimated in the first instance.
In view of the above, it was decided in 1954 to modify the 15,000 ha plan. The riparine areas were left outside the plan and replaced by land taken from the north of the first and second polders. The result of this modification was that the area to be drained by pumping increased to 14,000 ha instead of 8,700 ha. In the meantime, however, the pumping station had already been built for 8,700 ha.

Meanwhile during the construction of the first 6,000 ha, more considerations evolved which made an ultimate extension to 15,000 ha less acceptable:
— An economic mission of the International Bank (1952) visited Surinam in 1952 (to advise on the Ten-Year Plan) and considered Wageningen an attractive scheme, but it objected to an area of 15,000 ha as being out of line with the general development of Surinam. It advised limiting the project to 10,000 ha, and spending the investment money thus released on works of greater priority in Surinam. The mission also thought that the scheme had certain risks and that for this reason also a somewhat slower development would prove advantageous.
— As headway was made in the construction of the first polder, it was found that the cost estimates for the investments were considerably exceeded.
— Owing to higher operating costs and especially on account of the fall in the world market prices of rice the returns were less favourable than had been expected.
— Moreover, the view gained ground that the original plan to sell or to lease to Dutch farmers would have to be abandoned. Consequently for the time being the Wageningen scheme was operated by the STICHTING as a large-scale agricultural estate.

For the above reasons about 1956, it was again decided to limit the project provisionally to the first polder with an area of 6,000 ha (Fig. 12) which was completed in 1957.
The fact that the Wageningen project of 6,000 ha was originally constructed as part of a larger plan of 15,000 ha, has had certain consequences. In addition to the bigger capacity of the pumping station, various other works were carried out which, although desirable for 6,000 ha, were only economic for 15,000 ha, e.g. the construction of a complete village as a welfare and residential area and the construction of jetties for ocean-going and inland vessels. In general, in the broader conception a motive was found for com-

pleting the first 6,000 ha also in a more thorough fashion with more highly specialized personnel and more equipment than had been originally thought.

2. The lay-out of the 6,000 ha polder

Fig. 12 shows the location and dimensions of the canal system.
The main drainage canal runs from the pumping station in a northerly direction along the eastern boundary of the polder and is connected to three secondary drainage canals. The southernmost strip of the polder has its own drainage system which is not connected to the pumping station. The main irrigation canal also runs from the pumping station first to the north, but it turns off into the polder in the direction of the western boundary where it branches into three secondary irrigation canals. This canal system divides the polder into seven strips or series. The seven strips are divided by the alternating tertiary irrigation and drainage canals into a total of 80 rectangular parcels of a gross area of about 80 ha and into 6 triangular or trapezoidal parcels of 30–100 ha (near the main drainage canal). Each parcel of 80 ha gross is divided into 6 fields of 600 × 200 m of 12 ha nett. The field lay-out has been done in such a way that each 12 ha field can be irrigated and drained independently.

The drainage system

The most southerly first series of parcels was designed for natural drainage into the river, the other six series for artificial drainage.
HENS' calculations (1950, '51, '54) in connection with the capacity of the drainage system on which the construction was based, assumed a drainage modulus (run-off capacity) of 70 mm rainfall/24 hours, less 30 mm for evaporation and various catchments, so that about 40 mm would remain for the pumping station. In 1956, after carrying out the works concerned, a somewhat different estimate was made by OLDENBURGER, VAN ROSSUM and SPAN. They also assumed the basic rainfall of 70 mm/day, but they put the amount to be drained by the pumping station at 49 mm/day. Verification of the accuracy of either estimate is not yet possible. Hitherto no serious difficulties have been experienced with the pumping capacity for drainage.

The capacity of the main and secondary drainage canals was based on the above mentioned drainage of 70 mm precipitation/24 hours, evenly spread over the twenty-four hour period.
The tertiary drainage canals, however, were dug much larger than would have been necessary for the maximum drainage requirement, since their dimensions were based on an other essential requirement viz. the amount of soil needed for the construction of the dams.
Fig. 12 shows the canal capacities employed in cu.m of earth shifted per running metre. It is notable that in the north the tertiary discharge (and supply) channels were excavated with larger dimensions than in the south. This can be explained, as originally the ground needed for the tertiary

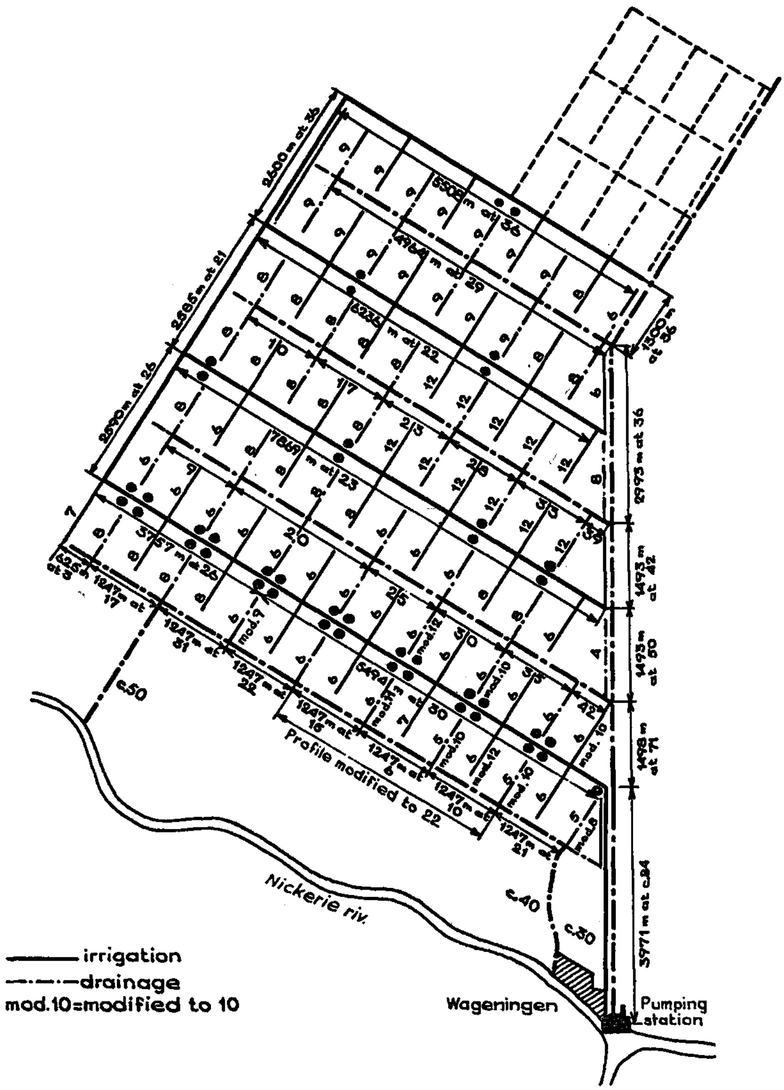


Fig. 12. *The canal system of the Wageningen polder.*
Numbers denote profiles of the canals in sq.m. Dots denote location of farmhouses.

N.B. a. The profiles of the main drainage canal have been considerably enlarged recently in connection with anticipated extensions in the N.E. No data on this are available, so that the original dimensions have been retained in the figure.

b. North of the trapezoidal 1st polder, which has already been completely laid out, the canal lines of extensions now being carried out are shown by broken lines.

channel dams was estimated at 3–4 cu.m/m and the first channels in the south were actually dug on that estimate. However, even in the course of the excavationwork (from south to north) this had to be doubled or even trebled as a result of experience gained in the interval. For, owing to the entrance and exit of tractors and combines, the small dams were very rapidly flattened down to such an extent that the water from the irrigated fields flowed over them.
In addition the maximum irrigation water levels of the fields often had to be put considerably higher than had been planned (30 cm instead of 10 cm) owing to cultivation requirements.
The former *Pterocarpus* forest complex formed a special area (see Fig. 9). Here the particular soft ground made it desirable to lay dams of 12 cu.m/m.

From experience gained with the tertiary irrigation and drainage channels, it was generally realized that under the given circumstances the best profile for all these channels would have been: profile cross-section 12 sq.m, depth 2 m, top width 10 m, bottom width 2 m and slopes 1:2.

In the naturally drained part (the 1st parcels series) the drainage demand was increased from 70 mm/day to 70 mm over 10 hours in connection with the period of sluice working. This area was provided with two separate drainage systems, the Sanica canal with an automatic Armco culvert of c. 17 cu.m/sec., and the Premchan canal with a culvert of c. 25 cu.m/sec. of the same design. In practice neither proved completely satisfactory.
Almost immediately after having been constructed the Sanica Armco culvert showed subsidence on account of inadequate foundations. Both culverts were often blocked by floating plants and pieces of wood. The Sanica Armco culvert had to be replaced by an automatic tide-gate of greater capacity. The two drainage systems were afterwards connected with each other by extending the E.W. collector channel over the whole series. In this way a more satisfactory spread of drainage and greater operating safety were obtained.

The supply system

The water requirements were not a factor in determining the dimensions of the supply canal system (Fig. 12) since in the case of the main canals navigability made higher demands, and in the case of the other canals the soil requirement for the dams themselves was considerably higher than the capacity needed for the water supply.
It was decided that heavy transport of equipment and produce would be solely by means of lighters, of an estimated size of 50 tons, via the irrigation canals. In the case of the main canal the $\frac{\text{F canal}}{\text{F ship}}$ ratio was put at 6; based on a lighter of 20 × 5 × 1 metres, the excavated cross-section of the canal was thus 6 × 5 = 30 sq.m. In the case of the more lightly trafficked secondary canals the ratio assumed was 4.4, i.e. an excavated canal cross-section of 22 sq.m, with widening of a few metres for the turning of the lighters as an extra provision near each group of farms.

Apart from the ships the large canals were required in order to obtain substantial bodies of soil for the dams since the light road network of the polder had to be constructed on their surface.
The capacity of the tertiary channels was entirely sub-ordinated to the requirements of the dam dimensions. If these small canals had been excavated on the basis of the necessary irrigation rates, they would have got only a fraction of the dam-dimensions required. In this case both the damming function of the bunds along the canals and the function of their practicability for traffic were of decisive importance. In the same way as in the case of the tertiary drainage channels, the profile originally estimated at 4 cu.m/m had to be increased two or threefold. Apart from the reasons for this correction already mentioned, it proved necessary to raise the channel dams as the needed water levels in the irrigation canals were considerably higher than had been calculated. Moreover, seepage through cracks resulting from drying was a more important factor in the case of the dams along the irrigation channels than in those along the drainage channels.

For calculating the necessary irrigation level the basic figures were an inlet rate of 1.75 litre/sec/ha (specified from the agricultural viewpoint) for an irrigation compartment of 12 ha, and an inlet rate of 0.8 l/sec/ha for a compartment of 120 ha. (The compartments were in fact $2 \times 72 = 144$ ha, but the area to be irrigated was reduced by 24 ha for the projected alternate cropping.) The rate necessary for several 120 ha compartments was estimated at 0.8 l/sec/ha minus 20%.
The inlet culverts of the 144 ha compartments in the first and second series in the south were dimensioned at 50 cm diam, and the other compartments in the north, all of which had a lower elevation, were given 40 cm diam culverts. Starting from a desired field irrigation level of 10 cm and a maximum field height of 9.06 m (above Nickerie Level) the irrigation level necessary at the pumping station was estimated at 9.25 m for the first polder to be constructed. With further extensions of the area this level could be increased to 9.50 m.
On utilizing the first polder, however, it was often found that a maximum irrigation level of 9.70 m at the pumping station was necessary so as to be able to irrigate the fields reasonably rapidly.
This difference between plan and reality is chiefly due to the fact that the supply-rates were wrongly based on data derived from peasant rice farming in Java. Large-scale mechanized rice cultivation as carried out on the project, requires considerable more irrigation water than the above rates. This principle also applies for instance to the dimension of the supply culverts to the tertiary canals.
These should be bigger to permit a rapid irrigation of all the fields connected with each canal for the sake of concentration of mechanized field operations. Questions relating to water requirement will be more fully discussed on p. 226–229.

The field lay-out

Fig. 13 shows the manner in which the land was parcelled out. Between the alternating tertiary irrigation and drainage canals lie parcels of 80 ha which are sub-divided into six 12 ha fields net.

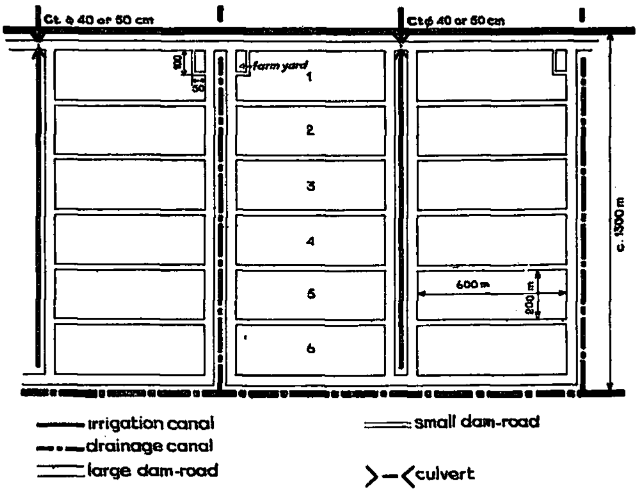


Fig. 13. *Outline of parcelling.*

The tertiary irrigation canals can tap water from the secondary or the main irrigation canals via a culvert. On the other hand the tertiary drainage canals are in open communication with the secondary drainage canal. The result is that the parcels can be reached via a through road alongside the secondary irrigation canal, whereas this is not the case on the other side, i.e. along the secondary drainage canal.

The farm buildings are located at the side of the secondary or main irrigation canal by the tertiary drainage channel. This location is favourable for connections by road and water, while good drainage of the farmyards is ensured by the proximity of a tertiary drainage channel.

Round each 72 ha parcel are dams giving access to the successive fields from either side. Along the tertiary irrigation and drainage channels, the dimension of the dams is 3–6 cu.m/m. Along the secondary channels they are much larger on account of the greater dimensions of these channels.

As a result of the lay-out the 600 × 200 metre fields are all located with their long side at an angle of N.60° W. This orientation of the fields is of importance for mechanized rice cultivation on account of the direction of the prevailing wind. Although this factor was not taken into account during construction, it so happened that the chosen orientation of the fields was fairly satisfactory in this respect. The direction of the prevailing wind is N.E.–E. so that usually it blows more or less at right-angles to the long side of the fields.

In the discussion of the rice cultivation it will be shown that a field siting at right-angles to the direction of the prevailing wind has certain important advantages.
In the recent design for polder extension in Fig.11–F this factor was therefore also taken into account, so that in this design the fields are planned to run N.–S. instead of E.–W. as in the old plan. This resulted in a 90° turn of the entire canal system.

Fig. 14 A, B and C shows three types of field arrangement which were considered in the planning. These types were tested in the Prins Bernhard polder. From experience gained type C was chosen for the Wageningen scheme as it satisfied best the following requirements of mechanized wet rice cultivation:
— it should be possible to supply the field rapidly with irrigation water and the water should also drain off rapidly;
— the fields must be easily accessible for machines and from different sides;
— mechanical up-keep of the field margins, ditches and dams should be possible at minimum cost;
— the field dimensions should be adapted to mechanized methods of cultivation.
In the three plans, the fields are the same as regards length, viz. 600 m, and also, up to a point, as regards width, viz. 200 m, except that design A has an irrigation ditch in the middle, as a result of which the working width is only 100 m. This length and width of 600 × 200 m were also chosen from experience gained in the Prins Bernhard polder where fields of various lengths and widths were laid out.
The various features of the three types A, B. and C are as follows:

TYPE A

There is separate supply and drainage of water within the field. Water is supplied from a ditch which is shut off on both sides by small dikes (of about 0.5 cu.m/m) and which can tap water from the tertiary irrigation channel via a shuttable culvert. The water should enter the field from this supply ditch via excavated openings, or via small culverts arranged at set intervals in the small dikes.
The openings might be cheaper in the first instance, but they have the serious drawback that the dikes are washed away at the points where the openings are made, so that water control becomes impossible in practice.
The field is drained via two drainage ditches each having a shuttable culvert. It is divided by the irrigation ditch into two parts about 100 m wide and 600 m long, so that it would be more correctly described as two fields.
According to this design the fields are only properly accessible for farm machinery at one side via the dam along the tertiary irrigation channel, since the dam along the tertiary drainage channel was kept small (1–2 cu.m/m) owing to the cost of earth moving and could only be used for light traffic. The 600 m dams between the drainage ditches of the fields have a volume of 2 cu.m/m and are also suitable for light traffic only.

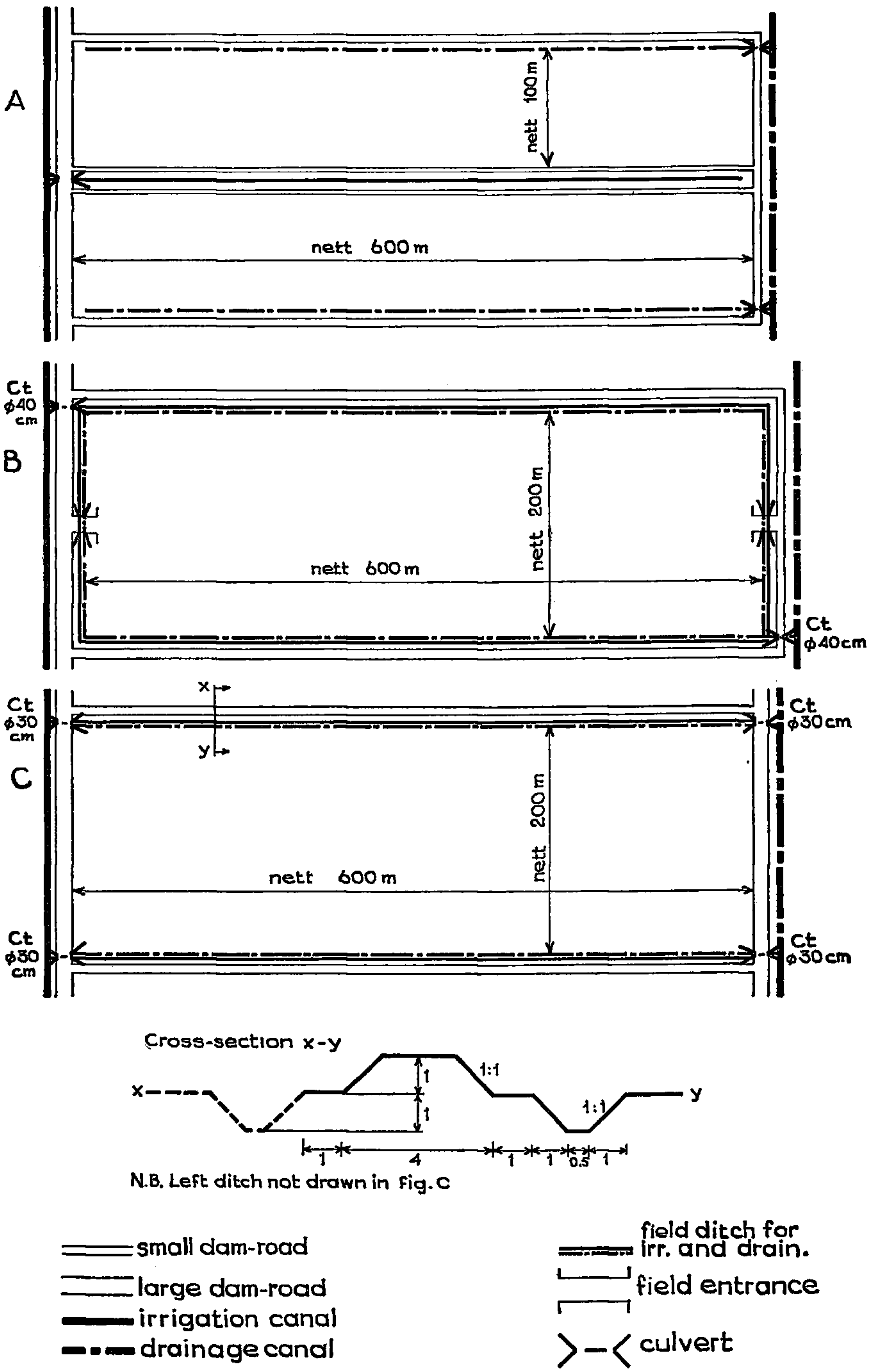


Fig. 14. *Field lay-out.* A *and* B: *alternative designs not carried out.*
C: *Final form of design used.*

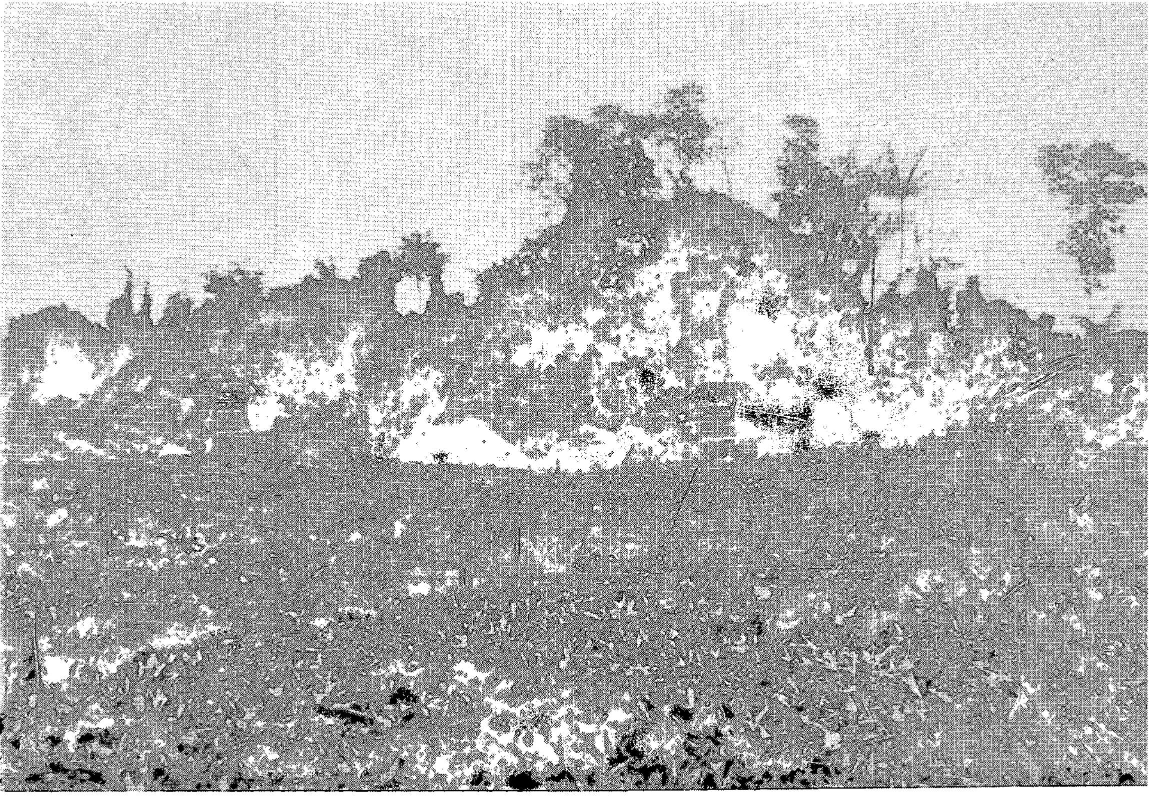
A part of the area of the Prins Bernhard polder was laid out according to design A. A few years after this polder had been constructed all the diked irrigation ditches in the field centres were levelled by bulldozers as being unserviceable.

TYPE B

In this design the raised irrigation channel in the middle of the field has been dropped. The field is 200 m wide and 600 m long and is surrounded on all four sides by an open ditch which serves both for water supply and drainage. The great advantage of this solution is that the water, at a given water level of the tertiary irrigation channel, flows on to the field via the open ditches much more rapidly than in design A via the culverts in the raised irrigation ditch. Moreover, this solution results in a considerable saving in land use and earth moving as compared with type A.
As in type A, the fields are only accessible for heavy traffic along the dam of the tertiary irrigation channel. Accessibility for machines is however worse in this type on account of the ditches at the field heads. In the middle of the field-head ditches entrances with culverts are planned along which the machines can reach the field.
In the Prins Bernhard polder this system proved entirely unsatisfactory because the entrances (say 5 m wide) were ruined by tractors and combines (and of course the culverts as well).
Since during the harvest period the carts were usually unable to enter the soft field, the sacks of rice had to be unloaded partly with the head ditches between cart and combine, which was obviously an unsatisfactory method.
The reasons why field head ditches would be considered desirable were:
— by using a surrounding ditch, only two culverts had to be constructed, one for supply and one for drainage;
— better drainage of the dams was obtained;
— a more rapid and uniform supply and drainage of the water on the field was obtained, in that the field head ditches also assisted in this.

TYPE C

Like type B this type has the great advantage of rapid water supply via the open ditches. The water drainage with two culverts is at least as good as in type A or B. Moreover the drawbacks of solution B are overcome by omitting the field head ditches, thereby obtaining two separate ditches, each having its own supply and drainage culvert.
The provision of two inlets and two outlets results in a welcome improvement in reliability because water control can be effected, although only at half capacity, when one of the culverts breaks down and is being repaired. Undermining and erosion of culverts was found to occur frequently at Wageningen as a result of the type of soil, so that this advantage is certainly of great importance.
In this type, the accessibility of the fields for machines is still further improved by giving the dams along the tertiary drainage channels such dimensions (3–6 cu.m/m) as to render them suitable for heavy traffic.



12. *Chain-clearing a poisoned forest.*

13. *As 12: close-up of chain.*

14. *Bulldozer miring down in soft spot.*

15. *Ploughing virgin land with a Rome heavy-duty disk-harrow.*

Owing to the smaller number of ditches and dams it is cheaper to maintain design C than the other designs and since all the dams are passable for tractors, most of their maintenance can be done mechanically.

The farm buildings

According to the original plan a farmhouse with machinery shed and a worker's house were to be built on each 72 ha.

As Fig. 12 shows, this was carried out only in the case of the southern two series which were constructed first.

When the first series was started in 1952 entirely different views were held on farm size and the method of allocation than in 1956 when the last (seventh) series was completed. We can now distinguish the following installations in the polder:

1. 1st and 2nd series: on each 72 ha parcel by the irrigation canal, one farmhouse (about 100 sq.m), and one machinery shed of 10 × 15 m on a compound of about 0.5 ha by the tertiary drainage channel; one worker's house (about 30 sq.m) by the tertiary irrigation channel.
2. 3rd and 4th series: one farmhouse to three 72 ha parcels. Per 72 ha parcel one machinery shed of 10 × 15 m on a compound of about 0.5 ha by the tertiary drainage channel, and one worker's house by the tertiary irrigation channel.
3. 5th, 6th and 7th series: per each four or five 72 ha parcels, one farmhouse, 6–10 workers' houses and two double sheds (25 × 10 m) on two adjacent 0.5 ha compounds; here and there outside the farm compounds a few workers' houses and small machinery sheds.

We can see therefore that the building lay-out within the polder from south to north reflects the evolution of the scheme from rather small independent farms to a large-scale agricultural enterprise.

The provisions for transport

Within the scheme, complete transport of the harvested product by motor lighters via the irrigation canals was envisaged. For this purpose ten boats were purchased, varying from 25 to 100 tons carrying capacity. A simple jetty was built in the polder at every other parcel. Loaded lighters from Paramaribo and Nickerie can enter the polder via the lock near the pumping station. The same applies to lighters which have taken on freight from ocean-going vessels moored in the river at the large jetty at Wageningen.

Originally it was intended to construct a road network in the polder for light traffic, but owing to the high costs of the metalling required hitherto only a small section has been built.

When uniformly levelled, the dams along the canals are suitable for wheeled traffic during the dry periods, but in the rainy periods all traffic is by water. In 1956–'58 about fifty boats with outboard motors of 15–35 h.p. were used for conveying staff.

Apart from the fact that this transport is expensive there was serious caving in of the canal banks.

The designers of the irrigation canal system had expected that encroachment of the banks would be sufficiently checked by the spontaneous growth of vegetation at ground level on the broad banks between the canal cutting and the dam. They had, however, not foreseen this busy traffic with speedboats travelling at 30–40 km/hr.

Moreover, the natural vegetation did not develop so well on the banks, which was partly due to the fact that in practice the irrigation level had to be raised higher than had been estimated, so that these banks were 60–70 cm below water instead of the calculated 25–50 cm.

To cope with these problems in 1956 JONGE POERINK and DIRVEN laid down some experimental strips of bank vegetation with *Phragmites communis*, *Cyperus articulatus* L., *Cyperus giganteus* Vahl., *Thalia geniculata* L., and *Toreluneum ferax* L. C. Rich. Except for *Phragmites*, all these plants already occurred as natural vegetation along the canal banks. Spontaneous growth of *Scleria microcarpa* Nees, *Typha angustifolia* L., *Canna glauca* L., etc., was also included in the observations. *Cyperus giganteus* was found to have the best characteristics for the purpose envisaged. After the planting of some 3 km of canal with this plant proved to be a success, it was decided to plant the banks of all the main and secondary irrigation canals with *Cyperus giganteus*.

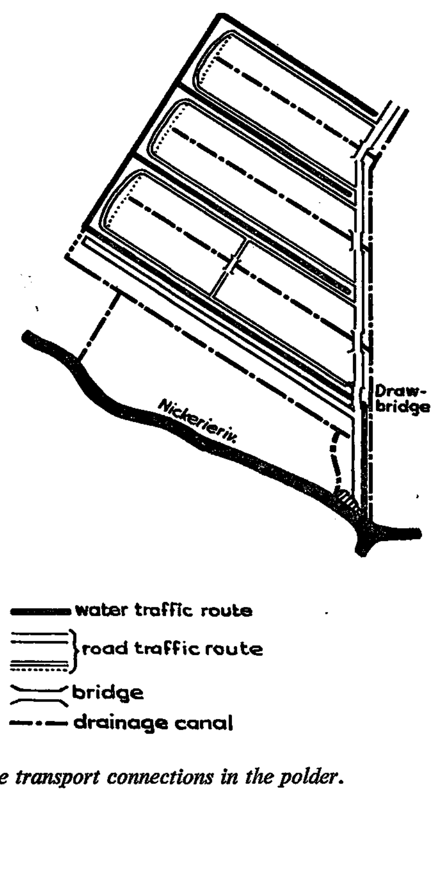


Fig. 15. *Outline of the transport connections in the polder.*

For the road connections, a wooden drawbridge (for the passage of ships) was built over the main irrigation canal at the entrance of the polder where this canal turns into the polder to the west. Moreover, simple wooden bridges were built over the three secondary drainage canals close to their entry into the main drainage canal (Fig. 15). In this way all points in the polder could be quickly reached from the village via the main road to the north.
In the middle and west of the polder connections by road are more difficult. In this area only one bridge was constructed, over the 1st secondary drainage channel about halfway between the 2nd and 3rd series.
The secondary irrigation canals, which are in open communication with the western surrounding main irrigation canal, cut off four western estate areas from direct road connections with each other. To overcome this isolation three expensive drawbridges would have to be built over the irrigation channels for the passage of ships, which was considered too expensive. On the other hand, connections by water in the western part of the polder, both to the village and within the area, are obviously much better located than in the eastern part (Fig. 15).

The excavation of canals and ditches

THE CANALS

Excavation of the canals was the first step required for opening up the land (drainage and transport).
Most of the canal lines planned ran through forested land, and before the excavation machinery could work, the trees had to be cleared away from the alignments plotted by the surveyors.
Excavation was by means of draglines of $1\frac{1}{2}$ and $\frac{1}{2}$ cu.yds which ran on so-called mats to prevent sinking into the ground. These mats consisted of tree trunks bound together with steel cables.
In the profiles of all the canals, account was taken of the poor mechanical properties of the clay soil. The depth of the canals was limited as much as possible. For the deep main drainage canals slopes of up to 1:3 were used. Wide banks were invariably left between canal and dam (1–2 m wide for the tertiary channels and up to 10 m for the main drainage canal).
The actual excavation work which totalled about 3,500,000 cu. m of earth, was carried out without great difficulties. An important setback was however experienced in the above-mentioned clearing of trees from the canal lines in front of the draglines.
In the initial period, the lines were cleared by the aid of winches. Use was made of: – Al Evans winches (American mfr.) mounted on Case S.I. tractors and on flat steel plates with drive by a stationary motor; – a Motormuli (Austrian mfr.), a snow track tractor equipped with winches, and – a Cuthbertson's Water Buffalo (English mfr.), a heavy amphibious crawler tractor equipped with winches. Work with all these machines proved very expensive, however, and not very dependable.
At a later stage of construction, clearing was done by hand when the work had

to be done under wet conditions. When soil conditions were good it was done by bulldozers, with previous poisoning of the trees if sufficient time was available (which was usually not the case).

THE DITCHES

A total length of about 600 km of ditches was excavated in the polder (1,200 m for each 12 ha-field), mainly by manual labour, although mechanical methods were also tried out.

A SIMESA ditch digger (Dominighetti, Milan) was purchased for excavating the ditches. This machine could however not be used, for the following reasons:

— The ground pressure of the machine, which weighed 20 tons, had been reduced sufficiently by means of large tracks. However, this was only applicable to the horizontal position and on uniformly level ground. As soon as the machine tipped forward or backward into a soft patch the local pressure was too much and it stuck fast.

— The machine was so constructed as to excavate the ditch between its tracks. In wet conditions the ditch was squeezed together by the weight of the machine, which therefore began to tip over backwards and stuck fast.

— In order to prevent blockage of the conveyor mechanism the short vegetation and the fibrous pegasse had to be removed beforehand. Previous removal of the pegasse was also necessary to prevent its incorporation in the body of the dam as this would cause leakages later on. Attempts to mechanize this work failed.

— The machine was equally ineffective on dry ground. Water always had to be supplied via the excavated ditch for loosening the soil of the excavator buckets. The water supply frequently caused difficulties.

— After the ditches had been excavated many subsidences in the tali occurred near the drought cracks. Moreover the dams were of poor quality, so that both the ditches and dams had to be finished by hand.

— The machine was so heavy that difficulties were frequently experienced in anchoring the winches for pulling the machine free.

Generally speaking the ditch profiles needed were too small for excavation with draglines. Draglines could, however, be used for excavating the berm ditches (2–3 cu.m/m) along the dams of the main and secondary irrigation canals. The other ditches were all constructed by manual labour on a piece-work basis. This construction consisted of the following operations:

1. cutting down the vegetation;
2. excavating the pegasse over the entire width for the future two ditches and the dam to 1 m exterior ditches and tipping this pegasse outside this line;
3. excavating a dam "cunet" of about 30 × 30 cm;
4. excavating two ditches of 1–1.5 cu.m/m each, and throwing up the field partition dam between these ditches;
5. planting the dams with *grinting* grass (*Cynodon dactylon*).

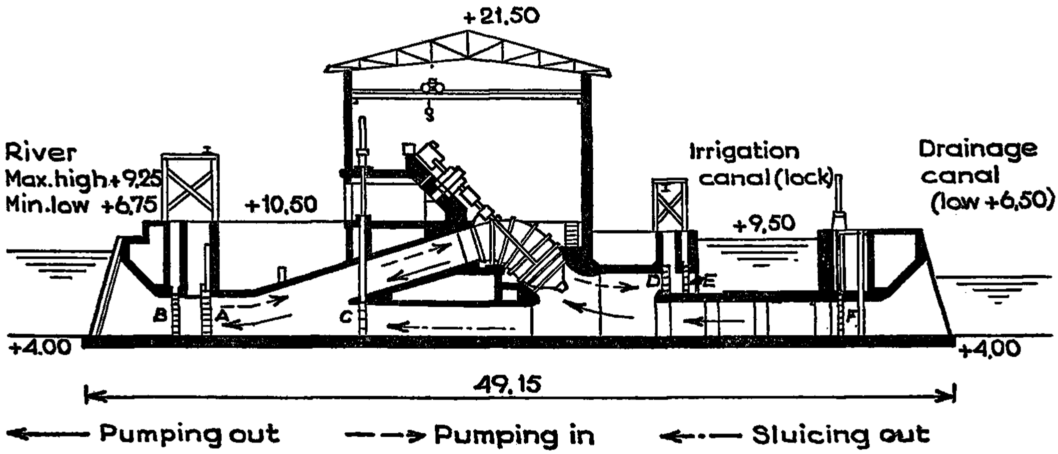


Fig. 16. *The Wageningen pumping station.*

3. **The pumping station** (Fig. 16)

The pumping station was designed for pumping in and out with the same pumps. Its capacity was based on the drainage requirements which were assumed to be predominating.

The required capacity of the first pumping station, called Wageningen, was estimated, within the framework of the 15,000 ha plan, at 33 cu.m/sec. for drainage, and 24 cu.m/sec. for irrigation. According to the plan (see p. 69) this capacity would be sufficient for the drainage of 8,700 ha gross (including the surface area of canals, dams and ditches, which amounted to about 10%) without using a reduction coefficient for shower distribution. For irrigation was started from a requirement of 0.64 litre/sec./ha in which case the capacity for pumping in would be sufficient for about 37,500 ha.[1] Calculated in this way, the dominant part allotted to drainage in the pumping station project is clearly seen.

Originally it was considered that it would be sufficient to instal two pumps of 11 cu.m/sec. drainage for the construction of the first 5,000 ha of the 15,000 ha plan, and not to instal the third pump until the acreage had been extended. It was, however, decided to instal all three pumps together because of the considerable ultimate saving which would result.

Three transverse (45°) electrically-driven screw pumps with reversible rotation and adjustable blades, manufactured by Werkspoor, Amsterdam, were bought.

With the aid of a suitable valve system these pumps could be used for pumping water both in and out. (Fig. 16). Preference was given to this model, despite the lower hourly output and the complex design, because foundation

[1] This is, in fact, a hypothetical figure because the Nickerie river does not supply sufficient fresh water for such a capacity in the dry periods without the construction of a dam.

costs would be reduced by such a concentration and also because it was assumed that lower running costs would result from the higher output per year of one dual purpose station.

The capacity[1] specified by the makers for drainage was, for each pump, for 1 m pumping head and 315 h.p. 800 cu.m/min. (for 1.5 m and 250 h.p. 700 cu.m/min., for 2 m and 380 h.p. 600 cu.m/min., for 2.5 m and 380 h.p. 500 cu.m/min., for 3 m and 360 h.p. 400 cu.m/min.). The capacity specified by the makers for irrigation was, per pump, for 1 m head and 250 h.p., 560 cu.m/min. (for 1.5 m and 270 h.p. 480 cu.m/min., for 2 m and 280 h.p. 400 cu.m/min., for 2.5 m and 270 h.p. 315 cu.m/min., for 3 m and 240 h.p. 240 cu.m/min.).

Thus the quotient $\frac{\text{output in cu.m/min.}}{\text{h.p.}}$ decreases from 2.5 to 1.1 in pumping out from 1 m $\rightarrow$ 3 m pumping head, and from 2.2 to 1.0 in pumping in over the same range of heads, from which it also follows that the power efficiency in pumping in is 10% lower than in pumping out.

The lower water flow for pumping in as compared with pumping out varies from 30% for 1 m to 40% for 3 m pumping head.

The pumps were ordered on April 2nd, 1951, and the building operations for the station began in March 1952. The first pump was put into service in April 1954 and the other two in the course of 1955.

4. The rice processing plant

The rice processing plant was so constructed that on the polder side it adjoins the inland port of the irrigation canal network via which the harvested paddy is conveyed by lighters. On the river side, moreover, the plant is connected by a conveyor to the jetty for sea-going vessels, enabling the finished product to be rapidly discharged (Fig. 10).

The plant consists of two main parts:

— installations for receiving, cleaning, drying and storing the paddy;

— installations for hulling, polishing and sorting the rice and for storing and shipping the manufactured rice products.

The maximum capacity of the first installations is about 600 tons paddy with 20% m.c./day. The storage capacity of the concrete silo is about 13.500 tons of paddy having a specific gravity of 0.53. The processing capacity of the milling unit depends on the type of manufactured product. Since Wageningen has been in production, cargo rice has been the main product. With this the capacity of the milling unit is about 250 tons paddy/24 hours. The entire rice processing plant is highly mechanized so that in practice a labour force of 35 is sufficient.

In the appendix a more detailed description is given of the lay-out of the processing plant and of the manufacturing methods used.

[1] As a result of various design improvements since the installation, and the failure of the Dijxhoorn watermeter, definite gauging of output is still to be done; this means that the capacities given should be viewed with some reserve.

CHAPTER VIII

THE RECLAMATION

Introduction

By reclamation is meant here making the virgin terrain ready for agriculture, particularly for mechanized rice growing, after it had been divided up into 12 ha fields by the canal and ditch system.

The requirements of mechanized rice growing were at first insufficiently known. On the basis of experience obtained with the first rice plantings the method of reclamation could however be gradually adapted.

The most important conditions which a newly reclaimed field should meet proved to be as follows:

a. it should be virtually free from timber;

b. the pegasse and plant remains must be worked completely under the clay;

c. the field should be level and have a carrying capacity sufficient for agricultural machinery.

For carrying out good reclamation work, a drying up of the land was a sine qua non. This drying up was largely dependent on weather conditions since much of it had to proceed by evapotranspiration.

The polder area to be reclaimed was about half covered with forest and half with a herbaceous vegetation, called grass swamp, in which scattered saplings occurred in places (see p. 46–49).

Bringing the grass swamps into cultivation was a simple and relatively inexpensive task. After adequate drying up they could often be ploughed in their natural condition and made ready for sowing the first rice crop.

Reclamation of the forest land was considerably more expensive and difficult. Owing to the high wages it was desirable to mechanize the disforestation work as far as possible. Mechanical disforestation was made difficult however by the high rainfall distributed over the year, and by the low capacity of the clay soil for carrying heavy tractors.

It was considered objectionable to clear the forest mechanically in the live state because this would disturb the naturally fairly level land.

Owing to these circumstances the forest stands were first poisoned with Na-arsenite. This required a great deal of labour as the trees had to be girdled and poisoned individually. At the same time care was taken to ensure the best possible drainage of the land with the object of stiffening up the soil. After one or two years the dead trees were flattened mechanically, burned, and the timber remnants were then bulldozed into heaps. Afterwards the land between the heaps of timber could be ploughed and prepared further for the first rice crop. After the rice had been harvested the heaps of timber

were cleared as quickly as possible, depending on the occurrence of periods of dry weather, and subsequently the first levelling operations took place.
In general the cleared lands were fairly flat so that they could be provisionally brought into cultivation without drastic levelling operations. The final completion of the levelling work could be done gradually over a period of some years, during fallow periods between rice planting.
Fig. 17 shows the successive acreages brought into cultivation. The reclamation work was begun in 1953; in 1954, 450 ha could be sown during the main season; in 1955, 1,940 ha; in 1956, 3,980 ha and in 1957, 5,820 ha. Comparison of the original forest vegetation shown in the top figure with the acreages brought into cultivation in successive years, shows that in 1954 and 1955 principally forest land was reclaimed.
In 1956 open grass swamp lands in particular were brought into cultivation and the central forest area was left untouched. This forest land was soft and difficult of access and it was preferred to let it lie a year longer. In 1957 the whole polder could be sown. In 1958 the net acreage sown was increased by a further 100 ha by the clearing of the heaps of timber, the filling up of creeks, etc.

1. **Draining the virgin land**

After shutting off the areas from the surrounding swamp water, by means of the banks of earth thrown up in digging the canals, the land was dried out by:
1. surface drainage via the ditch and canal system, with auxiliary trenches being dug in extra soft terrain, and
2. evapotranspiration of the natural vegetation.

Although a certain degree of drainage could be provided by digging canals, ditches and trenches, this did not mean that the soil itself was hereby dried out. This had to happen by evapotranspiration and to progress so far that drought cracks were formed, before the land in question had a carrying capacity sufficient for machines.
Reclamation could continue during dry spells when evapotranspiration had exceeded rainfall for some time. Hence in general the reclamation operations followed the rainfall pattern. Especially between September 1954 and March 1955, however, a fair amount of reclamation work was done despite heavy rainfall. During this period conditions were not really suitable but the operations went on for various reasons, e.g. psychological reasons so as finally to start up production, and practical reasons in view of the desirability of remunerating the available means of production (personnel, buildings, machinery) with its large fixed costs, as quickly as possible. The quality of this reclamation was quite poor.
The dilemma whether or not to continue working under wet conditions otherwise often arose to a lesser degree during other periods as well.

Surface drainage via the ditches and trenches

The drainage of the land began during the excavation of the canals, and was

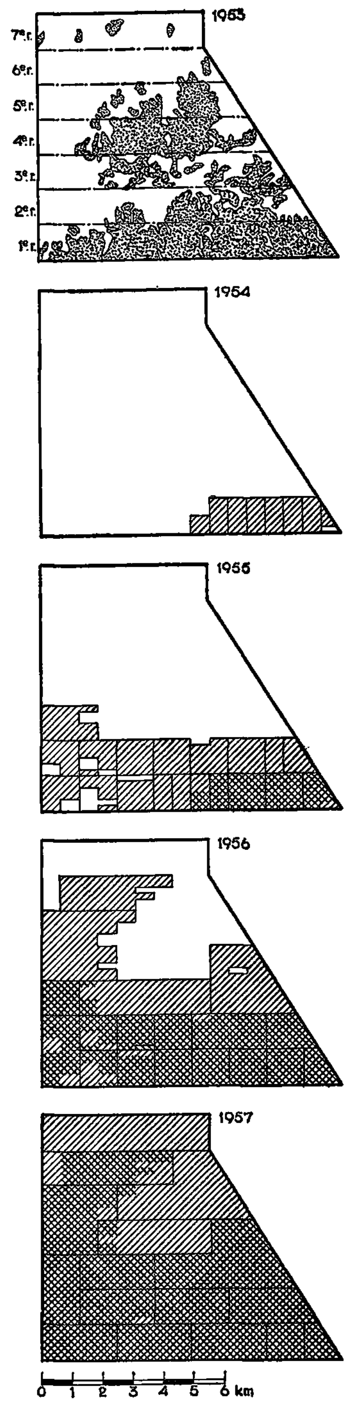


Fig. 17. *Survey of the progress of the reclamation operations from 1953 to 1957.*

The small top drawing of the polder is a diagrammatical representation of the original forest. In the other drawings the areas, made ready for sowing in the main season in the respective years, are hatched in such a way that the newly reclaimed areas can be distinguished by single hatching from areas already reclaimed earlier. The figure also shows in which farm units the acreage was developed in the years shown.

continued more intensely by the excavation of ditches. After the completion of the ditch system, fresh rainfall could only drain off on this land at a reduced rate because the pegasse excavated over the width of the ditch lines formed a barrier along the ditches on the field side. Moreover the dense vegetation and the pegasse mat caused so much friction that a relatively steep slope of run-off was formed from the ditches to the middle of the field.
Leaving the cost out of consideration, trenching of the 200 m between the ditches would also have been desirable. It will be appreciated, however, that digging these trenches at 10–30 m intervals and maintaining them, all work being done by hand, would have been very expensive. (Attempts to carry out this trenching with a Werklust trench plough failed because the crawler tractors stuck fast and the plant remains piled up in front of the plough.) What is more, as it was desirable to drain the top clay layer as well, fairly deep trenches would have had to be dug owing to the very poor permeability of the soil. Such a temporary trenching would in itself have been quite unattractive for future mechanized rice cultivation in which large undivided and level fields are required. Seen in this light, preference had to be given to the only alternative solution of drying out the ground by evapotranspiration of the natural vegetation. Only some very soft areas were trenched by hand.

Rainfall statistics show that long dry spells during which the swamp lands become bone dry occur quite frequently. A chief requisite for a reclamation project of the Wageningen type is patience, as it cannot be predicted when these droughts will occur. In the Wageningen reclamation bad luck was experienced in this connection. From the 1st up to and including the 4th year of reclamation (1953–1956) rainfall was high in the on average dry periods (see Table 21) and it was not until the 5th (and last) year of reclamation (1957) that favourable long dry periods occurred. In this respect 1958 and 1959 were also favourable years. Looking back, if the reclamation of Wageningen had been started some years later, much better work would have been done at a much lower cost.

TABLE 21 *Assessment of the probability of the rainfall at Wageningen (station W1: village) in 1952–1958 for the periods January–April and September–December, based on the frequency distribution of the rainfall at the Nw.-Nickerie station over the years 1907 to 1952, as calculated by Kras (1953)*

	January–April		September–December	
	rainfall (in mm)	% wet	rainfall (in mm)	% wet
1951			395	66
1952	308	17	466	78
1953	910	95	357	57
1954	807	88	659	> 95
1955	856	92	664	> 95
1956	584	59	794	> 95
1957	355	22	415	70
1958	550	33	280	38

The importance of evapotranspiration for drying up the soil

Evapotranspiration research may be divided into three sections:

1. determination of the evapotranspiration of various crops to establish what quantity of water is essential for good development of the crop;
2. methods of limiting evapotranspiration when little water is available;
3. methods of promoting evapotranspiration when there is too much water.

Investigations under 2 have long since led to the system of dry-farming in the prairie regions of N. America.

During recent decades evapotranspiration research under 1 and 2 has been greatly intensified because the view is continually gaining ground that, considerable increases in yield can be attained by improving the water supply to the crops in many farming areas, including the Netherlands. Expensive irrigation systems with pumps and sprinkler installations are being increasingly employed. Exact calculations of the water requirements of the crops are also necessary with a view to determining the profitability of such systems.

In some areas a serious water shortage is developing as a result of greatly increasing water consumption by agriculture, industry and the population. Also in view of the fact that the evapotranspiration of forests and other vegetations generally consumes a considerable proportion of the water supplies of an area it is essential to have information on this subject.

The third section of evapotranspiration research which we mentioned, viz. the promotion of evapotranspiration when there is too much water, has in our opinion hitherto received too little attention. Surplus water is a frequent source of trouble, and it is not always economic exclusively to adopt the conventional solution of drainage by ditches and pipes. Apart from adapting the environment to the plant, the adaptation of the plant to the environment also affords possibilities in this problem.

COSTER (1937) gives an example of this. He advised planting the low marshy basins on a number of tree plantations in Indonesia with certain Leguminosae in order to correct the hydrological regime.

Another application was discovered by chance during the reclamation of the N.E.-Polder of the Zuider Zee. During the Second World War the reclamation work in the N.E.-Polder in Holland came to a stop. In this period of neglect, extensive areas of reeds developed on this marshy land, and this caused some concern at first. When reclamation was restarted, the clearing of this vegetation turned out better than had been expected from both the technical and economic point of view: the reed represented a considerable value and it was also found that owing to evapotranspiration these reedy lands were dried out deeper and better than areas without vegetation, so that they could be sooner put to agricultural use. In this case a third and possibly greater advantage appeared after cultivation, as fewer harmful weeds were growing on the areas formerly covered with reeds. During the development of the Flevoland polder, use was made of this experience by aerial sowing of large areas with reeds (*Phragmites communis* Trin.) (BAKKER and BIEUWINGA, 1957).

An application of the third category also occurred during the reclamation of the Wageningen polder. Here it was found that owing to the impermeability of the soil, trenching and similar measures only drew off the surface water but were unable to effect drainage of the soil itself. The only course then open was to allow the soil to dry out sufficiently by the evapotranspiration of the original vegetation, before carrying out the mechanized reclamation work.

During the initial period of construction of the Wageningen project, some of those in charge of operations still thought that bare ground or ploughed ground would dry out better than ground covered with vegetation. The error they made was, in paying more attention to the screening effect of vegetation and the humid atmosphere beneath than to the evapotranspiration of this vegetation, which they could not in fact observe directly. Actually the conditions for evaporation from bare ground were considerably more unfavourable in the Wageningen polder than would normally be the case, because this ground was usually covered with a layer of pegasse, which sealed off like a blanket almost any direct evaporation. In Table 22 we see that insulation similar to the pegasse reduced direct evaporation from the soil to 10–15%.

TABLE 22 *Evaporation from a field soil with various covers* (BAVER, 1948)

Type of cover	Water evaporation in grams per 1000 sq.cm from July 12 to August 12, 1883
Bare	5739
0.5 cm chopped straw	2392
5 cm chopped straw	571
5 cm beech leaves	630
5 cm pine needles	878
5 cm fir needles	621

The fact that loosening up the topsoil does not promote drying out, but actually retards it, is one of the basic principles of the dry-farming system. Moreover, it has the further objection that surface run-off of rain water is reduced by absorption in the loose soil.

As was repeatedly experienced in the Wageningen project, whenever vegetation was flattened and burned too early, i.e. when the soil was still wet and soft, the further drying out of such soil turned out to be a very slow process. Ploughing effected no improvement in this situation. The best thing to do on similar soil was to allow a new vegetation cover to develop, after which further drying could take place by evapotranspiration. If a wet reclamation was followed by rice cultivation, it might take years longer before the soil had stiffened sufficiently to allow mechanized cultivation without much difficulty.

The importance of drying out the soil profile by evapotranspiration from a plant cover, was investigated by the author at Wageningen from November 1953 to January 1954 on the first reclaimed fields in the polder. For measuring the differences in soil stiffness (moisture content) under various conditions, pressure resistances of the soil were measured with BARENTSEN's hand probe apparatus. Table 23 lists some of the observations.

Rainfall at the measuring station W_1 (5 km away from the test) was 75 mm in September 1953, 32 mm in October, 96 mm in November, (probe measurements taken on 16 November 1953), 156 mm in December, 204 mm in Januari, 121 mm in February, 176 mm in March, and 287 mm in April.

TABLE 23 *Values of readings in kg/sq.cm from the Barentsen hand probe in measurements on 16 November 1953, on ground from which the vegetation had been removed at various times (means of 10 measurements), and yields of a soya crop sown afterwards*

Site of measurement	Field treatment	Probe depth			Soya yields
		10 cm	25 cm	40 cm	
9 West	*Without* vegetation. (This was flattened and burned at the beginning of September 1953) . .	3.9	3.4	3.3	
9 East	*With* standing vegetation . . .	9.5	6.8	5.7	
13	*Without* vegetation (Flattened and burned at the beginning of September 1953).	2.9	3.0	3.2	140 kg/ha (30 ha)
14	*Without* vegetation (Flattened and burned at the beginning of September 1953).	4.2	3.8	3.8	
15	*Without* vegetation (Flattened and burned at the beginning of September 1953).	3.8	3.6	3.5	
19	*With* standing vegetation . . .	9.3	7.3	6.1	
20	*With* standing vegetation . . .	9.7	7.4	6.6	1150 kg/ha (11.5 ha)

The figures in Table 23 show that fields 9 East, 19 and 20 were very much drier than the other fields. This cannot be but the result of evapotranspiration by the dense growth of tall grasses and herbaceous plants on these fields during the dry months of September and October. The previous history of the fields in question played no part in this, as can be seen from the differences found in the Western and Eastern parts of the same field 9.

In December 1953 fields 13, 14, 15 and 20 were sown with soya. Fields 13, 14 and 15 were waterlogged from the 25th December and throughout January. Field 20 did not become waterlogged until the 8th January, and it was waterlogged for only a few days in the month of January. (Fields 13, 14 and 15 were sown somewhat earlier than field 20, so that these fields had the slight advantage of greater evapotranspiration by the more advanced crop.) From 26th December to 8th January inclusive, precipitation was 109 mm. The higher absorptive capacity of rain by the "dry" field 20 was thus of the order of 100 mm.

Owing to the rainfall, the probe values of the "dry" fields had fallen off considerably in January and the difference from the "wet" fields was slight. The soya yield from the wet fields 13, 14 and 15 averaged 140 kg/ha for 30 ha, of which only 7.5 ha were harvested. However, the yield from the dry plot 20 was 1150 kg/ha for 12 ha. In our opinion this difference in yield is to be ascribed to the drying-out effect of the preceding natural vegetation.

Field 19 kept its wild vegetation until April 1954. The result was that up to 1956 this plot had the reputation of being the driest in the polder and the easiest to till. After these and other experiences, the usefulness of evapotranspiration was always carefully considered in assessing whether a certain area was ready for reclamation.

The quantity of water removed from the soil by evapotranspiration depends on various factors. According to PENMAN (1956), the intensity of evapotranspiration is mainly determined by the climate, viz. by solar radiation, air movement and atmospheric humidity. According to THORNTHWAITE (1955), the supply of soil moisture, the soil type, the plant species, its stage of development and the plant spacing are further factors.
It may be supposed that the hygrophytic swamp vegetation already has a high transpiration rate under natural conditions. Promotion of this rate may be achieved, however, by improvement of the growing conditions and of the composition of plant-associations.
For example the stage of development of a vegetation may possibly exert an influence. If by chance there is no fire in the grass swamps a large amount of dead foliage is accumulated, as a result of which the amount of living foliage decreases. Light burning of such vegetation, with resulting development of a young leafy plant growth, could promote drying.
Another possibility might be to dam flood creeks so that less salt water enters the swamp, which could effect a change in the vegetation.
The selective promotion of the swamp vegetation can possibly be achieved fairly readily by means of aerial sowing.
For example, the following considerations may be applicable:
— *Typha*, *Canna*, *Thalia* or *Cyperus giganteus* vegetation presumably gives better evapotranspiration than *Cyperus articulatus*, ferns or small grass-species, partly because of their greater leaf surface.
— Plants which remain in a state of full development during the dry seasons should be preferred to plants which mature and die in dry seasons.
— For some reclamation projects it may be desirable to give preference to legumes in these sowings. In the case of Wageningen the very opposite is preferable in connection with the excessive initial fertility of the newly reclaimed soils.
The practical importance of the above ideas was not tested in the Wageningen project.

2. Poisoning the forest

Mechanized clearing of the swamp forest in the live state was objectionable for the following reasons (DE WIT, 1954):
— With the prevailing climate the heavy clay soil is usually waterlogged, and even crawler tractors have only slight spare drawbar-power under such conditions. In the case of mechanized clearing of living forest by means of bulldozers, work can therefore only be done during the relatively rare dry spells.
— Mechanized clearing by means of winches is laborious and costly in this type of forest, in which there is a dense growth of relatively small trees.

— Mechanized clearing of living forest does considerable damage to the topsoil, because much soil is lifted out with the root stubs.
— Owing to the humid climatic conditions it is usually not possible to burn the uprooted trees in situ. *Koffiemama* for example, which was the most important tree in the polder, has the property of rapidly developing fresh shoots on the felled stem. It would therefore be necessary to push the heavy green trees into windrows immediately after uprooting.

Poisoning of the trees seemed to be the only method of overcoming these difficulties.
The method of poisoning *koffiemama* forest was investigated by VAN BEUKERING and DE LINT in 1950 in the Prins Bernhard experimental polder. The chemicals tried were Na-arsenite, Na-chlorate (both materials in solution and crystal form), 2,4-D and 2,4,5-T (emulsifiable oil solution). Various methods of application were investigated, e.g.: by smearing on to a girdle cut into the wood, by smearing on local cuts, by injecting into bored holes, and by spraying diluted solutions on the stem, roots or foliage. The best results (a practically 100% kill) were achieved with Na-arsenite, when this was smeared in the form of a 40–50% solution on a fresh girdle about 10 cm wide, cut into the bark unto the wood.
In connection with this investigation, the tolerance of rice to Na-arsenite was studied in the Prins Bernhard polder. 30 kg of 50% Na-arsenite per hectare was found to cause no visible damage to the rice. For poisoning forest vegetation, 5–15 kg/ha depending on tree density is sufficient.[1]
The usefulness of the poisoning method, described above, for other species of trees occurring in the Wageningen project area was investigated by KLEIN LANKHORST in 1951. The kill was less complete (about 90% of nearly 200 trees) and the dead wood rotted much more slowly in the case of the hardwoods and of such latex containing trees as *bolletrie* and *mirkiehoedoe*. A drawback of Na-arsenite was its great toxicity for human beings. Some cases of poisoning occurred through the workers' carelessness in handling the poison.
On account of these various difficulties, in 1951 the author again tested a 2,4-D and 2,4,5-T ester mixture (brushkiller) on various tree species. The following methods of application were used: spraying the base of the trees with a water or diesel oil solution of brushkiller; smearing a band of concentrated brushkiller round the bark and smearing concentrated brushkiller on a fresh girdle cut in the bark unto the wood. Only with the last method a percentage kill similar to Na-arsenite was obtained. As the price of the brushkiller was then several times that of Na-arsenite and other costs being the same, preference was given to Na-arsenite.

In the period 1951–1956 the whole forest area of the Wageningen polder (about 3,000 ha) was poisoned with Na-arsenite. After poisoning, a period

[1] In tests with sand cultures of rice, LOCKARD and MCWALTER (1956) found that arsenic can be harmful in contents of 3–6 p.p.m.

of 1–2 years was required for the process of decomposition, after which the forest could be flattened by bulldozers and chaindozers, followed by burning and pushing the remains of the timber into windrows and heaps.
Most of the forest land which was to be poisoned had already been divided according to the future layout of 12 ha-fields by the "tracé's" of the surveyors, thereby facilitating the organization of the work. In the initial period the areas where poisoning had to be done could only be reached after hours of marching through the swamp. The work was put out to contract at piece rates. Barrack encampments were set up for the gangs of workers. The zinc sheets for the first barracks were carried on the head for several kilometres through swamp 0.5–1 m deep. The poisoning work itself was very heavy and high wages had to be paid in order to attract sufficient workers. Before the actual poisoning work took place it was necessary to fell the impenetrable undergrowth. Thin saplings were felled together with the undergrowth.
Machetes were used for clearing the undergrowth and for the subsequent ringing of the trees.
The cost of poisoning was approximately as follows:

Cutting undergrowth	Sf 40 per ha
Ringing the trees	Sf 20 per ha
Applying poison by brush	Sf 10 per ha
Transport and shelter	Sf 10 per ha
Poison	Sf 5 per ha

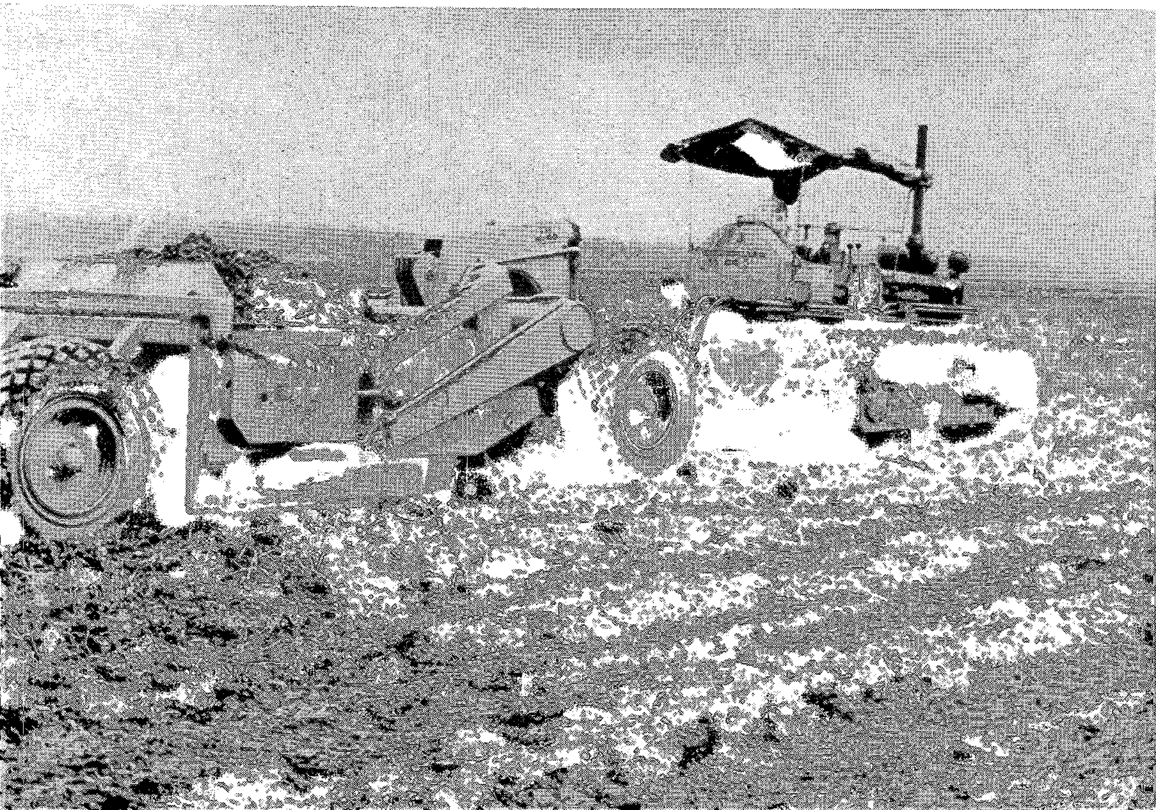
The following remarks can be made with regard to experience obtained in poisoning the various tree species:
The mixed swampland forest (about 100 ha): a 100% kill was not achieved. The scattered still live trees considerably slowed down mechanical flattening.
Koffiemama (*Erythrina glauca*) (about 1,000 ha): the kill was 100%. After a year most of the crowns had collapsed. Many stems of 40 cm diameter were after a year so far decomposed that they could be toppled over by hand.
Mirahoedoe (*Triplaris surinamensis*): this species occurred fairly frequently among the *koffiemama*; it could also be poisoned easily.
Panta (*Tabebouia insignis* group) (about 1,000 ha): poisoning of this vegetation was less attractive. The trees were small and there were often more than 1,000 per ha. The hard wood rotted only slowly. Direct mechanized uprooting was tested but proved to be unsatisfactory as:
a. the springy stems frequently bent right under the bulldozers;
b. large root clumps with adhering soil were lifted, the result being a terrain full of cavities and mounds;
c. some stems broke off so that the thick live stumps remained in the ground.
Finally, poisoning seemed the most satisfactory method. Areas with a thin and very scattered stand of *panta* trees in the grass swamp (Fig. 9) were usually not poisoned.
Bébé (*Pterocarpus officinalis*) (about 500 ha): a typical difficulty of this vegetation in connection with poisoning was formed by buttress-roots. These

16. *Ploughing virgin land with a Ransomes Solotrac plough.*

17. *Ransomes Solotrac plough with International disk-coulter: although the plough has ample clearance it still is subject to trash clogging and winding.*

18. *First rice-crop on newly reclaimed land with wood-piles.*

19. *Caterpillar Carry-scraper.*



made it somewhat difficult to cut a continuous girdle as high as one could reach, despite the fact that the wood of the buttresses was very soft. The dense stand of relatively small trees formed also a difficulty, although to a somewhat lesser degree than with the *panta*.

The question as to whether girdling the trees alone without subsequent poisoning with Na-arsenite could have succeeded, must be answered in the negative, as in this case the stem above the girdle dies, but the stump below with its root system frequently does not, and subsequently can put out new shoots. The visible effect achieved seems considerable but mechanical uprooting of such live stumps is at least as difficult as of a live forest.

By smearing Na-arsenite on the girdle the stump and the root-system die as well. Something similar to what we see happening above ground as a result of the collapse of the tree crowns also occurs below ground, owing to the successive rotting away of the root system from the smaller to the larger roots. With mechanical uprooting 1–2 years later, at most only a few main roots emerge together with the stump. Practically no soil comes to the top; so that only minor unevennesses occur in the terrain.

After the stands had been poisoned a thick mat of creeping and climbing plants always developed and gradually covered everything. This vegetation checked the rise of new trees and promoted the drying out of the land. It is possible that it also helped in accelerating the rotting of the dead trees.

Briefly summarized, the effect of poisoning the trees compared to the difficulties which mechanical uprooting of living trees would have caused, is as follows:

Owing to the dying and rotting away of stems and roots, the trees can be toppled over with little exertion, and there is only a slight disturbance of the soil. Medium-heavy crawler tractors can be used for this work. Although the latter can develop only little useful power on this soft terrain it is still sufficient in the poisoned forest.

Owing to the variable climate it is also important that the flattened poisoned trees can already be burned right after (N.B. after the wilting of the herbaceous vegetation). The combination of dead wood, withered undergrowth and dry litter makes a very good fire.

If mechanical reclamation work has to be stopped on account of increasing wetness of the terrain from rains, this does no great harm to the reclamation work apart from the unavoidable loss of time, since the wood continues to rot and when a drought occurs again, flattening and burning will proceed even more efficiently in a certain sense. The herbaceous growth which develops in a rainy period can easily be destroyed and moreover has a favourable effect owing to the more intense drying out of the soil caused by evapotranspiration.

3. Mechanized disforestation

Mechanized clearance of the poisoned forest took place in various stages:

1. Flattening;
2. Burning;
3. Mechanized gathering of the timber remnants into windrows or heaps;
4. Burning of windrows and heaps, if necessary with the help of mechanical gathering;
5. Levelling of the remnants;
6. Gathering wood by hand before and after ploughing.

Not all these six stages were used in each case. Burning for instance had to be omitted in rainy weather, so that flattening was then followed immediately by mechanical gathering.

Flattening and burning

Flattening the dead poisoned forest was done with 60–100 h.p. crawler tractors. Two more or less equal methods were employed, viz., chain-clearing and bulldozing.

The chain-clearing method. A heavy chain was dragged along by two crawler tractors, having bulldozer blades in front (photographs 12, 13).

The two tractors travelled about 5–10 m apart according to the density of the forest, with the chain in an arc behind them. The one tractor which had to drive its way through the forest had the heaviest task. In the green wilderness it was frequently impossible to discern obstacles and cavities until the machines were either on top of or inside them. The tractors were equipped with a tubular steel frame on top to protect the driver from falling trees and from the weight of the tractor itself should the latter overturn. Chain clearing was a heavy task for tractors and drivers, although the latter carried out the work with great enthusiasm. The principal breakdowns in the tractors arose through mistakes in driving, e.g. when the tractor was reversed slightly in turning, and a track rode on the chain, this often forced the end drives.

A variant of chain clearing is highball clearing (CRISWELL, 1951). In this a large steel ball is hinged in the middle of the chain between the pulling tractors. This system is especially useful where many deep-rooted heavy trees have to be pulled down; the chain gets a higher grip on the stems, thereby increasing the leverage effect. The highball was not required nor used in the Wageningen project. It should be noted that usually the rolling chain also wound a ball of lianas around itself.

After being flattened by chain the terrain was usually gone over with a brushcutter to cut up the wood and shrubs. The Marden brushcutter (Auburndale, Florida, U.S.A.) in the standard model consisted of a solid traction frame in which ran two drums set at a small angle behind each other, each having seven heavy steel knives mounted lengthways.

The bulldozing method, in which the vegetation was flattened exclusively by crawler tractors fitted with bulldozer blades. In the lighter forest this was occasionally preferred, because of the obviously smaller risk of accidents from trees, and because the bulldozers could sometimes also pull the brushcutter in the same operation.

In good weather the fields could be burned one or two days after the dead forest had been flattened. During the initial reclamation period it was thought that this burning should be done carefully to prevent burning away the pegasse as well. Subsequently, however, the pegasse proved to be a great hindrance to rice growing so that attempts were made to carry out the burning as intensively as possible (see p. 102–104). The effect of the burning was dependent, among other things, on the occurrence of dry sunny weather, on the state of decomposition of the timber, on the moisture content of the pegasse, on the direction of burning with regard to the wind, and on the general way in which the burning was carried out.
In the author's opinion, one obvious result of the apparent simplicity of burning was that probably too little attention was paid to this work. The fact is that when the field has been properly and uniformly burned, such subsequent operations as mechanical gathering of wood and the first ploughing, can be performed more smoothly, better and at lower cost, and this is one reason why higher rice yields can subsequently be obtained.

Clearing the remnants of timber

After burning, or, in wet weather, directly after flattening, the remnants of timber were systematically pushed into windrows and heaps by medium-heavy bulldozers and by farm-dozers (light model dozer attachment).

The reclamation tractors were equipped with radiator guards and steel plates to protect the gear box. A considerable number of the 45 h.p. crawler tractors purchased for rice cultivation were also employed on the reclamation work in the early years. The crawler tractors and accessory equipment (mostly International Harvester make) were generally satisfactory in the reclamation work.
A drawback that regularly caused time losses was the rapid overheating of the engines owing to the radiators becoming clogged with dust and plant remains.
The dozer blades used were of the normal plain plate.
In the beginning some tests were made with dozer blades fitted with steel rake tines underneath, the object being that less soil would be entrained. When the drivers became used to the work this provision was no longer found to be necessary. Furthermore it came to be realized that the entrainment of some pegasse from the field was not at all objectionable.

With fairly uniform distribution of the forest remains over the field, two or three windrows (or rows of heaps) were made along each field. Having regard to the first rice crop in particular, a certain standard had to be set for the regular construction of windrows and rows of heaps.
The first rice was often sown directly after the timber remnants had been pushed into heaps. It also happened that the heaps or windrows were burned first, after which the remains were pushed into a smaller compass, before the rice was sown. It was not very often that ploughing and first sowing were

done on land completely free from timber. The method used depended on the weather conditions, the combustibility of the gathered timber and the sowing times of the rice-crop.
With regard to the reclamation costs per se, it was cheaper to let the heaps of wood rot away undisturbed for some years. On the other hand the heaps of wood and especially the long windrows were a great hindrance to rice cultivation.
The principal difficulties for rice cultivation were the following:
1. uniform rectilinear tillage was not possible;
2. round the heaps of wood, where the soil was already soft as a result of bulldozer activity, bad patches and holes were made by the frequent turning of tractors and combines;
3. the heaps of wood were nests of weeds, insects, and rats;
4. loss of productive acreage (about 10%).
In the case of the windrows the following points also applied:
5. the central parts between the two or three windrows of each field had insufficient drainage of surface water;
6. the central parts of the fields between the windrows could not be reached with the motor dusters from the dams for insect and snail control.

To start with, we therefore insisted that the windrows should be immediately rolled up into heaps and the latter destroyed as quickly as possible, especially by burning. Thus, for example, much timber in the heaps was burned in the period when the rice crop was growing. The fire, which smouldered for weeks, did little damage to the surrounding crop standing in water. Most of the material of the burnt-out heaps consisted of earth, pegasse and rotten wood pulp. After the first rice crop, these remains were usually spread out over the field with light dozers.
In addition to the remains of wood in the burnt-out heaps, timber was afterwards ploughed up in the field. Also the levelling by means of landplanes brought remains of timber to the surface. These rests were hand-loaded into carts and brought to the edge of the field for burning.
Fig. 18 gives an idea of the influence of the windrows of timber on the level of a field after the remains have been spread. The levels were measured in December 1955 by ZUIDBERG, on the author's instructions. Intentionally, an example was chosen which is poor from the point of view of reclamation technique. The faults were as follows:
1. the timber windrows were crooked, and this made rice cultivation difficult in the intervening strips;
2. the pegasse ridges along the 600 m ditches, formed during the clearing of the pegasse from the ditch "tracés", had been pushed away in too great a depth by the bulldozers, hence the low elevation of these field-borders;
3. the remains of the timber windrows were insufficiently and unevenly spread out.

Fig. 18. *Example of field-topography after reclamation.*
The drawing represents field 140 (on parc. 24, 2nd series) in December 1955, after the first rice crop and after clearance of the timber windrows.
The thin lines denote the boundaries of the remains of the windrows after spreading out. The thick lines denote the course of a creek.

4. The clearing of the pegasse

In the case of the swamp reclamations at Lake Alaotra (Madagascar), which the author visited in 1956, it was realized that burning away of the peat layer (pegasse) present on the clay must be avoided, for the following reasons:

— The peat, which is also mixed with fresh sediments, is rich in plant nutrients but the clay subsoil is poor. As a result of burning the plant nutrients are washed away and a poor clay topsoil remains.

— The peat, which often occurs in a layer of more than a metre thick, cannot always be burned away uniformly. A partly unsuccessful fire leaves a difficult terrain with burnt-out pockets.

These two arguments do not apply to the pegasse of the Wageningen project: the clay itself is reasonably provided with plant nutrients and the thickness of the pegasse layer (0–40 cm) cannot cause any troublesome pockets by burning.

During the initial reclamation period at Wageningen it was thought, however, that the pegasse should be preserved because of its improvement of the structure of the underlying heavy Mg-clay. This was indeed important for dry crops as soya, maize, sorghum, etc., which were assigned an important part in the cultivation schedule of the general basic plan, as second crops alternating with rice. According to the basic report the aim of conserving humus even should be one of the all-important rules for the project. In the first experimental rice fields laid out at Wageningen in 1953, was immediately started to investigate the question as to what should be done with the pegasse.

In the first series of experiments on reclaimed forest land it was found that:

— an unmixed pegasse topsoil resulted in a bad plant spacing;

— a topsoil of mixed pegasse and clay gave a reasonably good plant spacing with good crop development, and

— an unmixed clay topsoil gave good plant spacing with meagre crop development.

It was concluded that partial preservation of the pegasse was desirable.

As during the reclamation seasons of 1953–'54 and 1954–'55, the weather was mostly rainy, only little burning could be done. In 1954 about 450 ha of rice was planted in the main season, and about 500 ha in the following second crop season.

A new aspect of the pegasse was revealed in the cultivation of this last crop in particular, since on fields with much pegasse which were poorly and shallowly ploughed the plants together with the pegasse layer began to float on the water. This phenomenon had a number of very unpleasant consequences which will be discussed later (p. 150–151). It was also found that the pegasse fields were very difficult to harvest by combine because the clay soil under the pegasse-cover remained wet and soft. In view of the above, attempts were made during the reclamation work in 1955 to burn as much pegasse as possible, but as a result of wet weather little progress was made in this

direction. Owing to floating pegasse the 2,000 ha planting of the main crop in 1955 had uneven stands, with many open spaces.
In the 1955–'56 reclamation season weather conditions were also such that only a small part of the reclaimed fields could be properly burned. In that year the occurrence of floating pegasse was however greatly reduced by ploughing it deep under. By 1956 the main planting already reached an extent of 3,900 ha. The yields did still not come up to expectations, this time primarily because the crop developed too rankly, especially on fields with much pegasse. This revealed a third disadvantage of the pegasse.
In the 1956–'57 reclamation season weather conditions were considerably drier so that the remaining 2,000 ha of the polder reclaimed in this period, could usually be more effectively burned and ploughed than the areas reclaimed in the preceding years. On a number of plots in the *Pterocarpus* area with thick pegasse layers, the precaution was even taken of pushing the entire pegasse mat into windrows and then burning it in order to avoid the harmful effect of the pegasse. One result of the effective burning in that year was that the soil could be especially well tilled, the N-rich humous topsoil being worked under to a depth of 15–20 cm.
Evidently floating pegasse did not occur. The planting was very well spaced. No difficulties were experienced in harvesting with combines. On the reclaimed areas where there had been a grass swamp vegetation yields were excellent. Yields in the forest regions did not, however, come up to expectations because growth was still too rank. In this area apparently neither the intensive burning nor the deep ploughing-under had sufficiently reduced the excessive "fertility".

Hindustani rice farmers predicted that on the new pegasse-rich fields of the Wageningen project, rank rice crops giving small yields would grow in the first few years, since this had been their unfortunate experience when cultivating new pegasse soils at Nickerie. H. N. VAN DIJK, the pioneer of mechanized rice cultivation in Surinam, had had the same experience. In 1940 he wrote on p. 37 of his report "MECHANISCHE RIJSTCULTUUR": "As soon as cultivation is practised on these plots the mixing of the humus with the clay proceeds automatically, and the only thing one can expect is that for the first few harvests the crop is excessively rank with a great deal of soft straw, which makes harvesting difficult, while grain yields are disappointing, but we must all put up with this. If only we could grow colza here.".
It was quite surprising that during the first two years (1954 and 1955) there was little or no evidence of such rank growth at Wageningen. It was only in the 3,900 ha main crop planting in 1956 referred to above, (and subsequently also in the 1,000 ha second paddy crop in 1956–'57, and the 5,800 ha main paddy crop in 1957) that rank growth occurred on most of the fields with much pegasse, causing a poor fruit set and low yields.

We can only explain this delay in the "fertility" of the soil by supposing that this process runs parallel with the degree to which there is aeration of the

soil. The fact was that the areas reclaimed in 1954 and 1955 had only recently been drained; moreover, because of the wet weather in these years, the soils had only slightly dried out.
In 1956 the "maturing" of the older soils, helped by periods of dry weather during which good ploughing could also be done, had so far advanced that rank growth began to occur. It was again found that the newest reclaimed lands in the 6th series had still not reached this stage; even when there was much pegasse they only exhibited a meagre growth of rice crop. However, in 1957 this 6th series also showed a rank development. That year the entire main crop developed rankly, this being certainly connected with the long dry sunny periods preceding this crop, which intensely dried out and aerated the soils.
The said development of increasing "fertility" was not foreseen originally, i.e. in 1956, as probably being a systematic development.

5. Reclamation tillage

By tillage in the reclamation is meant the first ploughing of the virgin land and the levelling of the fields.

The ploughing

The first ploughing in 1953 and 1954 was done with Rome heavy-duty disk harrows equipped with cut-out disks. This implement, further referred to as Rome plough, was chosen chiefly because it is tolerant for wood in the soil. The results were, however, not very satisfactory. The plough did not turn the soil sufficiently so that it was a further cause of the floating pegasse in the fields. On badly burned fields it frequently ran out of the soil and over the mat of plant remains.

In testing various types of ploughs in 1954 and early 1955, the Ransomes Solotrac, a heavy single-share plough, was found to be the best, especially because it enabled all the pegasse and plant remains to be worked 15 cm deep under the clay, thereby avoiding a floating topsoil and possibly also over-rank growth.
Ploughing with the Solotrac had however, its drawbacks, these being:
— the occurrence of breakages caused by wood remnants in the soil (mouldboard ploughs are generally more susceptible to this than disk ploughs);
— the possibility that the fields would become too soft for machinery after deep working with the plough;
— the probability of a poorer crop development on pure clay;
— the danger, a considerable one in the view of VERHOOG (verbal comm.), of working the pegasse layer under too deeply, as this confined organic material could cause "katteklei" acidification phenomena (see p. 41), especially in the case of dry crops.

Three models of one-furrow ploughs were tested:
Ransomes Solotracs with a narrow and a wide mouldboard, and an International Muckland Plow (No. 11).
The most satisfactory plough was the Solotrac with a narrow mouldboard but fitted with the disk coulter of the International plough. The Solotrac with the wide mouldboard did not turn over the tough pegasse mat sufficiently with the furrow slice, so that it tended to roll back (sometimes only after irrigation of the sown rice crop). The International was too low and too lightly built.[1]
On the other hand, the International 80 cm diameter rolling coulters with notched blade and fitted with Timken bearings, were far superior to the smooth Ransomes rolling coulters which were about half the size. In fact, the Solotracs could not be used without the International rolling coulters. (All Solotracs bought later were therefore fitted with the International coulters.)

An area of about 200 ha, with formerly little timber, was ploughed with Solotracs early in 1955. Due to rainy weather the ploughed land did not dry out, so that, owing to bogging down of the tractors, some fields could only be subsequently prepared for sowing with the greatest difficulty. No floating pegasse occurred and the plant spacing and development of the first rice crop were good. During harvesting, the combines experienced no more difficulties in travelling on the fields ploughed with the Solotrac than on those ploughed with the other types.
The yields of the fields ploughed with the Solotrac were the highest of the whole area. These higher yields were not, however, only due to the mouldboard ploughing since this was done on selected fields with little timber (originally grass swamp). Here, where development was less rank, fields which had not been mouldboard-ploughed also gave better yields in 1955 than the former forest lands. Fortunately comparative plough test strips had been laid out in 1955 in some virgin fields formerly covered with *koffiemama* forest, and these clearly demonstrated the favourable effect of ploughing with the Solotrac in the development of the rice crop.
At the end of 1955 it was decided to switch over entirely to Solotrac one-furrow ploughs in the reclamation ploughing. Owing to late delivery it was early 1957 before all the ploughing equipment required had been received. For the 1956 main crop, 1,400 ha (mostly virgin land) were ploughed with Solotracs, usually in rainy weather. The soil generally had a low carrying capacity for machines and as there was also high rainfall in the harvesting period (August and September 1956), many fields remained entirely or partially impassable for the combines. Harvesting was expensive and much grain was lost. However, the yields in that year for land ploughed with the

[1] Under similar reclamation conditions at Lac Alaotra, Madagascar, the International Brushbreaker Plow was being used in 1956. This International plough is much heavier and appears better suited than the Muckland-type.

Solotrac were still 2,765 kg/ha as against 2,496 kg/ha on the rest of the area (2,576 ha).
Of the above 1956 main crop area, hundreds of hectares of virgin grass swamp had been ploughed directly with Solotracs under waterlogged conditions (with water in the plough furrow), without burning and any other preliminary treatment or merely after flattening with the brushcutter. This method of working had however its drawbacks. It was found that the green vegetation-rests being worked under, decomposed slowly, with the result that the combines frequently sank through the surface clay layer and bogged down.
The forest areas south of the polder, for which the Solotracs were least suited from the point of view of implement design, were found to be most in need of this treatment because of the thick layers of nitrogenous pegasse occurring there. Despite many breakages owing to timber remains in the soil and much loss of time, in the course of 1956 and 1957 the whole southern forest area, that had already been brought into cultivation in wet weather in 1954 and 1955, was deeply ploughed with Solotracs as a supplementary reclamation measure in order to work under the thick pegasse layer.

As well as the Rome and Solotrac ploughs, the disk plough bought for normal cultivation (McCormick International No. 98, 5–3) was employed in the early years of the reclamation ploughing, usually with only 3 or 4 of the 5 disks mounted. The drawbacks of this plough were insufficient clearance, small disks and vulnerable construction.
Finally, during the wet years 1954–'56, fairly extensive areas of virgin land were sown without ploughing. These were fields which were too soft and wet to be ploughed after the timber remains had been pushed into heaps. They were prepared for sowing by puddling methods. For this purpose a few centimetres depth of water were added to the already waterlogged field. By means of a few passes with brushcutters and similar equipment, followed by dragging with a beam or plank, the weed was crushed and worked in the mud. Usually a seedbed resulted of a fairly satisfactory appearance.
As the resultant topsoil consisted almost entirely of pegasse, after heavy rain or irrigation the young plants floated in their entirety together with the topsoil.
The yields obtained after such a primitive soil cultivation were usually considerably lower than those of ploughed land.

The levelling

Levelling is the last important stage in laying out the rice fields.
The following considerations had to be taken into account in carrying out the levelling operations:
— In view of weed control a levelling accuracy up to 5–10 cm was necessary. From investigations in the Prins Bernhard Experimental Polder it was concluded in 1952, that the only method of preventing the development of grassy weeds was to keep the paddy during its early development in a constant and even layer of 15 cm water.

— Because of the chosen field lay-out with two open ditches both for supply and drainage, the sub-division of a 12 ha field into separate irrigated compartments according to differences in height could only be achieved by diking the ditches. The excavation work required for this would be fairly costly.

— Sub-division of the fields into compartments renders mechanized operations and correct timing of irrigation and drainage more difficult. It also means a loss of land and extra cost of maintenance of the compartment dikes.

— The majority of the fields only had substantial differences in height (up to 50 cm) over short distances (some tens of metres), resulting from creeks, heaps of timber, root holes and bulldozer tracks.

Only a small number of fields had a really gradual slope of 20–30 cm, very seldom more than 30 cm (wide creeks).

— The pegasse layer of the reclaimed fields decomposes and disappears in time. The actual level of the clay is thus the only factor which determines the levelling. As long as most of the pegasse is not decomposed or burnt, no adequate levelling is possible.

It must also be realized that in the original morass condition pegasse formation took place more quickly in the lower parts of the terrain, so that at the moment of reclamation the lands always seem flatter than they are.

A second reason why there is little point in levelling pegasse land is that pegasse is brought from higher sites to lower ones. As a result of further decomposition of this pegasse there will soon be approximately the same differences in height. Moreover, a field levelled in this way will give a bad crop, especially on the extra-thick pegasse of the raised sites.

— If levelling is done by moving top-soil from the higher towards the lower parts, the result will be non-uniform fertility within the field. This difficulty may be somewhat reduced by preliminary deep ploughing with the Solotrac.

— The cost of levelling work should be weighed as well as possible against the advantages which this work has for rice growing. It may happen that, in a given situation, levelling has to be abandoned owing to the low profitability of the high levelling costs.

The working method developed from these considerations was as follows:

1. After clearing the fields of wood, unevennesses over short distances were levelled as quickly as possible, with Marvin Landplanes.

This levelling work was simple and cheap (2–4 International TD9 hours/ha). Good dry weather was important, but this occurred only from 1957 onward; 1954, 1955 and 1956 were very wet years.

2. After some years of cultivation, a start was made during the fallow seasons on correcting the great differences in level over longer distances with the aid of carryscrapers.

This type of levelling which is still being carried out, is only required on 20% of the area of the present polder. It involves much shifting of earth and is rather expensive. Previous accurate surveying of the fields is essential.

The first Carry-scraper test was made in the Prins Bernhard polder in 1957, by OVERWATER and VAN GILS.
The work was done with a Caterpillar D4 crawler tractor (50 d.b.h.p.) and a Caterpillar No. 40 scraper (bucket capacity heaped – 3.4 cu.m; level – 2.7 cu.m). Four fields of 5.0, 8.6, 7.9 and 6.3 ha respectively, i.e. totalling 27.8 ha, were treated. The greatest difference in height in these fields was 0.41, 0.29, 0.26 and 0.28 m respectively. After the levelling-survey in a network of 20 m squares, the amount of soil requiring shifting on these fields was calculated at 284, 164, 220 and 171 cu.m/ha respectively.
The future level was assumed to be so much less than the mean height that 30% more cutting was needed than filling (Caterpillar data as the empirical value for clay). The experiments did show that this percentage was still scarcely sufficient for compact soil not freshly ploughed. For calculating the number of buckets, a volume increase of 40% was observed for the clay to be cut off into the bucket.
It was concluded that this implement was quite suitable for the levelling intended (up to 5 cm accuracy). The following points were of importance in this connection:
— The survey for the levelling work was best carried out on a compact field, for instance, in the maturing crop, or in the rice stubble after the harvest.
— The most efficient cutting work was done at a cutting thickness of 6 cm. The average bucket load for stiffened soil was 2.4 cu.m.
— The average cost (including surveying Sf 2.30/ha and excluding supervision) was calculated at Sf 61/ha, with an average amount of earth moved of 204 cu.m/ha (i.e. Sf 0.30/cu.m), with an average of 8.4 working hours/ha, and an average transport distance of about 260 m.

6. Trend of rice yields with regard to reclamation

Table 24 shows the mean paddy yields for the main seasons, split up according to years for areas reclaimed in successive years, and according to the type of the original vegetation. Many factors played a part in the trend of yields shown in the Table, one factor frequently balancing another. Nevertheless, some general influences can be seen quite plainly in the yield data. As far as the reclamation is concerned, these are the influences of the type of original vegetation, the "maturing" of the soil, and pests and diseases which are partly promoted by the condition of the reclamation. In this connection it should be remembered that the differences in production, caused by these influences, were partly removed in that efforts were always made to correct yield-depressing factors by such appropriate cultivation measures as: choice of varieties, type of tillage, fertilizing, control of weeds, insects and pests, etc.

As regards the original vegetation, the figures in Table 24 show that the

first rice crop on newly reclaimed grass swamp lands regularly gave (in 1955, 1956 and 1957) higher yields than on the forest lands.
There were two reasons for this:
— on the forest lands the tillage was usually inferior as a result of remains of timber and the damage done to the land by the bulldozers;
— the rice crop on forest land usually grew too luxuriantly.
In the subsequent rice crops there is no longer any regular difference in productivity between the vegetation types. The grass swamp areas reclaimed in 1954–55 and 1955–56 have even fallen below the level of production of the forest lands.

The "maturing" of the soil is a somewhat vague causative factor. It was found that, up to a certain point, the growth of the rice crop on new lands was influenced by the degree to which the soil had been previously aerated or dried out. In 1954 and 1955 the newly-reclaimed land was not well aerated owing to the wet weather, so that the crop developed quite normally.
In 1956 aeration increased, as in 1957, and was accompanied by too rank development of the crop. In our opinion this partly explains the higher yields of 1954 and 1955 over those of 1956 and 1957. In 1958 average production recovered owing to the gradual disappearance of the excessive supply of N in the soil.

Cultivation measures for controlling the rank growth have been applied since 1956. They have certainly had some favourable effects, and without them production presumably would have been lower. No method however gave a complete solution of the problem involved. Briefly, the applied measures were:
— deep tillage in order to remove the richly nitrogenous pegasse at least partly out of the range of the rice roots;
— sowing meagre-growing rice varieties on the rank fields;
— reducing the sowing rate; owing to the extensive tillering on the very fertile soil, the optimum yield was obtained at somewhat lower seed rates;
— low levels of water in the fields during the growth of the rice crop with longer drained periods.

Together with the rank growth, the occurrence of pests and diseases were the main reasons for the reductions in yield. The highest mean production was obtained in 1955, but this was not due to the quality of the reclamation which had been exceptionally bad as a result of the wet weather. Still less was it due to the quality of the tillage, as more than half the area could not be ploughed because of the soft condition of the fields.
Moreover, the plant spacing of the crop was poorer and the weed development more extensive than in other years. Despite all these unfavourable circumstances the yields in 1955 were good. The true reason for this contradiction was the healthy growth and maturation of the rice crop that year. In every other year this was not the case.
Especially in 1956 and 1957 the crop developed too luxuriantly, partly as a

TABLE 24 *The mean trend of yields of the main-crop rice on areas reclaimed in successive years, split up according to the original vegetation type*
In 100 kg paddy/ha–14% m.c.

PRODUCTION YEARS		RECLAMATION YEARS									
		to May 1954		June 1954 to May 1955		June 1955 to May 1956		June 1956 to May 1957		total mean	
		prod.	area in ha	prod.	area in ha	prod.	area in ha	prod.	area in ha	prod.	area in ha
1954	forest	27.2	451							27.2	451
	half forest . . .	—	—								
	grass swamp . .	—	—								
1955	forest	33.4	462	26.6	809						
	half forest . . .	—	—	33.0	203						
	grass swamp . .	—	—	30.2	468						
	total year . . .	33.4	462	28.6	1480					29.7	1942
1956	forest	24.1	458	24.2	877	25.1	198				
	half forest . . .	—	—	28.9	201	25.7	967				
	grass swamp . .	—	—	26.9	491	28.0	787				
	total year . . .	24.1	458	25.6	1569	26.6	1952			25.9	3979
1957	forest	23.1	455	25.0	886	26.6	212	23.5	718		
	half forest . . .	—	—	18.7	213	26.1	1023	24.9	114		
	grass swamp . .	—	—	20.7	498	24.2	801	30.0	900		
	total year . . .	23.1	455	22.8	1597	25.4	2036	27.0	1731	25.0	5819
1958	forest	25.0	463	27.8	889	26.1	221	30.9	751		
	half forest . . .	—	—	20.9	212	26.7	1026	26.6	118		
	grass swamp . .	—	—	24.6	495	24.3	804	31.8	930		
	total year . . .	25.0	463	25.9	1596	25.7	2051	31.1	1799	27.3	5909

TABLE 25 *The mean trend of yields of the second crops of rice on areas reclaimed in successive years, split up according to the original vegetation type*
In 100 kg paddy/ha–14% m.c.

PRODUCTION YEARS		RECLAMATION YEARS 1954 prod.	1954 area in ha	1955 prod.	1955 area in ha	1956 prod.	1956 area in ha	1957 prod.	1957 area in ha	total mean prod.	total mean area in ha
1954/55	forest	13.6	378								
	half forest . . .	16.1	22							14.1	517
	grass swamp . .	15.2	117								
1955/56	forest	19.9	71	—	—						
	half forest . . .	—	—	22.2	23					25.7	236
	grass swamp . .	20.2	12	30.1	130						
1956/57	forest	9.2	152	5.9	82	10.6	45				
	half forest . . .	—	—	14.3	139	10.7	166			15.6	1039
	grass swamp . .	21.4	12	19.9	119	22.9	324				
1957/58	forest	25.3	208	28.2	130	28.2	82	—	—		
	half forest . . .	23.8	24	27.8	47	21.0	348	26.5	12	26.6	1485
	grass swamp . .	28.3	36	25.9	144	32.0	217	30.1	236		
1958/59	forest	22.8	182	26.4	82	28.8	23	26.4	258		
	half forest . . .	—	—	—	—	19.6	197	23.9	24	26.0	1418
	grass swamp . .	—	—	28.5	178	23.0	190	32.5	285		

result of which there was a serious outbreak of fungus diseases and also many pests occurred. In 1958 also, production was depressed by the occurrence of fungus infections.

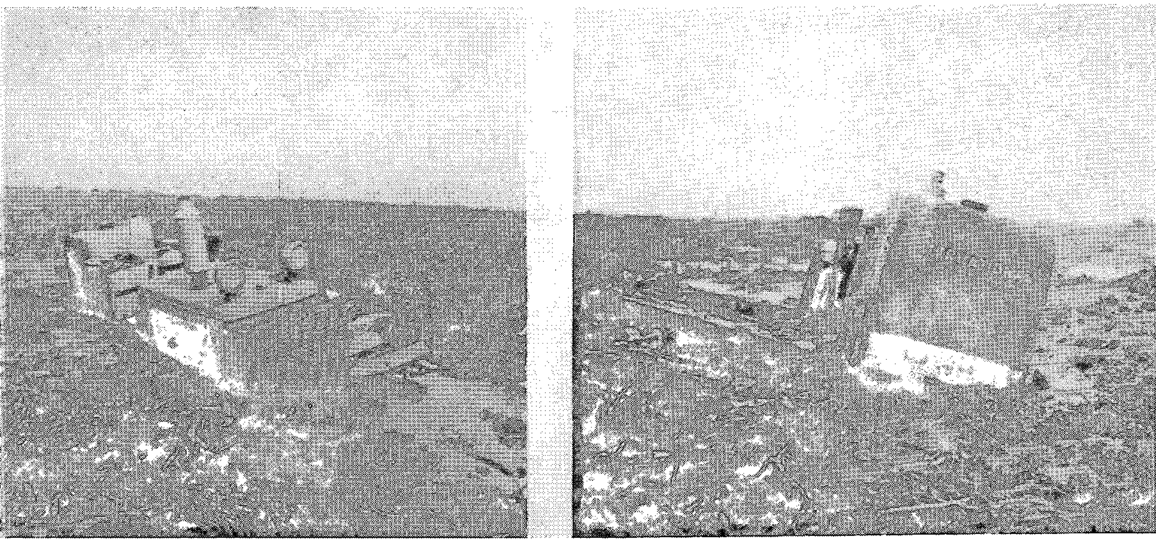
Although rank growth has a special connection with the reclamation, we do not believe that this problem can be entirely solved by adapting the method of reclamation (e.g. by burning or bulldozing the pegasse) or of tillage. However, it is a temporary phenomenon and the various measures discussed, both during reclamation and cultivation already considerably reduce the deleterious effect of the rank growth in the new lands, so that it may be said that the lower yields still occurring during the first few years simply have to be accepted.

Table 25 shows the trend of yields from the second crops according to year of reclamation and original vegetation type. For the years covered, the Table reveals a substantially higher yield level for the grass swamp lands. The differences are particularly impressive in the 1956–57 season. In this case, however, the main reason for the lower yields of the forest lands was the greater incidence of rat damage.
Insofar as larger rat populations are to be regarded as inherent to forest reclamation, this may be reckoned a disadvantage of forest land as compared with grass swamp.

7. Reclamation costs

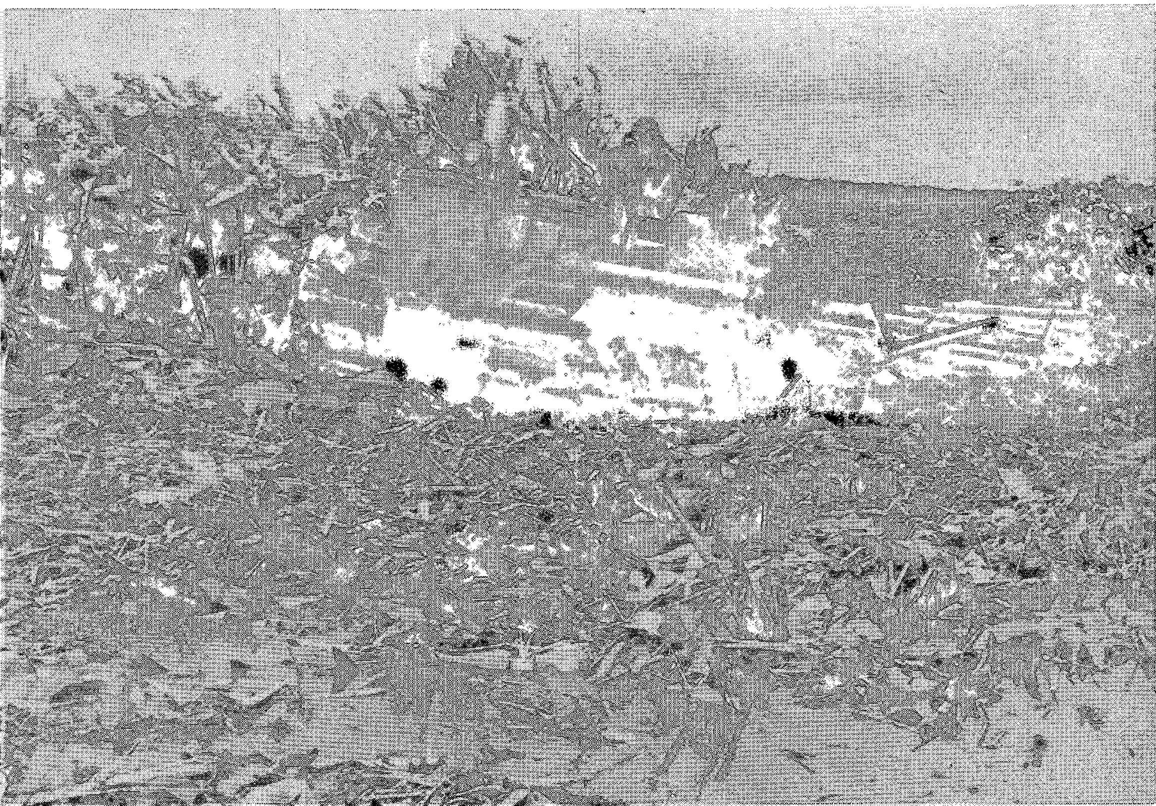
Owing to the considerable variety of methods employed during reclamation, and also because of the widely divergent costs of reclaiming otherwise similar lands as a result of weather conditions, there is little value in giving a detailed specification of the reclamation costs. The same is true of the operating hours required with bulldozers etc., since different equipment was used together. Furthermore, with favourable dry weather the number of operating hours required, frequently fell to a fraction of what was needed under fairly wet conditions.
Table 26 shows the mean costs of poisoning the forest, ditching, and clearing away the vegetation for three types of land: with 50–100 % forest, 20–50 % forest, and 0–20 % forest. The figures afford a criterion of the great investment advantage obtained by reclaiming grass swamp rather than forest lands.

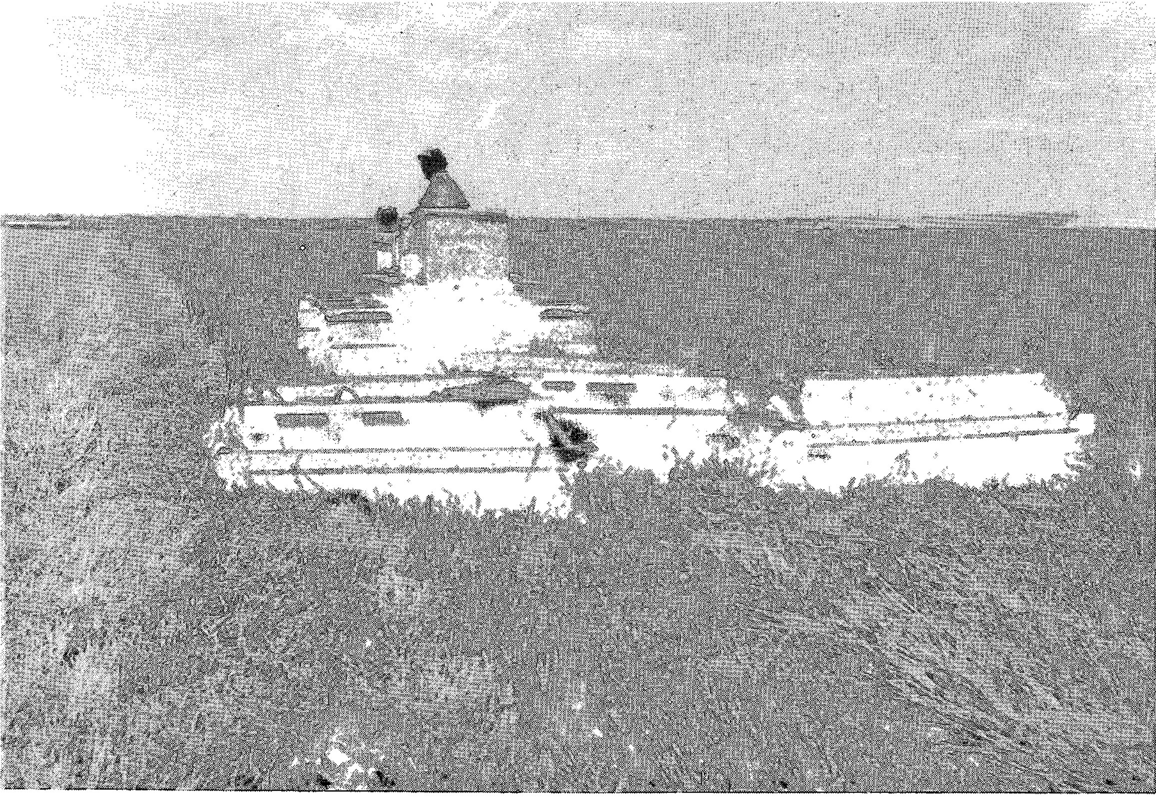
Poisoning was done entirely by hand, so that, with the exception of 5–15 % for chemicals, the costs chiefly consisted of the wages paid. Owing to the nature of this poisoning work, it is obvious that the costs closely follow the pattern of vegetation.
Ditching was almost exclusively manual labour. Draglines and bulldozers were partly used for removing vegetation and pegasse from the survey lines. The influence of the type of vegetation on the costs was limited to the costs of clearing the survey lines.
Clearing the vegetation consisted of flattening and brushcutting the poisoned



20. *Crawler bogged down during tillage (front and back view).*

21. *Preparing seedbed of virgin land by puddling only (with International stalk cutter).*





22. *Flattening of rice-stubble with Marden weedcutter.*

23. *International 5 disk-plough.*

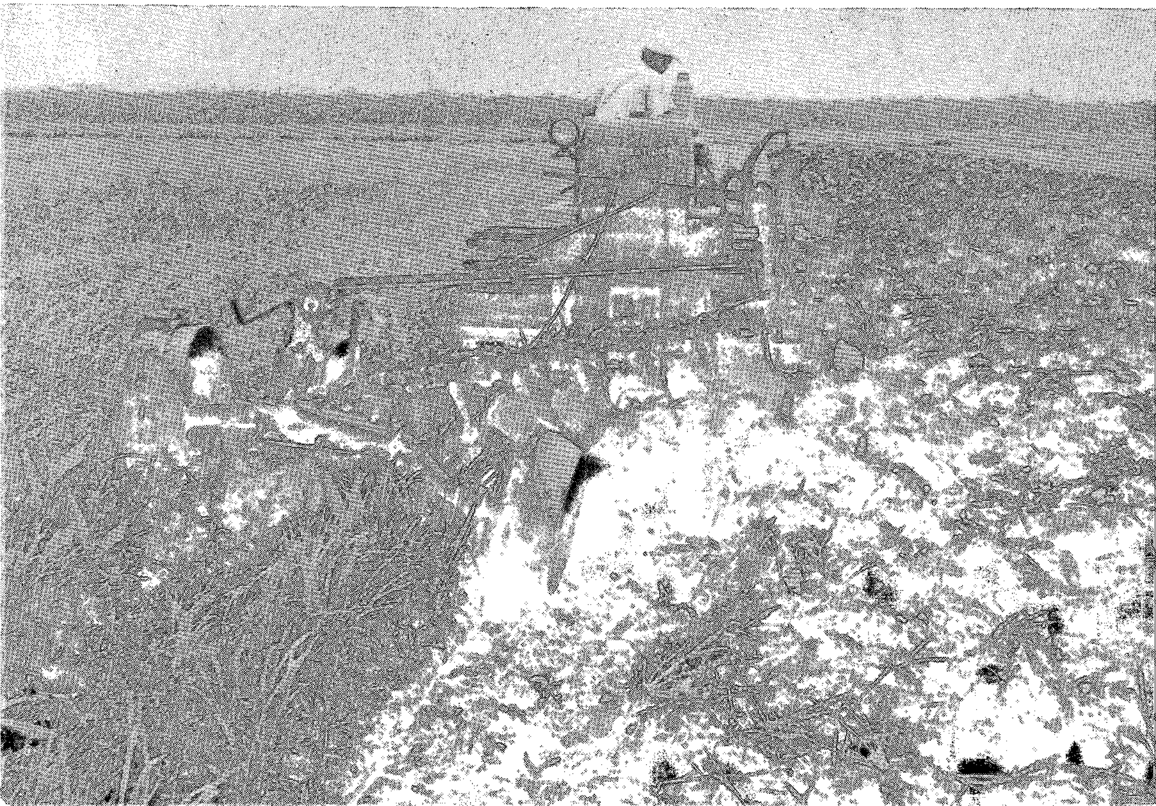


TABLE 26 *Comparison of reclamation and ditching[1] costs, excluding interest and overheads, per plot of approx. 80 ha gross and approx. 72 ha nett, for forest and grass swamp lands*
(Based on cost accounts for an area of c. 5000 ha by G. GAASTRA)

Type of costs	forest (50–100%)	half forest (20–50%)	grass swamp (0–20%)
	c. 40% of the area	c. 20% of the area	c. 40% of the area
poisoning	Sf 4300	Sf 2300	Sf 300
ditching	„ 13400	„ 12900	„ 11300
clearing vegetation	„ 9300	„ 7100	„ 3300
total	Sf 27000	Sf 22300	Sf 14900

forest, felling or bulldozing scattered living trees, brushcutting the grass swamp vegetation, burning, pushing the timber and sometimes the pegasse into heaps, removing the stacks of timber and making good some of the unevennesses in the ground resulting from these mechanized operations. Hence this group of costs mainly consists of machinery costs. The amounts given in Table 26 for "clearing vegetation" follow the original degree of forest cover less closely than is the case with "poisoning". This is acceptable, because in the grass swamp without trees some work had to be done in any case for flattening the herbaceous vegetation and spreading out the pegasse from the ditch survey lines, and because of the relatively lower timber clearing capacity of bulldozers etc. when few trees are scattered over the terrain, added to the fact that such trees were frequently not poisoned.

[1] In the general division of this study ditching is not dealt with under reclamation, although it was classified under this heading from the organization point of view.

CHAPTER IX

CONSTRUCTION COSTS

The estimate of costs on which the Dutch Government based its decision in 1949 to construct a 5,000 ha polder, totalled Nf 16,500,000 (see the report of the STAF Commission, 1948).
Finally, however, Nf 64,000,000 was invested in the project. A specification of the investment costs is given in Table 27. The main reason why the scheme cost so much more is that actually a quite different and more costly project was carried out than had been envisaged originally.
As a result there was no estimate for a number of subdivisions of the investment, or else most of the estimates were too low.

TABLE 27 *Investments in the Wageningen scheme up to 1st January 1958* in Sf 1,000

Rice processing plant	Sf 3,477.5
Pumping station	„ 1,579.4
Farm houses, sheds	„ 1,617.5
Agricultural machinery	„ 2,364.0
Transport unit	„ 409.7
Warehouse, workshop, field service, civil technical service	„ 549.7
Power station and grid	„ 1,248.7
Watermain and telephone	„ 151.8
Medical service, education, provision of meat, milk and vegetables, police, fire brigade	„ 159.4
Village housing	„ 1,434.3
Canteens and lodgings	„ 218.5
Administration buildings and fittings	„ 414.3
Costs of constructing the polder (incl. Sf 284.1 for equipment not written off)	„ 8,313.4
Overheads and initial costs	„ 2,718.6
Financing costs	„ 5,163.2
Agricultural research	„ 681.6
Liquid resources	„ 1,599.7
Total	Sf 32,101.3 (Nf 64,202.6)

In explanation of the trend of investments compared to estimates, the following should be mentioned (according to a report by L. G. WITTE and J. JONGERLING, 1959):

1. The basic estimate was made on the basis of 1 Surinam guilder being valued at 1.40 Dutch guilders. Shortly afterwards this ratio changed to Sf 1 = Nf 2.—. This meant an increase in costs for the project which WITTE and JONGERLING assumed to be proportionate to the change in the ratio of the monetary values. The altered estimate therefore becomes Nf 23,5000,00.

2. The basic estimate was for 5,000 ha, but 6,000 ha were constructed, i.e. 20% more = Nf 28,000,000.

3. There were considerable increases in prices during the period of the project, for which a correction of 10% appears acceptable, i.e. Nf 31,000,000

4. Important investments were made for subdivisions of the project which were not included in the basic estimate as it was thought that they would be financed separately. These investments are:

The rice processing plant	Nf 7,000,000	
A large part of the village housing	„ 2,100,000	
The agricultural research	„ 1,400,000	
		„ 10,500,000

For reasons not known other large investments were not estimated. These are mainly:

Buildings and fittings for the administration .	Nf 800,000	
Financing costs (interest, commission, etc.) .	„ 10,300,000	
Liquid resources	„ 3,200,000	
		„ 14,300,000

5. Several investment-items were estimated too low. Some of them (particularly the power station) to such an extent that they could have been equally well included in the non-estimated investments in point 4.

After correction for points 1, 2 and 3 the following higher cost amounts of items are found:

Pumping station	Nf 2,150,000	
Power station and grid	„ 2,300,000	
Construction and reclamation	„ 2,550,000	
Overheads and initial costs	„ 4,100,000	
Sundries	„ 1,400,000	
	Nf 12,500,000	
One item was estimated too low. Also after correction for points 1, 2 and 3 this amounts to:		
Farm buildings and agricultural machinery. .	„ 4,400,000	
Remaining		„ 8,100,000

So that this approximate explanation closes on a final amount of . . . . Nf 64,000,000

From the total investment of Nf 64 million, an estimate can be made of the amount allocated to the agricultural section of the project in the narrower sense.

To this belong the following items from Table 27: pumping station, farm houses and sheds, farm machinery, costs of constructing the polder, agricultural investigations and about 2/3 of overheads and initial costs, financing costs, and liquid resources. Rounding off, the total agricultural investment is found to be Nf 40 million.

PART II

OPERATION OF THE PROJECT

METHODS OF MECHANIZED RICE FARMING

CHAPTER X

THE PLAN OF CULTIVATION

Introduction

In the discussion of the choice of crops (p. 53) it was explained that a rotation of rice with other crops has not hitherto been found possible under the prevailing conditions. We shall confine ourselves in the description of the plan of cultivation to the present state of affairs, viz. a monoculture of rice. This plan of cultivation has three main aspects:

1. the timing of tillage, sowing and harvesting (choice depending on weather conditions and organization of farm operations);
2. the crop rotation (the annual number of rice crops);
3. the methods of fallowing (type of water control and tillage during the fallow period; possible application of green manures).

These three aspects are interrelated, so that they can only be discussed separately to a limited extent.

1. The main factor determining the choice of sowing and harvesting times is the character of the rainfall. In this connection the distribution of work in the field and the rice-factory also requires special attention. The greatest output from the farm machinery and the rice driers and silos is obtained when harvesting is spread over the whole year. But such a spread is made impossible by the climate and an anticipated drop in production per hectare as a result of increasing damage by pests and diseases.

2. In many areas of the world rice is grown continuously with one, two or even three crops per annum.
Also in Surinam conditions are fairly favourable for growing two rice crops per annum. This is not done to any extent in native agriculture as there is too much risk of water shortage during the short rainy season. In the Wageningen polder this hazard is eliminated by an irrigation system capable of supplying sufficient water throughout the year. When therefore it was found that the dry crops originally included in the crop rotation at Wageningen were unsatisfactory, more attention was paid to the cultivation of a second rice crop within a one-year cycle, and thus in 1957, 1958 and 1959 a second rice crop was grown on about a quarter of the area under cultivation. The rotation used was such that the same fields only had two crops per annum every four years. The problems presented by intercalating a second rice crop are numerous. They relate for instance to: choice of adapted varieties, type of tillage, influence on the main crop and rendability.

3. For three years out of four the fields on the project remained fallow for over six months a year between harvesting and new planting.
In the early years these periods were used for rounding off the reclamation work. Various experiments showed that the type of fallow (tilled, untilled, green manuring, wet fallow) influenced the yield of the subsequent rice crop.

1. The timing of sowing and harvesting

The main elements determining tillage, sowing and harvesting times are the climatological conditions, the growing properties of the rice crop, and the efficiency of operational organization.
For the maximal efficiency of operations such a degree of staggering in sowing and harvesting should be applied as is permissible for the prevailing weather conditions and for the behaviour of the rice crop as far as production-level is concerned.
In the past years on the Wageningen project the main rice crop was sown from about 1st April to 15th May and harvested from about 20th August to 5th October; the second crop on a quarter of the area was sown from about 15th October to 15th November and harvested from about 1st March to 1st April.
In conformity with this the capacity of the production-apparatus, in particular of the harvesting equipment, was based on a 6 week spread of the main harvest.

Of the climatological conditions, of which rainfall characteristics are most important for the choice of the above mentioned sowing and harvesting periods, the following aspects can be observed:
1. For the mechanical preparation of the seedbed by means of dry tillage rainfall is undesirable, so that these operations as far as possible have to be planned during the dry seasons.
2. For mechanical harvesting of the paddy dry weather is essential so that in any case the harvest should coincide with the driest periods of the year.
3. During the growth of the paddy rainfall is an advantage because then less irrigation is needed, and it is also thought that in the present project rain has a more favourable effect on the development of the paddy than the supply of an equal amount of irrigation water, as this irrigation water is often polluted and contains little oxygen.
4. The day-length, the photoperiod, may influence the duration of growth of the rice plant and subsequently the yields. The degree of influence is a varietal characteristic.
Most varieties used in mechanized cultivation (chiefly unawned types), and also the varieties grown in the Wageningen project, mature later when they develop during a period of lengthening days than during one of shortening days. In the case of the varieties grown to date at Wageningen, however, this influence on the duration of growth is very slight with the small variations in day-length in Surinam. On the other hand the rice variety chiefly grown

by the native smallholders, viz. Skrivimankoti, shows a considerable reduction in the period of growth when sown during the second half of the year, with low yields as a result.

5. A strong wind during and shortly after the sowing period may result in young seedlings being washed out by wave action.

6. Depending on a suitable choice of varieties, an increasing amount of sunshine during the growth of the paddy crop may augment yields to a certain extent.

The first two points are the most important for mechanized rice farming. They should be satisfied in the first instance, after which an attempt can be made to meet the other points as well.

It follows from the rainfall data that tillage and harvesting have the best chances of dry weather in the periods September-November and February-March. The chosen harvesting times fall in these periods. To a lesser degree also the tillage operations; for the main crop only to a limited extent as the sowing period starts at the beginning of the main rainy season, so that only prior to the actual sowing in February and March better weather conditions occur for seedbed preparation.

Tillage operations for the second crop on the other hand can wholly be carried out during the main dry season.

Earlier sowing of the main crop would usually be beneficial to tillage owing to the relative drought in February and March, but the harvest would then mostly fall in the rather rainy month of August (with the varieties in use). Another disadvantage of earlier sowing would be the greater chance of salt irrigation water, owing to the encroachment of sea water in the Nickerie river during dry seasons.

Later sowing makes it more difficult to prepare the seedbed, but it would not be disadvantageous for the harvest even be slightly beneficial.

In this connection it should be pointed out that in practice a rather early sowing is preferred as it is thought to give higher yields. It is difficult to analyse this phenomenon, because in comparative tests of sowing times undesirable disturbing factors such as greater damage by pests and diseases on late fields, insofar as these are the result of infection from the early fields, cannot be sufficiently eliminated. Moreover it is not impossible that photoperiodism is a factor in this connection.

The main season-sowing periods which were selected for the project are also favourable for points 3, 4 and 5.

For more sunshine a later sowing may be beneficial in principle, but so long as late sowing continues to give low yields owing to other influences, and considering the disadvantages for tillage and the higher irrigation water requirements, there is no point in shifting the growing period of the main crops on this account.

Concerning the properties of the rice-crop in connection with the plan of cultivation, the following aspects can be distinguished:

— Times of sowing may be limited by unfavourable crop reactions in production levels, owing to photoperiodism, weather conditions or necessity of soil recuperation.
— The growing period of the selected rice varieties restricts the flexibility of the plan of cultivation. It should of course be adapted, as far as possible, to the most favourable plan.
— Crop-free periods may be necessary to prevent an increase in pests and diseases.

With the experience gained until now, there is no indication that photoperiodism or seasonal weather conditions have any significant unfavourable effect on crop production. Comparisons of second and main crop yields are given on page 132 and an analysis of spread of sowing times and yields is attempted on page 161.
The factor soil recuperation appears more significant, especially in double-cropping as will be discussed on page 132.
Right after the harvest the land should be given an opportunity to dry up, before resowing it, for two reasons: to be able to give it a good dry tillage and to aerate the soil which is assumed to improve growing conditions. Should this opinion be correct, then it consequently limits the most proper length of the growing periods of the two rice crops per annum and thus also the rice variety assortment to be used.

The lengths of the growing periods of rice varieties are obviously an important element in the plan of cultivation.
Table 28 shows the average period of growth (at least the period from sowing to harvesting) of the varieties for the main season and the second crop season. In this connection it should be noted that up to 1957 inclusive, the period of growth was extra long owing to rank growth and delays in harvesting. Apart from this the growing period in the main season may be estimated to be 143–145 days for Dima and 80/5, and 140–142 days for Nickerie. In the second crop season this period, especially that of 80/5 and Dima, is shorter, however by a few days only, probably owing to photoperiodism.
Table 29 shows the influence of the spread of sowing on the growing period during the main season. The small differences found seem of no significance to the plan of cultivation.
It may now be asked, whether a particular adaptation of the stock of varieties should be aimed at in order to obtain a better plan of cultivation.
The rice varieties in use all have an approximately equal growing period of 140–150 days. Moreover, the differences in the grain type are so small that mixing is not objectionable from the point of view of processing and marketing. A drawback of using varieties having widely divergent growing periods, is also that these varieties cannot be cultivated in rapid succession on the same field as is the case with double-cropping, the reason being that growth of volunteer plants from seed left behind in harvesting would often result in a mixed crop.

TABLE 28 *Mean periods (in days) from sowing to harvesting of rice varieties for main and second crop seasons*
Figures in brackets indicate the number of fields from which the average was determined

Main season (long day)	1954	1955	1956	1957	1958
Rexoro	145 (32)	—	—	—	—
Paradise	—	—	160 (33)	—	—
Dima	—	147 (161)	158 (302)	148 (201)	144 (169)
Nickerie	—	—	153 (11)	145 (128)	140 (103)
80/5	—	—	—	149 (119)	145 (187)
80/7	—	—	—	145 (18)	147 (51)
Second crop (short day)	**1954–55**	**1955–56**	**1956–57**	**1957–58**	**1958–59**
Paradise	—	146 (6)	—	—	—
Dima	143 (35)	141 (6)	143 (39)	139 (32)	—
Nickerie	—	138 (6)	146 (10)	139 (51)	—
80/5	—	—	143 (14)	142 (27)	—
80/7	—	—	—	—	—

On the project experience on this matter was gained in 1954–55, with succession on the same fields of Bluebonnet (120 days) and Rexoro (135 days) and also with Rexoro and Dima (145 days). In practically every case the production losses caused by mixed crops were considerable.
Of course the mixing could be reduced by adaptation of tillage methods, when the advantages of the use of varieties with divergent growing period would motivate this.
In our opinion this is not the case, also because the length of the growing period of the varieties now in use appears to fit quite well into the situation.
If it is then assumed that a uniform growing period is desirable for the entire assortment of varieties, it may still be asked whether lengthening or shortening the growing period of the group as a whole would offer advantages. Lengthening the growing period is not attractive because it would increase the difficulties of growing two rice crops per annum..
Shortening the growing period is undesirable for the main crop season owing to the length of the main rainy season (4½ months). For the second crop though, shortening the growing period by a few weeks, would cause the harvest to fall partly in February, resulting in a better spread of work.

It appears to us that in this last aspect, viz. shortening the growing period of the second crop, there are possibilities of improving the stock of varieties, since this could be done by finding rice varieties with such a sensitivity to photoperiod that they mature, say, two weeks earlier in the second crop.

The desirability of maximal crop-free periods, for the control of pests and diseases between main and second crop and vice versa, is a controversial problem.
On the Wageningen project it has often been emphasized that the occurrence

TABLE 29 *Mean periods (in days) from sowing to harvesting of rice varieties in the main seasons, split up according to sowing weeks*
Figures in brackets indicate the number of fields from which the average was determined

Sowing weeks	1955	1956	1957	1958
	DIMA			
1/4–7/4	148 (5)	156 (37)	148 (65)	—
8/4–14/4	146 (25)	159 (44)	148 (84)	—
15/4–21/4	146 (25)	160 (31)	147 (47)	—
22/4–28/4	146 (28)	158 (50)	—	146 (30)
29/4–5/5	147 (21)	156 (48)	—	144 (70)
6/5–12/5	147 (19)	154 (30)	—	143 (66)
13/5–19/5	144 (25)	160 (25)	—	—
	NICKERIE			
1/4–7/4	—	—	—	—
8/4–14/4	—	—	149 (12)	—
15/4–21/4	—	—	146 (38)	140 (32)
22/4–28/4	—	—	144 (48)	141 (54)
29/4–5/5	—	—	144 (15)	141 (11)
6/5–12/5	—	—	—	—
13/5–19/5	—	—	—	—
	80/5			
1/4–7/4	—	—	—	144 (68)
8/4–14/4	—	—	—	147 (85)
15/4–21/4	—	—	—	146 (12)
22/4–28/4	—	—	146 (18)	—
29/4–5/5	—	—	150 (43)	—
6/5–12/5	—	—	148 (47)	—
13/5–19/5	—	—	—	—

of pests and diseases on the project could be substantially reduced by omitting the second crop system or by at least applying longer crop-free periods. There is no experimental proof of this conception being true however neither of it being false.

In the plan of cultivation hitherto employed at Wageningen, only about 10 days are left, viz. from 5th to 15th October, as a period with no standing crop at all in the whole polder area. Of course the crop-free period of each field is on average much longer, even when only the double-cropped area is considered.

In practice little attention was paid to the strict maintenance of crop-free periods. Usually complete overlap occurred by several fields as a result of chance factors, such as overtime harvesting, etc. The principle did not appear very important with the comparatively small margins which the given plan of cultivation allows.

The requirements for an efficient organization of the operations form the third principal element for the choice of the plan of cultivation.
Maximum use of the harvesting equipment, by which are meant the combine harvesters, waggons and ships for harvest transport, and the rice-factory units used for unloading, cleaning and drying, and of storage capacity for harvested paddy, would only be made with continuous sowing and harvesting all year long, postulated, this being taken into account when equipment etc. was acquired.
It is understandable that this system cannot be applied. The staggering of sowing and of harvesting in use on the project is about 6 weeks for the main crop and 4 weeks for the second crop. This system is based on a compromise between farm managerial and agricultural requirements. The capacity of the harvesting equipment, as has already been mentioned above, is also based on a minimum spread of the main crop of six weeks. This capacity is for cleaning and drying 500–600 tons of paddy per day (24 hours).
By introducing a greater spread, the working capacity of each harvesting unit will be increased; this is also true for the silo capacity, as in that case the turnover via the rice-mill will be greater so that silo-space can be used more intensively. If the main crop spread of 6 weeks could be lengthened the extension could best be distributed over both earlier and later sowing, on account of weather conditions, and if it should be shortened (for better rice crops) the starting date need not be changed, so then sowing would end earlier in May.
The intercalation itself of second crop rice has evidently a similar favourable effect on the efficiency of the production-apparatus as the spread of sowing within the cropping seasons. Besides, the silo is at the time of the second crop usually practically empty, so that as regards the use of storage space this second cropping is more advantageous than the foregoing spread within seasons. But it also makes the pattern of operations more complex, as next to weather also the distribution of needed labour and operating equipment have to be taken into account. When sowing is made to coincide with harvesting of either of the two crops the result is a peak in labour requirement. Overloading of machinery and personnel then may lead to a reduction in the quality of the work and higher costs. The net gain in the capacity of the production apparatus, as a result of which the cost price of the rice product may be substantially lowered, is one of the main advantages of the second crop. It can even be imagined that, in case of enlargement of area under cultivation, this advantage becomes so great that it may even be profitable in that case to sow the equivalent of the new area in the second crop season and to fallow it in the main crop season. This is one reason why the pros and cons for the rice crop in both seasons will be systematically evaluated below.

2. Weather conditions and harvesting

According to the plan of cultivation described the main harvest occurs from about mid-August to mid-October and the intermediate harvest in March.

Both harvesting periods are selected in the first place on account of low rainfall occurrence. Rains during the harvest are disadvantageous, due to:
— wet land which is difficult to drive on with combines;
— loss of time in harvesting;
— greater chance of lodging.

In this connection the following weather characteristics are important:
1. the amount of rain (see Table 30);
2. the frequency of the showers. Table 30 shows the average number of dry periods and the chances of precipitation per month for the Nw.-Nickerie station;
3. the duration of the showers; no data are available on this;
4. the diurnal pattern of the showers; regarding this the Paramaribo station was the only one, on which we had some data (Table 31);
5. the evaporation; evaporation from an open water surface in Nickerie was estimated in 1959 by the NED. HEIDE MIJ. at 6 mm/day for the period February-March-April, and at 5 mm for the period August-September-October.

Comparing the second crop-harvest month of March with the chief main-harvest month of September, it can be observed that in March the occurrence of dry periods is lower and that the mean precipitation as well as the chance of injurious heavy precipitation are considerably higher.
It would then follow that the second crop would suffer more on account of the difficulty of combine driving on wet ground. But this is not the case; the greater wetness is, in fact, fully compensated in that the second crop usually gets a better dry tillage (in the main dry season) than the main crop and thus has firmer fields.
Secondly it may be expected that in the March harvest a greater loss of time will occur as a result of rains. This is true to a certain extent. The loss of time is less serious however, than the monthly precipitation figures in Table 30 would suggest, the reason being a more favourable diurnal rainfall pattern in March than in September. Night rainfall, which according to Table 31 comprises on average about 35% of the total rainfall in March, against only 5% in September, causes practically no loss of harvesting time. Even if it does not rain there usually is a heavy dew at night which wets the crop almost as much as a shower of rain, so that the combines can about never start working before 9 a.m. The afternoon rainfall (10% in March and 54% in September) causes the greatest loss of time because the subsequent sunshine is then often no longer strong enough to dry the crop, while if it keeps dry in the afternoon the combines can work on in the dark until 8–9 p.m., before the dew makes the crop too wet again.
The third disadvantageous effect of harvesting in March compared with September, would be more lodging of the crop because of rains. In considering this problem the effect of precipitation of the preceding months February and August, respectively, should also be included.
The latter months do not appear to differ very much; February probably is

TABLE 30 *Mean number of dry periods per month (over period 1923–'52) and chances of precipitation per month (calculated over period 1907–'52) at the Nw.-Nickerie station*
(KRAS, 1953)

Months	Dry periods (number)		Precipitation (mm)		
	of one day	of five days	means from table 7	with probability of excess	
				25%	10%
January	14	0.5	195	260	350
February	16	0.8	109	170	240
March	19	1.3	112	160	240
April	16	0.9	172	210	350
May	10	0.3	249	300	380
June	7	0.0	318	370	450
July	9	0.1	265	310	410
August	17	0.8	149	200	250
September	23	2.2	59	80	120
October	25	2.5	56	50	130
November	22	1.9	77	110	160
December	14	0.5	173	220	280

TABLE 31 *Mean diurnal pattern of the rainfall at Paramaribo (over period 1922–1933) for the main harvest months September and March* (BRAAK, 1935)
Expressed in % of the rainfall per 24 hours

Hours	September	March
9 p.m.–7 a.m.	5%	35%
7 a.m.–12 noon	2%	34%
12 noon–3 p.m.	39%	21%
3–9 p.m.	54%	10%

slightly more favourable. Another point which may reduce lodging of the second crop is that this crop often grows somewhat shorter than the main crop and is thus less prone to lodging. If lodging in the second season indeed proves to be more serious, correction could take place by lowering N-fertilizing, but this would of course also lower production.

It can be concluded that from a point of view of harvesting both cropping seasons are acceptable, the best one being the main season.

3. The timing of tillage operations

Both normal "dry" tillage and "wet" tillage are employed in rice growing. Wet tillage or puddling also occupies a very important place in the Wageningen project and various satisfactory methods were developed. The reason, why it is essential to use wet tillage, is that the tillage operations become less dependent on rainfall. Moreover, the heavy stiff soil can be prepared more quickly by puddling.

It has been found, however, that puddling cannot entirely replace dry tillage. The production figures from both practice and trial-fields have shown that it is desirable for the soil to be ploughed in the dry state before each crop, or at least that a treatment should be applied in which the soil is turned in a similar way. In Table 32 we have assembled the yields of the areas sown during the main seasons, split up according to the type of tillage. The figures relate to the whole area, so that no exceptions were made for special conditions. During these years it did, in fact, happen that fairly large areas could not be ploughed owing to heavy rainfall, soft condition of the fields, and lack of time, and could only be prepared for planting by means of puddling. Moreover, we have divided up the ploughing (in Table 32) into ploughing with the single-furrow Solotrac and other methods of ploughing, principally with the N° 98 International disk plough. The figures in Table 32 show that on the fields that were not ploughed and only puddled, the yields in all three seasons were lower than on the ploughed fields. The results of tillage trial fields (Table 33) point in the same direction. It should be noted that the increased yields of the ploughed fields may conceal some favourable effect simply on account of the ground having better dried out (i.e. independently of any treatment applied), as inevitably only fairly dry fields could be ploughed.

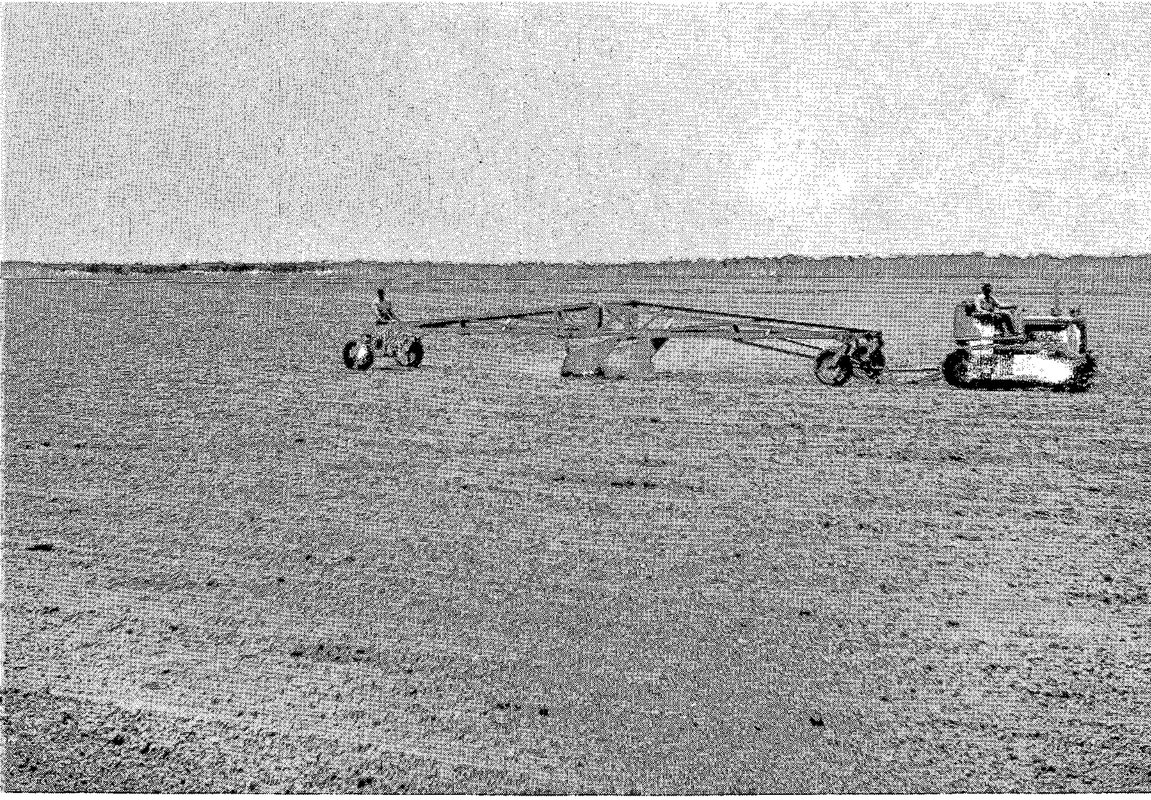
Apart from the ploughing, a dry field condition is also necessary for levelling with landplanes. We do not know of any wet treatments having the same effect.

Once the land has been ploughed and possibly levelled then the seedbed may be prepared under wet or dry conditions. In case of much rain treatment in the wet is the obvious course. At Wageningen puddlling is even preferred as the last treatment for seedbed preparation. Hence owing to these alternative possibilities tillage is only partly dependent of the weather conditions.

The above-mentioned points have, among others, the following consequences for the plan of operations:

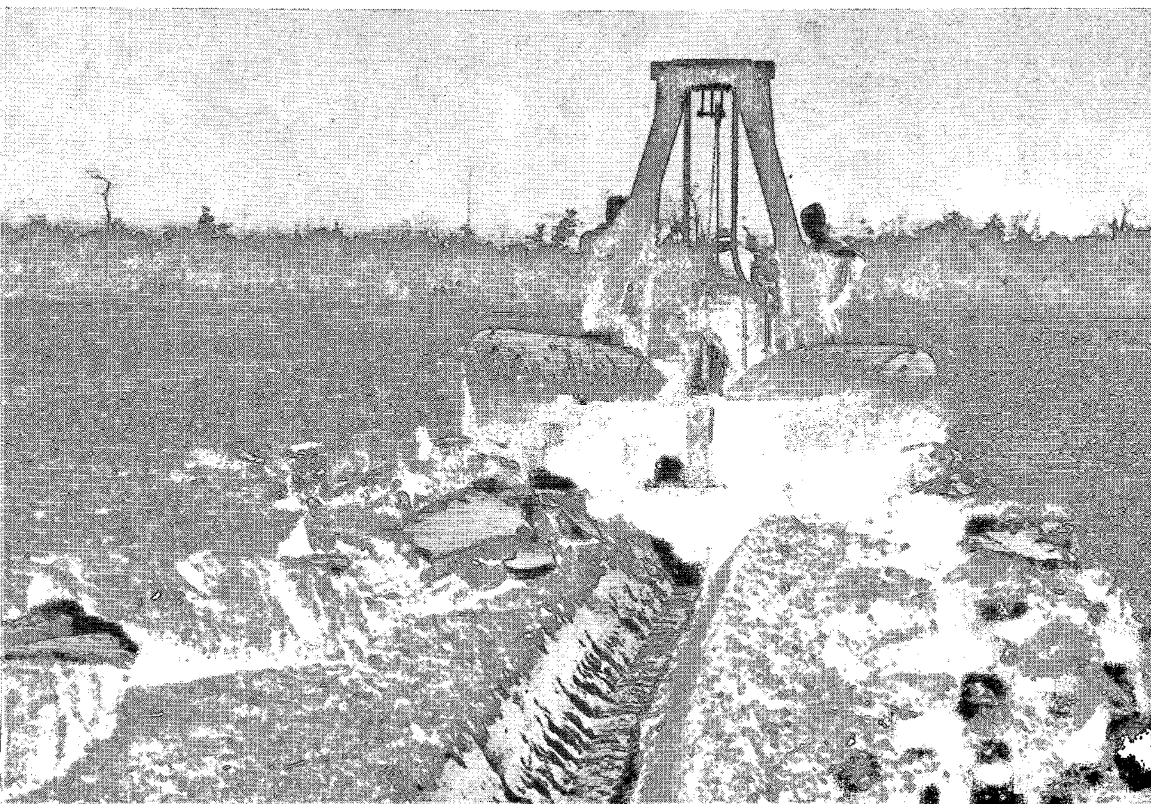
1. in the sowing and harvesting schedule one should bear in mind as far as possible that the tillage, especially the ploughing and the levelling, can profit by the driest seasons of the year;
2. when dry periods occur, even some months before sowing, as much ploughing as possible should be done to spread the risks and to prevent peak loads of staff and equipment;
3. in growing two rice crops a year, with the varieties now in use, the principal difficulty experienced is that fairly often the months of March and April are not dry enough for good ploughing, on fields harvested at that period.

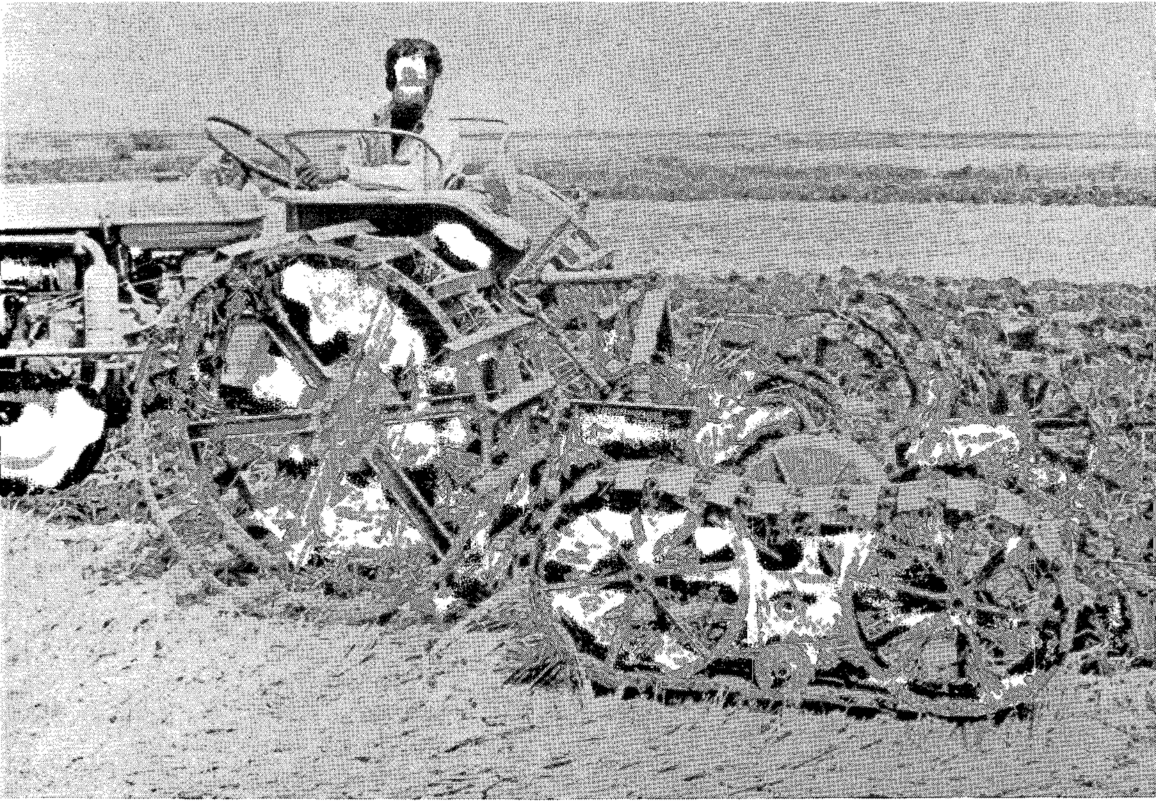
With regard to the second point it should be added that, according to the plan of cultivation described, the fields of the main crop come successively free



24. *Marden-junior landplane.*

25. *Werklust ditcher.*





26. *Experimental spade-plough.*

27. *Ransomes Baronet disk-harrow.*

TABLE 32 *The relation between the type of tillage and yield in practice*
In 100 kg paddy/ha–14% m.c.

Type of tillage	main crop 1955		main crop 1956		main crop 1957			
					after second crop		after fallow	
	yield	area (ha)	yield	area (ha)	yield	area (ha)	yield	area (ha)
Ploughed with single-furrow Solotrac . . .	34.3	284	27.7	1403	20.6	c. 300	26.6	c.2750
Ploughed by other methods	31.1	541	25.8	1814	17.9	c. 700	26.4	c.2000
Not ploughed, puddled only	28.1	1202	22.9	763	7.4	c. 50	—	—

TABLE 33 *The relation between the type of tillage and yield in trial fields*
In 100 kg paddy/ha–14% m.c.

Type of tillage	1957		1958
	virgin land	cropped land after second crop	cropped land after fallow
Ploughed with Solotrac (depth in clay)			
30 cm	19.3	. . .	33.6
20 cm	20.7	29.0	. . .
15 cm	. . .	. . .	30.0
10 cm	17.3	29.6	. . .
Not ploughed, puddled only	. . .	17.9	29.1
(99% sign. diff.).	(2.3)	(5.0)	(?)

from the end of August to the beginning of October. About a quarter of the area then has immediately to be tilled for the second rice crop. With dry weather, ploughing of the remaining three-quarters of the area can be continued in November-December for the following sowing, although the latter does not occur until April of the following year. As a result of rains these early ploughed fields may again be covered with weeds, which requires extra cultivation when the seedbed is prepared in March.

If, however, ploughing is left until February, it is possible that a part of the area can not be ploughed at all owing to rainy weather.

Table 34 summarizes the tractor working hours performed in 1954–58 in rice cultivation on the Wageningen project. There are two marked peak periods, viz. in March–April and in October–November. In February, March and April, in particular, work proceeds at full pressure owing to the simultaneous harvest of the second crop and the tillage and sowing of the main crop.

Staggering these peak periods is of importance for management of the scheme. The possibilities thereof are as follows:

— the above-mentioned autumn ploughing for the main crop in the following year;

— a greater spread of the period of sowing of both the main and second crop;

— expanding the second crop area and reducing the main crop area;

— starting to prepare the seedbeds for the main crop in January and February; these fields then can be kept conserved until the sowing period in April by flooding them, after they have been made ready for sowing.

The latter possibility known as "wet fallow", affords particularly good prospects for practical use as it has a second main effect. As certain processes take place while the soil is inundated, it becomes richer in nitrogen, probably, owing to the action of algae. In the Prins Bernhard polder it seems that this effect may be approximately equivalent to a top-dressing of about 100 kg sulphate of ammonia per hectare. The effect has been observed in an other way at Wageningen, as here it usually resulted in decreases in yield, due to over-rankness.

4. One or two rice crops per annum.

By growing a second rice crop a considerable increase in total production can be achieved. Nevertheless up to date the second crop has been limited to about 25% of the area. The following reasons can be mentioned for this:

1. Tillage and harvesting of the second crop partly overlap harvesting and tillage respectively of the main crop. This leads to a work peak, the capacity of staff and equipment having a limiting effect.
2. Growing the second crop usually causes a considerable reduction in the yield of the subsequent main crop. The determining factor in this connection is that after a second crop it is often not possible to carry out a good tillage for the following main crop.
3. On new lands the fallow periods during the first few years had to be used for completing the reclamation (clearing timber, levelling, deep ploughing). At the same time it was often not desirable, or even impossible, to grow two crops a year, as the soils were still quite soft. By giving the new soils a rest during the relatively dry fallow periods, they could become firmer, which would benefit the quality of the mechanized tillage and harvesting of the subsequent main crops.

The question naturally arises, whether growing a second crop of rice is desirable and, if so, what is the optimum area which can be sown with two rice crops a year when reclamation conditions cease to be a factor (which is now the case for the 6,000 ha polder).

This problem has an agricultural as well as an economic side. In order to determine the profitability it is first of all necessary to investigate the production possibilities afforded by growing two rice crops.

TABLE 34 *Hours worked per month and per annum for crawler and wheeled tractors on the rice farms*

Months	1954		1955		1956		1957		1958	
	crawler	wheeled	crawler	wheeled	crawler	wheeled	crawler	wheeled	crawler	wheeled
January	?	?	330	5	1180	44	3131	252	3429	572
February	?	?	1042	20	1346	45	17294	754	4887	548
March	265	?	2810	10	9088	225	17527	1581	12301	1134
April	1927	?	8270	9	16147	383	17025	2032	10218	896
May	1436	?	6380	281	7803	294	6460	1099	4776	951
June	62	8	281	10	374	36	690	469	1039	456
July	44	1	167	4	599	57	1113	691	1283	515
August	125	—	153	—	582	88	868	546	1345	658
September	243	31	1786	?	1936	277	5011	1525	5175	1646
October	1849	17	3418	60	7014	1064	13984	1525	19445	1510
November	3359	19	8787	96	10587	723	12224	1034	6693	1015
December	1171	7	1823	71	341	109	1031	250	1656	636
	10481	83	35247	566	56997	3345	96358	11758	72247	10537

In this connection we shall successively discuss, on the basis of experience gained, the following topics:
— comparison of the production trend of the second crop and the main crop;
— the yield-reducing effect of the second crop on the subsequent main crop;
— comparison of the cultivation conditions during the main crop and the second crop;
— the results of the crop rotation trial fields.

The yields of the second crop

The pattern of the second-crop yields in the different years is shown in Table 35, while the yields of the main crops are also given in the same Table for comparison.

TABLE 35 *Average yields of second crops and main crops in the years 1954–59*
In 100 kg paddy/ha–14% m.c.

Seasons	Yield	Area
Second crop		
1954–55	14.1	515 ha
1955–56	25.7	236 ha
1956–57	15.6	1039 ha
1957–58	26.6	1485 ha
1958–59	26.0	1418 ha
Main crop		
1954	27.2	451 ha
1955	29.7	1942 ha
1956	25.9	3979 ha
1957	25.0	5819 ha
1958	27.3	5909 ha

The low yields in 1954–55 and 1956–57 are not a criterion, since they were caused by conditions connected with the reclamation. If we compare the other yields with those from the main crops it is found that they are on about the same level. This means that, at least as far as yields go, in the plan of operations priority should not be unreservedly given to the main crop.

The yield-reducing effect of the second crop on the main crop

The yield-reducing effect of the second crop on the yield of the subsequent main crop, is shown by the summary, given in Table 36, for the relevant areas for the period from 1955 to 1958 inclusive.

We attribute this reduction in yield to:
1. the lower quality of the tillage caused by lack of time, and soft soil;
2. poor emergence and weed development because of difficulties with sowing in water;
3. the development of unfavourable soil conditions for rice growing;

TABLE 36 *Paddy yields of the main crops in 1955–58 after a second crop of paddy and after fallow*
In 100 kg/ha–14% m.c.

	1955	1956	1957	1958
After second crop	26.0 (518 ha)	23.4 (247 ha)	18.8 (1088 ha)	22.9 (1483 ha)
After fallow . . .	31.1 (1424 ha)	26.1 (3732 ha)	26.4 (4731 ha)	28.8 (4425 ha)

4. more pests and diseases due to the change-over from one crop to another and late sowing.

The influence of these factors varies from year to year, partly as a result of weather conditions. With favourable dry periods the quality of the tillage on fields which have borne a second crop may be as good as on the fallow area, and a fair crop can be expected. But as soon as the fields remain too wet and cannot be ploughed, there usually is a considerable reduction in yield.
In this connection some improvement is expected of the spade ploughs now being tested as these can also work under very wet field conditions (see p. 146).
Even when the quality of the tillage was good and no particular diseases or pests were in evidence, it was still noticed that growth was often less favourable on fields which had had a second crop. The exact reason for this phenomenon is uncertain. We assume that the soil needs periods of rest or drying out, e.g. for aeration and for release of plant nutrients.
It may be supposed that more pests and diseases can occur on second-crop fields as a result of infection from the preceding crop. On such fields non-disinfected dropseed develops, as a result of which more fungus diseases can occur. Moreover, infection is possible from the remains of the old rice crop and more trouble may be given by water snails and rats, which have been able to develop in the preceding crop.
The usual late sowing of main crop fields after a second crop, is primarily due to the fact that these fields are only available for tillage late in the year and are not always immediately dry enough to be ploughed. Actually this is a result of the second crop, but as these fields are still planted in the specific sowing schedule, other fields would be subject to the same disadvantageous effect of late sowing if the second-crop fields could be sown earlier. It is therefore better to keep the yield-reducing effect of late sowing separate from the disadvantageous effect of the second crop.

It was found that a correct choice of varieties was a considerable step towards lessening the yield-reducing effect of a preceding second crop.
In plantings on a practical scale in 1957, it was discovered that the Dima variety grew better on the second-crop field than the Nickerie and 80/5 varieties. It was therefore decided to test this phenomenon in the crop rotation experiment by sowing these three varieties in 1958. The results of the experiment were confirmatory (see Table 37).

TABLE 37 *The relation between varieties and crop rotation*
In 100 kg paddy/ha – 14% m.c.

Crop rotation experiments						Yields of 1958 main crop in practice		
Rotation			1958 main crop yields			Dima	Nickerie	80/5
1956	1957	1958	Dima	Nickerie	80/5			
Rice + rice	rice + rice	rice + rice	26.4	21.2	22.9	—	—	—
Dry fallow + rice	d.f. + rice	d.f. + rice	36.7	34.3	32.9	29.7[1] (584 ha)	28.9[1] (1137 ha)	27.9[1] (2259 ha)
Wet fallow + rice	w.f. + rice	w.f. + rice	32.5	35.6	31.3	—	—	—
Rice + rice	d.f. + rice	rice + rice	30.2	22.8	28.8	23.5[2] (1334 ha)	17.4[2] (80 ha)	17.1[2] (57 ha)
Rice + rice	w.f. + rice	rice + rice	30.7	22.9	29.6	—	—	—
Green manure + rice	g.m. + rice	g.m. + rice	44.0	37.6	39.1	—	—	—
Rice + rice	g.m. + rice	rice + rice	31.7	26.4	29.8	—	—	—
(99% sign. diff.)			(8.8)	(7.2)	(7.7)			

[1] After fallow in 1957-58; preceding rotation schedule left out of consideration.
[2] After second crop in 1957-58; do.

In anticipation, the greater part of the area of the 1958 main crop that had had a preceding second crop was already sown with Dima (yields also shown in Table 37).

Hitherto we have always spoken of a yield-reducing effect of the second crop on the subsequent main crop. In principle, however, it might be expected that the main crop would have a yield-reducing effect on the second crop, immediately following, as well. Surprisingly enough we overlooked this aspect so that there are little relevant data.
Only during the reclamation period it occasionally happened that newly-reclaimed fields were sown for the first time in the second-crop season. Comparison with the yields of other fields might afford an idea of the effect of the preceding crop, at least under such special conditions. The results of this comparison are given in Table 38.

TABLE 38 *Comparison of yields of second crops on virgin soil, after main crop, and after main crop and several preceding crops*
In 100 kg paddy/ha–14% m.c.

	1954–55 *	1955–56	1956–57
On virgin land	12.3 (337 ha)	30.1 (119 ha)	22.7 (111 ha)
After one main crop	17.3 (179 ha)	21.1 (94 ha)	16.9 (425 ha)
After several crops	—	22.2 (23 ha)	12.9 (504 ha)

On the face of it the 1955–56 and 1956–57 figures seem to give the expected effect. Admittedly it was just the reverse in 1954–55. In fact, however, these big differences in yields have other and quite obvious causes.
In 1954–55 the yield on virgin land was lower because reclamation and tillage had been very bad and consequently there was much floating pegasse. In 1955–56 the yield on virgin land was better, chiefly because tillage had been done with Solotrac ploughs and was therefore of better quality than on the older areas. In 1956–57 the yield on virgin land was higher as there was no damage of rats in this area.
All things considered these figures are definitely not conclusive.

Starting from the mutual effect of main crop and second crop, there might be something to say for not comparing the second-crop yields in Table 35 with the full average yields of the main crop, but only with the average yields of the main crop after the second crop (Table 36). In that case the second-crop yields are substantially better than those of the main crop.

Comparison of the conditions of cultivation of the main and second crop

A summarizing comparison of the effect of the weather conditions in both seasons does show some important differences.
The tillage for the second crop is generally of better quality and cheaper than that for the main crop, as it is carried out in the long dry season.

The rainfall in the second-crop period is generally lower, so that more irrigation is required. For the 1956–57 and 1957–58 second crops, an average of 1.2 and 1.0 pumping hours/ha were required (including seepage losses over the whole area), against 0.5 and 0.6 pumping hours/ha for the 1957 and 1958 main crops. On the other hand, owing to the small area of the second crop, the total pumping requirement was still only about half that for the main crop (see also Fig. 19).
The amount of sunshine which the second crop receives appears also lower (13 % lower on average at the Nw.-Nickerie station), which would hardly be expected having regard to the lower rainfall. This smaller amount of sunshine might well be a factor which systematically causes some reduction in yield. Since the second-crop area has been scattered over a total area 4 times its size and there was no rice crop at all in the vicinity, greater damage by insects, birds and rats might be expected, but hitherto, except for rats, not much extra damage has been observed.
Finally there are the greater harvest risks with the second crop due to weather conditions. In the past second-crop seasons, the harvest could always be brought in safely. Difficulties were only experienced in the 1958–59 season as a result of severe lodging caused by heavy downpours (however, also in the main crops quite some lodging did occur). Comparison of the combine working hours (Table 39) required for main and second crops gives a by no means unfavourable result for the second crop.

TABLE 39 *Average working hours/ha of combines during the various seasons*

	Main crop	Second crop
1954	2.8	
1954–55		2.2
1955	2.6	
1955–56		2.3
1956	2.8	
1956–57		1.7
1957	2.2	
1957–58		3.1
1958	2.0	

It should be noted that the rather favourable results, thus far obtained with the second crop of rice, do not imply that this will remain the same with a considerable extension of this crop. Part of the success has been inherent to the limited area planted, by which it was possible to drop some bad fields, to apply good cultivation and maintenance and to profit sufficiently for combine-harvesting from even short dry periods.

The result of crop rotation experiments

The permanent crop rotation experiment at Wageningen was laid out in 1954 with nine singly replicated treatments. Later on the experiment was changed

to seven treatments with two replications. For this reason, and because the experiment has only been in progress for a short time, we cannot draw any definite conclusions from the yield differences found and we will not yet publish the figures. But where the results are based on conditions corresponding to those of the main area they afford some help in explaining the yield differences occurring there. The following are important analogies:
1. On rank soil a second rice crop may exert a yield-increasing influence on the succeeding main crop. If the soil is "normal" it reduces yields.
2. On rank soil green manures and wet fallow may have a yield-reducing effect on the succeeding rice crop. If the soil is "normal" these methods increase yields.

Insofar as green manuring is concerned, point 2 above was confirmed in another test in the same way (Table 40).

TABLE 40 *The effect of green manuring on the rice crop in two years on the same experimental field*
In 100 kg paddy/ha–14 % m.c.

Treatment	1957	1958
Crotalaria quinquefolia (turned under).	38.3	34.5
Dry fallow	35.4	39.0
(99 % sign. diff.)	(3.2)	(2.6)

In this experiment *Crotalaria* gave a slightly increased yield in 1957, but a significant decrease in yield in 1958. The explanation is that in 1958 the rice crop grew too rankly, partly due to the worked-in *Crotalaria* crop being better developed than in 1957. When the large supply of N has disappeared in the recently reclaimed soil, of the Wageningen project area, the response to green manuring in the crop rotation certainly will become highly positive (see also 1958 in Table 37). This is supposed in conformity to some promising results of series of experiments by TEN HAVE (1959 c), on the older, cultivated soil in the Prins Bernhard polder.
Crotalaria quinquefolia was selected by VAN DER MEULEN and TEN HAVE (1959 c) as the best known green manure for the given conditions. It is not woody, relatively resistant to wet soil conditions, gives a good yield of green matter, does not occur as a weed in the rice, and its seed can be harvested mechanically.
According to TEN HAVE a particular advantage is that the hard-shelled seed remains viable in the soil for a long period, so that (after a *Crotalaria* crop has grown on a field) there may be a spontaneous regrowth of this green manure in succeeding fallow periods after intervening rice crops.

CHAPTER XI

TILLAGE

Introduction

In the early years of the Prins Bernhard polder, the tillage operations were always carried out according to Dutch agricultural theories. However, wet years occurred in which such tillage proved to be unfeasible, so that a number of fields had to be made ready for sowing by puddling, with a varying degree of success. About 1953 the idea gained ground that a final puddling treatment of the field might offer certain advantages in dry weather as well. This was because the soil had a poor structure so that, unless a few light showers fell, good crumbling of the furrow slice with dry tillage could only be achieved after protracted cultivation. Instead, by flooding the field, an even mud seedbed could be obtained easily with only one light drag or roller treatment.

During the period when only dry tillage was employed, regardless of cost, some apprehension was obviously felt about deep cultivation, as well as mouldboard ploughing, since efforts were made to keep the clods-formation as small as possible. This occasionally resulted in a shallow topsoil with many weeds and volunteer paddy, and a middling crop.
In the Prins Bernhard polder it was initially also feared to employ wet cultivation, since owing to some less favourable experiences it was assumed that the tractors would bog down and that such a tillage would make the land too soft for the use of combines. These fears proved exaggerated.
A valid objection made was the greater wear of the tractor tracks in the wet fields. This disadvantage was reduced by more intensive lubrication and by better sealing of the track rollers. There is no doubt though, that the greater wear of the tracks was more than offset by the smaller number of working hours required, and especially by the better seedbed obtained.

GIGLIOLI (1959, and verbal comm.) regards wet cultivation as a necessary evil under the conditions of the Mahaicony-Abary Scheme (in the coastal plain of British Guiana, to the east of Georgetown).[1] He only employed this method when weather conditions made dry cultivation impossible. On this scheme nevertheless the use of this method averaged 30% of the acreage over the years 1951–1957.

[1] A project of about 4,400 ha, of which 1,000–2,000 ha are large-scale agriculture. It was set up during the Second World War under the plan for providing food for the Commonwealth. Over the period 1945–57 the mean yield was almost 2000 kg paddy/ha (GIGLIOLI, 1959).

GIGLIOLI's view is probably based on the fact that in the Mahaicony-Abary Scheme only heavy wheeled tractors are used. Soil and climate being fairly similar to Wageningen, wet cultivation with wheeled tractors is, indeed, a difficult task.

When the Wageningen project came into production in 1954, the Gordian knot had to be cut and puddling was employed at once because continuous rains made dry cultivation impossible over the whole area. In 1955, after the experience with the floating pegasse, and subsequently in 1956 when the pegasse gave rank low-yielding crops, deep ploughing with Solotrac ploughs was adopted to an increasing extent. Dry preparation of the seedbed on the heavy furrows would have required many working hours as well as dry weather, so that intensive use was made of seedbed preparation in the wet. Wet cultivation is now being used as a standard method for preparing all the fields for sowing, although with the restriction that efforts are made to plough and (if necessary) level them previously.

Some efforts were made to investigate the influence of wet or dry seedbed preparation on the yield of the rice crop, with comparable intensity of working, and both after dry ploughing. The difficulty was that the emergence and the plant spacing were usually better with the wet seedbed preparation, resulting in greater yields.

But, apart from this influence, it was never possible to observe any considerable differences in the development of the individual plants due to wet or dry treatments.

1. The tillage methods

Depending on the moisture condition and the carrying capacity of the fields, the operations were selected as shown in Table 41.

Basic data on the implements.

Solotrac. Ransomes TS.1K, single-furrow plough, working width c. 35 cm, weight 650 kg. Fitted with International cut-out disk coulter of about 80 cm diameter with Timken bearings. D.b.h.p. required according to manufacturer about 25. Rate about 0.2 ha/hr (Photographs 16, 17).

Disk plough. International No. 98–53, 5 disks (cut-out or smooth), of 66 cm diameter. The plough can also be used with 4 or 3 disks. Weight about 1,700 kg. Working width 130 cm. D.b.h.p. requirement about 45. Rate about 0.5 ha/hr (Photograph 23).

Spade plough. Experimental machine being developed by Mulder (Kampen, the Netherlands) with the help of the Netherlands Land Development and Reclamation Society in Arnhem. The implement may be compared to a slow-running mounted p.t.-o.-driven rotary cultivator in which the cultivator blades are replaced by spades which perform a digging movement. Number of spades 18. Weight 850 kg. Working width 200 cm. Power requirement about 35 h.p. Hydraulic lifting capacity required about 1,200 kg. Speed 1,200–1,400 m/hr. Rate about 0.2 ha/hr (Photograph 26).

TABLE 41 *Plan of tillage operations in connection with the carrying capacity of the field*

Field condition	Ploughing	Rough seedbed preparation	Fine seedbed preparation	
			dry (levelling)	wet (puddling)
Dry and firm reclamation land.	Solotrac	Romeplough	landplane	mud roller + plank
Dry and firm cropped land	disk plough	disk harrow	landplane	mud roller + plank
Wet and firm reclamation land.	Solotrac	none	none	mud roller and/or plank
Wet and firm cropped land	none or spade plough	weedcutter	none	mud roller and/or plank
Wet and soft reclamation land.	none	none	no sowing	no sowing
Wet and soft cropped land	none	none	none	tractor alone or mud roller + plank

Rome plough. This is not actually a plough but a heavy reclamation disk harrow. Rome A-16″-26″, 16 cut-out disks 66 cm in diameter in two sections behind each other, the first section turning inwards (the left half to the right, the right half to the left) and the rear section outwards. Weight about 1,800 kg. Working width 250 cm. D.b.h.p. requirement 45–55. Rate about 0.8–1.0 ha/hr (Photograph 15).

Disk harrow.

1. Ransomes Baronet, with 24 smooth disks 56 cm in diameter, in two sections behind each other, turning like the Rome plough. Weight 1,200 kg. Working width 300 cm. D.b.h.p. requirement about 45. Rate about 1.0 ha/hr (Photograph 27).
2. Ransomes Baron, with 36 smooth disks 51 cm in diameter, in two sections behind each other, turning like the Rome plough. Weight 1,350 kg. Working width 320 cm. D.b.h.p. requirement about 45. Rate about 0.8 ha/hr.
3. Rome offset disk harrow. Three models are under investigation viz. TEH 24″-22″, TCH 24″-24″ and TBH 16″-26″, with 24, 24 and 16 cut-out disks respectively, 51, 61 and 66 cm in diameter respectively, in two sections, one turning to the left and the other to the right. Weight about 1,200, 1,500 and 1,600 kg respectively. Working width 290, 290 and 210 cm respectively. D.b.h.p. requirement about 45. Rates about 1.0, 1.0 and 0.6 ha/hr respectively.

Weed cutter. Marden T5. Normally supplied in three sections, although for wet cultivation under difficult soil conditions one section can be used separately. Drum diameter 50 cm, length 150 cm; 8 blades, 13 cm high, along the drum. Weight of one section empty 420 kg, filled with water 650 kg. Working width of one section 150 cm, of three sections 450 cm. Drawbar power required entirely depends on the field condition as does also the rate of work. (Photographs 22, 28).

Landplane.

1. Marvin Junior 94, 12 m long, sliding blade 270 cm wide at 60 cm high. Front and rear sets of wheels have rubber tyres. Weight about 1,800 kg. Working width 270 cm. D.b.h.p. requirement about 40. Rate about 0.7 ha/hr. (Photograph 24).
2. Marvin Standard 86, 18 m long, sliding blade 240 cm wide at 90 cm high. Front and rear sets of wheels have rubber tyres. Weight about 3,600 kg. Working width 240 cm. D.b.h.p. requirement about 50–60. Rate about 0.7 ha/hr.

Mud roller with plank. A simple implement built to our own design. It is an open roller in a draught frame. The open roller consists of two iron wheels of about 1 m diameter, about 3.5 m apart, connected by welded-on iron bars (e.g. narrow-gauge lines) in such a way that an open cylinder shape is obtained. The plank, of varying dimensions, is dragged on a steel cable behind the roller. Weight about 600 kg. Working width 350 cm. Drawbar power required is variable. Rate about 1.0 ha/hr. (Photograph 30).

Description of the tillage scheme (Table 41)

DRY AND FIRM FIELD.

A. Reclamation land.

After ploughing with the Solotrac, the Rome plough is excellent for the first seedbed preparation, possibly in two passes at right angles. In continuous dry weather the Marvin Landplane then follows which has both a levelling and a crumbling action. Afterwards about 10 cm of water is put on to the field and subsequently it is quickly rolled and dragged. This has to be done quickly as otherwise the carrying capacity of the soil decreases too much.

B. Cropped land.

International disk ploughs are used for ploughing to a depth of about 15 cm. Then follows disk harrowing with Ransomes Baron or Baronet, or perhaps still better with the Rome off-set disk harrows. A treatment with the Landplane is usually desirable. Finally, wet rolling and dragging.

WET AND FIRM FIELD.

A. Reclamation land.

Since the upper layer of the topsoil consists of pegasse, ploughing is desirable, although this may lead to the danger of the field becoming soft. In continuous wet weather the subsequent operations should therefore be limited to what is strictly necessary. It is preferable to wait for some dry weather which stiffens

up the clay somewhat. Usually a single final working by wet rolling and/or dragging is sufficient.
Sowing may eventually be done on fresh plough-furrows if the carrying capacity proves insufficient for further operations.

B. Cropped land.

The condition of the field is not suited to normal ploughing. Two possibilities remain, spade ploughing, or no ploughing at all but loosening the soil and removing the herbaceous growth with the weedcutter. Under these conditions the spade plough has the advantage that the tractor, at least during ploughing, cannot slip because the spade shaft is driven by the p.t.-o. (Spade ploughing is at present still in the experimental stage).
Spading, or 1–2 passages with the weedcutter, is followed by wet rolling and dragging.

WET AND SOFT FIELD.

It may be necessary to employ two crawler tractors, connected by a chain, for pulling one implement.

A. Reclamation land.

In the early years of development attempts were made to prepare these fields for sowing by repeated treatments with brushcutter or weedcutter, followed by wet rolling and/or dragging with mud roller and plank, or with a heavier beam. The resultant pegassy topsoil usually produced a bad crop, which was also difficult to harvest because the combines often stuck fast.
Under such circumstances the best course is to let these fields lie fallow for another year.

B. Cropped land.

Wet, soft fields will occur after wet years, if tillage and harvesting have been repeatedly done under less favourable conditions.
In any case these fields are kept to the end of the sowing period so as to be able to take advantage of any period of dry weather. If no dry weather occurs an attempt must be made to get the fields "black" (weed-free) with one or two light treatments, such as with the mud roller and the plank or even with the crawler tractor alone (the wooden cleats 60 cm wide which are mounted on the tracks give a "working width" of 1.20 m), after which a middling crop can still be obtained. After continued investigation it may possibly be found that the spade plough can also be used on these fields.

2. Crawler tractors or wheeled tractors

Hitherto crawler tractors of appr. 45 d.b.h.p. have been used almost exclusively, for tillage operations.

The first series of 64 International TD9 crawler tractors purchased in 1951 were fitted with broad tracks (45–50 cm) of standard length.
On the basis of experience gained in the meantime, the 8 International TD 9, and 4 Caterpillar D 4 crawler tractors ordered in 1956, were delivered with the same broad tracks, but with an extended track frame which increased by a further 20 cm the length of the track resting on the ground. On newly re-reclaimed soft land the tracks of the crawler tractors were always fitted with wooden extension blocks (photograph 31) which gave a smaller ground pressure and a better grip.
Many tests have been made (in particular by TH. H. M. BOSSE) with various models of wheeled tractors, fitted with rubber tyres (with anti-slip chains, strakes or cage wheels), or with iron wheels (with spikes or with wooden blocks), but the results were, at least at Wageningen, entirely unsatisfactory.

According to HAWKINS (1958) traction in the wet (with rice cultivation) can be obtained in two ways: by penetration unto a firm layer and by flotation. Under rice-field conditions wheeled tractors depend chiefly on penetration, and crawler tractors on flotation.
Apart from a surface crust, the depth of which varies with the degree of drying out, the soil on the project has a consistency of putty. Because of the small pressure distribution of wheeled tractors (compared to crawler tractors), the rear wheels easily sink through this crust, after which slip and bogging may result. Moreover the properties of the soil are such that there is slipping and soil piling on to the wheels even with slight rainfall. With the use of heavy wheeled tractors in particular there is the further disadvantage of deep tracks in the moist field.
It is quite possible that in course of time the firmness of the fields will increase to such an extent that some of the tillage can be done by wheeled tractors. This is of some importance because work can be done more cheaply with wheeled tractors.

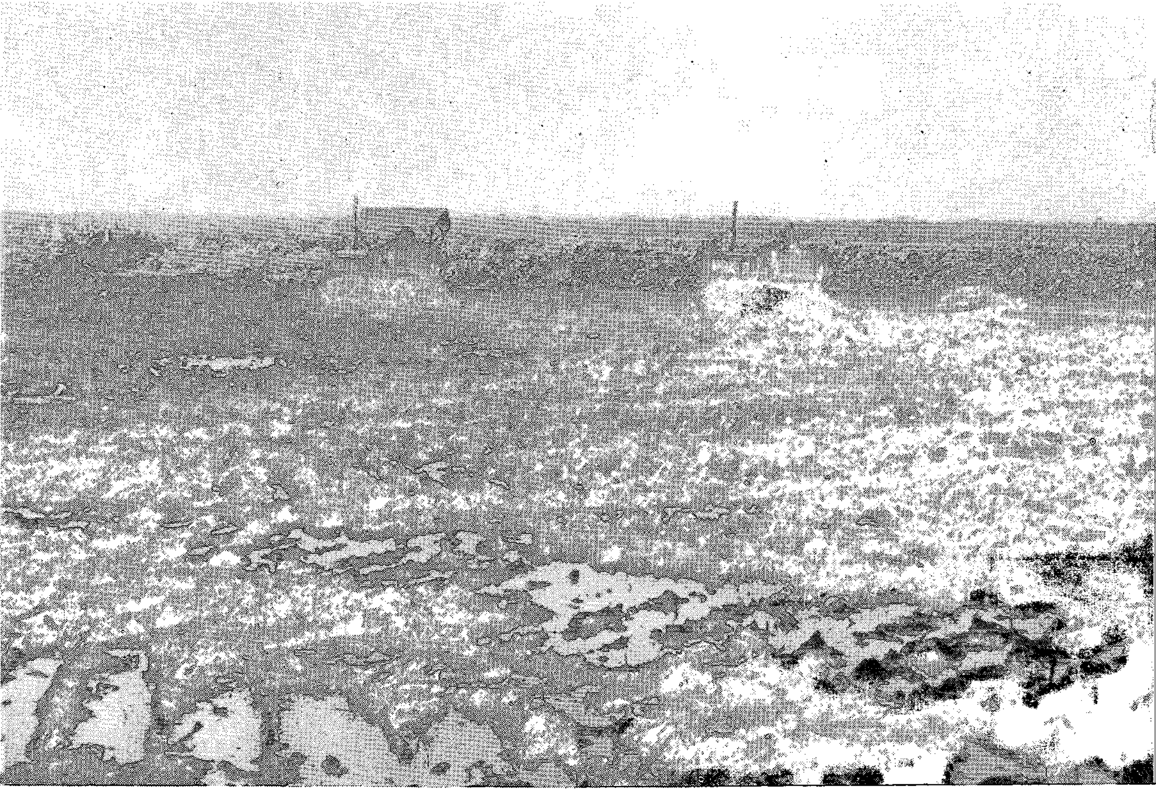
The Mahaicony-Abary Scheme, as already mentioned, has, since its inception, worked exclusively with 50 h.p. wheeled tractors on iron wheels. It is true, its soil seems to have somewhat more bottom than at Wageningen. Another difference is that a second paddy crop is not grown. However at the Mahaicony-Abary Scheme very great difficulties are repeatedly experienced with the tillage operations, especially when the tillage season is rainy and they have to carry out puddling with the wheeled tractors. The yields are otherwise so low that for this reason only no comparison with Wageningen is possible. After repeated visits to this undertaking, we are of the opinion that better results would be obtained if some of the wheeled tractors were replaced by crawler tractors.

As to the general problem of choice of crawler or wheeled tractors for mechanized rice cultivation, HAWKINS (1958) states that the crawler tractor has seldom proved economic on small farms (in general) even in temperate countries, because of its relatively high initial and maintenance costs. On

such farms the basis of mechanization are wheeled tractors and this will probably apply in greater measure to mechanized rice-growing, where the units are smaller and the capital and income less.
It should be noted that HAWKINS expressly excludes big farming, which is the case on the Wageningen project. On big rice farms in the U.S.A. crawler tractors are common, more especially on heavy wet lands.
On the Niger-project (DE WIT, 1958) exclusively heavy crawler tractors are used for tillage on rice and cotton lands, for reasons of high capacity and low personnel needs (the latter on account of the scarcity of skilled labour).

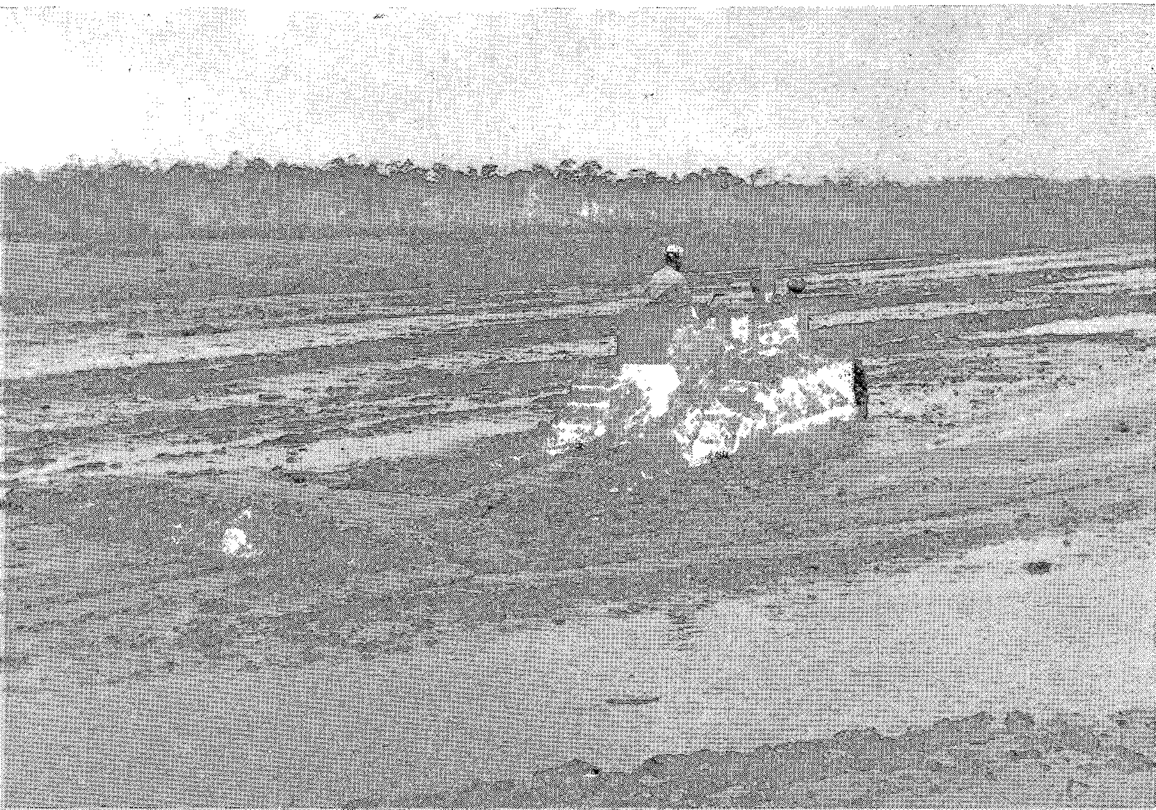
In connection with the foregoing it will not be so surprising that the smallholder-rice farmers in the Nickerie-district (also in British Guiana) use wheeled tractors extensively, whereas this is considered unpractical for the large-scale farming on the Wageningen project.
We can otherwise give a more detailed explanation, based on the widely divergent conditions in either area.
On the Wageningen project crawler tractors are preferred, because:
— A greater capacity per unit is obtained leading to less personnel for driving, maintenance and repair.
— As self-propelled 12–14 ft combine-harvesters are used, wheeled tractors are not able to cope with the dimension of the ruts caused by those harvesters.
— The purchased crawler tractors could be used in the construction phase for reclamation operations such as light bulldozer work. The reclamation equipment capacity was thus raised considerably, which was important owing to the short dry workable periods under the prevailing weather conditions.
— During the first years the use of wheeled tractors was decidedly impossible owing to soft land.
— Practically no metalled roads were constructed in the polder area, so that moving of wheeled tractors on rubber would be impossible during rainy periods and iron wheels would destroy the dams completely in a short while.

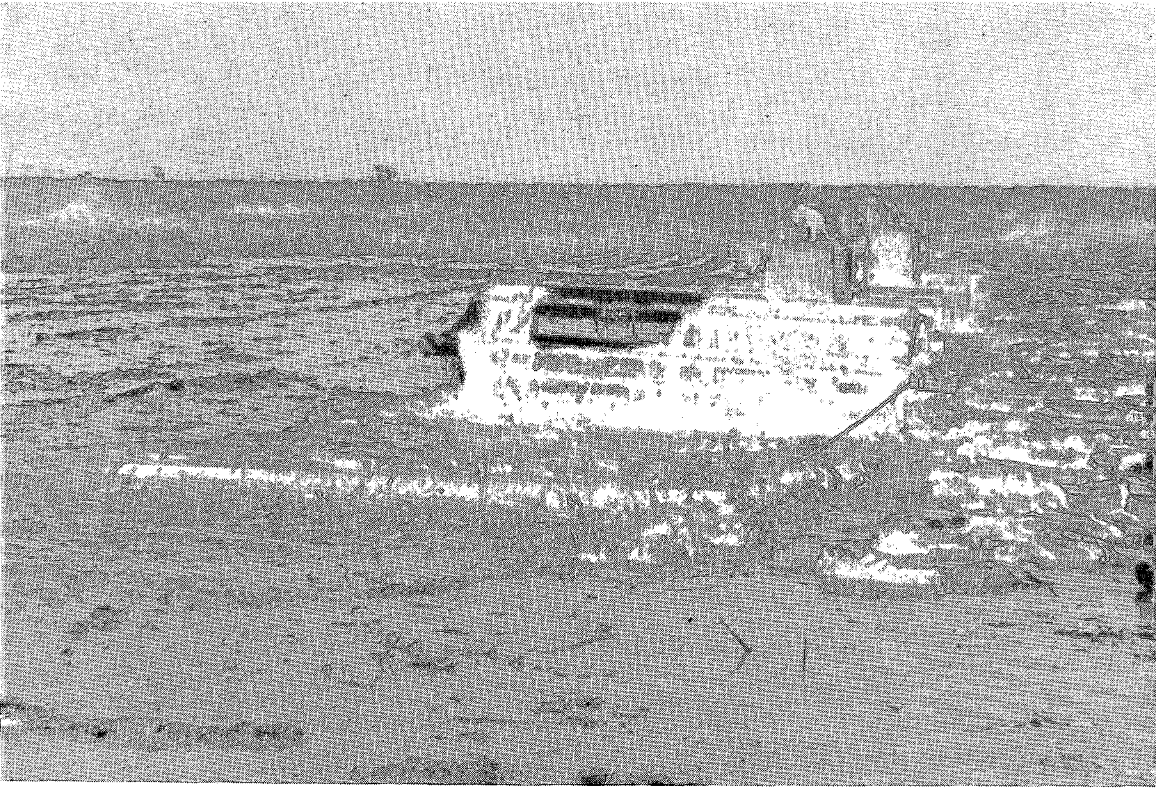
On the other side it can be understood that wheeled tractors are preferred and more or less successfully used by the smallholders as:
— Crawler tractors are too expensive for them.
— An important part of the work for which these smallholders like to have wheeled tractors, consists of small transports with a few bags of rice and other trifling commissions throughout the district (which has comparatively practicable roads).
— In Table 1 (page 19) is recorded, that in the Nickerie-district in 1952 worked 128 tractors (practically all wheeled) which prepaired that year 3893 ha of rice fields. This amounts to about 30 ha per tractor. We do not believe, however, that this capacity is achieved on average. 1952 was very favourable for mechanized tillage of rice fields, with sufficient drought in February, March and April.
In our opinion the efficiency of those wheeled tractors is rather questionable.



28. *Puddling with one weedcutter element.*

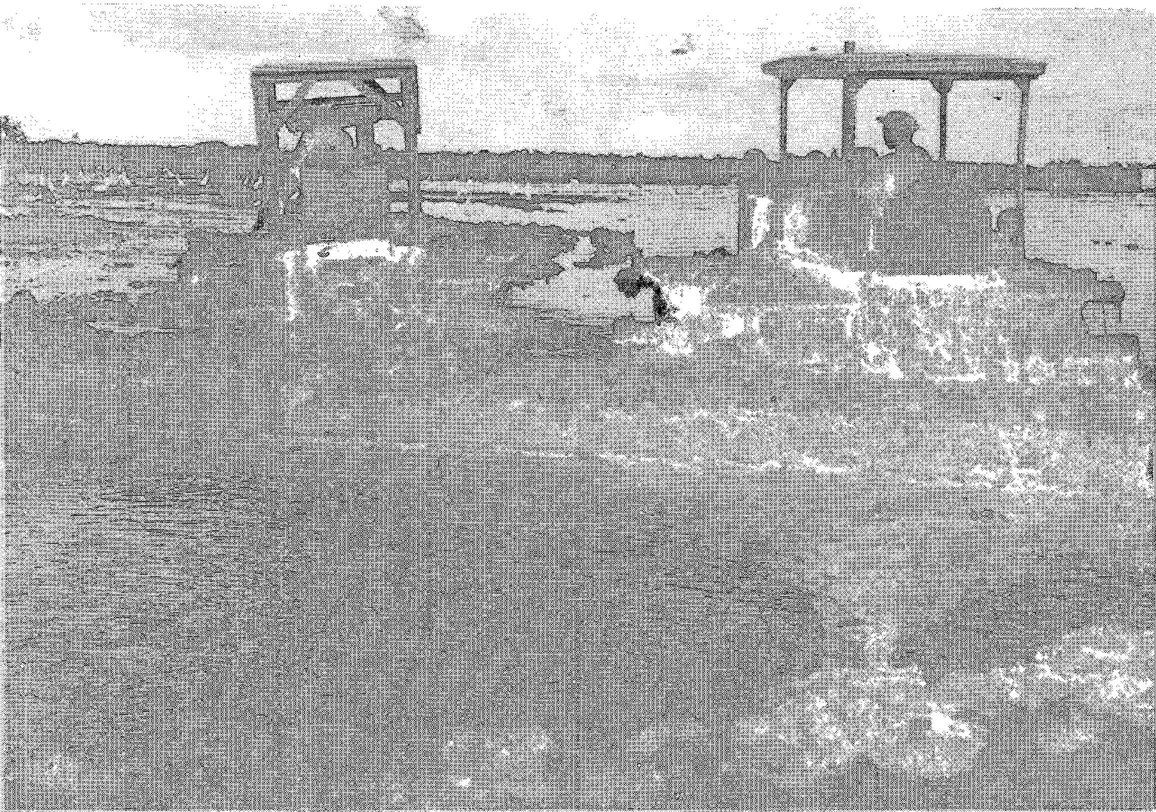
29. *Puddling with plank.*





30. *Puddling with mud-roller and plank.*

31. *Puddling with heavy beam.*



More research on the surprising mechanization of smallholder rice farming in Surinam and British Guiana seems important.
— The flexibility of a smallholder farming, partly at a subsistence level, is naturally much bigger as compared to large-scale farming.
In wet, unfavourable years the smallholders may be:

- — only prepair part of the land with the tractors and the rest with oxen or by hand,
- — or they spend twice as much tractor hours as usual,
- — or they work day and night for some time when a favourable short dry spell occurs.

Such alternatives may take place without much ado on small family-sized farms, but they are impossible on a large estate. In this connection should for instance be thought of the rigorous overtime hours – regulations of the Surinam government and the impossibility of attracting extra skilled labour in Surinam for short periods.
— The lands of the smallholders in the Nickerie-district are usually firmer thus better suited for wheeled tractors. Moreover they cannot plant rice in the second season (by lack of irrigation water), and this double-cropping system at Wageningen constitutes a prime element in making the fields less suitable for wheeled tractors. However, new reclamations for smallholders executed and issued by the Surinam government are only very slowly put into cultivation. One of the reasons for this will be the low efficiency of wheeled tractors at the disposal of the new farmers.

3. **Ploughing**

Conditions for ploughing on cropped land are better than on reclamation land because the soil has become firmer and the problem of turning the pegasse mat under no longer occurs.
Prior to ploughing, usually right after harvesting, the rice-stubble is flattened with weedcutters and if possible subsequently burned.
In case the fields are not ploughed directly afterwards, especially when they have a low carrying capacity, provisional drainage trenches may be ploughed. This is done cheaply by a "garland" pattern in which the plough (Solotrac) is not set in by the ditch, but drawn close along it in a sharp bend. The short connections with the ditches are subsequently dug by hand.

In the discussion of the plan of cultivation various aspects of the ploughing have already been touched upon. These related to the desirability of this ploughing operation in general, in connection with the increased yields obtained, and the difficulties of carrying it out within the selected scheme of cultivation. The advantages of the second crop are indeed so great that we must accept the greater risk to the subsequent main crop whenever ploughing may have to be omitted. This drawback of the second crop can be reduced by:
— sowing it as early as possible;
— drawing off the water as early as possible;

— keeping the harvested second-crop fields to the last for the following sowing;
— developing special ploughing or spading methods for wet fields.

Since the beginning of 1958 experiments have been carried out with spade ploughing at Wageningen. In the beginning the difficulties were mainly the result of the construction of the spade apparatus itself being too weak. Its design was strengthened, after which the difficulties centred on the supporting and driving wheeled tractor. The tractor sank repeatedly (and the spading machine with it) or could not be transported over the muddy dams from one field to the other.

In our opinion the designers (at any rate for the Wageningen scheme) have erred in wanting to take two steps at once. The spade machine was in reality designed for Dutch agriculture which is carried out almost exclusively with wheeled tractors. In a wet autumn in Holland there are sometimes many wet fields in the clay areas where normal ploughing with wheeled tractors is difficult or entirely impossible owing to slip. The p.t.-o. driven spade machine mounted on the wheeled tractor might be the answer for such fields. In the Wageningen project in Surinam, however, crawler tractors are used exclusively in the ploughing. The chances of dry weather are so slight that, with the present soil conditions, wheeled tractors are unsuitable for the job. Hence, it is basically wrong to try to dig with a spade machine driven by a wheeled tractor in fields which cannot even be ploughed normally with crawler tractors.

If however a spade machine were to be designed which can be supported on the 45–55 h.p. crawler tratcors in use at Wageningen, we think that there is a better chance of obtaining a useful and reliable machine.

For ploughing under normal conditions International No. 98 disk ploughs are used.

From the beginning of the project the choice between disk or mouldboard ploughs has been debated. Disk ploughs were bought on the following assumptions:

1. they are more resistant to remains of timber in the soil;
2. they require less traction in the heavy, sticky clay soil;
3. the rice crop does not make very high demands on the quality of ploughing.

Especially point 3 appears rather questionable. We consider that on wood-free land mouldboard ploughing has various favourable aspects.

In connection with the choice of ploughs in general, HAWKINS (1958) makes the following statement: "In the tropics on dry land, where weeds can be controlled by uprooting them in the sun and crop residues are needed at the surface to reduce erosion, the discplough and the chisel plough have become standard. On paddy fields, however, where there is little or no chance of killing weeds by drying them out and no erosion problem, the mouldboard plough is preferable."

According to GIGLIOLI (1959) disk ploughs would not be very useful (at the Mahaicony-Abary-Scheme) as unlike mouldboard ploughs they could not be used under waterlogged field conditions. In our experience this may be true of disk harrow ploughs, but certainly not of disk ploughs. The ploughs originally bought for the Wageningen scheme through Marshall Aid were disk harrow ploughs. These ploughs were little used, their drawbacks being:
clogging on wet land because of the small distance between the disks, and excessive working width, so that too small a plough depth had to be set in connection with the drawbar power of the crawler tractors.
With the International No. 98 disk ploughs however, which were purchased in the period 1955–57, these difficulties did not occur.

The mouldboard plough (Ransomes Solotrac) was introduced at Wageningen for reclamation work.
Subsequently these ploughs were also used for ploughing the cultivation land. The advantages were a large range of depths and good inversion of the soil. The great disadvantage, of course, was the small working width. For further testing, two-furrow mouldboard ploughs (Ransomes Duotrac) were bought. These were, however, somewhat disappointing owing to the small disk coulters and the limited clearance under the plough beam.
It seems desirable that testing of other models of mouldboard ploughs should be continued. The most important feature of the mouldboard ploughs in our case is their better inversion. This results in cleaner cultivation: fewer remains of straw from the previous crop, less weeds, and less volunteer growth (and thus for instance less favourable conditions for rats). Moreover the neat look of the share-ploughed fields has a psychological effect on the accuracy of subsequent cultivation measures.

4. Levelling as a cultivation measure

The importance of levelling in general was explained in the chapter on Reclamation, p. 106–108. After the reclamation levelling differences in level still occur for a considerable time owing to decomposing organic matter and soil stabilization.
Mechanized rice cultivation itself also somewhat disturbs the level of the fields every year during tillage and harvesting, and if this is not continually corrected the unevennesses may reach serious proportions. For example, a hole made by the bogging of a machine, may, if left untreated, grow in the course of years into an extensive pool owing to the constant movement of farm machinery.
The disadvantages of an uneven field in wet mechanized rice growing are great and moreover varied in their effect. The chief drawbacks are as follows:
1. The surface drainage of irrigation or rain water to the ditches is not so good. Puddles form; in these puddles the ground softens and the carrying capacity for machines remains slight or decreases still further.

The results of this are:
a. In tillage: a longer time is needed before the field can be worked, as the work for the whole field has to be adjusted to the low carrying capacity for machines admissible for the few soft patches.
b. In sowing: if (for any reason) the sown rice cannot be flooded, a poor emergence is often obtained in the puddles. This may result from an unfavourable environment for germination and initial growth (high temperature, high silt content and low oxygen content of the puddle water), and also from damage by pests (water snails, and ducks which like surfacing on shallow puddles).
c. In harvesting: after the water has been drawn off, puddles remain. These again become soft patches where the combines sink in deeply or even stick fast.
In all these situations trenches must be dug by hand in order to drain off the puddles.
2. In sowing in water on an uneven field, an unsatisfactory compromise must be made between the depth of water desired for weed control and the depth of water admissible for the growth of the rice crop. This leads to field sections with too little water resulting in much weed and a relatively too dense stand of rice growth, or with too much water which gives sparse emergence and poor growth of the rice crop. The drawbacks of uneven plant density are yield reduction and uneven ripening. With great differences in height, certain parts remain dry, which leads, apart from weed development, to poor emergence because of drying out and to depredations of birds and rats.
3. All weeds found on the Wageningen project possess the characteristic that they cannot germinate nor develop under a layer of water of more than about 15 cm, although some weeds are more resistant than others. On an uneven field such a minimum layer of water cannot be obtained over the whole area, so that weeds begin to grow on the higher parts. Where such weeds are species which can be controlled with herbicides, the damage is slight. But there is always the danger that grassy weeds may develop, which can only be removed by hand weeding.
4. During the growth of the rice crop the uneven depth of water causes various smaller difficulties which, when viewed as a whole, may become considerable.

a. in deep water (> 20 cm) the rice crop does not develop at its best so that there is some reduction in yield;
b. rat damage is concentrated on the dry and almost dry patches;
c. in top-dressing with sulphate of ammonia, the best yields are achieved by letting the fields run dry beforehand (hence lower yields in the puddles);
d. it was found that complete submersion gave the most efficient caterpillar control at an early stage of growth; this cannot be done on an uneven field so that the caterpillars remain alive and moreover concentrate on the higher parts.

Whenever weather conditions are suitable, some annual levelling with landplanes is advisable. Owing to the variable nature of the rainfall distribution in Surinam, no definite tillage schedules can be introduced. Wet years, during which dry cultivation cannot be carried out in part of the project-area, occur regularly. In the case of tillage in the Wageningen project the proverb "Don't put off till tomorrow what you can do today" is particularly true. On the other hand one should, of course, beware of overdoing things.
There are a fairly large number of types and models of levelling implements on the market. The Marvin Landplane was selected because of its robust simple design and easy adjustment. The automatic levelling effect of the implement is provided by the great distance between the front and rear wheels; the sliding blade, suspended between them, scrapes off elevations as the unit moves and entrains the soil until a low patch is reached. The levelling effect decreases rapidly when the extension of the unevennesses is larger than the distance from the front to the rear wheels of the landplane. For this reason, the heavier Marvin Landplane of the Standard type was purchased in addition to the Marvin Landplane Junior. The former has a greater draught requirement but also a larger levelling range because of its greater length, viz. 18 m instead of 12 m.
Good work with landplanes demands a preliminary, accurate examination of each field to determine the dimensions and directions of the unevennesses. From this the pattern of passes should be made. It will be clear that at least two passes approximately at right angles are always necessary. The soil must first be loosened by ploughing and harrowing before levelling with landplanes can be started.

5. Preparation of the seedbed

The demands on the quality of the seedbed made by the rice crop apart from ploughing and levelling, are almost solely aimed at the promotion of a good emergence after sowing. The reason of this is that the structural properties of a soil which can be so important in the case of dry crops, are of minor importance in growing wet rice, owing to the submersion.
For a successful emergence, the seedbed should satisfy the following conditions:
1. *No large clods.*
In sowing in water, these clods break up under water, covering the seed and preventing it from emerging. In sowing on dry soil or on mud the same effect occurs after heavy rainfall. The quickest and most effective way of crushing the soil is by wet seedbed preparation, i.e. puddling.
2. *No weeds or germination of weed seed.*
The best assurance that weeds do not have a lead on the rice crop is obtained by sowing directly after the last tillage operation. In practice this immediate follow-up does not always succeed owing to the distribution of work and the sowing schedules. An attempt is then made to "conserve" the freshly worked fields. The usual form of conservation at Wageningen consists in inundating

with a layer of water of about 15–20 cm. This involves the risks of development of real water plants such as *Nymphaea* sp. and the possibility that the fields may run dry through seepage. Moreover, the provision of extra water is expensive, especially when the flooding period lasts several weeks.

In the plain of the Po in Italy, use is made of temporary disinfection against germinating weeds by applying a dressing of calcium cyanamide during tillage operations. Under Surinam conditions such a dressing is not attractive.

3. *No remains of straw or weeds on the surface of the seedbed.*

In sowing on mud, seed falling on these remains dries up easily. In sowing in water the seed does not root well on the trash or it may sink down too far between such remains. Some of the remains also float, so that similar difficulties may arise as in the case of floating pegasse (see below). Furthermore, an environment of decay occurs which may have a toxic effect on the germinating rice. At a later stage decomposing plant-trash can give rise to a more intensive development of algae or other water weeds, which may also impede the growth of the young rice plants. By employing wet cultivation the remains of straw and weeds are eliminated better than by dry cultivation, since they are broken up and mixed in the mud.

4. *No substantial quantities of pegasse on the seedbed surface.*

This question only arises in virgin fields or fields which have only recently come into cultivation. In the wet reclamation years 1955 and 1956 floating pegasse occurred on an extensive scale. Fields of 12 ha were observed on which 100% of the seedlings came to the surface with the pegasse during irrigation.

This phenomenon had the following drawbacks:

— many seedlings got loose during the flotation process and succumbed thereafter;

— with partial flotation good parts of the field were covered by drifting of the floating sections;

— the pegasse formed a too soft a bottom for the plants so that early lodging occurred;

— the pegasse was a bad nutrient medium, and the roots did not reach through the layer of water into the clay;

— evidently the crop could not be protected by a layer of water from pests and weed development.

It proved necessary to keep such pegassy fields unflooded after sowing. Uneven fields had therefore to be trenched for the drainage of rainwater. Sowing was done on moist mud (viz. without crust) directly after the last tillage. The fields were then kept in a soggy condition. A dense emergence could be obtained in this way especially after some rain, but usually there was also a vast development of weeds. When the pegasse was not too thick, it was often found that in the course of time the rice could get a firm hold in the clay, in which case was switched over to normal irrigation. If this did not happen (the difference was easy to observe from the resistance felt when pulling the plants) the field remained "dry" until harvest, although in severe droughts flush irrigation had to be carried out.

The above described method was obviously not very satisfactory and therefore it was important to carry out such a tillage on new land that the pegasse was worked well under the clay. From the second year after reclamation onward, it rarely happened that the pegasse again came to the surface insufficiently mixed. For the seedbed preparation one should of course avoid to return the pegasse being ploughed under before. For eliminating pegasse remains, wet seedbed preparation proved more effective than the dry method owing to a better mixing of the topsoil.

DRY SEEDBED PREPARATION AND IMPLEMENTS.

By dry seedbed preparation is meant the part of the cultivation after ploughing and levelling and before puddling. In its simplest form it consists of one or two disk harrowings.

The method used depends on the condition of the field, viz. the firmness, dryness (weather conditions), weed growth and the lie of the furrow slices. With decreasing firmness of the field, the number and intensity of the dry treatments is limited (and may be altogether replaced by puddling). If the field is ploughed considerable time beforehand, we have to deal with weeds and dropseed growth, which may necessitate additional operations. In practice a preliminary light stubble ploughing with the disk plough was often found to be an effective method in this connection.

For the very large plough slices of the Solotrac plough, the heavy Rome ploughs with cut-out disks are more satisfactory than Ransomes disk harrows, even when the latter are weighted with ballast.

As regards the choice of disk harrows, Ransomes Baron was bought first. Further testing did show, however, that the Ransomes Baronet was more satisfactory, owing to the larger disks and the greater space between them. According to the latest opinions, it seems that the Rome offset disk harrow is also an attractive implement under the given conditions.

Tined harrows have never been able to find acceptance.

WET SEEDBED PREPARATION AND IMPLEMENTS.

The workability of a clay soil depends on its moisture content. With a low moisture content heavy clay especially is very hard and difficult to work. Then follows the range in which dry treatments, such as ploughing, harrowing, and levelling, can be carried out. With a further rise in the moisture content, a certain point is reached where adherence of the clay to the implements begins, as a result of which the operations are again greatly hampered. Finally, with high moisture contents both the cohesion and adhesion of the soil become very low, and this is the moisture range in which puddling is possible.

Also the carrying capacity of the clay is determined by its moisture content. After reclamation and drainage this moisture content falls and the carrying capacity increases. During submersion for rice cultivation, it increases again, but, in the case of the unworked subsoil at least, still remains lower than it had been in the original condition. The land then acquires a bottom.

Subsequently the carrying capacity depends greatly on the care and knowledge with which the tillage-operations are carried out. As in freshly deep-ploughed reclamation land this bottom is still absent, it should only be puddled after a period of drying out (both of the furrows and the plough-sole). In case the chance of dry weather was considered slight in practice, or if there was no time to wait for it, these fields were sown on the furrow slices without further operations. The yields obtained in this way were, unexpectedly, fairly reasonable.

In wet cultivation four points should be emphasized in connection with the choice of implements:
— the drawbar power of the crawler tractor is considerably less;
— also considerably less work is to be done owing to the low cohesion of the soil;
— since less resistance is encountered both the tractor and the implement penetrate the soil fairly easily;
— the mud-water medium is corrosive; it readily penetrates into the bearings and then causes rapid wear.

On the basis of the foregoing we can draw up the following list of desirable features in puddling implements:
1. simple design making the unit both light and robust;
2. a minimum number of rapidly-moving parts;
3. watertight bearings;
4. large bearing surface;
5. an implement shape which does not easily penetrate in the soil.

The implements used in the Wageningen project possess these features, mainly, because basically they consist of no more than a rolling drum or a dragging plank.
For the rough wet seedbed preparation of a firm field the Marden weed cutter was used. These weed cutters work fairly intensively owing to the sharp blades; if necessary its operation can be reinforced by filling the hollow drum with water. The weed cutter is used when the soil is compact or much weed has to be eliminated. In most cases intensive puddling is, however, unnecessary, or even undesirable as it will make the field too soft. Normally the mud implement par excellence is the mud roller and the plank. The mud roller has the following features:
— light construction owing to the open drum shape;
— slow movement owing to the large diameter;
— a large bearing surface on the ground;
— the narrow-gauge bars are blunt and do not protrude much;
— the openings between the longitudinal bars are sufficiently large for regularly discharging the soil entering the drum.

Usually one pass with the mud roller and plank (dragging behind) is sufficient to provide a good seedbed (after ploughing and 1–2 harrowings).

The methods described above are the result of trial and error. Many types of implements were bought, or built on the site, for carrying out experiments. The greatest difficulty in mechanized puddling is really the fact that there are virtually no machines suited for this work on the market. This is true both of the tractors and the implements.
This situation may change in the future. In our opinion the development of special machines for puddling will have to be in the direction of driven and self-propelled implements.

CHAPTER XII

RICE VARIETIES AND SEED PRODUCTION

The varieties

At the inception of the project there were no adapted rice varieties available. The varieties grown by smallholders in Surinam, the chief of which was Skrivimankoti, had very weak straw, so that mechanical harvesting became virtually impossible with the severe lodging that occurred.
In anticipation of the results of the rice selection programmes of the SML experimental farm in the Prins Bernhard polder and of the Agricultural Experiment Station at Paramaribo, which began to work on selection with a view to mechanization in 1950–51, the American rice varieties Rexoro and Bluebonnet were still planted at Wageningen in 1954. These Rexoro and Bluebonnet varieties were found to be very susceptible to *Cercospora oryzae* and *Piricularia oryzae*, the infection increasing considerably in successive plantings.

Hence it was fortunate that the new rice variety Dima, selected by MASTENBROEK (1953) of the Agricultural Experiment Station at Paramaribo, became available in 1954 (DE SURINAAMSE LANDBOUW).
The properties of Dima were so far superior to Rexoro, Bluebonnet and Skrivimankoti, that the long testing period, normally desirable before a variety is introduced, was omitted.
Despite unfavourable field conditions in the second crop season 1954–55, the desired rapid increase of Dima was one of the most important reasons for nevertheless sowing a fairly large area of rice.
The superior characteristics of Dima compared to the American varieties were as follows: greater potential yield, better grain quality (1,000 seed weight = 30 g), resistance to *Piricularia* and *Cercospora*, at least equal resistance to lodging, and a more robust crop, partly because of vigorous tillering and growth.
Compared to Skrivimankoti and other Surinam rice varieties, Dima excelled on account of its resistance to lodging, low photoperiodic sensitivity under Surinam conditions, better grain quality, less shattering, and better response to N fertilizing resulting in a higher yield ceiling. An unfavourable characteristic of Dima was its susceptibility to *Helminthosporium*. It was thought, however, that this was not so serious because a similar susceptibility occurred in Skrivimankoti, which has nevertheless remained the main rice variety grown in Surinam since about 1900.
Apart from the higher yields anticipated, a second reason for the rapid

switch-over to the new Dima variety, was to prevent the newly reclaimed areas from becoming polluted with a volunteer vegetation of Rexoro and Bluebonnet, which varieties had a shorter growing period. Moreover, the smaller American rice grains in the Dima product would reduce its market value.

In 1955 and 1956 other new varieties became available which had been developed at the SML experimental farm by VAN DER MEULEN with the assistance of TEN HAVE. These varieties had a habit similar to Dima, with the following differences:
Nickerie var.: 1,000 seed wt. at 14% m.c. 29.5 g, somewhat less vigorous than Dima, smaller flag leaf, more susceptible to *Cercospora* and *Piricularia*, not very susceptible to *Helminthosporium*, more sensitive to poor growing conditions, more sun-cracks after maturation, very good response to N fertilizing.
Paradise var.: 1,000 seed wt. 32.8 g, somewhat more vigorous than Dima, more susceptible to *Cercospora* and *Piricularia*, not very susceptible to *Helminthosporium*, less resistant to lodging, fairly poor response to N fertilizing. This variety was scrapped as early as 1957.
80/3/1/5/5 var. (called 80/5 in the text): 1,000 seed wt. 30.6 g, considerably less rankly growing than Dima, much more susceptible to *Cercospora* and *Piricularia*, not very susceptible to *Helminthosporium*, very good response to N fertilizing.
80/3/1/6/7 var. (called 80/7 in the text): like 80/5, but growing somewhat more vigorously.
All these varieties, as well as Dima, are derived from the same basic material which was supplied to the breeders by A. VAN DIJK, a mechanical engineer, who had been engaged on rice selection work for some time as an amateur on the experimental farm of his father, H. N. VAN DIJK, at Nickerie. It was a great surprise for VAN DIJK himself that such good strains were produced from his material. Owing to these circumstances the descent of the varieties is not known with certainty, although it is assumed that Skrivimankoti was one of the parent plants. As a result of further rice breeding research being carried out by TEN HAVE, several new promising rice strains have recently been developed, and it is expected that in the near future some of these will partly replace the varieties mentioned above.

The influence of the assortment of varieties on the yields in the Wageningen polder has been considerable.
Table 42 gives a survey of the yields of the principal varieties in the different seasons, the yields of the main crop plantings being divided whether fallow or a second crop preceded. No further division has been made for other factors influencing yield. When evaluating these figures a large chance variation should therefore be taken into account.
For comparison with the yields of the production area, Table 43 shows the yields of variety trial fields.
In 1954–55, 1955, 1955–56 and 1956 practically only Dima was grown. In

TABLE 42 *Areas and yields/hectare of the principal varieties in the different seasons*
In hectares and in 100 kg paddy/ha – 14% m.c.

Seasons	Dima						Nickerie						80/5						80/7					
Main seasons	after 2nd crop		after fallow		total		after 2nd crop		after fallow		total		after 2nd crop		after fallow		total		after 2nd crop		after fallow		total	
	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield	area	yield
1954	—	—	23	28.5	23	28.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
1955	457	26.2	1302	31.1	1759	29.8	10	32.6	59	34.7	69	34.4	—	—	—	—	—	—	—	—	—	—	—	—
1956	142	25.0	3344	26.1	3486	26.0	36	18.2	61	29.7	97	25.5	—	—	26	19.6	26	19.6	—	—	11	32.3	11	32.3
1957	31	25.6	2305	26.0	2336	26.0	171	21.2	1196	29.3	1367	28.3	771	18.1	1063	24.9	1834	22.1	56	10.7	170	21.3	225	18.7
1958	1334	23.5	584	29.7	1918	25.4	80	17.4	1137	28.9	1217	28.1	57	17.4	2307	28.0	2365	27.8	12	14.4	445	31.8	457	31.4
Subtotal weighted mean	1964	24.3	7558	27.2	9522	26.6	297	20.2	2453	29.3	2750	28.3	828	18.1	3396	27.0	4225	25.3	68	11.4	626	29.0	693	27.3
Second crop seasons	area			yield			area			yield			area			yield			area			yield		
1954–'55	393			15.9			—			—			—			—			—			—		
1955–'56	104			25.0			89			28.5			—			—			—			—		
1956–'57	455			15.1			258			12.5			183			21.8			51			12.8		
1957–'58	378			22.1			603			28.6			350			28.6			154			25.7		
Subtotal weighted mean	1330			18.1			950			24.2			533			26.3			205			22.5		
Total weighted mean 1954–'58	10852			25.5			3700			27.2			4758			25.4			898			26.2		

1956 Dima exhibited rank growth and increasing *Helminthosporium* infection. Since the Nickerie, 80/5 and 80/7 varieties had meanwhile become available, which were free from these drawbacks in test fields, from 1956–57 onward these varieties were also sown. The results in 1957 indicated that Nickerie was somewhat better than Dima and 80/5.
The Nickerie acreage was not increased in 1958 due to the slightly inferior grain quality of this variety. In 1958 less Dima was sown and more 80/5 with a view to greater productivity of the latter on soils rich in pegasse (see tests 2, 3 and 6 in Table 43).
But in 1958 Dima was found to be the best yielding variety, thus confirming our belief (based on the superiority of Dima already observed in previous years on the poorer soils of the Prins Bernhard polder) that it would reach a good production level after the reclamation rankness had decreased.
This led to an increase of the percentage grown with Dima in 1959.

The grain quality and market value of Dima were on the average somewhat better than the other varieties.
At first the Nickerie variety had a rather shorter grain than Dima. This drawback was subsequently overcome by selection of a new strain. In our opinion the greater susceptibility of Nickerie to sun-cracks was more important. As a result of the latter, if for any reason the crop had been left standing too long in the field, the broken grains in hulling sometimes reached very high percentages (the market value decreases by about 1 % for every 2 % more brokens).
The difference in quality between 80/5 and Dima was due to the occurrence of *Piricularia* and *Cercospora* in the former, owing to which there was sometimes a fairly large number of chalky grains in the hulled product.

The seed production

Starting from 6.000 ha main crop and 1,500 ha second crop in the Wageningen project, with a sowing rate of 100 kg/ha, 750,000 kg of seed would be required annually. Actually the quantity needed is larger because account must be taken of re-seeding some unsuccessful fields, risks of deterioration during storage, and changes in the choice of varieties. The extent of the risks which these three factors involve is reduced by the possibility of growing seed twice a year. The bulk of the seed is cultivated during the main crop seasons. Usually in the following second-crop season, the seed stock is adjusted more closely to the quantities and varieties desired for the following main crop. This is in fact a further advantage of the two-crops-per-annum cultivation scheme.
There are several reasons why a method in which all the seed for the main crop is obtained from the second crop season cannot be recommended.
The most important is that the risk involved in good seed provision would be too great. A second reason is that the second crop is harvested so shortly before the sowing of the main crop, that difficulties are experienced owing to the periods of dormancy occurring in the varieties in use.

TABLE 43 *Yields of varieties in test fields in the different seasons*
In 100 kg paddy/ha – 14% m.c.

No.	Sowing date	Original vegetation	Rotation	Dima	Nickerie	80/5	80/7	Sign. diff. P = 0.01
1	1955 ?	forest	after ½ year fallow, previously 1× paddy	26.6[1] 32.7	36.3 33.9	—	—	3.7
	1956							
2	21–4–'56	forest	after ½ year fallow, previously 2× paddy	35.8	37.2 37.3	40.7	39.5	3.2
3	28–4–'56	forest, with much pegasse	after second crop, previously 1× paddy: total 2× paddy	34.2	31.6 35.7	38.0	36.2	?
4	?	grass swamp	virgin soil	31.2	31.8 34.2	33.4	36.4	5.0
	1957							
5	13–4–'57	forest	after ½ year fallow, previously 3× paddy	36.0 36.4	36.2	35.1	38.3	3.2
6	12–4–'57	forest, with much pegasse	after ½ year fallow, previously 2× paddy	19.5 20.4	20.7	25.4	18.4	4.4
7	24–4–'57	grass swamp	after ½ year fallow, previously 3× paddy	30.9 30.7	33.6	36.5	34.5	3.4
8	11–4–'57	grass swamp	after ½ year fallow, previously 1× paddy	38.5	37.1	35.1	32.2	6.2
9	14–4–'57	grass swamp	virgin soil	30.2 30.6	27.6	30.4	29.6	4.0
	1958							
10	17–4–'58	forest	after ½ year fallow, previously 7× paddy	33.0	26.5	25.7	—	5.7
11	28–4–'58	forest	after second crop, previously 4× paddy: total 5× paddy	29.7	26.0	21.1	25.6	4.8
12	21–4–'58	forest, with much pegasse	after ½ year fallow, previously 3× paddy	32.0	33.7	29.9	—	2.9
13	14–4–'58	grass swamp	after ½ year fallow, previously 3× paddy	44.5	32.3	30.6	—	7.6
14	6–5–'58	grass swamp	after second crop, previously 2× paddy: total 3× paddy	22.6	16.6	15.5	—	6.2
	1957–'58							
15	22–10–'57	forest	previously 4× paddy	48.4	45.1	53.3	53.4	4.0
16	21–10–'57	forest, with much pegasse	previously 3× paddy	32.4	37.3	36.5	32.4	4.0
17	23–10–'57	mixed grass swamp and forest	previously 2× paddy	42.0	42.7	45.6	44.0	?
18	29–10–'57	mixed grass swamp and forest	previously 2× paddy	33.9	43.2	43.5	40.5	3.8
19	20–10–'57	grass swamp	previously 1× paddy	36.3 32.7	35.6 38.1	37.7	37.3	?
			Total mean	32.8	33.8	34.1	32.7	

[1] N.B. Double figures for two strains of the same variety.

When only a part of the seed is obtained from the second crop, an adequate period can be selected between harvesting and sowing.
A third reason is the increased risk of the growth of volunteer rice in the second crop. In the main crop, fields can be chosen which have had six months of fallow.
Table 44 shows that, as stated above, considerably more seed was always obtained than was used.
The second crop seed production was necessary in 1955–56 to replace a spoilt batch, in 1956–57 for the switch-over to new varieties, and in 1957–58 and 1958–59 to obtain more Dima seed than had been provided for in the main crop.

TABLE 44 *Seed used and produced.*

	Total crop area	Seed used	Seed produced
1955–56.	236 ha	?	136 tons
1956	3979 ha	272 tons	447 tons
1956–57.	1039 ha	109 tons	482 tons
1957	5819 ha	575 tons	1021 tons
1957–58.	1485 ha	145 tons	194 tons
1958	5909 ha	c. 700 tons	875 tons
1958–59.	1418 ha	146 tons	231 tons

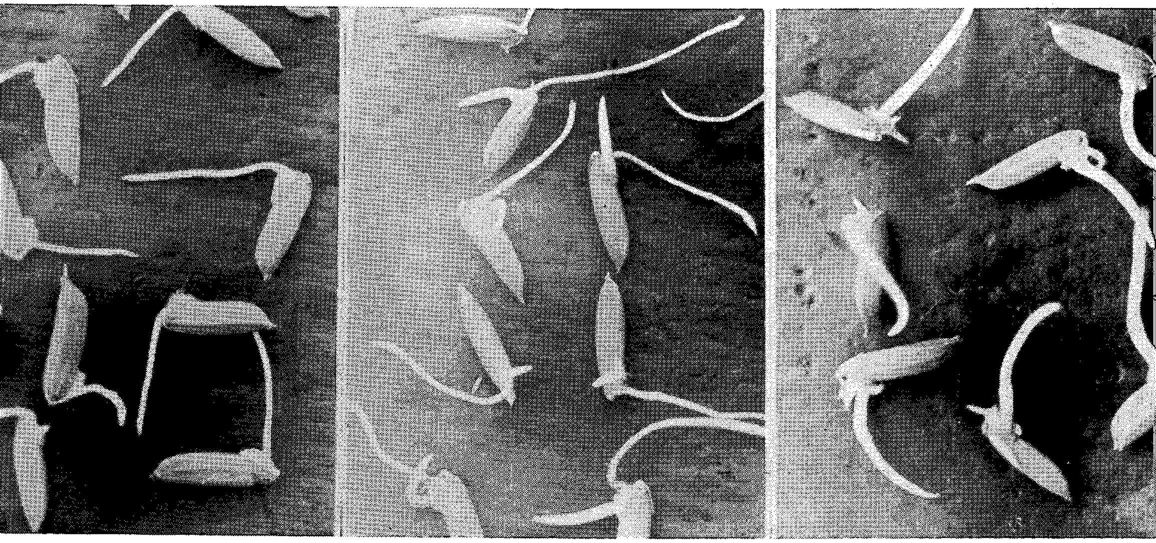
The principal points to which attention was paid in seed production were: the occurrence of red rice, diseases and certain weeds; the mixing of varieties and the germinating capacity.
Seed production requires the following procedures: production of pure original seed, multiplication, transport of harvested seed, its drying, cleaning and storage and finally its distribution. During all these operations the quality of the seed may undergo changes. Owing to the special nature of seed production, it is desirable that it should be kept as separate as possible from the ordinary commercial production. Initially, on the project, drying, cleaning and storage of the seed, took place in the central rice processing plant. Afterwards the drawbacks of this were understood and when an extension of the capacity of the storage space was found necessary, a completely separate installation was built for seed treatment and storage, in the polder. Pure original seed was first produced on the experimental farm of the STICHTING in the Prins Bernhard polder under the direct supervision of the plant breeder. When the amount was not sufficient it was carefully multiplied at Wageningen.
During the reclamation years newly reclaimed fields were always used for seed multiplication, the great advantage being that infestation with dropseed, or diseases originating from previous rice crops, were avoided. This method did, however, have the disadvantage that these fields were scattered over various farms. After the completion of reclamation in 1957, cultivation on

new fields was no longer possible. Since then, seed has mostly been grown on a special seed farm.

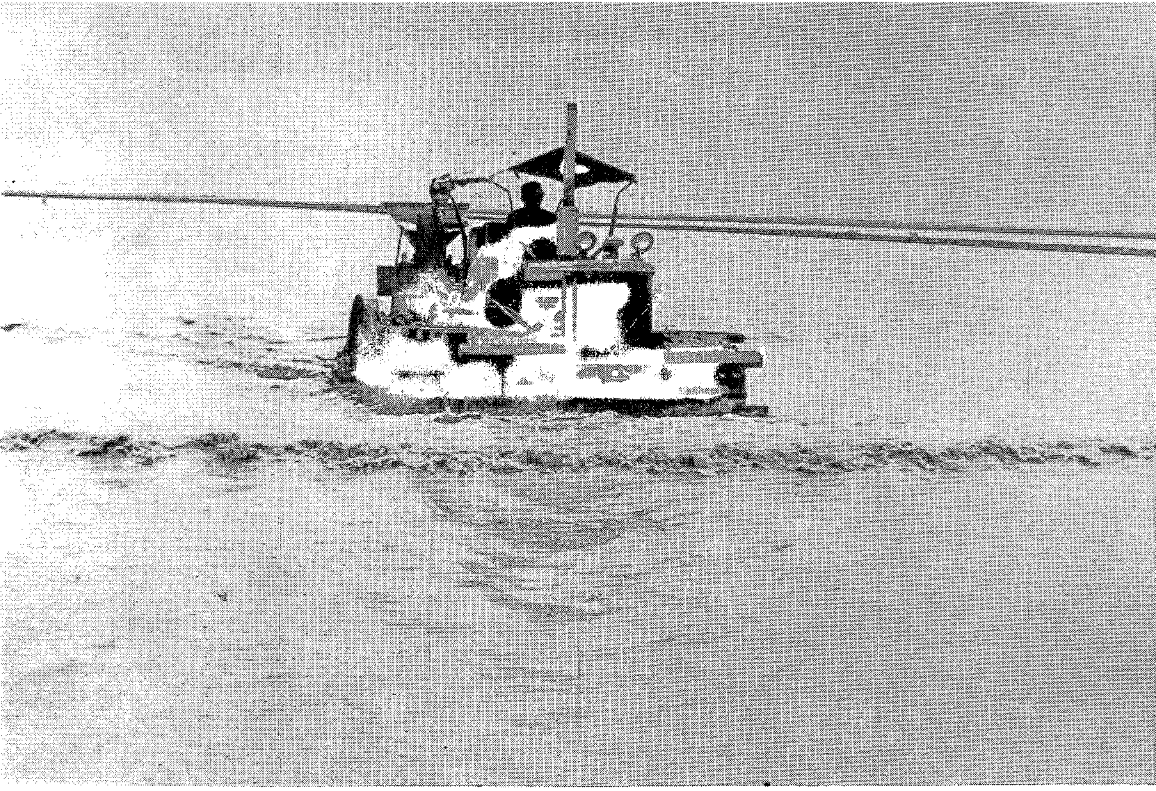
Tillage for seed production fields should be carried out more carefully than usual and in particular the aim should be to reduce dropseed growth to a minimum. The seed should therefore be produced, as far as possible, on fields which have had a six months fallow.
During its growth the seed crop is rogued several times. In addition to red rice and other varieties, all aberrant and diseased plants are eradicated. Fields often have to be definitely rejected if they contain too many aberrant plants or if the crop does not grow healthily. Hence many more seed fields have to be laid out than the production requirement actually calls for. A further reason for this is that estimates of the requirements of the different varieties may change while the crop is developing. All this indeed adds to the cost of seed, but is more or less unavoidable.

Red rice is the main problem in seed production. The red rice found in the Wageningen project is a vigorous, wild type of rice which volunteers easily. It ripens rather earlier than the cultivated varieties and the grain readily shatters. The trouble with infestation by this source is that the market value of rice is considerably reduced if only a few red grains occur in it. Infestation of the Wageningen polder area with red rice, occurred in 1954 via the first seed, which obviously had come from elsewhere.
If red rice were not controlled at Wageningen, within a few years it would increase to a content of several per cent in the harvested product. Once this stage is reached control is very difficult. The chief method of controlling red rice is the use of pureline seed. A seed field on which a single red rice plant is still found in a thorough check after rogueing, is rogued again, then inspected again, and if necessary it is finally definitely rejected. Red rice can be recognized by the extensive and vigorous tillering, the colour of the plant, the brownish colour of the chaff and the short grain shape.

Another difficulty in producing pure seed was the fact that the varieties in use have only a slightly different habitus. Without the assistance of the breeder, who regularly supplies elite seed by means of which pure blood is constantly introduced into the seed production, the varieties would quickly become impure.
Otherwise, in the production of rice seed every precaution is taken which is normal in seed growing for the prevention of impurities, interchanging of batches, etc. The harvested rice seed is dried at a somewhat lower temperature than the commercial seed. Cleaning is done immediately after drying and before storage. During storage the seed is repeatedly turned over and ventilated. Viability is determined regularly. The seed is treated with organic mercury compounds in dust form, just before sowing.

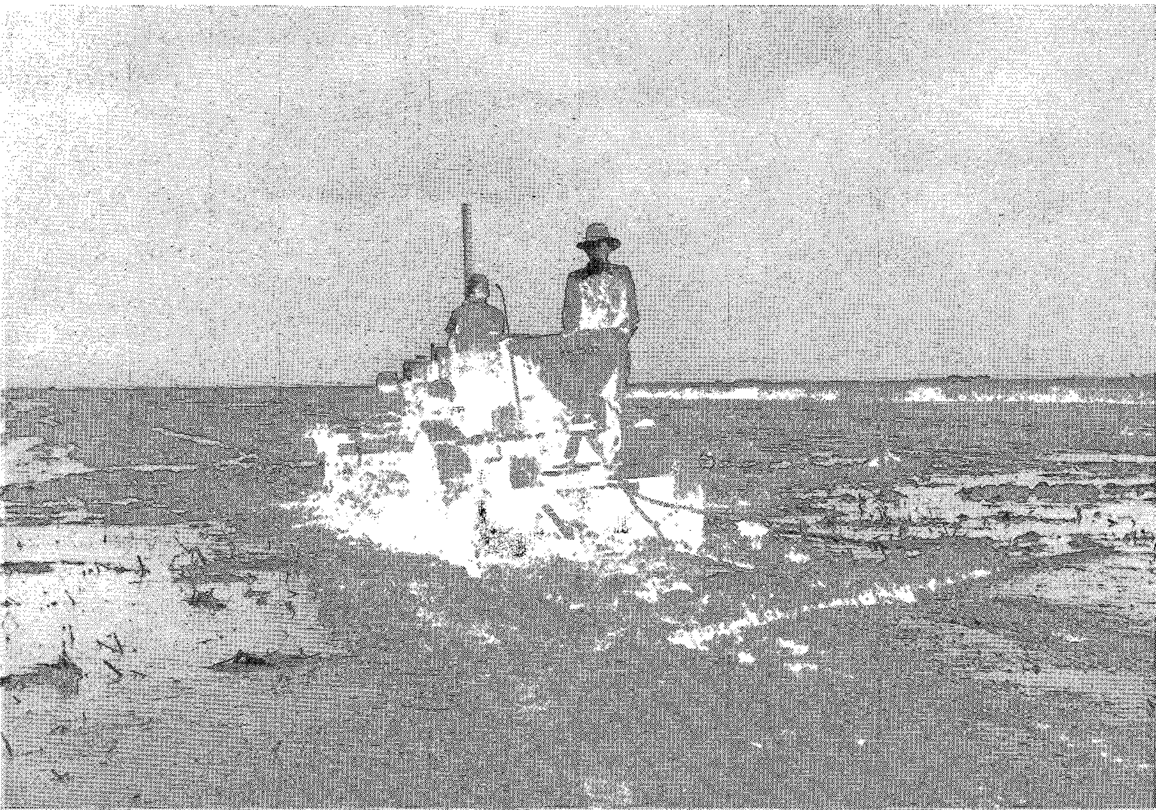


32. *Divergent rice seed sprouting under normal conditions, probably caused by varying oxygen supply. From l. to r.: radicle sprouts only, both radicle and stalk sprouts, stalk sprouts only.*



33. *Sowing in water by broadcasting with endgate seeder.*

34. *Sowing on mud with endgate seeder.*



CHAPTER XIII

SOWING

1. *The sowing times*

Under the present scheme sowing is done from about 1st April–15th May (6 weeks) for the main crop (the whole area), and from about 15th October–15th November (4 weeks) for the second crop (about a quarter of the area).
In Tables 45 and 46 the yields of the main crop in 1957 and 1958 are divided up according to weeks of sowing, and according to the preceding second crop, as well as to varieties. The latter is necessary as for reasons of management the varieties were sown in successive periods.
From the trend of the yield figures follows that the yield drop with late sowing is mainly due to the after-effects of a second crop.
The results of the variety trials are important for assessing the variety effect. (These have already been surveyed in Table 43.) In 1958 the depression of yields in fields which had had a preceding second crop, was less than in 1957, which can be attributed to varietal influence. Apart from the marked depression in yield caused by the second crop, the chronological yield trend of crops sown in 1957 was successively influenced by: the fairly low productivity of the first-sown Dima due to rank growth, a rise in the average yield as a result of the good Nickerie yield, and finally a sharp drop with the late sowings because the 80/5 was severely attacked by *Piricularia* and *Cercospora* at the very last moment.
In the case of 1958 the most striking fact, with the exception of the second-crop fields, are the low yields in the first sowing week. This was found to be due to low production of 80/5, probably caused by a severe *Piricularia oryzae* attack on this variety. However, it has still not been proved whether there is a connection between the occurrence of *Piricularia* and the earlier sowing. This might have been the case in 1958 in particular, due to the fact that the early-sown fields originally had to be flooded with fairly salt water, which may have weakened these plantings and thus made them more susceptible to blast.

It was also tried to ascertain from yields obtained in practice whether in the second crop there was a correlation between sowing times and yields. Such a correlation, however, could no more be found than in the main crop.

Differences in yield from full-scale plantings should be evaluated with great caution, as the influence of the factor under consideration (in our case the sowing date) can be mitigated by various factors. With reference to the

TABLE 45 *Average yields of the 1957 main crop, divided according to weekly sowing periods and varieties*
In hectares and 100 kg paddy/ha with 14% moisture

Sowing periods	Dima		Nickerie		80/5		80/7		Total	
	area	yield	area	yield	area	yield	area	yield	area	yield
a. *Total area.*										
1st week 31/3–6/4	714	26.2	35	26.8	47	30.1	—	—	795	26.5
2nd week 7/4–13/4	999	25.8	106	26.1	—	—	—	—	1105	25.8
3rd week 14/4–20/4	571	26.5	416	29.3	—	—	—	—	986	27.7
4th week 21/4–27/4	—	—	475	31.3	344	26.4	—	—	819	29.3
5th week 28/4–4/5	27	27.6	189	27.3	540	25.0	—	—	756	25.6
6th week 5/5–11/5	16	24.5	82	18.1	690	19.8	29	15.9	816	19.6
7th week 12/5–18/5	11	3.8	58	20.0	213	13.2	184	20.0	466	16.5
8th week 19/5–25/5	—	—	8	17.3	—	—	12	6.4	20	10.6
Total	2336	26.0	1367	28.3	1834	22.1	225.4	18.7	5763	25.0
b. *Area with previous second crop.*										
1st week 31/3–6/4	—	—	—	—	—	—	—	—	—	—
2nd week 7/4–13/4	—	—	—	—	—	—	—	—	—	—
3rd week 14/4–20/4	—	—	—	—	—	—	—	—	—	—
4th week 21/4–27/4	—	—	36	32.3	47	20.2	—	—	83	25.4
5th week 28/4–4/5	27	27.6	43	18.8	107	22.2	—	—	177	22.2
6th week 5/5–11/5	4	13.4	70	17.3	460	18.9	17	11.5	551	18.5
7th week 12/5–18/5	—	—	23	20.6	157	12.4	26	12.2	206	13.3
8th week 19/5–25/5	—	—	—	—	—	—	12	6.4	12	6.4
Total	31	25.6	171	21.2	771	18.1	56	10.7	1029	18.5
c. *Area excluding fields with previous second crop.*										
1st week 31/3–6/4	714	26.2	35	26.8	47	30.1	—	—	795	26.5
2nd week 7/4–13/4	999	25.8	106	26.1	—	—	—	—	1105	25.8
3rd week 14/4–20/4	571	26.5	416	29.3	—	—	—	—	986	27.7
4th week 21/4–27/4	—	—	439	31.3	297	27.4	—	—	736	29.7
5th week 28/4–4/5	—	—	146	29.8	433	25.6	—	—	579	26.7
6th week 5/5–11/5	11	28.7	12	22.9	230	21.6	12	22.2	265	22.0
7th week 12/5–18/5	11	3.8	35	19.6	56	15.4	158	21.2	260	19.0
8th week 19/5–25/5	—	—	8	17.3	—	—	—	—	8	17.3
Total	2305	26.0	1196	29.3	1063	24.9	170	21.3	4733	26.4

N.B. *Footnote to Tables 45 and 46.*
The value of each average yield figure is determined by the area over which it is calculated. The figures relating to the average from only a few fields are obviously almost worthless as indicative values for the point being made. They have, however, been included in order to complete the picture. The low yields of the small late-sown areas are particularly striking. This is due to the fact that fields which are in bad condition for tillage, are kept till last. Moreover, there are always some fields in which sowing is unsuccessful and then have to be re-seeded at the very last moment, usually without much success. Owing to this situation, on a cursory inspection of yield figures, one is always inclined to assume that late sowing is the cause of low yields. In this case, however, it is a matter of coincidence.

TABLE 46 *Average yields of the 1958 main crop, split up according to weekly sowing periods and according to varieties*
In hectares and 100 kg paddy/ha with 14% moisture

Sowing periods	Dima		Nickerie		80/5		80/7		Total	
	area	yield	area	yield	area	yield	area	yield	area	yield
a. *Total area.*										
1st week 31/3–6/4	—	—	—	—	1012	26.9	—	—	1012	26.9
2nd week 7/4–13/4	—	—	—	—	974	28.4	95	34.9	1068	29.0
3rd week 14/4–20/4	—	—	321	30.9	282	30.3	352	30.6	955	30.6
4th week 21/4–27/4	275	27.4	702	27.7	62	23.3	10	25.0	1047	27.3
5th week 28/4–4/5	744	25.7	138	24.1	12	25.2	—	—	894	25.4
6th week 5/5–11/5	889	24.7	47	29.4	12	28.5	—	—	947	25.0
7th week 12/5–18/5	11	13.3	—	—	12	11.2	—	—	23	12.2
8th week 19/5–25/5	—	—	10	14.6	—	—	—	—	10	14.6
Total	1918	25.4	1217	28.1	2365	27.8	457	31.4	5957	27.3
b. *Area with previous second crop.*										
1st week 31/3–6/4	—	—	—	—	—	—	—	—	—	—
2nd week 7/4–13/4	—	—	—	—	12	11.3	—	—	12	11.3
3rd week 14/4–20/4	—	—	—	—	12	24.1	12	14.4	24	19.2
4th week 21/4–27/4	118	25.2	24	19.5	34	17.1	—	—	176	22.9
5th week 28/4–4/5	468	24.1	56	16.4	—	—	—	—	525	23.2
6th week 5/5–11/5	736	23.1	—	—	—	—	—	—	736	23.1
7th week 12/5–18/5	11	13.3	—	—	—	—	—	—	11	13.3
8th week 19/5–25/5	—	—	—	—	—	—	—	—	—	—
Total	1334	23.5	80	17.4	57	17.4	12	14.4	1484	22.9
c. *Area excluding fields with previous second crop.*										
1st week 31/3–6/4	—	—	—	—	1012	26.9	—	—	1012	26.9
2nd week 7/4–13/4	—	—	—	—	962	28.7	95	34.9	1056	29.2
3rd week 14/4–20/4	—	—	321	30.9	270	30.6	340	31.2	931	30.9
4th week 21/4–27/4	156	29.1	677	28.0	28	30.6	10	25.0	871	28.2
5th week 28/4–4/5	276	28.4	82	29.3	12	25.2	—	—	369	28.5
6th week 5/5–11/5	153	32.6	47	29.4	12	28.5	—	—	211	31.7
7th week 12/5–18/5	—	—	—	—	12	11.2	—	—	12	11.2
8th week 19/5–25/5	—	—	10	14.6	—	—	—	—	10	14.6
Total	584	29.7	1137	28.9	2307	28.0	445	31.8	4473	28.8

above we may conclude, however, that the sowing periods of six weeks for the main crop and four weeks for the second crop have hitherto only brought about small – in any case not distinctly observable – systematic differences in yields, for the sowing dates within the period specified.

In our opinion the usual low yield of the second-crop fields is only incidentally due to late sowing per se. This means that, at least in as far as the production aspect is concerned, a greater spread of sowing of the main crop will be admissible. The main restriction in this case may be the yield-depressing influence of the spread of sowing and harvesting owing to pests and diseases, which is impossible to assess however.

The sowing methods

IRRIGATION MANIPULATION

The chief aspects of the sowing methods are water control, mechanical or hand sowing, pre-germination of the seed, and the seed rates.

Water control is the dominant factor. The possibilities of rice sowing are between: dry sowing and emergence, and sowing and emergence in a permanent layer of water about 15 cm deep. Dry sowing and emergence are characterized by:

— dependence of growth on rainfall;
— almost equal chances for the growth of rice and weeds;
— bare places in the crop resulting from various pests as caterpillars, birds and rats.

Sowing and emergence in about 15 cm water, are characterized by:

— independence of rainfall;
— unfavourable chances for weed growth;
— protection of the fields from the above-mentioned pests;

but also by:

— bare places caused by snails and algae;
— washing out of seedlings by wave action;
— influence of the quality of irrigation water on emergence;
— uniform distribution of the seed being more difficult;
— mechanized sowing being less easy than on dry land;
— psychological strain of the farmer owing to the long period of emergence.

Starting from "dry sowing and emergence" (method 1) and trying to reduce the drawbacks, there are the following possibilities:

1a. Sowing on dry land and inundating the field immediately afterwards for a few days. Some 10 days after sowing gradually add a permanent layer of water, without inundating the seedlings;
1b. Sow on a "fresh" mud bed with pre-germinated rice seed, and after some 10 days gradually apply permanent water as under 1a.;
1c. Sow on a "fresh" mud bed with pre-germinated seed and immediately afterwards, or within a few days, inundate the field for a short time. Some 10 days after sowing add gradually permanent water as under 1a.

With "sowing and emergence in water" (method 2), there are also possibilities for corrections:

2a. Sow on a "fresh" mud bed with pre-germinated seed and inundate the field permanently immediately afterwards;
2b. Sow in water with pre-germinated seed, after a few days leave dry for a short time and then inundate permanently;
2c. Sow on a "fresh" mud bed with pre-germinated seed and inundate

immediately afterwards, but after some 5 days leave dry for a few days, and then inundate permanently.

Reviewing the variations in sowing, it is found that it chiefly amounts to a wide range of irrigation manipulations, from the day of sowing to about two weeks afterwards.

In the Wageningen project method 2: sowing and emergence in water, is generally considered the most satisfactory one. It is the standard method which is only deviated from in urgent cases. The preference is based on the following aspects:

1. With completely dry sowing and emergence the seed would have to be introduced *into* the soil (for germination) with the aid of drills. During rainy weather work with these machines on the heavy clay is difficult, and the quality of the work is bad, partly because of the clogging of the seed tubes. The main reason why this method is unsuitable, is that if the drilled field becomes waterlogged due to heavy rains, emergence may be bad and in the puddles even absent altogether.
Variants 1a, b and c are better in this last respect, but with sowing (broadcast or in rows) *on* the soil, and preferably with pre-germinated seed. Sowing in water is, however, superior because, more than with the other methods, all the rice seed on the field is given a good chance to grow.

2. With dry sowing and dry emergence, the weed has almost the same opportunity to grow as the rice.
With the variants 1a, b and c, this tends to be to the advantage of the rice, but often insufficiently. Only with complete sowing and emergence in water the chance of weed development is practically nil. Sowing in water is especially important when the grassy weed *Ischaemum rugosum* occurs (on most fields at Wageningen).

3. With dry sowing and dry emergence, caterpillars (especially *Laphygma frugiperda*), rats and small seed-eating birds may cause much damage. Puddles on the sown field form a suitable environment for water birds which feed on the seed and wash away the seedlings. Sowing time is a period when rats and birds can find little alternative food.
When sown in water, the seed and seedlings are effectively protected from rats and small seed-eating birds, and also from aquatic birds when there is sufficient water. In this case also caterpillars only cause limited damage to the parts of the plants above water.

4. Sowing in water has certain drawbacks, but these can usually be corrected by suitable measures. The damage from snails and control measures will be discussed on p. 187. Some other problems in connection with sowing in water will be dealt with below.

The depth of water on the field after sowing is an important factor. TEN HAVE (1959b) found in careful container experiments in the Prins Bernhard polder in 1957–1958, with an unspecified variety of rice, that 10 cm of clear

water gave an emergence (with pre-germinated seed) of about 60%, decreasing by about $7\frac{1}{2}$% for every 10 cm of additional water.
In dirty water (containing silt; not specified by TEN HAVE) the emergence was about 40% for a depth of water of 10 cm, and an 11% decrease in emergence for every additional 10 cm.
In other experiments TEN HAVE examined the influence of water depth with the same emergence, when the 10 and 25 cm water treatments were not begun until the plants were 35 days old. In the case of the 25 cm treatment the average loss of yield in 7 experiments was 300 kg/ha.
With a view to weed control, which is less effective with a shallow layer of water, TEN HAVE advises a 15–20 cm layer during the first period subsequent to sowing. He states that after the crop has grown dense, at an age of about 7 weeks, 10 cm are sufficient.
The latter depths of water also seem to be most appropriate for the Wageningen project, under normal conditions.

A very special complication of sowing in water is the washing out of seedlings. The wind direction on the project is mostly N.E. From morning to afternoon the wind becomes more northerly and then reaches maximum force, after which it veers round again to the N.E. towards evening. As a result of the prevailing wind direction, the orientation of the fields is of importance for the washing out of seedlings.
Their 600 m long sides lie EES-WWN, so that the average maximum winds blow approximately at right angles to the long sides of the fields. This is favourable, as in this way all the longitudinal dams act as wind-breaks and wave action is less able to develop.
Apart from the wind effect other growing conditions probably also play a part in the amount of loosened seedlings. Obvious reasons are the soil being too hard for radicle penetration or too soft for taking hold. According to BEST (verbal comm.) another important factor may be lack of oxygen leading to stagnant radicle development.
The washing away of rice plants in the production area of the project, has differed every year, but has seldom reached damaging proportions. When this threatens to occur the water level is lowered.

SOWING UNDER ADVERSE CONDITIONS

There are three reasons why it is often impossible to sow reclamation fields in water (by method 2), viz.:
1. too great differences in height in the field;
2. floating pegasse;
3. checked germination and dying of the shoots.

Points 1 and 2 have already been dealt with in detail. Slow growth and dying of rice seed on reclamation fields under water also occurred when pegasse was turned under well, notably on fields which had not previously had a good period of drying out. This phenomenon was probably caused by the

anaerobic condition of the soil. (A similar stagnant seed-sprouting was experienced on some main crop fields which had remained in a wet condition after a preceding second crop.)
Fields with great differences in level, or where checked germination was expected, were sown by methods 1b and 1c, and by method 1a where the field was also too soft for puddling. Fields with floating pegasse were preferably puddled but remained dry after sowing, for as long as was necessary for the rice plants to obtain a firm hold in the clay.

Under various other conditions temporary draining off should succeed during or after sowing (methods 2a, b, c), viz. when:
— checking of the quality of sowing appears necessary;
— a heavy growth of algae or other water plants occurs;
— snails have caused much damage;
— germination is generally poor.
Sowing in water usually needs a higher standard of viability and seed quality in general, than sowing on mud. In cases of poor seed quality it may therefore be necessary to adopt the last sowing method.

The water used for puddling is usually drained off before sowing and replenished, as the emergence of rice is worse in muddy water. Possibly, however, when the financial side of supplying water has been worked out in detail (the data required for this are still lacking), it may be found that this disadvantage does not warrant the greater cost of supplying such extra water.
There are also other reasons, why such replenishment may be omitted, viz.:
— lack in capacity of the pumping station and canal network in the peak sowing periods;
— poor quality of the irrigation water owing to high salt and silt contents.
When the water is muddy the layer of water should be as thin as possible after sowing and more seed should be used per hectare. It has been observed that there is also a poorer growth of weeds in muddy water, so that with a shallower layer of water weeds could still be sufficiently checked. In practice, however, the fields are always somewhat uneven, so that parts may run dry in that case.

MACHINE OR HAND SOWING

Sowing at Wageningen is either broadcast by hand or machine. Mechanized sowing is usually preferred, but it sometimes happens that after puddling the fields have become too soft for this. For this reason the reclamation land in particular, was sown almost exclusively by hand.
Before 1957 mechanized sowing was therefore only occasionally employed. The rate of hand sowing is 0.2–0.3 ha/man-hour. Its chief drawback is the irregular distribution. In 1957 about 20% of the area was sown with the seeder and in 1958 about 35%.
The machine used is the International Endgateseeder (photographs 33, 34),

with a capacity of 2–3 ha/hr. It works well, but the construction is really too light. The distributing width is 10–12 m; the seed rate can be changed by supply valves in the storage hopper. The two distributing paddle wheels are driven by the axle of the small two-wheeled trailer on which the machine is placed, so that the seed rate automatically varies a little with the speed of travel. The main advantages of sowing with the endgateseeder are: the speed, the saving of manual labour and the uniform distribution of the seed. The disadvantages are as follows:

— If the field is soft the machine is unable to travel at the same speed and this causes unequal seed distribution (at very low speeds the working width also decreases).

— The machine leaves tracks, in which emergence is generally poor. Attempts were made to overcome this by dragging a small plank close behind the seeder, but a drawback was then: increased wave action behind the machine and hence washing away of the seed. This could be prevented by only flooding the field after sowing, although in that case another type of washing away could be caused, viz. by floating of the meanwhile dried up seed.

— The chance of damage to the shoots (the coleoptilums). For mechanical sowing the shoots must not have emerged far outside the glumes.

PRE-GERMINATION OF THE SEED

In the Wageningen project it is usual to pre-germinate the seed. The normal method is to soak the seed for 18–24 hr in clean irrigation water in large, closed sacks, about half full (owing to the volume increase). Afterwards the sacks are kept "dry" for a further 18–24 hr in the dark under a tarpaulin, during which time the swollen seed begins to germinate. Then it is ready for sowing.

During the pre-germination the radicles normally appear first, followed by the shoots. Sometimes they appear at the same time, and on rare occasions the shoots appear first (photograph 32). The exact reason for this has not been carefully examined. According to BEST (verbal comm.) the development of radicles is retarded in anaerobic conditions, which is not the case with the coleoptilums. For mechanical sowing the premature emergence of the shoots is a disadvantage, since any injury to the very young shoot usually means a total loss of the seedling, while damage of the radicles only causes a small check in growth.

The main advantages of pre-germinating are as follows:

1. the growth of the rice plant is accelerated by two days, enabling it to compete better with weeds;
2. in its most sensitive stage of growth the rice plant is exposed for two days less to conditions in the open field;
3. the emergence of pre-germinated seed is usually more regular and dense than that of dry seed;
4. less seed is required.

Pre-germination also has some minor drawbacks:
— the moist germinated seed causes some difficulties in sowing, and
— after pre-germination the seed can not be stored.
The first drawback is overcome by letting the seed drip out sufficiently after the soaking and by seeing to it that during sowing germination is still in the initial stage.
In this way the seed does not remain in clusters in the storage hopper of the seeder, and the shoots are not damaged by the distributor paddle wheels. (In some rare cases, however, when the seedbed consisted of a very soft mud, specially long-germinated seed applied by hand-sowing was preferably used, as it did not sink in so deeply.)

Concerning the method of pre-germination, in 1953 the author, with the assistance of VAN GILST, made several hand-sowing tests in 10–15 cm of water. It was found that soaking for 18–30 hr and subsequent germinating for 24–48 hr gave an emergence of about 50 %, for seed of the Rexoro variety with a viability of 94 %. With shorter or longer soaking (12 and 48 hr), the emergence percentage fell to 40–45 %. With shorter germinating (12 and 8 hr), emergence also fell off slightly to 40–45 %, even when longer periods of soaking, e.g. 48 hr, were employed. However, with soaking for 18–30 hr and very long germinating times of 72 and 96 hr, the emergence percentage remained satisfactory. Tests plots sown with ordinary dry seed, had an average emergence of only 37 %.
The better emergence of pre-germinated seed as opposed to "dry" seed when sown in water, is generally attributed to the oxygen requirements of the rice seed during the germination process.
It should be mentioned that the above described phenomena will certainly not occur in the same way under different conditions. Much depends on the field conditions and presumably also on the rice varieties and the quality of the seed. In small pilot tests in 1953 we obtained deviating results with different varieties.
In these tests emergence with some varieties was virtually the same whether or not there had been pre-germination, whereas with other varieties emergence after pre-germination was 5–6 times as great.
Unfortunately these pre-germination tests were not carried out with the new varieties in subsequent years.

The method of pre-germination which is used in practice is partly based on the above tests. Owing to the need of short shoots for machine sowing, germination is not applied for longer than 24 hr. To a lesser degree this requirement also applies to broadcast hand sowing, in order to prevent the seed landing in clusters on the field, resulting in an uneven plant spacing.

SEED RATES

The seed rate required may depend on the variety, the quality of the seed, the quality of the irrigation water, the quality of the tillage, the fertility of the

Table 47 *Results of seed rate and N level experiments with the Dima variety during the mean season 1956*
In 100 kg paddy/ha–14% m.c.

Seed rate kg/ha	Fertilizer level kg amm. sulph./ha	Newly reclaimed field (grass swamp)	Previously cropped field	
			after fallow (forest)	after 2nd crop (grass swamp)
			N.B. seed rate 20% more	
30	0	33.3	48.4	28.9
	100	—	48.2	27.8
	150	36.0	42.6	—
	200	—	47.1	27.8
	300	—	—	27.3
50	0	33.5	49.4	32.1
	100	—	45.7	34.6
	150	39.1	41.5	—
	200	—	41.3	36.3
	300	—	—	40.2
70	0	32.1	46.7	33.4
	100	—	43.3	34.1
	150	38.4	43.4	—
	200	—	44.7	37.9
	300	—	—	38.9
90	0	32.2	43.8	31.5
	100	—	43.0	33.4
	150	40.7	46.0	—
	200	—	38.6	41.3
	300	—	—	35.8
(Sign. diff. not available)				

soil, the degree of flatness of the field, and the method of sowing. The choice of seed rates influences weed development, uniformity of ripening, the occurrence of lodging, and the yield.

Tables 47, 48 and 49 show the results of some seed rate tests. The principal conclusion to be drawn from these figures is that the effect of the seed rate was of little importance in the tests. This is very clearly shown if we compare it with the effect of 100 kg. of sulphate of ammonia, or with the differences in yield as between varieties.

However, more attention is paid to the quality of the sowing on trial fields than under practical conditions. Also, excellent uniform parts of plots are selected for test fields. This means that in practice a higher rate has to be used than is indicated by the tests. The higher the seed rate, the less chance there is of open patches in the crop. Therefore, when it was found in experimental fields that higher seed rates caused no reduction in yield either, such higher rates were being employed all the same for the practical area. In 1955 the rate was about 60 kg/ha; it gradually increased afterwards to

TABLE 48 *Results of seed rate and N level experiments with the Dima, Nickerie and 80/5 varieties during the 1957 main season*
In 100 kg paddy/ha – 14% m.c.

Seed rate	Fertilizer level	On newly reclaimed field (grass swamp)			On previously cropped field after fallow (forest)			On previously cropped field after 2nd crop (grass swamp)		
		Dima	Nickerie	80/5	Dima	Nickerie	80/5	Dima	Nickerie	80/5
60	0	29.7	30.6	39.1	28.2	32.6	31.1	24.0	32.0	22.7
	100	30.4	37.2	43.4	29.7	39.9	35.2	26.6	32.3	27.1
	150	—	—	—	29.1	33.8	31.4	—	—	—
	200	30.5	36.1	42.3	—	—	—	30.7	34.4	31.6
	300	—	—	—	—	—	—	31.6	36.7	30.1
90	0	29.5	28.9	34.7	30.5	31.8	28.9	21.2	28.1	22.2
	100	29.7	31.4	42.1	30.8	38.2	34.3	28.8	32.0	30.7
	150	—	—	—	30.4	34.6	30.6	—	—	—
	200	29.6	36.6	41.6	—	—	—	28.1	28.4	29.9
	300	—	—	—	—	—	—	29.7	30.8	32.0
120	0	28.6	28.5	34.7	26.5	34.5	31.3	22.0	23.4	23.3
	100	30.0	33.7	40.8	28.4	38.5	36.0	23.6	30.9	29.2
	150	—	—	—	29.0	35.6	33.8	—	—	—
	200	28.1	32.7	39.9	—	—	—	26.0	31.1	31.9
	300	—	—	—	—	—	—	26.3	33.2	32.9
(Sign. diff. 99% seed)		—[1]	—	—	—	—	—	(5.0)	—	—
(do. fertilizer)		—	(3.5)	(1.7)	—	(4.7)	(2.8)	(2.9)	(2.7)	(4.0)

[1] Not available

about 100 kg/ha in 1958. Moreover, the denser stand of the crop reduced weed development and ripening was more uniform.
Some disadvantages of the dense stand might be more fungus diseases, more difficult control of insect pests, and weaker stems which might lead to more lodging. Hitherto it has not been possible to show that these factors have any considerable effect.
According to TEN HAVE (1959 a), however, seed-rates should be diminished somewhat on very fertile soils.

RE-SEEDING OF UNSUCCESSFUL PLOTS

For various reasons rice sowing may be less successful or a complete failure. The chief causes, which have already been discussed above, are diseases, pests, weeds, drying up, smothering by too much coverage of water and soil or by lack of oxygen, washing away, and poor seed quality.
When confronted with an unsuccessful field it is always difficult to decide whether or not to re-sow. During the first week after sowing, especially if sowing is done in water, it is difficult to obtain a good idea in how far plant spacing is deficient. But the first week is the only one in which the emergence can still be corrected by supplementary sowing. Afterwards, this measure is

TABLE 49 *Results of seed rate and N level experiments with the Dima, Nickerie and 80/5 varieties during the 1957/58 second crop season*
In 100 kg paddy/ha – 14% m.c.

Seed rate	Fertilizer level	After main crop (grass swamp)		
		Dima	Nickerie	80/5
60	0	48.2	39.2	40.5
	100	57.6	49.3	43.6
	200	55.0	52.2	45.1
100	0	46.0	40.3	41.7
	100	53.3	44.9	41.9
	200	55.2	52.8	45.2
140	0	45.2	41.2	38.0
	100	52.8	47.4	41.2
	200	53.3	50.9	42.2
180	0	44.6	41.1	35.0
	100	52.1	44.4	40.3
	200	54.0	49.0	40.0
(Sign. diff. 99% seed). . . .		(4.2)	—[1]	(7.1)
(do. fertilizer)		(2.3)	(2.7)	(2.6)

[1] Not available

no longer effective owing to the difference in ripening between the first and second sowings. The remains of the unsuccessful crop should then first be eliminated by cultivation. This frequently presents difficulties on account of the soft soil, so that in many cases a mixed crop still results. Even if only few plants from the first sowing remain alive, their harmful effect is great owing to the vigorous tillering of these plants resulting from their start on the second sowing. If possible it is best to remove the older plants by hand. From experience in the Wageningen project it has become evident that the result of re-seeding is usually disappointing; therefore, it should not be too readily adopted. Owing to the vast tillering capacity of the rice varieties in use, even an extremely sparse emergence may still lead to a good yielding crop. The results of the seed rate tests indicate in the same direction (Tables 47, 48 and 49).

CHAPTER XIV

WEED CONTROL

In weed control in the rice fields of the Wageningen project we should distinguish between control of grasses and control of other weeds. This distinction is essential, since, whereas the latter group of weeds can be controlled directly by weedkillers, the grasses cannot.
The grassy weeds must be controlled preventively by means of a permanent layer of water on the sown field.

Control of grassy weeds

In 1951–52 weed control was still the big unsolved problem in mechanized rice growing in Surinam.
In the Prins Bernhard polder at this period very serious infestation of the fields by grassy weeds had to be contended with. It was clear that with the method of cultivation used, grass infestation in the rice fields was increasing steadily and mechanized rice growing could no longer be carried on in this way. This method of cultivation was entirely similar to the general method of growing cereals, except that about three weeks after sowing the fields were flooded to a depth of 10–15 cm.
In consequence of the favourable results obtained in the control of grassy weeds in the U.S.A., Italy and other countries by sowing in water and maintaining permanently a substantial layer of water on the field, this method was also tested in the Prins Bernhard polder. It was, in fact, found that the grass could be effectively controlled as well as the other weeds. Initially it was, however, difficult to obtain a satisfactory emergence of the rice through the water. The principal cause proved to be damage by water snails and after appropriate control measures could be developed (p. 189) sowing in water subsequently was generally applied.

In the discussion of sowing it was stated that although sowing in water is accepted practice there are often reasons why this cannot be done. In the first place there was the category of newly reclaimed fields. In the case of the latter, sowing in water was definitely not so urgent because grass infestation on these fields was always slight at the beginning. With the various other special conditions described in the chapter on sowing, some risk exists that harmful grass growth may occur.
However, this need not become a serious affair as the conditions forcing to dry sowing do not occur every year on the same field. Furthermore, also a partial application of a layer of water during the period from sowing to some

two weeks afterwards already gives a sharp check on grassy weed development.

In 1953 DIRVEN (1953, 1955 and not publ.) collected some important data on weeds in rice fields in Surinam, especially in connection with the possibilities of control by selecting the correct methods of cultivation.
Table 50 shows the results of his observations on the number of seeds per stalk, the maximum viability by which is meant the viability after the effect of any periods of dormancy, and the depth of water at which various weeds can no longer grow.

TABLE 50 *Properties of rice-weed seeds*
(Dirven, 1953, 1955 and not publ.)

Weed species	number of seeds per stalk	maximum viability %	water depth at which no further growth occurs
Grasses:			
Leptochloa scabra Nees	c. 5000	82	...
Echinochloa colonum (L.) Link.	c. 300	27	5 cm
Echinochloa cruspavonis (H.B.K.) Schult.	c. 1400	10	5 cm
Ischaemum rugosum Gaertn.	c. 50	100	10–20 cm (at 10 cm considerable suppression)
Other weeds:			
Cyperus articulatus L.	...	1	...
Fimbristylis miliaceae Vahl.	...	38	15 cm
Jussieua sp.	...	...	20 cm

... No observation made.

Owing to the small number of seeds of *I. rugosum* it might be expected that rapid spread of this species could be prevented. However, this grass is the only one of the species investigated which has a period of dormancy of about three months, rendering control very difficult. The high viability is also an unfavourable characteristic.
The layer of water required to prevent further growth of the weeds was in some cases fairly high. But in the experiments growing conditions for the weeds were rather favourable, so that in practice 15 cm will be usually sufficient.

The principal grassy weeds found in the project area were, in order:
Ischaemum rugosum Gaertn., *Leptochloa scabra* Nees, *Echinochloa cruspavonis* (H.B.K.) Schult. and *E. colonum* (L.) Link.
At the beginning *I. rugosum* did not occur. It was found, that infestation

took place via imported seed. The seed of *I. rugosum* is so large that it is not sufficiently sorted by mechanized seed cleaning. Hence, *I. rugosum* should on no account occur on seed fields.
I. rugosum is the most dangerous weed at Wageningen and in the whole of Surinam. Its common name is *saramakka* grass. This species of grass also occurs in other rice areas in the world. In Madagascar, for example, it is considered the greatest foe of rice growers. *I. rugosum* is characterized by an exuberant vegetative growth which completely smothers the rice plants. It has a growing period as long or even longer than the rice varieties in use in Wageningen.
Leptochloa scabra does most damage to the rice crop in the tillering period as it then reaches its maximum development. This grass ripens earlier than the rice, so that the crop can still recover somewhat towards the end of the growing period. If *L. scabra* infestation occurs, it may be advisable to apply extra top-dressings of sulphate of ammonia to promote the growth of the rice.
Echinochloa cruspavonis chiefly occurred at Wageningen on newly reclaimed fields. The damage was not as serious as expected owing to the fairly slight tillering of this grass.
E. colonum is a less aggressive species of grass which usually causes only limited damage to the crop.

Apart from the damage which the weed grasses do to the rice crop by direct competition, they are also a source of infection for diseases and pests.
In particular it was found at Wageningen that *Helminthosporium oryzae* regularly appeared on Dima plants in and around patches of *Leptochloa scabra.* Fields with much grass were also often found to be worse infested by such insects as Jassidae and Delphacidae.

Just as in the Prins Bernhard polder, it was found at Wageningen that fields which for various reasons could not be sown in water for some years, developed such a grass vegetation that rice growing became impossible, unless the crop was sown in water. Hence the only solution was always to remove as quickly as possible the impediments to sowing in water.
If sowing in water were always possible, and always by the right method, virtually complete weed control would be obtained both in the case of grasses and non-grassy weeds. Floating water plants and Algae are the only exception. This group of water plants caused occasionally limited damage, especially when the fields could not be temporarily drained for their control. *Nymphoides* sp. (*pankoekoe*) and duckweed appeared on fields which had stood a long time under water without a crop, e.g. for wet fallow, or on patches where little or no rice had emerged. Control by chemical means had little success. Otherwise little is known about these Algae and floating water weeds.
Chemical control of grass weeds was not possible. For direct control hand weeding is the only method.

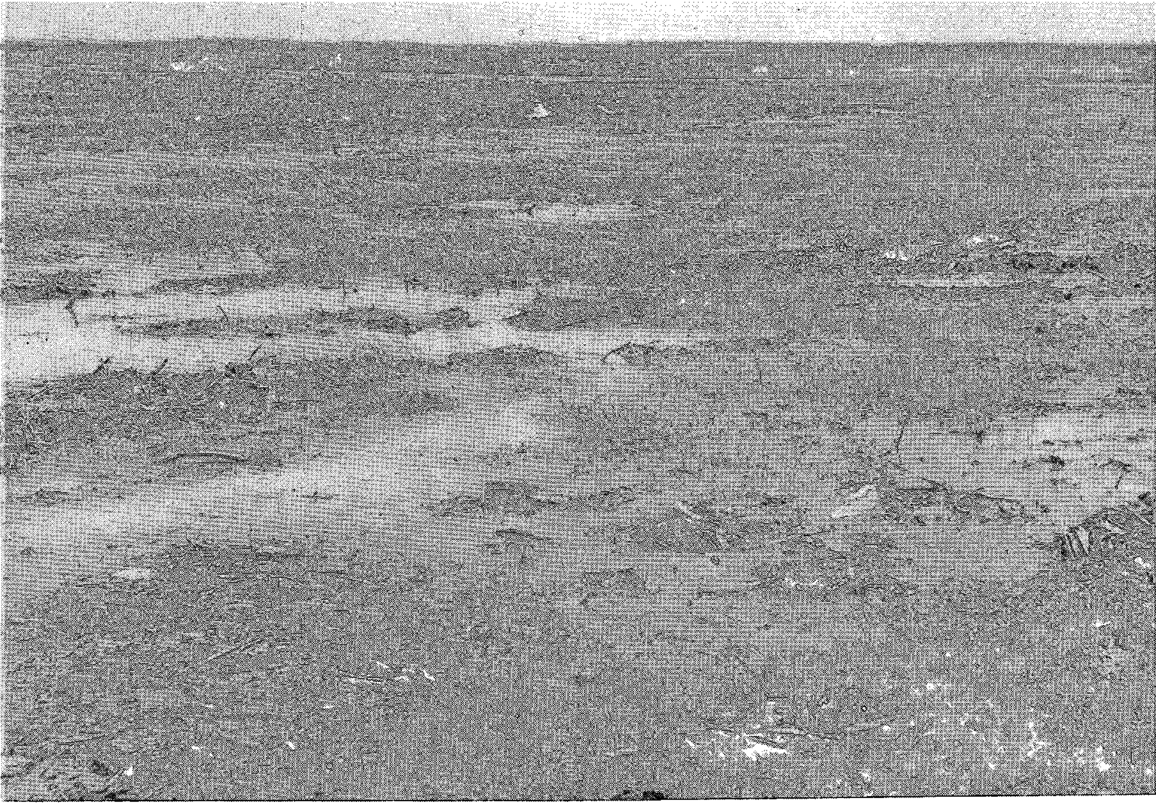
Control of non-grassy weeds

Apart from control by manipulating the water-level in the fields, the non-grassy weeds can also be controlled with herbicides.
The principal non-grassy weeds are, in order: *Sphaenoclea zeylanica* Gaertn., *Aeschynomene sensitiva* Sw., *Jussieua* spp., *Cyperus articulatus* L., *Fimbristylis miliaceae* Vahl, *Thalia geniculata* L., *Cyperus giganteus* Vahl, *Torulinium ferax* Urb., *Sesbania exasperata* H.B.K., *Nymphaea* spp. and *Nymphoides Humboldtianum* (H.B.K.) O. K.

The occupation of the fields by these weeds was different for virgin reclamation fields in grass swamp and forest, and for fields which had already been in cultivation for some years. In the grass swamp reclamation, some of those species usually predominated, which had already occurred in the original vegetation, e.g. *C. articulatus*, *C. giganteus* and *Typha angustifolia*.
Aeschynomene sensitiva was a special exception; this plant occurred only rarely in the original vegetation, but after the reclamation tillage it appeared repeatedly as a uniform dense stand.
In the forest reclamation the original weed vegetation was more varied and of greater extent. *Jussieua* spp., *Thalia geniculata*, *Cyperus giganteus*, *Torulinium ferax*, *Sesbania exasperata* and *Canna glauca* predominated in various combinations.
Except for *Jussieua* all these weeds occurred less after some years of cultivation.
In the older fields *Sphaenoclea zeylanica* and *Fimbristylis miliaceae* were more noticeable than other weeds. As in the case of the grasses, the principal and most difficult weed among the non-grasses, viz. *Sphaenoclea zeylanica*, did not originally occur in the Wageningen area.
It would, however, not have been possible to avoid infestation, as it has an abundant production of a powdery seed, capable of adhering to any object and of "floating" on the water. *Sphaenoclea* also occurs in rice fields in the U.S.A. (RYKER, 1948) and West-Africa (DE WIT, 1958).

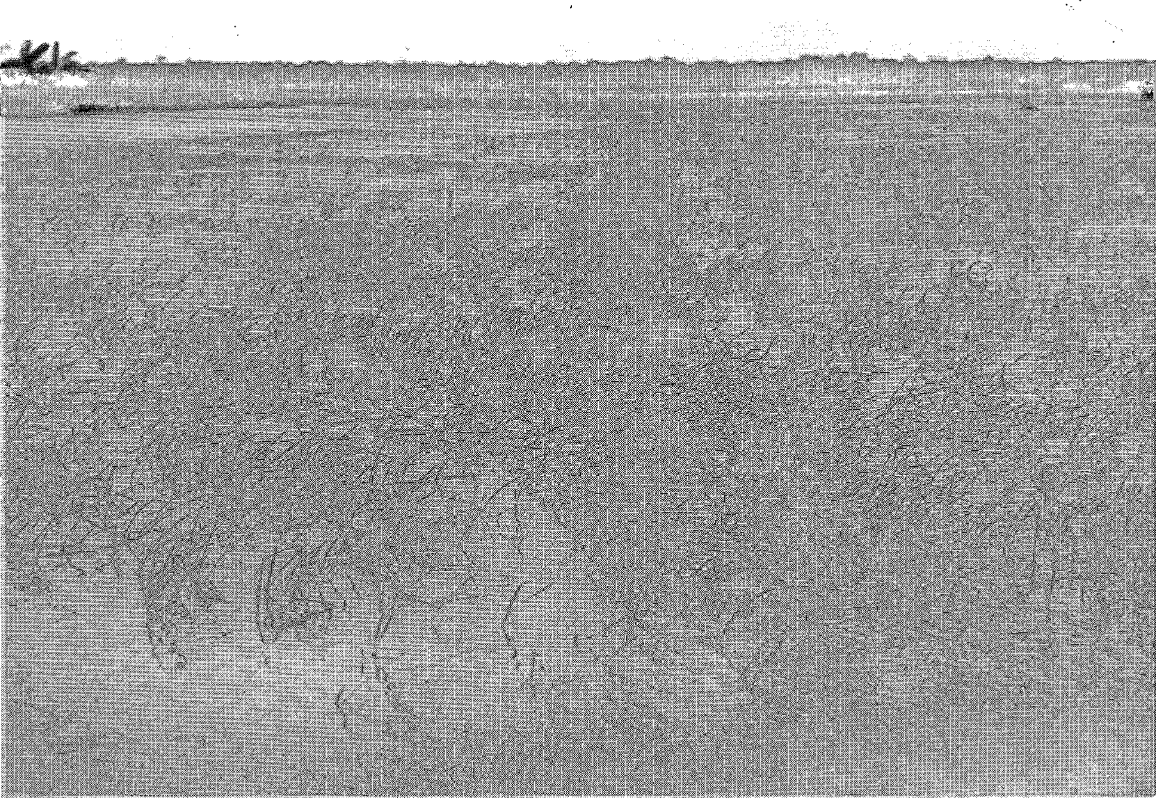
Of the weeds mentioned, *Sphaenoclea*, *Jussieua* and *Fimbristylis* are especially harmful to the young crop in that they smother the rice plants and check tillering. *Aeschynomene* and *Sesbania* often do not reach full development until the rice ripens; during harvest they can consequently cause clogging of the combines.

The main aspects of chemical control of the non-grassy weeds occurring at Wageningen, were investigated by JONGE POERINK (1953). He demonstrated that except for *Aeschynomene* sp., *Sesbania* and *Sphaenoclea*, the said weeds could be controlled with 1.7–1.8 kg acid equivalents of MCPA and 2,4–D/ha. He stated that MCPA was preferable as it does less damage to the paddy; moreover, it was more effective against *Thalia*. For control of *Aeschynomene* and *Sesbania*, JONGE POERINK advised 50/50 mixtures of 2,4–D and 2,4,5–T, at rates of 0.9–1.2 kg acid equivalents/ha, and for *Sphaenoclea* the same mix-



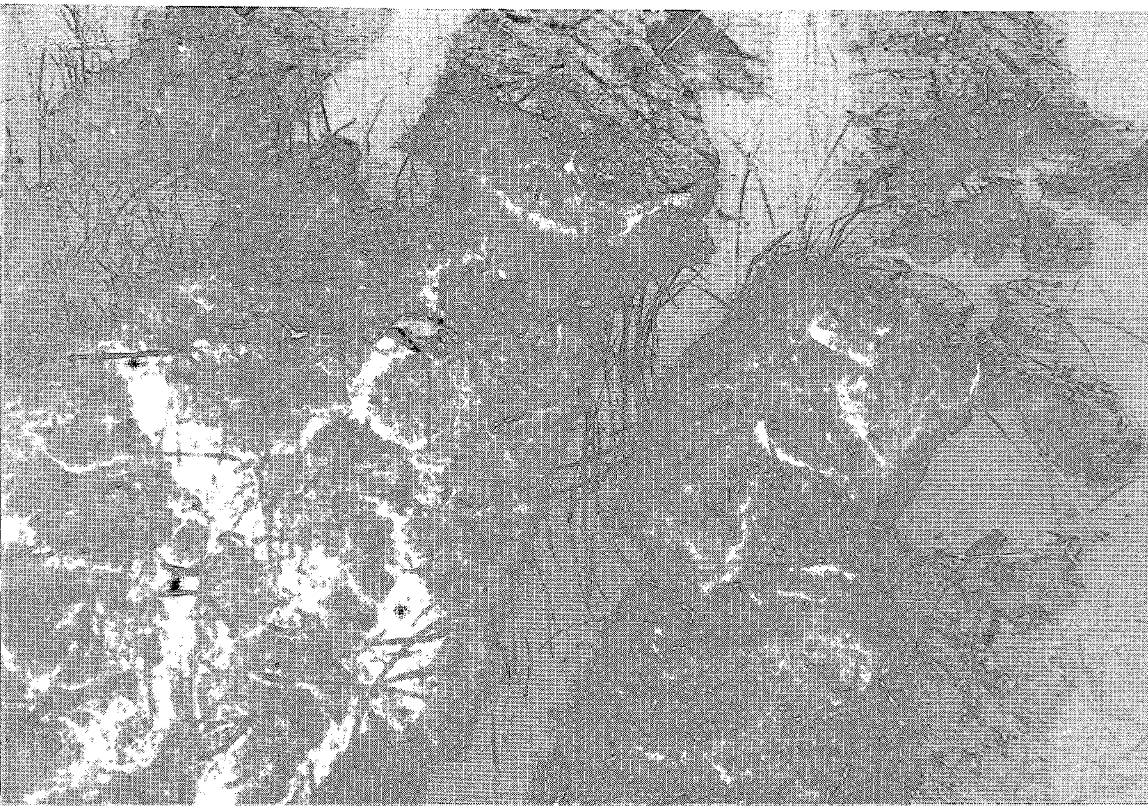
35. *Young planting sown on pegasse-mud of virgin field; bad stands in puddles and on trash.*

36. *Young planting sown in water.*



37. *Young planting sown on furrow of Solotrac plough on virgin land.*

38. *As 37: close-up. On top of the furrows the plants have a shortage of water; between the furrows there is too much water and much seed has been covered by silt.*



ture but at 1.2–1.6 kg acid equivalents/ha. These mixtures were also effective against the other weeds.

In practice at Wageningen the following materials and rates were used: 3 litres MCPA (50% NH_4 salt) or 1.8 kg acid equiv./ha, except for *Aeschynomene*, *Sphaenoclea* and *Sesbania*;

2–2.5 litres Brushmurder (26.5% isopropylester of 2,4–D and 26.5% isopropylester of 2,4,5–T) or about 1.0–1.2 kg acid equiv./ha where *Aeschynomene* and/or *Sesbania* occurred in considerable quantities; 2.5–3 litres Brushmurder if *Sphaenoclea* also occurred. Since *Sphaenoclea* and/or *Aeschynomene* almost always occurred in the weed population, Brushmurder was used almost exclusively.

The chief drawback of chemicals containing 2,4,5–T compared to MCPA or 2,4–D is its higher price.

JONGE POERINK found that the best time for application was when the rice crop was between five and eight weeks old. Spraying when the crop is older than 8 weeks is definitely inadvisable, owing to the increase in damage of the rice.

JONGE POERINK's chemical weed control investigation in 1952–53 in the Prins Bernhard polder was based on the then usual spraying rates of 100–200 litres/ha. The application of such quantities with knapsack sprayers was obviously expensive, which is why knapsack spraying was not considered attractive in the early years. Hence, in the initial period mechanical application with mobile sprayers was the preferred solution and when this frequently proved impracticable due to the softness of the fields, it was thought that the only way to provide a good solution to the weed control problem on the Wageningen project was by the use of aircraft. Purchasing of aircraft was seriously considered, but has not hitherto been effected. The reason for this was not the cost of one or two aircraft, but the cost of constructing an airfield which could be used under all weather conditions, while attracting staff for flying and maintenance of the aircraft also formed an expensive complication.

Moreover, it was then not yet known how weed development would progress on the fields. By sowing in water it was found possible to keep the fields practically free from weeds, so that it now only depended on whether this method could be regularly applied to the entire area. Hence, there were uncertainties which made it desirable to exercise caution before making large investments.

After the Surinam Aviation Company (a government's subsidiary) had been established in 1954, its object being to improve inland communications to which end it purchased small aircraft (4–8 persons) and two helicopters, it was obvious that Wageningen should co-operate with this company. In 1955 matters had progressed so far that a Bell helicopter with pilot and mechanic was made available for weed control at a cost of Sf 120/flying-hr. About 1900 ha of the 1955 main crop were sprayed by this means with fa-

vourable results. (A not foreseen nuisance was, however, that almost all non-graminaceous plants outside the rice fields in the polder, such as various fruit trees and even the indoor plants in the houses, were killed as well.) With the helicopter were applied only 25 litres spray/ha. At a working width of 10 m, the mean rate, including fuelling and charging time, was 33 ha/flying hour. The tanks were filled mechanically with a mobile battery of 4 Urgent mist sprayers[1], from which the spray booms had been removed. In this way the mobile sprayers, which could not be used much due to the soft terrain, found a useful application.
The mentioned spray rate and working width were based on experience gained in the U.S.A. With a view to achieve a higher capacity/flying hour, we also tried a working width of 15 m and a spray rate of 18 litres/ha.
The results were less perfect, but sufficient enough to warrant preference to this method, in case of the rental of Sf 200/flying hour which was being envisaged by the aviation company for 1956.

However, in 1956 the said company was unable to station the helicopter at Wageningen at the appointed time, and we were obliged to carry out all weed control with knapsack sprayers (Saval, Breda, Neth.).
Fortunately, since mist nozzles had come on the market in the meantime, it was possible to reduce the quantity of spray to 20–30 litres/ha. This was important as sufficient distances could now be covered with a tank only half full, and moreover less time was lost by filling up. Carrying full tanks (15 litres) was too hard a task for the labourers, especially on soft virgin land; consequently, working rates were low and the quality of the work left much to be desired.
A further advantage of the fine mist which remained suspended in the air for a short while, was that it spread out over parts of the fields which the labourers had, in fact, missed. The rate of work which could be achieved with Saval knapsack sprayers with mist nozzles was about 0.3 ha/man-hour.
The final results of control with knapsack sprayers were considerably better than had been expected and from the point of view of costs even preferable to the helicopter. The most important advantage of application by knapsack sprayer was the saving in spray materials, since every patch of weeds could be tackled individually, which is, of course, impossible with helicopter application.

After 1956 it was decided to carry out chemical weed control provisionally with knapsack sprayers, one reason being that the investments involved were small, and so that a long-term view could be taken of the development of the problem.
It was, in fact, found that the part of the area on which chemical weed control had to be carried out, became rapidly smaller in later years. This

[1] Urgent mist sprayer: manufacturer – Saturnus, Haarlem (Neth.); Model 2 TM, working width 12 m, driven by a small petrol engine, 400 litre tank, mounted on a two-wheeled trailer.

was because the condition of the fields improved (a.o. through levelling and the clearance of the pegasse), so that they could be sown in water, or at least were dry only for such short periods after sowing that weed development remained small.
In 1955, chemical weed control was applied to about 100% of the area, in 1956 to about 50%, in 1957 to about 20% and in 1958 to about 25%. In 1958 it was decided to replace the Saval knapsack sprayers by Kiekens-Dekker (Wadenoijen, Neth.) powered knapsack misters, with which about twice the amount of work per man hour could be done than with the Savals. In 1958 a fresh start was also made on experiments with mobile tractor-sprayers which, owing to the gradual stiffening of the soils, now began to afford better possibilities than in the early period of the reclamation.

The floating water plants in the irrigation and drainage channels formed a separate control problem. The principal plant is the water hyacinth (*Eichornia crassipes* Solms). Although the water hyacinth is fairly susceptible to hormone weed-killers, when spraying was carried out on a practical scale the result was always unsatisfactory, owing to the ability of this species to spread rapidly. Moreover, other weed-species occurring in the channels, such as Polygonaceae and Gramineae, are resistant to chemical control. Control is therefore done by manual cleaning. The costs of this become exorbitant, however, if the channels are not attended to regularly and carefully in order to remove every single water hyacinth.

CHAPTER XV

MANURING

From numerous fertilizer trials carried out by TEN HAVE (1958a), VAN DER MEULEN, DE LINT, GEERTSEMA, STUBBS and the author, between 1950 and 1958, it can be concluded that only green manuring and dressing with N-fertilizers had an effect on rice production.

The question is whether this state of affairs will continue. In order to provide information on that, permanent N-P-K-trials were laid down in the Prins Bernhard polder and at Wageningen. Our objection to these permanent trials is that they are not related to the state of the practice fields.
Suppose, for instance, that in 1965 a distinct P-effect is found for the first time in the trial, and that this is repeated in the succeeding years. In such a case all we know is that after some 10 years of annual phosphate dressing there is an increase in yield. This is a situation which owing to economic reasons does not arise at all in practice. For this reason, in 1956 we earmarked a particular 10 ha field for an N.P.K. block test shifting every year, i.e. the trial is laid down permanently but always in a different part of the field. Hereby was stipulated that cultivation on this field should correspond to average practical conditions. In view of the fairly high cost of tending trial fields, there is for the rest much in favour of repeating the N-P-K-trial only once every two or three years.

Green manuring

Green manuring has already been discussed in connection with the cultivation plan (p. 134,136). Owing to the natural richness of the young reclaimed land there was little sense in carrying out many green manuring experiments at Wageningen.
TEN HAVE (1959c) in particular, pointed out the importance of this form of manuring in experiments on the poorer soils of the Prins Bernhard polder.
If we compare green manuring with dressing of artificial N-fertilizers, it is noticeable that the rice crop often grows up healthier after green manuring. The function of green manuring is not only to make up N-deficiencies.
The organic material also increases the activity of the soil, and can supply the rice plants with various minerals in a more readily absorbable form. Up to date at Wageningen rice does not respond to phosphate fertilizers but *Crotalaria quinquefolia*, for example, does, so that in this roundabout way it might be possible to improve the P-nutrition of the rice.

It may also be supposed that, owing to their deeper root system, green manure plants are better able to utilize the higher P contents of the sub-soil.

Some attention was paid to the wild legumes occurring on the fields of the project. *Sesbania exasperata* and *Aeschynomene sensitiva* were not attractive as they occur as weeds in rice fields and because of the difficulties of obtaining seed. *S. exasperata* moreover had a fairly woody stem. Somewhat more was expected of *Phaseolus pilosus*, a creeping kudzu-like plant, which did grow well on a waterlogged field. The tough twines were however a drawback during tillage. A greater disadvantage was the slow initial growth, it being frequently unable to compete with other weeds. Seed would have to be obtained by hand, and the seed production of the plants was also quite small. Propagation by cuttings was fairly successful so that it would be possible to form a stand by harrowing in parts of plants. *P. pilosus*, like *Crotalaria quinquefolia*, sows itself so that it may return of its own accord after interruption with a rice crop, but usually only with insufficient stand density.
The investigation of *P. pilosus* was stopped when it was found that *C. quinquefolia* was superior in various respects. Nevertheless, there are possibilities in the selection of wild legumes, one reason being that some of these plants, such as *P. pilosus*, grow much better than *C. quinquefolia* under waterlogged conditions.

Nitrogen fertilizing

Even the first fertilizer trials in the Prins Bernhard polder did show that only NH_4 fertilizers were suitable, and moreover that these had to be applied as a top-dressing (TEN HAVE, 1958). Nitrate fertilizers had practically no effect and the same may be said of any N fertilizer applied before sowing.
The most obvious explanation of this is that the nitrate fertilizers are reduced in the sawah environment, as a result of which the N is released in gaseous form and escapes. The small effect of the application of NH_4 fertilizers during tillage is explained by oxidation to nitrates which are then reduced again to free N, etc.
Further research on this subject is desirable.

THE CHOICE OF FERTILIZER.

The choice of ammonium fertilizers was small, viz. sulphate of ammonia, ammonium phosphate, ureum and calcium cyanamide. Hitherto preference has been given to sulphate of ammonia.
Urea was equally good in fertilizer trials but caused difficulties in storage because of its hygroscopic properties. It now seems that a non-hygroscopic grade has recently been marketed, in which case urea will be a competitor of sulphate of ammonia. Objections to sulphate of ammonia are the sulphate residue and, of course, the higher cost of transport per kg N.
Application of ammonium phosphate has no sense as long as no increase in yield is obtained by applying phosphatic fertilizers.

Calcium cyanamide is unsuitable for application by top dressing and no definite results have yet been obtained by applying it during tillage. As weather conditions frequently make the use of fertilizer distributors impossible, application is always done by hand. This is not attractive with calcium cyanamide, even in granular form. Finally, calcium cyanamide does not keep well in a damp climate on account of its tendency to caking.

THE APPLICATION TIMES AND RATES.

The investigation into the best times and rates of application was chiefly carried out with sulphate of ammonia.
Most investigations on this subject were undertaken by TEN HAVE (1958a) in the Prins Bernhard polder. He found that with rates of up to 150 kg sulphate of ammonia/ha, the best application time was at about 8 weeks after sowing and that with rates higher than 150 kg/ha, two applications were preferable at about 7 and 10 weeks after sowing. TEN HAVE obtained the following mean increases in yield with different fertilizer rates:
100 kg sulphate of ammonia/ha: 520 kg paddy (average of 26 field trials)
200 kg s.a./ha : 940 kg paddy (average of 22 field trials)
300 kg s.a./ha : 1200 kg paddy (average of 11 field trials)
According to TEN HAVE, main and second crops respond approximately the same to sulphate of ammonia dressings.

The results of the fertilizer trials at Wageningen reflect the peculiarity of the fertilizing problem on such reclaimed soils.
Table 51 shows the average yield increases from a great number of trials in 1956 and 1957.

TABLE 51 *Average yield increases from fertilizer trials with sulphate of ammonia for the main seasons 1956 and 1957 at Wageningen*
In kg paddy/ha, with 14% moisture

	Control		100 kg s.a./ha		200 kg s.a./ha	
	yield	no. of trials	yield increase	no. of trials	yield increase	no. of trials
1956: from all the successful trials	3615	11	135	8	195	8
From the trials with 99% positive significant differences only	3408	4	321	4	497	4
1957: from all the successful trials	3001	15	367	14	390	8
From the trials with 99% positive significant differences only	3040	10	482	10	577	5

The fertilizer effect was much less evident than on the "poorer" soils of the Prins Bernhard polder. In many tests the effect was nil or negative.

In agreement with the field tests, fertilizer consumption was low in the commercial production area of the project during the initial period. The average consumption was as follows:
in 1954 and 1954–55: 0 kg/ha, 1955 20 kg/ha, 1955–56 10 kg/ha, 1956 70 kg/ha, 1956–57 150 kg/ha, 1957 70 kg/ha, 1957–58 60 kg/ha, 1958 130 kg/ha. The increase in sulphate of ammonia consumption was gradual, except in the second cropping season 1956–57, during which an unsuccessful attempt was made to restore by fertilizing a planted area which had partly failed on account of rats and borers. In the 1956 harvest it was found that with an average of 70 kg/ha the crop was overdressed. The causes were an unexpected increase in the "fertility" of the reclaimed land and the occurrence of *Helminthosporium oryzae*.

The reason why despite the doubtful results of the trials a fair amount of fertilizing was done, was mainly because two types of fields did need fertilizing, viz.:
— Newly reclaimed grass swamp which had still not had a good period of drying out ("maturing") and on which the rice crop grew meagre (p. 109).
— Main crop plantings after a second crop, especially if the fields could not be ploughed. In the 1957 and 1958 main seasons the second crop fields were given about 150–200 kg sulph. of amm./ha.

A great advantage of fertilizing by topdressing was, with the conditions of the Wageningen project, that one could wait and see how the crop progressed before making a decision on the amount of dressing required. The mapping of the original vegetation was also of some help in determinating the amount of N to be applicated, as the results of fertilizing – as to be expected – were generally better on the grass swamp lands than on the forest lands. In the 1957 main season, for example, 40% of the area, mostly consisting of forest land, was not fertilized at all.
Regarding the times of application, the results of trials and practice agreed with the data found by TEN HAVE, except for some "non-matured" reclamation fields in the grass swamp area, where a tendency was found towards a better response to late applications (10–12 weeks).
In general, fertilizing on the project was done rather late in the season owing to the scant knowledge available on the fertility of the new soils, the development of the crop itself forming the main basis of information.

CHAPTER XVI

DISEASES AND PESTS

Introduction

During the entire period from the first sowing in 1954 up to the present date, a large number of diseases and pests have been encountered in the Wageningen project. Several of these were new to Surinam and for most of them no control method had been evolved which was suited to the conditions prevailing.

The new paddy-land at Wageningen suffered more from diseases and pests than the native ricefields in other parts of Surinam.
A number of reasons can be adduced for this, viz.:
— The reclamation work at Wageningen was rapid and thorough. In the space of a few months the entire surroundings were changed. All vegetation was cleared and as much as possible was burned, leading to a disturbance of the biological equilibrium.
Such sudden changes never occur in native rice growing. When new land is reclaimed there, it is an extremely slow process.
— If we compare the lay-out of the native polders with the Wageningen polder, it is noticeable how in the former case small plots alternate with gardens and groves, whereas at Wageningen the fields are large and form an interlocking whole which is only separated by ditches, dams and canals. Groups of trees or even bushes are practically nowhere in evidence. In such a bare land, living conditions are less favourable to numerous natural foes of pests. It is also conceivable that diseases can spread more rapidly on the large fields.
— Large-scale farming at Wageningen, in particular mechanization, has inevitably resulted in different methods of cultivation from those in normal use among the native population.
In certain respects this adaptation has led to an increased occurrence of diseases and pests, viz.:
a. The two-crop per year system might enhance the occurrence of some pests and diseases.
b. The newly selected rice varieties had stiff straw, high productive capacity and good quality, but on the other hand greater susceptibility to diseases and may be also to pests.
c. The use of the direct sowing method, instead of the nursery method followed by transplanting, exposes the rice plant to a greater extent to various pests, particularly during the very sensitive early period.
d. The frequent use of direct and preventive chemical control in a very non-

selective form (termed "blanket applications" by SANGER (1958)) destroys predators and parasites at the same time.

In a thus "disinfected" environment it is difficult to ensure such a biological equilibrium as will provide the rice plant with a satisfactory natural protection.

According to LAIRD (1959) chemical control of an insect plague may actually lead to a very rapid resurgence thereof, the reason being that the natural foes usually have a longer life-cycle than the insects causing the plague, so that the latter are able to recover more quickly.

— The water management system applied at the project resulted in a pollution of the irrigation water with drainwater. This caused a rapid spread of infection of snails and possibly also of some diseases.

This typical difference between small and large-scale agriculture with regard to diseases and pests, was also found by VAN FREYBURG, when he tried from about 1950 to 1952 to establish a large estate in the Saramakkadistrict (Sur.) for the mechanized cultivation of groundnuts. Despite chemical control measures his crop of 100 ha, for example, was continually stripped by caterpillars. And Javanese peasants near his estate were growing groundnuts at the same time in their gardens, in which not even the slightest leaf-damage could be found.

1. The diseases

The chief diseases occurring at Wageningen were: *Cercospora oryzae* Miyake, *Piricularia oryzae* Cav., and *Helminthosporium oryzae* Breda de Haan (Syn. *Cochliobolus miyabeanus* (Ito & Kuribayashi) Drechsler ex Dastur).[1] It is difficult to estimate the average loss in production caused by these diseases. At a very rough estimate it can be said that during the years 1956, '57 and '58, the average losses were at least of the order of 10%.

The occurrence of diseases was related to the choice of variety and the excessive nitrogen content of the reclamation soils.

For the first paddy-fields planted at Wageningen in 1954, use was chiefly made of the Rexoro variety, with some additional Bluebonnet. These varieties were subject to severe attack by *Cercospora* and *Piricularia*, the latter occurring as a temporary seedling blight with recurrence in the ripening stage as so called (FARMER'S BULL. NO. 1854, 1951) rotten-necks. This was partly the reason why a rapid change was made to the new Dima variety. Dima did very well in 1955 and despite numerous defects in cultivation, the healthy growth of crop enabled a fairly good harvest to be gathered. Dima was also grown exclusively in 1956, but from this time onward things went wrong. In the initial stage the crop exhibited splendid growth and a good yield was anticipated. However, gradually too heavy leaf development occurred on a considerable part of the area planted. Flowering was still fairly good, but

[1] The Latin names are taken from G. WATTS PADWICK (1950).

afterwards the crop rapidly deteriorated. Spots formed on the foliage and stems. Ripening was unhealthy and resembled withering. Grain setting was poor. A number of fields were so badly infected that the panicles partly rotted away in the stems before emergence. In a later stage the infection was not confined to the paddy-fields with luxuriant growth, but also occurred in many fields with normal or poor development. DEL PRADO (1953) was able to diagnose *Helminthosporium oryzae* as the causative factor.
Disturbed by this trend it was decided to spread the risk to a greater extent in 1957 and to plant not only Dima but also the new Nickerie, 80/5 and 80/7 varieties which had been hardly infected by this disease in the experimental fields. Yet these new varieties were known to be more susceptible than Dima to *Piricularia* and *Cercospora.*
In 1957 Nickerie behaved fairly as regards diseases, but 80/5 was severely infected by *Piricularia* and *Cercospora,* and due to rank growth and *Helminthosporium* Dima also remained at a low level of production.
The three varieties Dima, Nickerie and 80/5 were again sown in 1958. In that year Dima was the best producer and little affected by disease, whereas 80/5 was very severely attacked by *Cercospora* and to a lesser extent by *Piricularia.*
It is worthy of mention that in the Prins Bernhard polder, i.e. on somewhat older cultivated land, Dima gave a better yield than the other varieties in practically every year mentioned, so that most of the area of this polder was regularly sown with this variety.

Little could be achieved in the way of fungus disease control, save by selection of resistant rice varieties. Hitherto no effect has been observed in chemical control experiments. All seed was constantly treated with organic mercury compounds, but as yet comparative experiments proved no marked effect.
Neither could any relationship be found between the occurrence of diseases and the type of cultural practice (tillage, sowing time, etc.).
The investigation of these problems is still in the initial stage and will therefore not be further discussed.

2. The pests and the control equipment

During and shortly after sowing damage could be caused by snails, seedling-flies, rats, birds and caterpillars. During the development of the crop rats and caterpillars continued to be a danger; the following insect pests then also occurred: delphacids, jassids, stinkbugs and *Diatraea* borers. Finally, during ripening the rats were also a menace, as well as birds, stink-bugs, *Diatraea* and *Rupela* borers.

The control equipment used were Wervelwind motor drift-dusters (manufactured by Haring, Boskoop, Neth.), Saval knapsack sprayers with low volume nozzles, and K.W.H. (Kiekens-Dekker) motor knapsack atomizers. The drift-dusters were used for the rapid application of large amounts of comparatively inexpensive BHC, DDT and Toxaphene powders. In operating these machines, one is dependent on wind direction and force and vertical thermal air currents. The dust has to be applied when there is practically no wind or thermal current, viz. usually in the early morning and towards the evening. The wind direction should be approximately at right angles to the long side of the field, so that the duster travelling along the 600-metre dam has most chance of covering the field width of 200 metres. The fields are fairly well sited with respect to the prevailing north-east winds. During good weather conditions the total range of the motor duster exceeds 200 metres, but the distance over which the dust is fairly evenly distributed is considerably less, so that attempts are often made to work the field again from the other side when the wind changes direction (e.g. as a result of land and sea winds).

The more expensive control chemicals, which are generally used on small areas, are applied by knapsack sprayers fitted with atomizer nozzles, and since 1958 with motor knapsack atomizers as well. Against the better distribution of the control chemical which this equipment provides, stands the lower performance per man-hour. With the Wervelwind duster operated by two men the maximum capacity is 30 ha/hour, or 15 ha/man-hour, with the knapsack sprayer about 0.3 ha/man-hour, and with the motor knapsack atomizer about 0.6 ha/man-hour. But, unlike the motor dusters, the knapsack sprayers can be used all day. Less chemical was used with manual equipment and this usually meant a saving which exceeded the cost of extra working hours. The motor duster was mainly used when there was danger of serious damage and rapid action had to be taken, or when there was a shortage of labour (during the sowing period). For infestations occurring during the growth of the crop, i.e. in off-peak labour periods, more use was made of the knapsack sprayers or motor knapsack atomizers.

3. Snails

The destructiveness of water snails, when rice is directly sown in water, was ascertained by the present writer and studied in further detail (DE WIT, 1955). During the experimental period of sowing in water in the Prins Bernhard Polder a very poor emergence was often obtained. This was explained on the assumption that this method was generally inapplicable in Surinam and the tropics, because the rice seed-sprouts would be unable to grow at the high water temperatures or the low oxygen contents of the water resulting from such high temperatures. This opinion was supported by the pattern of damage, since it often happened that no single seedling remained alive out of a sowing covering several hectares. It was difficult to believe that this could have been due to a disease or pest.

Nevertheless the cause was found to be water snails. The snails suck the newly emerged stem buds from the rice-seed, after which the seed soon dies. They work very thoroughly, each bud being systematically consumed. As a result, even when there is only a small number of snails, a considerable number of bare patches are formed in the field, and when there is severe snail in-

fection practically no emergence at all is obtained. The most dangerous period for snail damage is the first week following sowing.
Snail damage in its most serious form means re-sowing, in which case it is actually and advantage if the entire area has been destroyed by snails, because then re-sowing can be done without renewed tillage.

Two types of snails are found in the rice-fields, viz. *Pomacea lineata* (Spix) and *Pomacea glauca* L., the former being the dominant type.
The easiest way of distinguishing the two types is by the egg clusters. Those of *P. lineata* are red in colour, with considerably more but smaller eggs, whereas the egg clusters of *P. glauca* are green.
The snails have dark-coloured striped shells and are 3–5 cm when fully grown. They are only active in water. On dry land they withdraw far into the shell and in this state they can continue to live for a long period.

In practice it proved a difficult task to establish with certainty the presence or absence of snails on a field to be sown or already sown. This is because the animals may have crept into the soil during a previous drought period or have been worked under during tillage operations. When the field is flooded the survivors gradually reappear.
According to STUBBS (not published) snails found in the drying fields in the quiescent state, do not usually sink more than 5 cm into the ground. They can, of course, reach greater depths by falling in fissures or as a result of tillage. In 1959 the same research worker observed that snails which had been in a quiescent state for four months under dry conditions, had all become active again only five hours after being placed in water. Stubbs conducted experiments in glass pots in 1959 in order to examine the ability of the snails to work upward out of the soil after the field had been flooded. Live snails were placed under layers of soil of varying structure and 5, 10, 15 and 20 cm thick, covered by water to a depth of 10 cm. From under the 5 cm soil layer the following percentages of live snails emerged in 24 hours: silt 20 %, fine clods 40 %, coarse clods 50 % and very coarse clods 75 %. From the soil layers of 10 cm and over, it was only with 10 cm of silt that 5 % emerged. All the others that had not emerged after 24 hours, had suffocated.
This shows that the snails have only a very limited ability of working their way upward. The main determining factor is that the snails under water have to take in air at regular intervals, so that if they are too deep in the soil under water, they are unable to reach the surface of the water in good time.
In addition to the snails found in the field-ditches, pools, and in the soil, they may also be brought in by the irrigation water. In view of the special situation obtaining at Wageningen, where part of the drainage water is pumped from the polder into the irrigation system (see page 229), this source of infection should not be overlooked.
Moreover, owing to their earthy colour it is fairly difficult to notice snails, either in mud or turbid water. We were repeatedly surprised by the extensive snail damage in fields, where previous careful examination had been unable

to reveal a single snail. At Wageningen we first tried control methods only, when at least one snail had been found on a given field, but this method did not work well owing to the extensive cultural practices employed, with little supervision. In the end the snails were preventively controlled in every field in which rice had been sown in water.

The snails were controlled with the well-known molluscicide copper sulphate (fine crystals) and also with BHC (dust). The chemicals should be applied from simultaneously with sowing up to a maximum of 24 hours afterwards. After the field has been thus treated it is preferable not to supply any fresh irrigation water for about a week, unless a grid is placed in front of the inlet culvert to prevent the entrance of snails. But the disadvantage of such snail screens is that they are soon clogged up with all kinds of material entrained by the water.

In case of severe snail infection, a dressing of 5 kg of copper sulphate (fine crystals) per ha in a water layer of 10 to 15 cm, applied by hand broadcasting (e.g. from the seeder), followed by 10 kg BHC-dust (7 % γ and 7 % δ-isomer) per hectare, blown over the field with a motor duster, is nearly always efficacious.

We often applied a smaller dressing, but then the field had to be carefully watched in case a further local application was required. After protracted periods of drought, as well as on newly reclaimed fields in general, there was usually much less snail infection. Fields which had not been sown in water did not have to be treated for snails until they were flooded. In case this first flooding occurred 10 to 14 days after sowing, the rice was less vulnerable and control measures were occasionally omitted. But during intermediate irrigations of short duration when the planting was from 0 to 10 days old, it was always safest to proceed to control measures. Copper or BHC also had to be applied immediately to all pools formed by rainfall (on fields newly-sown on the mud).

In view of investigations, quoted by BROWN (1951), relating to the particular toxicity of the BHC delta-isomer for snails (it was even said to exceed the gamma-isomer which is usually esteemed as the active insecticide), the present writer carried out an experiment in 1953 with *Pomacea* snails, using BHC samples with $3\%\ \gamma + 3\%\ \delta$ and $3\%\ \gamma + 8\%\ \delta$, supplied by Noury & v. d. Lande of Deventer, Neth. It was, in fact, found that the delta-isomer is at least as effective as the gamma-isomer.

Accordingly, attention was henceforward paid to both the gamma-isomer and delta-isomer contents when making purchases of BHC for snail control. A considerable saving was thereby effected, since the delta-isomer is usually regarded as a worthless contamination of the BHC and even injurious as it may effect the flavour when applied to crops late in the growing season, with the result that crude BHC products having high delta-isomer contents are cheaper than the purified products (e.g. lindane).

In 1959 BHC was even applied containing practically only delta-isomer, but the results were not particularly satisfactory. This will be referred to again below.

VAN DINTHER (1957) studied snail control in 1954–56 at the Paramaribo Agricultural Experiment Station. Among other things he found that newly-hatched snails were less sensitive to BHC than the older snails, unlike copper which is also very effective against young snails. This difference in susceptibility favours the combined application of copper and BHC advised by us. In his laboratory experiments performed in vitro, VAN DINTHER obtained an effective kill of young snails with 2 kg of 50% BHC (7% γ + 7% δ) per ha per cm of water; with the use of copper sulphate an effective kill was obtained with 100 g/ha/cm. The control effect of low doses was proportionate to the concentration, viz. the water level.
In practice, however, we found that the amounts of insecticide recommended by this worker were too high for BHC and too low for copper.

On comparing BHC-dust and copper sulphate, BHC appeared preferable, since it can be applied rapidly and distributed fairly uniformly over the field with the motor duster. In this connection it should however be acknowledged that only scant experience has been gained on cuprous dusts, as they were discarded fairly prematurely as ineffective and expensive. The copper sulphates employed are fine crystals and have to be applied by hand broadcasting. Since under the conditions obtaining at Wageningen this cannot be done under continuous supervision such broadcasting is often done badly. A further drawback of copper is that it is rapidly absorbed by the clayey soil, with the result that there is no effective homogenization via solution and diffusion in the water. Consequently, although copper has been occasionally applied at Wageningen at the irrigation inlet, this is a less attractive method.

But the control results were also frequently disappointing with BHC-dust. A plausible explanation of this was given by STUBBS in 1959 (not published), since he was able to demonstrate that there was better control when the BHC, or a part of it, formed a connected film on the surface of the water, because the snails have to come up to the surface about every five hours to get air and thus come into contact with this concentrated film of BHC. On the fields film formation depends on weather conditions (wind) and is also related to the type of BHC used, and in particular the carrier.
When BHC is applied in the form of dust it is possible therefore, to distinguish two toxic effects, viz.: via the film of powder on the water and via the BHC dissolved or suspended in the water or deposited on the bottom. If for any reason there should be no or insufficient temporary film formation when the BHC is applied, a weaker control effect may be anticipated. In VAN DINTHER's laboratory experiments, referred to above, he probably ignored the film effect and, in fact, mixed the BHC doses well with the water with the result that no film at all was formed in the experimental treatments. This would explain why he found higher BHC doses than proved necessary in practice.

In view of the film effect the merits of the BHC gamma-isomer and BHC delta-isomer should be re-examined. According to BROWN (1951) the delta-isomer is more readily soluble in water than the gamma isomer and this may possibly heighten the toxic effect on snails so long as they remain under water, but in our opinion this may be offset by the fact that the toxic effect of the film is reduced by decreasing BHC concentrations. This might also be an explication why applications of BHC delta-isomer only, were not all together satisfactory in practice.
Further research work in this direction will no doubt help to perfect control methods.

In Surinam the snails have a very important natural enemy, viz. the snail hawk (*Rosthramus s. sociabilis* (Vieillot))[1], of which the local name is *pakro-akka*. The birds can be frequently seen in the fields busy catching snails. When they have caught one they always fly with it to a particular tree, post or other prominence in the neighbourhood where they eat their prey. Below these established resting places heaps are found of hundreds of empty snail-shells.
A further study of these birds with a view to snail control would be very desirable. Regarding this we are of the opinion that in the treeless plain of Wageningen more should be done to comply with the habits of the snail hawk, by planting trees or bushes, or by providing simple wooden posts with "landing laths". When the snail population could be further suppressed with the aid of this natural enemy it would be possible to effect a saving in chemical control (which costs about Sf 35,000 to Sf 50,000 per annum for snails alone on the 7500 ha area under cultivation at Wageningen), as well as reduce damage from this cause.
Finally, the interesting fact should be mentioned that at the neighbouring Mahaicony Abary Scheme snails are of no importance as a rice-pest. Biological control methods might be evolved from comparative research on this subject.

4. Seedling flies

The occurrence of this injurious insect was demonstrated by the present writer in rice plantings in the Prins Bernhard Polder in the middle of 1953. The fly was identified through the intermediary of the Agricultural Experiment Station at Paramaribo as a *Hydrellia* sp.
The insect is injurious in the larval stage, on rice seedlings from one to four weeks old. The adult fly (size about 1 × 2 mm) lays its eggs on the first rice leaves. Usually only one or two eggs are found per leaf, although the number may be higher in case of severe infection. Practically 100% of the rice seedlings are affected during only a normal occurrence of the pest.
The larvae hatch about 24 hours after the eggs have been laid and then bore into the leaf where they mine passages which can be identified as white

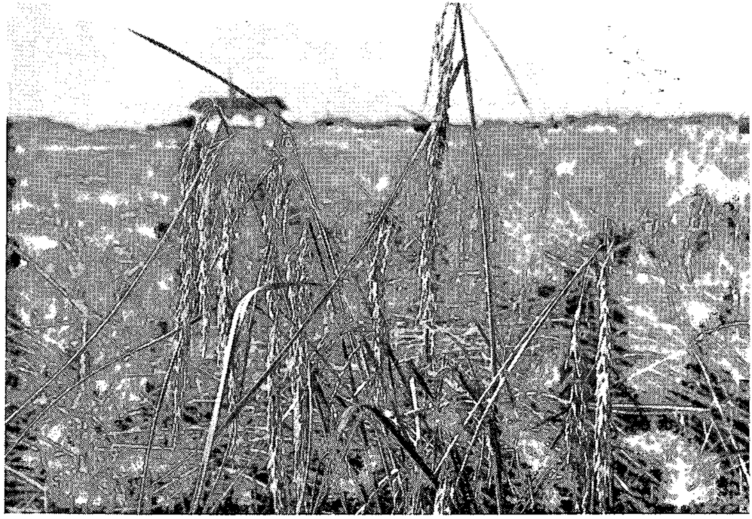
[1]) Latin name taken from F. HAVERSCHMIDT (1955).

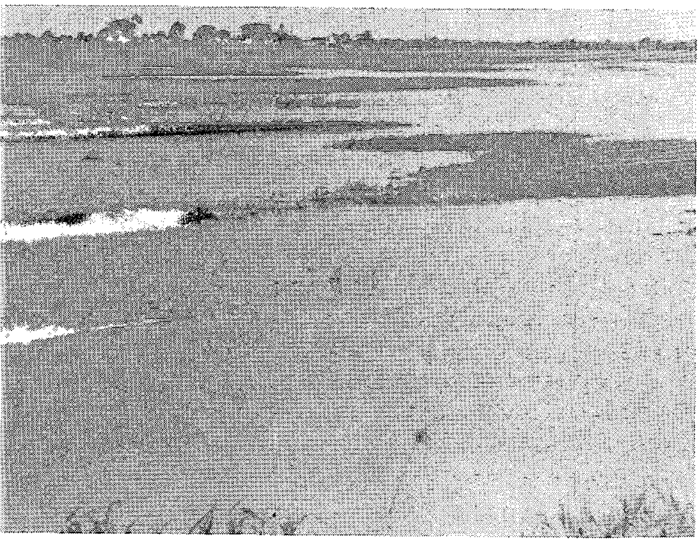
streaks. With rice seedlings standing dry, they also bore to a large extent into the plant-hearts. It therefore follows that the symptoms differ whether the seed is sown in water or on mud.
When it is sown in water the eggs are laid on the first leaf breaking the surface of the water and initially resting on the water. The mining larvae make a wound in this leaf which immediately begins to rot and dies as a result. Meanwhile the rice-seedling sends a second leaf to the surface and this may be infected in the same way. At this stage the rice-plant may be so weakened as to die. In deep water the young plant may be destroyed when only the first leaflet has been infected. The damage is aggravated by Algae and other aquatic plants which cling to the rice plants and draw them down.
When sown on mud there is little or no rotting of the mined leaf, but inasmuch as the larvae can then penetrate into the growing points of the seedlings, also a great many of them die. The growth of another number of young plants is so retarded (up to about four weeks) that they become smothered in weeds. Hence, even under such conditions a great deal of injury is done, although less than when the seedlings are planted in water, when an entire planting can easily be wiped out.

In the Wageningen production area the fly pest occurred every year during the main crop period, but only on late-sown fields. When the sowing period lasted from 6 to 7 weeks it was only found on fields that had been sown during the last three weeks. At a given moment there was a very rapid increase in the fly population, so that the last fields bore the brunt of the infection, especially when they were successively attacked by two generations. As the crop grew older the pest disappeared.
An approximate generation cycle (which according to VAN DINTHER (1960) may last about 3 weeks) could be observed in the infestation pattern. When the egg deposits were first found in any part of the polder they were usually also present on all the newer fields. No fly eggs were ever discovered by the present writer in the second-crop plantings.

Our first impression was that the damage done by these flies was not serious. No control measures were taken in 1954, and, in fact, the damage was not severe during that year. In 1955 the infected fields were only temporarily drained, but in that year considerable damage was caused by the occurrence of hollow patches as well as by retarded growth and weed development. For this reason a systematic chemical control was begun in 1956, the efficacious insecticide dieldrin being employed. Dieldrin was used on the recommendation of articles (e.g. in the RICE JOURNAL, 1953) on the control of an unusually severe plague of the leaf miner (*Hydrellia scapularis* Loew) on rice-fields in California in 1953. According to the description this pest appeared to be closely related to or identical with our seedling-flies.
The insecticide was applied at the project in amounts of 1 to 2 litres of 20% dieldrin/ha to about 20 litres of water, by workmen walking with knapsack sprayers at intervals of about 4 m, with the spray-booms held up.

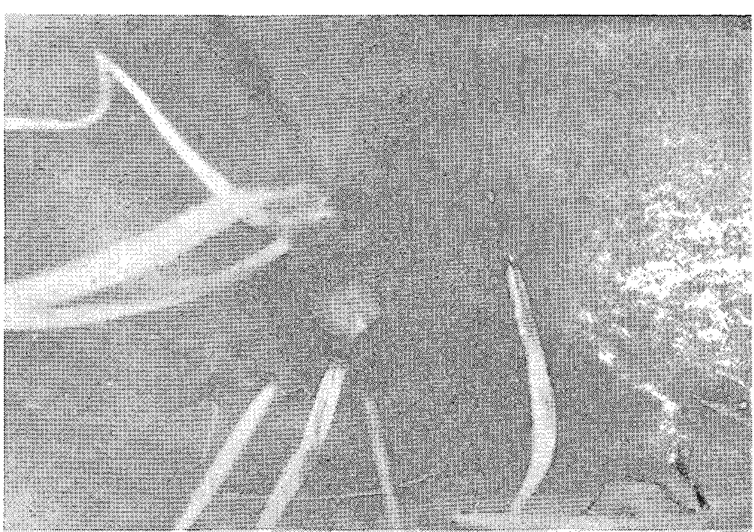
39. *Piricularia oryzae on the 80/5 - variety.*

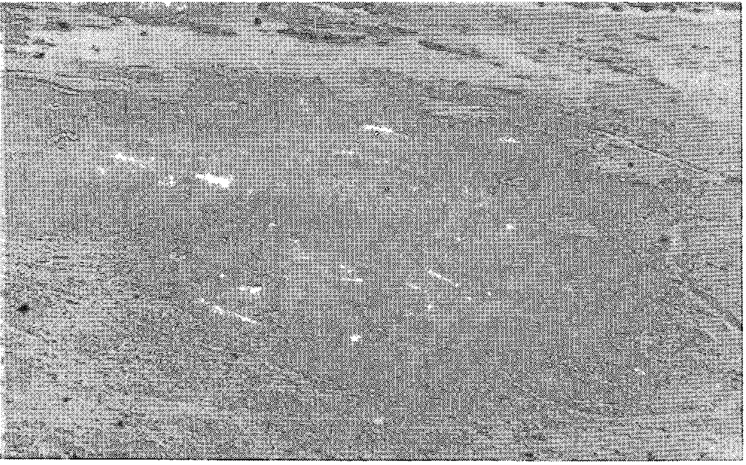




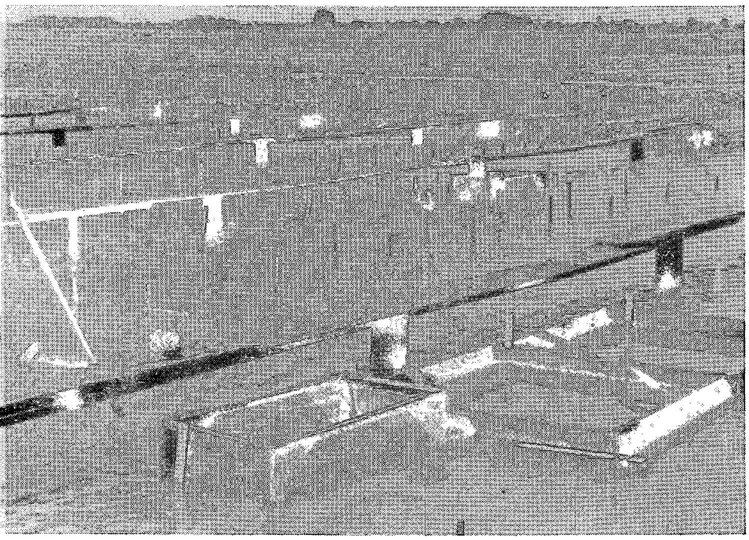
40. *Bad stands of rice due to damage by Pomacea snails.*

41. *Pomacea snail sucking a young rice plant.*





42. *Snail trails on mud after failure of sowing in water.*



43. *Part of experimental set-up in the Prins Bernhard polder in 1953 for studying sowing in water.*

44. *Gadget for catching animals feeding on rice-seed sprouts under water.*

Performances of 0.5 ha/man-hour were obtained in this way. In 1957 and 1958 all late-sown fields were preventively treated in this manner when the first eggs appeared in them, without it being necessary to draw off the water. The costs of the chemical control measures were about Sf 7/ha and from Sf 10,000 to 15,000 per annum for the whole project area.
The susceptibility of the flies to dieldrin was very selective. Such insecticides as aldrin, parathion, BHC and DDT had practically no lethal effect.
Attempts were made in experiments to treat the seed with dieldrin beforehand to prevent fly infection. Hitherto this method has given no satisfactory results, possibly, because for the great bulk of the seed comparatively large amounts of dieldrin are required.

No progress was made with biological control since L. RAZOUX SCHULTZ demonstrated the substantial occurrence of two types of ichneumon-flies.
It is possible that this pest is more severe in a reclamation area and that it will gradually become less aggressive. However, no clear signs were found of a trend in this direction.
The pest would probably disappear altogether if the sowing period of the main crop could be reduced to three weeks instead of six.

5. Rats[1]

During the reclamation period of the project there was often serious damage by rats, particularly in small second-crop plantings.
The worst damage occurred in the second 1956–57 crop, in which season a plague of rats led to a partial harvest failure. Of the 1,000 hectares planted about 250 were entirely wiped out and this, without the ravages to the rest of the area, meant a loss of over Sf 50,000.
Rat damage occurred in all stages of growth of the paddy crop from sowing to harvest. Even some of the seed was consumed by rats on fields which had been sown on the mud and not flooded at once. During the growing period of the paddy until flowering, the rats caused most damage by gnawing innumerable stems, so that bare patches were formed in the field. Towards the ripening period there was less damage to what still remained of the crop, the reason being that a surplus of food had gradually become available to the rats. The rats showed some preference for fields or parts of fields in dry locations, thus these were the first to be affected. On dry land the ravages were more scattered as compared to fields under water. In the latter case the typical pattern during the vegetative development of the paddy were compact floating masses of gnawn stems grouped in radial circles, in the centres of which gnawed remains and excretions were often found. This showed that the rat built itself a raft of stems on which it could continue its meal in greater comfort. Hence it was easy to understand that severe damage could still be caused to fields deep in water. One remarkable feature of rat damage observed was that the stems were always gnawn off in a rough transverse plane. Another typical feature was that the margins of the fields were left alone by

[1] Various species of rodents, customarily called rats.

the rats up to a depth of some metres, so that is was necessary to penetrate a field for some way to ascertain whether any damage had been done. This obviously made inspection more difficult.
When the rice stems had been gnawn off at a very early stage, the field could afterwards recover fairly well by throwing out new shoots.
When the plants were gnawn after tillering it sometimes seemed from a distance that there had been a fairly good recovery. Actually, then only a limited number of small new stems had developed which ripened later than the non-infested plants and produced little.

The rat plagues occurring in this project bore some resemblance to those that occur in the rice-fields in Java and which have been described by JOOSTEN (1938), VAN DER GOOT (1951) and KALSHOVEN (1951).
An important difference is that the rats did not always build their nests in the soil of the dams, but to a great extent in the planted area itself just after the paddy stems had elongated. Before building their nests the rats lived during the day on and in the dams and in other dry parts of the area. This limited location of the rats was an important factor in connection with their control.
According to VAN DER GOOT sawah rats[1] (at Java), kept in the laboratory, required such concentrated foodstuffs as rice, soybeans etc. to stay alive. When fed with young green paddy-stems they died in 5 days on average and with flowering rice in 9 days. But fed on green rice grains the rats kept on living for some 84 days and on mature grain 108 days. JOOSTEN found that in the fields also the rat population died en masse when only green rice plants were available as food and he took account of this phenomenon as a main principle in taking control measures.
Another important field observation made in Java was that the rats only started breeding on a large scale when the paddy in their environs had reached the swelling-stage. This breeding then continued until after the harvest. In view of their enormously destructive activities in the vegetative stage of the paddy-crop the rats apparently have a great need to satisfy their hunger. It is estimated by VAN DER GOOT that in Java a single rat is capable of gnawing off as many as 100 green paddy stems in 24 hours. Our impression is that the rats which occur in the Wageningen project area can achieve at least the same destructive capacity. In this connection it invariably struck us that the rats only consumed a very small part of the gnawn-off stems, possibly the parts which afforded the most nourishment.

The rats were controlled by three methods, viz.:
1. preventively, by making their environment less favourable;
2. directly, by poisoning with cumarin preparations, or
3. by catching by hand or crushing with machines.

Preventive measures. During the construction of the polder there were various reasons why conditions were conducive to a rapid increase in the number of rats, viz.:

[1] *Rattus rattus brevicaudatus* (Horst & De R.).

— Workmen's camps were built in scattered locations in the polder in connection with the work of construction. There was a low standard of hygiene in these hutments. Remnants of food were usually thrown away on the surrounding land. As a result extensive colonies of rats grew up even at this early stage.
— Owing to the forest-clearing work there was a period in which countless piles of timber were scattered about the fields. These remains of timber made suitable refuges and breeding places for the rats.
— When these wood piles were cleared during the dry between-seasons and the fallow fields were subsequently ploughed, the rats were expelled and driven to the rice-fields. This aggravated, for example, the damage caused during the 1956–57 season.
— Owing to the mechanized reclamation operations such natural enemies of rats as snakes, lizards and birds of prey were mostly killed or scared away.
— During the first few years of rice cultivation in the new fields, much grain was lost during harvesting owing to lodging and the inaccessibility of the fields. Hence the rats were able to find food everywhere even after the harvest.

In order to keep the rat population within certain bounds these five factors were taken account of, viz. by trying to leave as little food as possible in spots accessible to rats, by quickly clearing the wood piles and other refuges such as shrubs along the dams, and by protecting their natural enemies.
In addition to the reclamation work the cultivation plan adopted also favoured multiplication of the rats. The application of two rice crops per year and the staggering of the sowing result in long periods in which the rats have plenty food and favourable breeding conditions. Especially the second crop is in a susceptible position as:
— it is only sown on a quarter of the area but it has to cope with the large rat-population which developed during the maturing of the main crop;
— it is sown more or less in scattered locations due to the type of farm-organization (see p. 237) applied and to the fact that field conditions not always permit a concentrated planting;
— weather conditions and operating capacity limit the measure to which the surrounding fallow stubble-fields can be ploughed, or otherwise prepared, in due time, in order to clear away rice seed and volunteer plants on which the rats can feed.

The necessity of keeping fallow fields reasonably clean during the second crop constitutes a further advantage of the early autumn-ploughing of fields which will only be sown next spring (discussed on p. 129). Moreover the preference of mouldboard-ploughing as compared to disk-ploughing (p. 146–147) is accentuated, because of its better turning resulting in less subsequent volunteer rice.

Partly owing to the rat danger only a small area of second crop was sown in 1955–56 (about 250 ha). In the hope that there would be no recurrence of the plague 1,000 ha were sown in 1956–57, but considered in the light of subsequent events, the sowing of a second crop of rice should have been omitted during this season as well. Admittedly it is not so easy to modify a scheme of cultivation and to reduce production for the sake of avoiding a possible plague of rats.

Rat damage was almost entirely confined to land or the vicinity of land which previously had a forest cover, and this would emphasize the significance of the timber remains. But this may also have been a coincidence or else due to the workmen's camps which were usually located in the southern part which was covered with forest.

Whatever the cause may have been, the plague arose in the forest areas which had been first reclaimed and did not spread over the grass-swamp areas which were reclaimed at a later stage.

During the 1956–57 season the average yield of the forest area was 950 kg/ha (613 ha) and of the grass-swamp area 2230 kg/ha (466 ha) and these differences were actually due in the first instance to the depredations of rats. There were also differences in productions from the same cause in the 1955–56 season, but less extensive.

Poisoning with cumarin. As early as 1953 the Phytopathological Service at Wageningen, Netherlands, recommended the use of cumarin for rat control. At first, however, we did not expect much from chemical control because the rats, being scattered over extensive araes, appeared to be almost inaccessible. This opinion was modified after a study of the results obtained by REIFF, BUXTROF and VILÀ (1954) in controlling rats with cumarin in rice-fields at Valencia, Spain. According to the methods given by these workers, control experiments were begun on the Wageningen project in January 1955 which proved so successful that they could be applied almost immediately to the entire production area. The bait used was paddy (viz. unmilled rice) which, after being lightly sprinkled with water (e.g. 1:40), was mixed in the ratio of 1:10 to 20 with 0.5% cumarin poison. This bait was placed on the dams surrounding the fields at 30 to 50 m intervals, under small wooden shelters, in amounts of from 250 to 1,000 g. In Spain old roofing tiles were used for shelters, but these were not available in Surinam.

The wooden shelters, afterwards also occasionally made of tin, consisted of a loose bottom plank, about 20×30 cm, and a roof of two planks of the same size nailed together. They were required for protecting the bait from rain and birds and also for shelter to the rats while eating the bait. After the bait-containers had been put into position they were checked and rebaited almost daily. Containers from which no bait had been taken were shifted by way of experiment, e.g. to the runways of the rats, on the dams nearer the water, etc. In 1956 and 1957 the entire polder area infested by rats was planted with tens of thousands of baited rat boxes. The bait was usually well consumed; dead and diseased rats were found everywhere and it seemed as though the rats could be kept down by this method.

But things went wrong during the 1956–57 second-crop season, when great

numbers of rats were found in the fallow areas between the second-crop fields. Such control measures as were taken had little effect in fields in dry locations with volunteer-rice everywhere and unharvested remains of the former planting. Owing to the dry weather large-scale land preparation and reclamation work was undertaken in this fallow area. An incessant stream of rats deprived of their food and shelter in the cleared areas then headed for the rice-fields. The rat boxes baited with cumarin proved unequal to the situation which was however a very special one, that could not recur during normal cultivation after reclamation has been completed.
We therefore still think that the cumarin bait control method developed for the Spanish rice-fields by the research workers REIFF ET AL. of MESSRS GEIGY, is quite suitable for use under the conditions prevailing in Surinam. It should, however, always be applied in combination with other measures.

As regards the selection of bait, a number of practical observations were made by alternately placing the various types of bait in series of boxes (DE WIT, 1955). It was discovered, for example, that remains of seed treated with a mercury compound were consumed as readily as ordinary paddy. Fish-meal in the form of shrimp-husk meal was found to reduce consumption rather than increase it. No clear experimental results were obtained with milled rice. This material became fairly rapidly covered with mould, as a result of which consumption fell. The advantage of milled rice is that more of the cumarin powder is consumed by the rats. With unmilled rice the toxic effect is mainly achieved by powder adhering to parts of the mouth and paws, since the rat removes the husk from the rice grains and does not eat the chaff to which the powder adheres. A more detailed investigation of the relative efficacy of unmilled and milled rice would still seem desirable. For the time being unmilled paddy is used in the project area.

The best period for chemical control is immediately after sowing. The rats are then unable to stay in the fields (open water surfaces) and are all concentrated in the dams. At this period the rat population should be adequately suppressed by an intensive baiting of the whole area. When the paddy is a few months old it is too late to do this as some of the rats remain in the fields and are difficult to reach with bait.
The cost of chemical rat control chiefly consists of wages. Compared to wages the cost of bait and poison is trifling. It was found that an inadequate control effect was very often due to a poor appreciation of the manner in which the work should be done.

Control by catching. On a large mechanized undertaking work requiring a great deal of manual labour is often unpopular and is soon said to be impossible. This was the case with the rat control measures taken at Wageningen. Controlling rats with poisoned bait required a great concentration of labour, so that this work was sometimes forced into the background by other necessary operations. Nothing at all was expected from hand catching, having regard to the relatively high level of wages and the difficulty of obtaining enough staff.

But hand-catching, adopted as an additional measure through sheer necessity when chemical control measures proved less effective, nevertheless produced remarkable results. The same opinion has been held as regards Java by JOOSTEN (1938), but not by VAN DER GOOT (1951) who doubted the merits of hand catching.

Since at Wageningen the clay of the dams was hard at the surface and moist and sticky at some depth below, the rats were not able to burrow deep. They concealed below the sward, in which connection the *Cynodon dactylon* planted on the dams offered them a favourable closed layer of vegetation. Many of these rats could be quite easily discovered though and knocked down by hand. Very good catches were occasionally made by rolling the sides of the dams with brush cutters. Some of the rats were crushed and others crept out behind the roller and were then clubbed to death by workmen who exhibited great skill in this respect (up to a hundred rats an hour were killed by one man). Colonies of thousands of rats were also caught by cleaning out old creeks which were filled up with timber remains.

Finally, the fact that there were very few dogs in the thinly populated area no doubt assisted the plague. We have often marvelled at the ceaseless energy with which a dog will bite to death one rat after another. The hundreds of dogs that roam about the native rice polders are certainly more useful than most people realize.

6. Birds

Up till now the project area has remained free from severe plagues of birds. This is a particularly fortunate fact as regards the cultivation of the second crop, which ripens during a period in which there is practically no rice in the fields for hundreds of kilometres in the vicinity. Probably this is not due to the remote situation compared to other inhabited areas, because the Prins Bernhard polder, situated among native polders, has also experienced only slight damage from birds during the ripening of the second crop.

But what the future may hold in this respect is a moot point. It is true that there has been a considerable increase in the population of granivorous birds since the construction of the Wageningen polder. Undoubtedly bird damage will increase when the sowing is staggered to a greater extent than at present.

Occasional damage was caused by aquatic birds as well as by such granivorous birds as Redbreasts (*Leistes m. militaris* (L.)) and Yellow-headed Marshbirds (*Cacicus c. cela* (L.))[1]

Wis-wissi-ducks (*Dendrocygna autumnalis discolor* Sclater and Salvin)[1] sometimes alighted on newly-sown fields in flocks of several hundreds. The ducks showed a preference for shallow pools or parts of the field. They consumed the rice-seed and in the first instance they also ate the grains off the seedlings.

[1] Latin names taken from F. HAVERSCHMIDT (1955). English names as in use in Br. Guiana taken from L. D. CLEARE (1952).

They caused further damage by washing away the plants and burrowing them in the mud.
It was possible to protect the fields from the ducks either by flooding them to a depth of at least 10 to 15 cm or by keeping them entirely dry.
(Owing to the rainfall on uneven reclamation fields this was not always possible.)
Spurwings (*Jacana spinosa jacana* (L.)) caused occasional damage in the ripening crop. In this case the consumption of ripening rice was of minor importance. Most damage was due to the fact that the birds are in the habit of soaring and alighting again on the field, and when they settle on the stalks of a heavy crop, part of it is broken, resulting in poor ripening.

7. Caterpillars

Caterpillar plagues occurred nearly every season. The species were *Laphygma frugiperda* (J. E. Smith) and *Mocis latipes* (Guen.)[1]
Generally speaking the damage caused to the crop by caterpillars was not regarded as serious, except in the seedling stage.

In fields sown on mud *Laphygma* was already frequently found on seedlings a few days old. At this stage of growth of the rice the caterpillars were most dangerous. Older plants, even if largely stripped of foliage by *Laphygma*, usually made an almost complete recovery in a few weeks.
The most effective form of control is to flood the field. The submerged parts of the plant are not attacked and when there is sufficiently deep flooding, which is possible when the crop is still young, the caterpillars can be entirely washed away and float with the wind towards the sides of the field.
Pupation only takes place in the soil, so that there is no risk of a second generation on flooded fields.
If the crop is too large for complete inundation, or there are reasons that prevent flooding, the next step may be chemical control. 4 kg of 50% DDT dust per hectare, 6 kg of 40% Toxaphene dust per hectare and 1 to 2 litres of 20% aldrin, dieldrin or endrin were effective.
When the seedling fly had been controlled with dieldrin the crop also remained free from caterpillar infestation during the first few weeks.

Mocis latipes only occurred in the later stages of growth of the rice crop until about the flowering period. They are lively, voracious caterpillars capable of stripping an entire crop in a few days. Pupation takes place in the foliage of the rice crop. They were chemically controlled in the same way as *Laphygma*.

The caterpillars have many natural enemies. Ichneumon-flies and preying wasps are very active. There are many kinds of birds that feed on caterpillars, e.g. the Kiskadee (*Pitangus s. sulphuratus* (L.))[2], and according to VAN

[1] Latin names taken from J. B. M. VAN DINTHER (1960)
[2] Latin names taken from F. HAVERSCHMIDT (1955). English names taken from L. D. CLEARE (1952).

DINTHER (1953b) the Readbreast and Old Witch (in Surinam called *Kawfoetoe-boi*) (*Crotaphaga ani* L.) as well.
In order to encourage these natural enemies in the project area, a more variegated landscape would be desirable, with woods, gardens, etc. as in the native polders.

8. Jassids and Delphacids

Of most importance are the jassid *Draeculacephala clypeata* Osb. and the delphacid *Sogata oryzicola* Muir.[1] They belong to the potentially very dangerous rice insects in Surinam. In 1952 a plague of these insects occurred in the Nickerie district which according to VAN DINTHER (1953a) led to an estimated loss in production of 4,500 tons of paddy.
Jassids and delphacids may damage the rice crop practically throughout the growing period. The injury they cause consists in sucking sap from the plants, blocking leaf veins by oviposition, and in general causing wounds on the plant which promote diseases. Another possibility of damage recently found is that the delphacid *Sogata oryzicola*, which is a vector of the *Hoja Blanca* virus, may transmit this disease to the crop. Hitherto, however, *Hoja Blanca* has not been found at Wageningen.
Our experience with jassids and delphacids is that every rice-field containing large numbers of them has stunted growth and low yields. When these insects became a serious pest chemical control measures were invariably taken at Wageningen, but the results were often disappointing.
In our opinion this is mainly due to the fact that the insecticide does not sufficiently reach the insects, since:
— they are usually just above the surface of the water on the base of the stems of the rice plants;
— they generally occur when the rice is a closed crop, so that the leaf cover hinders the penetration of the insecticides;
— the present methods of applying the insecticides have little power of penetrating into the mass of foliage of the crop, and moreover there is by no means a uniform distribution of the insecticide over the crop.
The economic return of chemical control was also frequently doubtful, mainly because in repeated cases the plague was not discovered, or at any rate control measures were not taken until most of the damage had already been done.

The chemical control measures found most satisfactory during 1954 to 1958 were the following:
The Delphacidae were controlled with about 4 kg of 50% BHC dust per hectare applied with the Wervelwind-driftduster. In an open field the effect was usually satisfactory. We should mention in this connection that this obviously need not apply to the control of any virus disease transmitted by

[1] Latin names taken from J. B. M. VAN DINTHER (1960).

the Delphacidae, as in this case a higher knock-down rate would be required. This problem is now being investigated.
The Jassidae were usually more difficult to control than the Delphacidae. 50% BHC dust was practically ineffective. Among other insecticides use was made of about 4 kg of 50% DDT dust per hectare applied with the Wervelwind, or about 1 litre of 50% Malathion per hectare, applied by atomization with knapsack sprayers on the basis of about 20 litres of spray per hectare. Sometimes a repeated application was necessary for both Delphacidae and Jassidae, for instance, in order to control the young larvae which had hatched in the meantime.

It would appear from what has been stated above that the control of both types of insects requires further investigation.
There is much to be said for the study of these insect pests to be more directed towards preventive measures, such as the study of the host-plants growing outside the fields. A study should also be made of the average chance that small incipient insect populations may increase to plague dimensions, and how the plague is distributed over large areas from local sources of infestation. This information is required to enable control measures to be taken in good time. In general a more detailed investigation of the relationship between the life history of the insects and the control possibilities is important. In order to overcome the drawback of insufficient penetration of the insecticides it would be advisable to pay attention to the adaptation of the plant spacing by employing less seed, or possibly even by sowing in rows. On the other hand, methods of application should be found, which give a greater degree of penetration of the insecticide, e.g. spraying from aircraft, and in particular from helicopters.

The most important natural enemy of the Delphacidae and Jassidae which was observed is a coccinellid, but owing to the methods by which the Jassidae and Delphacidae were usually controlled the population of these predators continued to be small. It might be worthwhile therefore to investigate a more selective application of insecticides.
According to SANGER (1958), the Coccinellidae are more susceptible to DDT than to endrin. The latter was found effective against Delphacidae in experimental sprayings carried out by STUBBS in 1958 in which 1 litre of 20% concentration was used per hectare.

9. Stink-bugs

Various species of stink-bugs occurred in the area under cultivation.
From the point of view of damage to the crop the blackbrown leaf bug (*Tibraca limbativentris* Stål)[1] and the lesser, yellow-brownish patterned ear bug (*Oebalus poecilus* Dall.)[1] are important.

[1] Latin names taken from J. B. M. VAN DINTHER (1960).

During one season, viz. in the 1954–55 second crop, the leaf bug was a catastrophic plague. At that time we did not have a good collection of insecticides. Neither DDT nor BHC were sufficiently effective, and the plague was so serious that entire fields were practically destroyed. Some reduction in the insect population was effected by repeated applications of BHC.
This population was enormous. The clusters hanging on some plants were large enough to fill a jam pot. In course of time the plague died out of its own accord. The impression was gained that these bugs had flown in from the surrounding swamp, this being also found by GEIJSKES in the case of earlier bug plagues in Surinam. In later years this bug occasionally caused a large number of empty heads when it came in the flowering period, this being due to rotting of the stalk caused by the holes which this insect bores. It was found in control experiments that dieldrin gives fairly good control during this stage of growth of the rice crop.

The ear bug occurred at regular intervals and often affected the quality of the harvested rice grain ("pecky rice", see Circ. 632 USDA, 1942).
Chemical control of this insect was a fairly easy matter. It is found in the upper part of the plant on the panicles where it is easily reached by insecticide powders. 50% BHC was particularly effective against these bugs.

10. Borers

The stem borers belong to the important pests occurring in the Wageningen polder. Their importance is also due to the fact that hitherto no practical means of control has been discovered.
Two kinds of borers occur, viz. *Diatraea saccharalis* (F.) and *Scirpophaga albinella* Cram.[1]

The *Diatraea* is found in the rice crop as early as the tillering stage. It then destroys the growing points of the young stems. But the plants will subsequently produce new shoots which may partly compensate the loss.
When the plant is attacked during elongation of the stems the panicle withers and rots in its husk and new stem buds emerge below the infected part. These new shoots mature later than the rest of the plant and only produce small heads. The infected stalk may also appear in the form of a whitish straight head.
Finally, infection occurs during and after florescence, resulting in bad setting of the grain with chalky-white and empty grains, as well as lodging of the crop caused by the weakening of the stems.
The *Diatraea* does not uniformly infect the area but chiefly occurs in the form of local eruptions. On some fields the damage may reduce production by more than 50%. We also gained the impression that *Diatraea* generally occurs more in the second-crop season and in general during periods of dry weather.

[1] In Surinam the usual name is *Rupela albinella*. The Latin name was taken from W. F. JEPSON (1954).

One precaution frequently taken when *Diatraea* had been found consisted in raising the water-levels of the fields. It was assumed that this measure was particularly effective when infection broke out during tillering, since the passages bored were not yet waterproof and the larvae would be forced upward by the water. But this effect is not at all certain and requires more precise research.
One great difficulty of the *Diatraea* infestation is that the development of the populations cannot be followed with light traps because the moths are not attracted to light. Moreover, the egg masses and the newly-hatched larvae are scarcely visible to the naked eye, so that it is equally impossible to base practical control advice on timely observation in the field, particularly in the case of extensive rice cultivation of the kind practised at Wageningen.
Little has been achieved to date with the chemical control of *Diatraea*. Endrin was the only insecticide which appeared to have some effect, but so long as the infestations are not observed in good time the application of endrin would not seem to be of much use. Since the pest must either be controlled when the damage becomes visible, viz. after most of it has been done, or else controlled preventively by repeated sprayings on the entire area, which would be too expensive if only intended for the control of borers.

For further investigation into *Diatraea* control it appears important to work out a method of observation of the moth swarms.
It is also emphasized, to follow closely the results of (biological) control studies of this insect in the surrounding areas of South, Central and North America where *Diatraea* is one of the worst pests encountered in the sugar-cane estates.

The other rice borer occurring in the project area is the *Scirpophaga albinella* Cram.
The *Scirpophaga* only assumes some importance in the rice crop when the stems emerge, and during flowering and maturation. It chiefly occurs in the main season, particularly in late-sown fields.
Table 52 shows mean borer counts classified according to the fields sown each week. No distinction was made between *Diatraea* and *Scirpophaga* in the observations, so that the figures represent the total borer infestation.
However, the vast majority were *Scirpophaga*. The counts were taken by walking diagonally across the field during the last week preceding harvest and sampling a hundred random stems. The stems were cut open lengthwise in order to ascertain whether they contained borers. All stems containing borer larvae or pupae were counted as infected, as well as those in which distinct traces of borer injury were found.
The figures (in Table 52) show that both in 1956 and 1957 borer infestation was considerably higher on the late-sown fields. The yield figures, also included in this Table, of the fields classified according to week of sowing, may give the impression that the yields had decreased through this cause, but

this can only be true to a slight extent since the main reason for the low yields of the late-sown fields was the production-depressing effect of the second crop previously grown on these fields (cf. p. 132).

TABLE 52 *The relationship between date of sowing, borer infection and yields*

Period of sowing	1956			1957		
	mean % borer in-fection	number of fields	mean yields/ ha in 100 kg paddy —14% m.c.	mean % borer in-fection	number of fields	mean yields/ ha in 100 kg paddy —14% m.c.
1st week from 25/3–31/3	23	26	27.1	—	—	—
2nd week from 1/4–7/4	24	40	26.6	23	70	26.4
3rd week from 8/4–14/4	31	43	25.9	21	98	25.4
4th week from 15/4–21/4	24	61	26.8	22	84	27.4
5th week from 22/4–28/4	30	59	26.3	22	75	29.0
6th week from 29/4–5/5	28	49	26.0	31	63	26.0
7th week from 6/5–12/5	40	34	23.2	46	70	19.0
8th week from 13/5–19/5	51	29	24.4	43	40	16.7
9th week from 20/5–26/5	58	8	19.2	—	—	—

Despite the mass occurrence of the *Scirpophaga* it was often assumed that the damage they caused was limited, as the plants were chiefly infected during the maturation period when the only injury was a somewhat poorer setting of the grain. But this theory has not yet been proven by experiment.
We tried to discover such proof by laying out series of experimental fields, in which one plot was kept free from insects by periodical applications of an insecticide such as endrin, another plot being control.
But hitherto there have always been disturbing factors at work, e.g. other insect plagues, or that insects, including borers, avoided both the sprayed and control plots over a wide area surrounding the experimental field. We believe, however, that experiments of this kind will gradually add to our information on this damage.

The *Scirpophaga*-moth is easily caught in light traps, so that the development of the generations can be fairly accurately followed. Moth swarms occur at monthly intervals and they uniformly cover the entire polder.
In the beginning of the main season the swarms are hardly noticeable, but towards the end they are very extensive.
It seems evident that the damage to the crop can be lessened by reducing the staggering of sowing (see Table 52).
It has been found that the larvae may remain dormant in the rice stubble. In practice, therefore, the stubble was flattened by weed cutters as much as possible after harvest and then burned.

In certain regions of Java effective control of *Scirpophage innotata* Wlk. could be achieved by VAN DER GOOT by regulating the times of sowing or of transplanting according to the cycles of moth swarms (VAN DER GOOT, 1948, VAN DER LAAN, 1951). This method was based on three habits or properties of the insect:

— the larvae may have a period of dormancy (diapause) in the stubble which lasts until the next rains set in;

— the moths show preference for laying its eggs on certain growing stages;

— the moths only live for a week maximally.

In the Wageningen project though, such an application could not yet be developed. As the rains are irregular no clear start by a so called stubble-flight could be determined.

Little or nothing is known of the possibilities of chemical control of the *Scirpophaga*.

Subjects for further study in this connection should be the most suitable time for chemical control having regard to the peak-periods of moth swarms, the best insecticide, the amounts required, and the methods of application.

Some investigators (e.g. VAN DINTHER) are of the opinion that the more or less preventive chemical control is uneconomic, but in our view a more thorough knowledge of the control possibilities is nevertheless important considering for instance the economic desirability of a still wider harvest spread, especially during the main season.

The chief natural enemies of the rice borers are ichneumon-flies. Many parasitized larvae and pupae were found on the *Scirpophaga* in particular, but no careful observations have been made on this subject.

CHAPTER XVII

HARVESTING

In order to harvest with combines rice varieties had to be cultivated which were little subject to lodging. Hence this was regarded as the most important requirement in the rice selection programme for the project conducted from 1950 onward.

This selection work soon proved successful. In 1954 and 1955 the new Dima, Nickerie and 80/5 varieties became available, all three of which had good stiff straw and did not lodge under normal conditions of cultivation.

Another important factor was the suitability of the fields for carrying the combines. During the first three reclamation years in particular, continuous rainy weather created extremely bad field conditions. To prevent the combines from sinking into the mud and bogging down, structural changes were made in the machines with the object of obtaining a better distribution of weight and a reduction in the soil pressure per sq. cm. Attempts were also made to improve the bearing capacity of the fields.

Up to 1955 the harvested paddy was all conveyed in sacks from the combines to the lighters in the irrigation canal. Subsequently bulk transport proved more satisfactory and it was decided to make a gradual transfer to this method when replacing the worn-out combines which were equipped for harvesting in sacks.

1. Crop and field conditions for mechanized harvesting

The fields are usually drained two to three weeks before the crop is ripe for harvesting and are afterwards kept as dry as possible. If a field is so soft that there is a risk of the combines sinking too deeply into the mud, drainage is started at a fairly early date. In practice the earliest date taken for drainage was the end of the flowering period. Earlier drainage was considered undesirable owing to possible drought injury.

For effective drainage it was an important requirement that the field should be level. On unlevel fields extra ditches had to be dug by hand for draining off the water, and these occasionally had to be repeatedly deepened for subsequent rains. This manual labour was all the more difficult in that it partly occurred in a period in which all staff was badly needed for harvesting.

After the fields had been in cultivation for some years it was found that their bearing capacity gradually increased to such an extent, that even in a wet condition they were often fairly suitable for supporting combines.

Their suitability then chiefly depended on how the land had been previously prepared, and in particular, whether this had to be done in good dry conditions or in wet.
Except for levelling no other measures were taken for improving the drainage of the 12-ha fields.

In this connection it may be worthwhile that more attention is being paid on the project to the effect of tillage methods on the drainage of the fields. On rice-fields in the Po-delta the normal practice is to plough in such a way as to form a network of open plough furrows in the field which are connected to both the irrigation and drainage systems. For the present project such a method would probably still make too heavy demands on the tractor drivers, and it would also be difficult to avoid the trenches during puddling operations for preparing the seedbed. It was also found that the combines were particularly prone to sink deeply in these furrow-trenches.

In rice cultivation it is very important to select the right time at which to start harvesting. If the harvest is too early there is loss of product owing to insufficient grain setting and bad threshing. The quality is also reduced by the occurrence of chalk-white and green grains and increased breakage in milling.
If the rice is harvested too late the decline in milling quality is the chief factor involved. All the time the ripe rice is standing in the field it is subject to rapid fluctuations of wetting and drying. This results in increasing sun-crack percentages.
Sun-crack occurrence has been investigated in detail by TEN HAVE (1958 b and c). His main conclusions are as follows:
— In the case of the varieties cultivated at Wageningen the optimum moment for harvesting has come when the moisture content of freshly harvested and reasonably clean rice grain is in the region of 19–21 %.
— Measurement of the percentage of sun-cracked grains in freshly harvested samples affords a reasonably accurate idea of the percentages of broken rice which will occur during milling. From TEN HAVE's curve, representing the relationship between crack percentage and brokens percentage, the following approximate formula can be inferred, for crack-values above 10%: (brokens %) $= 5 + \frac{1}{2}$ (crack %).

In practice it was usually ascertained by visual examination whether the fields were ripe enough for harvesting. This did not lead to any difficulties except at the commencement of the harvesting season when an occasional premature start was made.
It would seem that in the initial stage of harvesting one's powers of judgment required a fixed criterion. Such a criterion was automatically provided in that samples were daily analysed for moisture, cracks, and for green, dead-white, yellow and red grains, of every separate batch per field and per farm delivered to the rice mill.

In 1956 (main crop only) the crack percentages averaged 14.1 in 1357 samplings taken from a total of 10,306 tons. In 1957 the total average crack percentage was 16.4 and the moisture percentage 19; in 1958 the average crack percentage was 22.1 and the average moisture percentage 18.
One reason for the increase in the crack percentages in these years is the partial change-over from the slightly crack-sensitive Dima to more sensitive varieties, particularly Nickerie. A further factor involved may be the gradual refinement of the analytical methods.
At the time it was occasionally checked whether there was any connection between the crack percentage and the type of rice-field, but no distinct correlations were found.

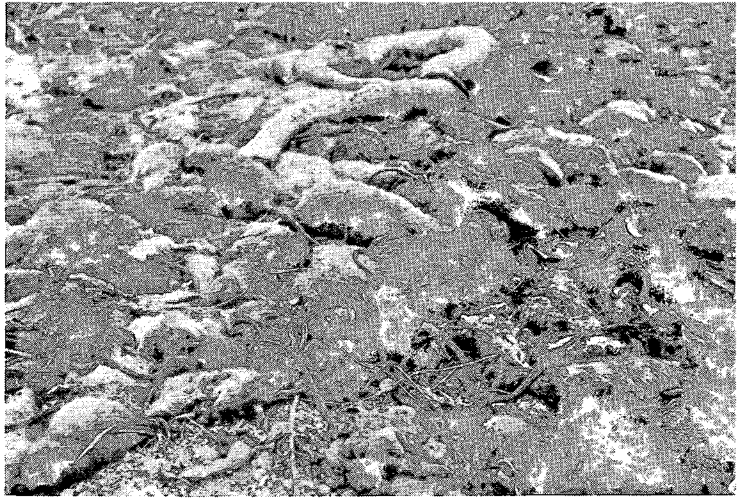
An important character of a field which is ripe for harvesting is the degree of lodging. When harvested with combines, a part of a lodged crop is lost and there is also a great decline in the capacity of the combines. If in addition the field is wet some of the grain lies in the water so that grain rotting occurs.
When a lodged field also has a soft soil the driver needs to be exceptionally alert to prevent his machine from bogging down. Although the varieties cultivated had a good resistance to lodging, it nevertheless occurred fairly frequently, owing to the rank growth on the reclaimed fields or as a result of diseases and plagues.
Of the types of combine used, viz. Massey Harris 27, Massey Harris 90 and Claeys MZ, the latter was the most suitable for lodged grain owing to the greater straw-processing capacity of the threshing mechanism and the hydraulic operation of the pick-up reel.

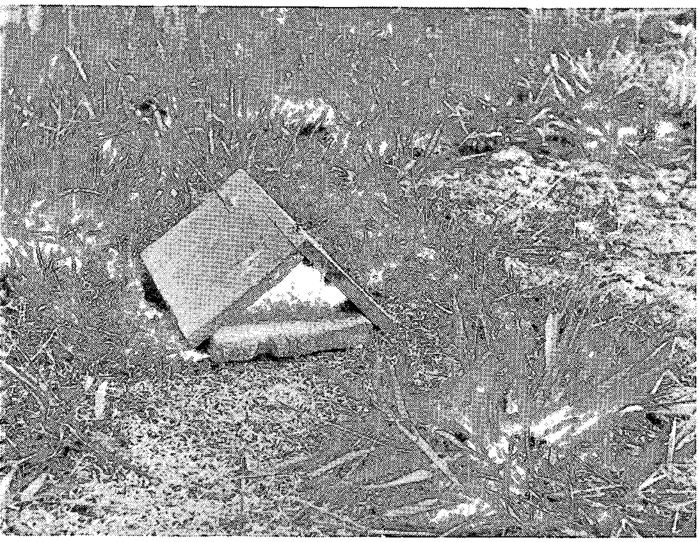
2. Combine-harvesting

Soon after the project operations began, 32 Massey Harris No. 27 bagger-combines on tracks, with 12-foot width of cut, were purchased under the Marshall Aid plan. These machines arrived in 1951. One was put into commission at once by the Experiment Field and Selection Station of the STICHTING in the Prins Bernhard polder. Of the remaining 31 machines the first four began operating in 1954, then 18 in 1955, and the others in 1956. Hence the combines stood idle for an average of four years and in a tropical climate. Moreover in the meantime Massey Harris brought out their new model No. 90, which in many respects was superior to the old machine.
This procedure of early purchase, necessitated by the Marshall Aid budgets which ran from year to year, was thus a serious drawback to the project. (It had to pay the equivalent fund in Dutch guilders at the official rate of exchange. The moneys of the equivalent fund were used for other purposes in the Netherlands.)

In 1956 were purchased the following new machines which started work at once: 6 Massey Harris No. 90 bagger-combines, 6 Massey Harris No. 90

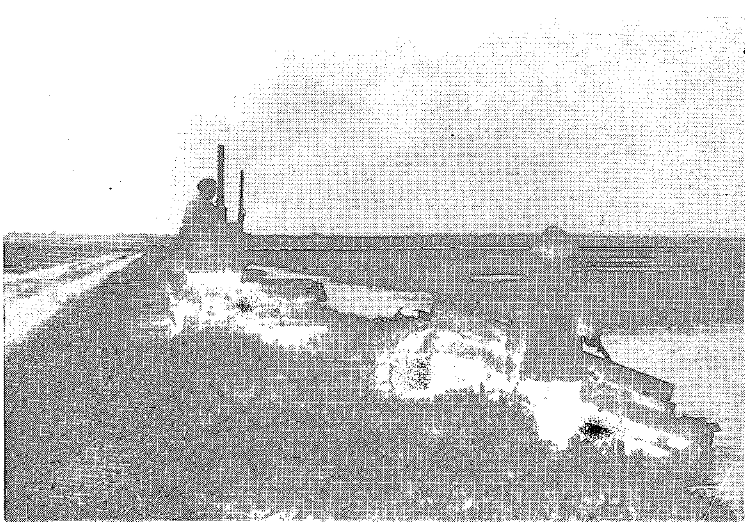
45. *Thousands of rats were caught by hand in the early part of 1957.*





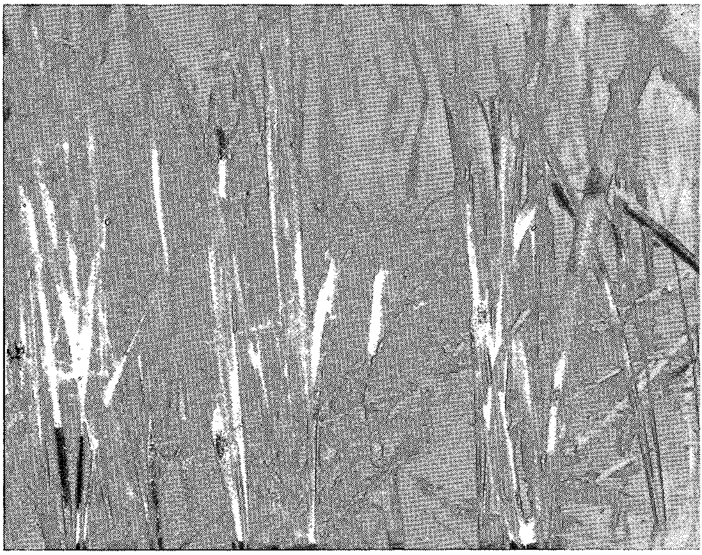
46. *Container used for rat bait.*

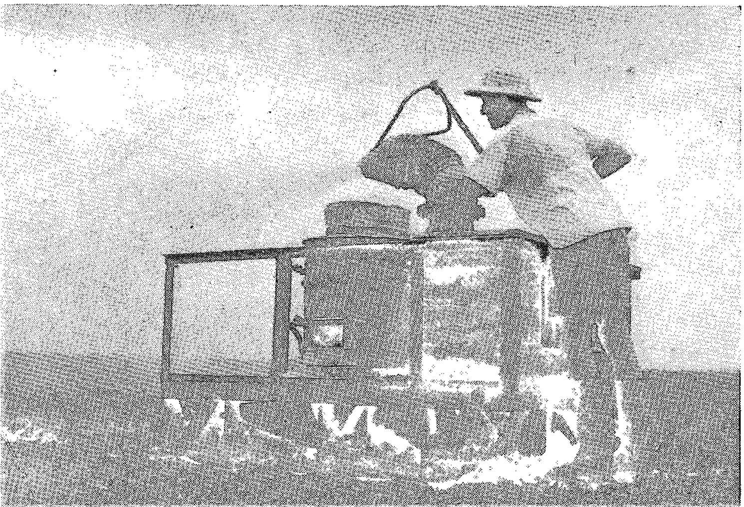
47. *Eradication of rats on dams between rice-fields.*



48. *Footmarks of ducks indicate cause of damage.*

49. *Laphygma frugiperda-caterpillars feeding on rice.*





50. *Whirlwind drift-duster on sledge.*

combines with grain tank and 1 Claeys M.Z. with grain tank, all of them on tracks and with 14-foot width of cut.
To these were added in 1957, 8 Claeys M.Z., also on tracks and with grain tank and 14-foot width of cut.
The most important technical data on the combines employed, are given in Table 53.

The chief difficulty experienced on the Wageningen project from the beginning was that the combines bogged down. It happened because either the tracks or the steering-wheels sank into the soft parts of the field. Sinking of the steering-wheels was often accompanied with a piling-up of straw, weed and pegasse in front of them under the combine, since when these wheels had sunk to about the axle they stopped revolving and dragged instead. A great deal of clay was also dragged along in front of and between this heaped-up material. The increased tractive effort which the combine had to develop as a result of this material easily led to entrenchment of the tracks. Eventually the bottom of the combine could come to rest on the ground, leading to free spinning of the tracks.
The immediate cause of bogging down was usually the fact that the driving tracks slipped both forward and backward. This slipping occurred with varying loads, depending on the condition of the soil.

TABLE 53 *Technical data relating to combine harvesters used on the project, based on the design supplied by the factory*

	Massey Harris Super No. 27 12-ft., on tracks	Massey Harris No. 90 Rice special 14-ft., on tracks	Claeys M.Z. 14-ft. for rice, on tracks
Weight	4032 kg	4927 kg	5055 kg
Engine	Chrysler 6 cyl. petrol 62 B.H.P. (at 1865 r.p.m.)	Chrysler 6 cyl. petrol 62 B.H.P. (at 1865 r.p.m.)	Perkins P6 diesel c. 65 H.P. 2000 r.p.m.
Forward speed . .	0.8–5.6 km/hr (2 gears)	0.8–13.9 km/hr (3 gears)	0.8–10.3 km/hr (4 gears)
Backward speed .	1.2–3.6 km/hr (1 gear)	0.6–2.3 km/hr (1 gear)	0.7–1.4 km/hr (1 gear)
Width of cut . . .	365 cm	425 cm	425 cm
Width of threshing drum	80 cm	88 cm	103 cm
Capacity of bulk tank	(2180 litres)	2180 litres	2000 litres (1 machine 1500 litres)
Track-length (centre distance end rollers) . . .	105 cm	105 cm	170 cm
Track-width . . .	40 cm	40 cm and 50 cm	50 cm
Tyre size of rear wheels.	7.50–18	7.50–18	10.00–24 (1 machine 7.50–20)

In order to illustrate the difficulties experienced we quote some remarks made in the relevant annual reports. The comments only relate to the harvesting of the main crops.
1954: "Owing to the bad harvesting weather heavy demands were made on the combines. There was a good deal of bogging down and the machines occasionally had to be pulled out with Al Evans winches. Some 15 hectares could not be harvested by machine. The yields were reduced by the poor harvesting work."
1955: "Harvesting was hampered by wet weather and soft fields, but since all combines were fitted with extended tracks only a small proportion of the paddy acreage was left on the field as being unharvestable. At a cautious estimate the harvest losses due to soft fields and lodging amounted to about 4%."
1956: "Owing to the continual rains harvesting work with the combines was laborious. Fields which were wholly or partly inaccessible to the combines owing to the softness of the soil were reaped by hand (6–7% of the entire area). There were considerable harvest losses."
1957: "Weather and soil conditions were unusually good so that the (harvesting) work could be done rapidly and at a low cost. It was only the lodged sections that gave rise to some difficulty."
1958: "Owing to the good weather conditions harvesting proceeded very smoothly."

There were three ways in which attempts were made to face the above-mentioned situation, viz. by improving the field conditions, improving the combine design, and by purchasing combines which were better suited to the prevailing conditions.
In these questions of soil pressure/sq.cm of machines and the carrying capacity of fields, it should be particularly borne in mind that small changes of either force in their area of equilibrium may have decisive consequences to the floatability of machines.
For instance, whenever the tracks sink slightly but the rear wheels remain on top, more weight of the combines is shifted to the tracks, thereby accelerating the sinking process. The same thing occurs when only the rear wheels start to sink, or anytime when the combine is in an inclined position. The chance of sinking is also increased by driving slowly for harvesting lodged grain. This applies as well to turning, when the grinding effect of the tracks is an additional factor. Therefore, combines often stuck fast on the head lands and round the woodpiles.
The open spaces in the fields were dangerous owing to the absence of rice-plants which promote grip and bearing capacity with their root system and mass of straw and especially by their soil-dehydrating effect during growth.

Naturally, every effort was made to improve the bearing capacity of the fields for the combine harvesters.
When new fields were reclaimed, the bearing capacity was increased in that

the natural vegetation was not removed until substantial progress had been made in drying out by means of evapotranspiration.
Attempts were also made to limit the number of deep craters caused by uprooting the trees, to rapidly clear the fields of timber and pegasse, and to achieve good levelling, in other words, to carry out a good reclamation as explained in the chapter on this subject.
In the case of the fields already in cultivation the following methods were possible: levelling, limiting rice cultivation to one crop per annum, limiting tillage for seedbed preparation to the bare essentials, early drainage of the fields to be harvested.

In 1954 several attempts were made to improve the passability of a field for combines by flooding it, so as to wash the combine tracks which were clogged with clay.
This method, which was also occasionally adopted in the Mahaicony/Abary Scheme (GRIST, 1959), did not, however, have any good effect at Wageningen since clogging up of the tracks was not so much a cause as well as a result of bogging down by sinking and slipping.
Moreover the drawbacks of flooding were considerable:
— there is a great reduction in the average carrying capacity of the field as dry crusts with sufficient bearing capacity are again softened;
— the land cannot be prepared for some time after harvesting, owing to the wet condition and the deep tracks of the combines;
— the lodged part of the rice crop is lost.

The first step taken to reduce the soil pressure of the combines was to fit greenheart blocks 75 cm in length on every other track-shoe. Owing to the small clearance between the track and the side-wall of the combine these blocks had to be fitted eccentrically. This was considered somewhat of a disadvantage owing to the anticipated excessive wear on one side of the track chains, etc. (as a result the blocks were shortened to 60 cm in 1957). The floating capacity was much increased by the blocks but in practice this was still found to be inadequate.
The actual constructional alterations to the combines were hesitatingly begun on an experimental scale, in 1954. The aim of these experiments was to obtain a lower soil pressure per sq. cm of the tracks and an improved weight distribution of the machines resulting in reduced weight on the rear wheels. On the experience gained most of the MH super 27 combines in use were altered in 1955 and thereafter in 1956 (much of this work was done under the guidance of H. ENGELAGE), the main modifications being:
1. the operating platform with controls and instruments was moved from the side of the machine to the front, above the elevator which leads to the cylinder;
2. the bagging platform was extended at the front side, in the space formerly occupied by the operating platform;
3. the tracks were extended by one or two rollers, thereby increasing by

35 or 70 cm the track length resting on the ground; this was achieved by welding an extension piece in the centre of the track frame and then fitting one or two extra rollers and afterwards additional links and plates so that the track could again be joined all round;

4. steel lugs were bolted round the tyres of the rear wheels;
5. a hook-eye was welded to the frame at the back of the combine above the rear wheels.

As a result of these modifications the combines could be driven on considerably softer land than was the case with the standard model, since:

— Owing to the forward extension of the bagging platform the entire weight of the harvested grain could be made to bear on the tracks, and also to act as a counterweight for relieving the load on the steering wheels.

— The increase in the track bearing surface raised the floating capacity, in the first place by the relative decrease in the soil pressure/sq. cm and secondly by the greater chance of overlapping small soft field patches.

Moreover, the increased track surface improved the grip and thus reduced slipping, irrespective of whether the combine sank into the mud.

— Owing to better grip and larger diameter the steel lugs fitted to the rear wheels checked slipping.

In the standard model MH 27 combine the soil pressure/sq. cm of the tracks is about 0.4 kg/sq. cm, at an average loaded weight of 4500 kg and an estimated pressure on the rear wheels of 1,000 kg.

By bolting hard wood blocks the tracks are widened 35 cm, but not to their fullest extent owing to the intervening spaces. In our opinion this widening will certainly have a 60% or 20 cm nett effect. Taking this as our basis the soil pressure would be about 0.3 kg/sq. cm. If we also assume that the alteration of the loading platform reduces the weight on the steering wheels to, say, 750 kg, then with the track-extension by 2 rollers or 70 cm, the pressure on the soil will be reduced to less than 0.2 kg/sq. cm.

This is considerably less than the pressure on the soil exerted by a man walking (about 0.3 kg/sq. cm), as we repeatedly experienced when walking behind a combine in the field, when we sank in up to calf or knee while the combine advanced over the surface of the soft ground at undiminished speed.

During 1955 and 1956 various other types of steering wheels and tyres were tried out instead of the standard wheels (750 × 18), including the sizes 1200 × 12 and 1500 × 16 (second-hand aircraft tyres used for farm carts, etc.) and 900 × 24 (rear tyres for 20–25 H.P. wheeled tractors).

Concerning their behaviour as regards sinking and piling up weeds or straw, all three models were more satisfactory than the standard model, viz. in the order of the diameters, so that the 1500 × 16 tyres were the best. But the latter were expected to exert an excessive strain on the rear carriage. Several combines were afterwards fitted with 900 × 24 tractor tyres, and these were eminently satisfactory.

Owing to the difficulties that had been experienced, the 12 new MH No. 90 combines which arrived at the middle of 1956, were delivered by the factory, without extra charge, with an additional set of tracks 10 cm wider.
In practice, however, these wider tracks did not afford much help, so that on these machines the tracks had to be lengthened as well by one or two rollers, and also the bolting of blocks proved necessary. Two machines were even lengthened by three rollers, in which case the bearing axles of the tracks were also shifted to the rear.
Of some of the new combines the tank was moved more ahead. Of others the steering wheels were replaced by larger 900 × 24 wheels. Owing to technical difficulties the operating platform was not shifted in this new series.

On account of the difficulties experienced the Massey Harris factory sent an experimental combine from Cuba to the Wageningen project. Exhaustive tests were conducted with it in 1957 by LLOYD KELLY and AGUSTIN SANCHO, both of Massey Harris. This operation was carried out entirely at the expense of Massey Harris.
However, to our disappointment the report on this investigation was not released by Massey Harris.
The Massey Harris technicians, supported by the evidence of their own investigation, were in substantial agreement with the structural improvements which had already been made at Wageningen. One point of difference was that they preferred an eccentric lengthening of the track frame, from the pivoting axle to the rear (photograph 55).
During the discussions held the question often arose as to what was of more importance in the given situation: to fit rear tyres of greater diameter and width, or to lengthen the tracks, or to shift the bearing axles of the tracks. No definite reply has been received on this point.

Due to the trouble experienced with the Massey Harris combine a better machine was looked for. In 1956 a Claeys MZ 14-ft. bulk combine was purchased as an experiment, on the advice of CH. L. VAN STEEN. When this machine was brought into use, it was found that the floating capacity and weight distribution (only 500 kg on the rear wheels) of the factory model was a considerable improvement on the original Massey Harris combines. The only initial alteration which had to be made to this machine was to bolt 60 cm long hardwood blocks on the tracks, after which it worked as well or even better than the modified MH combines.
Apart from the fact that, since no alterations were required, there was a considerable immediate saving (alterations made to the MH combines Sf 1,000–Sf 2,000 per machine), there were no technical imperfections resulting from make-shift alterations and which could lead to excessive strain and breakage of other parts of the machine, e.g. of the gear-box.
A further important difference between the Claeys and the Massey Harris machines was that the former were equipped with a diesel engine and the

latter with a petrol engine, so that the fuel costs per working hour of the Claeys machines were lower.
Other advantages of the Claeys over the Massey Harris machines were the wider threshing cylinder and straw walkers and the hydraulic control of the pick-up reel. This made the machines more suitable for lodged paddy and for heavy crops with a good deal of straw.
The drawbacks of the first Claeys machine bought were the following: too small grain tank (capacity 1500 litres), too small rear wheels, a threshing cylinder with raspbars (instead of pegs), too weak track chains.
With regard to a fifth drawback there was some difference of opinion. Some thought that the Claeys machine had too little weight on the rear wheels, so that when reversing in the field it tended to tip forward. In our opinion this was exactly the right alternative to the situation in the MH combines which have to much weight on the rear wheels and quickly sink in the mud.
After the Claeys factory (of Zedelgem, Belgium) had satisfied us concerning the first three points (the grain tank was enlarged to a 2,000 litre capacity, rear wheels 10 × 24 in size and the threshing drum with pegs) 8 new Claeys MZ machines were ordered at the beginning of 1957 which started to work halfway through that year. The technical data on these modified machines are given in Table 53.

Our subsequent experiences with the Massey Harris No. 90 and Claeys combines warrant the conclusion that on the whole the machines were about equal as regards performance and cost. The advantages of the Claeys machine, as outlined above, were balanced by, as was afterwards found, the quality of construction of Massey Harris 90 machines being superior. However, from experience gained in the Prins Bernhard polder, the Massey Harris No. 92 machine, which came on the market in the meantime, proved superior to both the others referred to, provided it had been equipped with 5-roller tracks and larger rear wheels.

2. Transport

The rice harvested with the combines can be transported either in bags or in bulk.
In 1951 we had no clear idea of the possibilities and difficulties of the project to be established, so that it was decided to adopt the safe conservative method of bag transport, and for this purpose 32 bagging combines were purchased. In 1954 and 1955 this was the only type of machine used.
In 1954 the bagged harvested product was conveyed to the jetties of the irrigation canal by means of 4-wheeled farm waggons pulled by crawler tractors, then loaded in bags on to lighters which sailed to the rice-mill at the yard, where they were discharged via a bag elevator on to a platform and emptied.
This method, being cumbersome, was modified by SCHRAMM in 1955 in such a way that the bags were already emptied into the lighters at the polder jetties.

The lighters were then unloaded at the factory by means of a newly fitted scoop elevator.

Although this modification, with its resultant saving of labour, may now seem an obvious step to take, it did not appear altogether obvious at the time. In this connection it should be remembered that, according to the original plan, 72-hectare farms were to be leased or sold. With this idea in mind, the Dutch farmers who at that time had been enlisted under the scheme were opposed to this partial transfer to bulk transport, since they assumed that the weight and quality of the rice they supplied would cease to be accurately measured and accounted for separately. Viewed in this way, the transfer to bulk transport is characteristic of the gradual reappraisal of the project at this period which led to the change-over from 72 ha-farming to large-scale estate operations.

Apart from any interest which the individual farmer might have in a proper separation of harvested batches, from the general agricultural viewpoint also it was considered essential that the yields should be gathered separately field by field. When, however, the bulk transport method was only adopted from the farm jetties to the mill this aim could still be achieved by employing harvest checkers who measured (roughly) and sampled every batch of bags harvested each day on each field (before it was put in the ship). Only after the contents of the entire lighter had been weighed at the factory the batches were then finally specified in kilos.

In 1956 the first 7 bulk combines started operating, and in 1957 a further 8. Provision was made for conveying the bulk rice from the combines to the lighters at the jetties by the purchase of 2-wheeled tipping-bulk-carts built to specification.

A fairly satisfactory method of measuring was obtained in this case by reading the volume scale of each waggon to be tipped, this data being afterwards converted back at the factory into weights on the basis of the total lighter weight.

The cargo-gauging scales at the water-line of the lighters were not used for determining the weights.

Transport in bulk

Compared to transport in sacks, bulk transport offers considerable advantages. These are:

— The bagging combines require, in addition to the driver, two men for removing sacks and unloading. On the bulk combine the driver can carry out the operations alone, although a workman is generally available to help the driver.

— Mechanical unloading of the combine tank at the ends of the fields occupies about the same amount of time as manual unloading of sacks. The difference is that in the first case staff can take a short break during unloading.

— Dispensing with bags means a saving in purchase costs, as well as a saving in transporting, grading, cleaning and repairing bags.
— Since the tipping waggons with bulk paddy are hydraulically discharged into the lighters at the jetties, there can be disposed of unloading the bags by hand, stacking them on the jetty and loading them on the vessel.
— Bulk transport by ship dispenses with the need for stacking in the vessel and the partial unloading by hand at the factory.

Bulk transport has requirements in the following four items: 1. the combine-tanks, 2. the bulk waggons, 3. the lighters and 4. the unloading equipment of the mill.

Re 1. The capacity of the combine-tanks should be adapted to the volume needed for a 600 m run (= the length of the fields). Assuming a maximum working width of 4 m for the 14 ft-machines and a maximum yield of 4 tons paddy per hectare, with a s.g. of 0.5, the required capacity amounts to 1900 litres (cf. actual capacities in Table 53). The positioning of the MH combine-tanks to the rear was somewhat unfavourable for the floatability of the machines. It proved difficult to shift these tanks more forward. This was in fact one reason why at the beginning there was some hesitation about buying bulk combines. However, after lengthening the tracks and fitting larger rear wheels, the above drawback appeared more or less acceptable. The weight distribution of the tanks of the Claeys MZ was better and created no difficulty.
Another point was the unloader worm of the combine tank. The waggon into which the combine has to discharge the paddy, stands on the dam at the end of the field. The combine discharging the paddy rides alongside, but may better remain in the field because the dam is too narrow and would soon be worn down by driving the combine up and down it. Also the combine tracks and the blocks fitted on them would be severely strained on the incline of the dam. This situation calls for a certain minimum height and length of the unloader worm. Owing to this the worms of the MH combines had to be lengthened. The worms of the Claeys machines were supplied at our request about 1 metre longer than standard.

Re 2. The farm waggons used on the project had to be suitable for carrying 3–4 tons of paddy to the jetties, via the dams, thus not for loading in the fields.
As regards the bulk waggons we also allowed for the following requirements:
1. a limited height of the upper edge so that the combine could discharge into the waggon;
2. sufficient height of the lower edge with respect to: the level of the ship, the water levels in the irrigation canal and the jetty floor heights;
3. a sufficient reach of the loading hopper over the vessel to permit ready discharging when the waggon is tipped up;
4. hand hydraulic operation in order to avoid the necessity of buying

additional attachments for the tractors, and also for reliability of operation and the prevention of serious accidents;

5. a great degree of manoeuvrability of the waggons in connection with the narrow jetties and field dams;

6. appropriate design to prevent tilting forward, backward as well as sideways;

7. limited soil pressure by the fitting of large tyres;

8. maximum alternative suitability of the bulk waggons for ordinary transport;

9. reasonable price.

Taking these requirements into consideration it was concluded that a two-wheeled tipping waggon would provide the best solution.

Only Spijkstaal (Netherlands) gave a satisfactory reply to the tenders requested from various factories. After a trial order of two waggons the entire fleet of bulk waggons required was ordered from this firm. The specification was as follows: two-wheeled farm waggon, carrying capacity 5,000 kg, dimensions of the loading hopper 4 × 2 m, no brakes, tipping backward hydraulically with a handpump, sideboards 80 cm in height, front and rear board 100 cm in height, with chain connection in the middle for supporting the sideboards, with bottom discharging rear flap, loading-floor height 115 cm, supported on two used aircraft tyres 1500 × 16, with a dragfoot on the drawbar provided with a footplate of generous dimensions and a jack with 15 cm minimum and 60 cm maximum adjustment of the eye of the drawbar.

The bearing axle is fitted somewhat to the rear of the centre, so that a loaded weight of about 500 kg comes to bear on the drawbar.

Re 3. For bulk harvesting the lighters have to be ready at the jetties all day long. This constituted a problem when small farm units of 72 ha were envisaged, since in this situation the paddy would be harvested at some 40 different points in the 6,000 ha polder, so that if the large lighters purchased were to be used the bulk waggons would have to cover long distances, or else it would be necessary to adopt a different transport system by water (e.g. with 20-ton pontoons as in the sugar-cane estates where they are towed in groups). But the problem was greatly simplified at Wageningen when it was possible to change over to centralized large-scale operations. From 1956 onward the area was gradually divided up into larger agricultural units of 400 to 600 ha. Each unit of this size could be harvested with a group of 3 to 4 combines, the capacity of a bulk-lighter of 50 to 100 tons fitting well into this scheme.

The 10 or more boats used for transporting the harvest are a various selection of models. With one exception they were primarily purchased on account of their utility in civil engineering operations during construction work. But both for loading, transporting and unloading paddy in bulk, the shape of the vessel has to conform to certain specific requirements, and in our case these were not always particularly well complied with. A number of important requirements in this connection are as follows:

— a width of the gangways and height of the upper edge of the side of the ship adapted to the reach of the tipping waggons;
— a disposable minimum clearance between tipped waggon and loaded paddy until the vessel is full;
— a steady position in the water making it possible to tip the paddy on one side for some time and to load the vessel high up;
— holds of such a shape that discharging can proceed smoothly.

Re 4. With regard to the discharging installations at the factory the following points were important: the reach of the unloading crane for the various types of vessels, the speed of unloading, the wear of parts which came into contact with the paddy, and the damage to the paddy through unloading.
A scoop elevator was installed for the actual unloading and a pneumatic suction apparatus for cleaning up, i.e. for sucking up the remnants in the ship's hold which could not be reached by the elevator. Pneumatic suction was limited as far as possible owing to the increase in paddy brokens said to be due to this method, and also on account of the rapid wear of the suction pipes.

Other aspects of the transport by waggon from combine to vessel

In the previous pages we have discussed bulk transport as compared to transport in sacks, and the two-wheeled tipping-waggons designed for this bulk transport.
Other important aspects of the harvest transport on the Wageningen project are:
1. the equipment of the waggons, having regard to the nature of the terrain;
2. possibilities of discharging from the combines in the field, both when stationary and moving;
3. the suitability for harvest transport of the field lay-out;
4. the tractors used for transport.
In practice the normal method was to place the waggons on the road dams along the head lands of the fields. The combines travelled distances of 600 m across the length of the field and then discharged the paddy into the waggons. The head lands had been previously harvested as to give the combines enough room.

During the past years it only seldom happened that the fields were firm enough to enable the waggons to be driven into the field and loaded, thereby limiting the unloading trips of the combines. When such a situation occurred it was also made use of. Both sacks and bulk paddy were then unloaded in waggons parked in the field.
Dropping the sacks in the field while the combine was harvesting appeared unattractive and was never tried. Discharging bulk paddy while harvesting with the combine, was first tested in 1959 by OVERWATER in the Prins Bern-

hard polder, on a firm field, but he was forced to admit that the field was still too soft for a loaded waggon. According to the time measurements taken in the bulk-combine operations in the P.B.P., which are carried out under conditions similar to those at Wageningen, an average of about 30% of the combine operating time is spent on driving to the waggons on the dams and on unloading paddy. Further experiments in this direction are therefore considered desirable.

The possibility of driving the harvest waggons in the fields can be increased by improving the bearing capacity of the fields and adapting the waggon design to the field conditions.
The first point has already been dealt with.
With regard to the second point, a number of experiments were conducted in the project area from 1952 to 1954, various types of tyres as well as sledges being tried out with the waggons. One particular experiment was the construction of a platform above a crawler tractor (in two sections above the tracks), thus creating a self-propelled transport vehicle.
The problem of carting away produce from wet land which is difficult to drive on, is one that occurs fairly frequently in agriculture. MORRIS (1959), for instance, gives an interesting account of the solutions applied in practice for transporting sugar cane from wet lands in South Africa.
He mentions:
— a temporary narrow-gauge railway in the field (expensive, liable to subside);
— waggons on p.t.-o.-driven tracks;
— laying down old ships plates;
— double wheels (risk of strain owing to clay drying up in between);
— waggons with a p.t.-o.-driven set of wheels;
— low waggons with large tractor wheels;
— waggons on sledges;
— cable traction by means of winches.
Most of these solutions were also considered at Wageningen, but rejected owing to the cost or the slight effect which would be achieved thereby.
MORRIS's final conclusion is that the only good solution of this problem is drainage. But this is a solution which is not always feasible, particularly in the Wageningen project area.
Our conclusion, based on the transport experiments conducted on the reclamation lands of the project area, was, that during harvesting most fields are so soft that no conventional equipment is suitable for the harvest transport in these fields. The construction of special equipment on the other hand is expensive and also necessitates further costly experiments.
Therefore the alternative solution of transporting via the dams was chosen. In this case the combines have, however, to be driven idly over additional distances. For the transport work via the unmetalled clay dams, the waggons had to be equipped with wide tyres of large diameter, for instance the follow-

ing tyre sizes in order of suitability: 1500×16, 32×1000×15, 1250×14 and 1200×12.
When the fields have acquired more bottom in the course of time, the possibility of transport in the field will have to be to reconsidered, especially with regard to the more efficient use of the bulk combines.

The lay-out of the project area for transporting the harvest may generally be regarded as satisfactory. The communication between the fields and the water transport is very good owing to the location of jetties at 1200 – metre intervals, for each 144 ha, and the presence of road dams on either side of every field. Moreover the dividing dams between the fields are also quite suitable for traffic.
Due to the wide sweep of the navigation canal, the north-eastern corner of the polder area is not so well situated for water transport. For this section has been thought of bulk transport by road, from the combines to a jetty where the irrigation canal enters the polder, or else direct to the rice mill yard. This plan has not, however, been put into practice yet.

During the initial years the only traction used for transporting the harvest were crawler tractors, but since 1956–1957 most of this transport work has been done by means of 50 H.P. WDR9 International wheeled tractors or 35 H.P. Ferguson wheeled tractors. The heavy 50 H.P. wheeled tractors were especially intended for conveying the 2-wheeled bulk waggons. During bad weather the wheeled tractors were replaced by crawler tractors.

CHAPTER XVIII

ASPECTS OF WATER CONTROL

The polder drainage works well, but with respect to the irrigation a number of difficulties have arisen, which are connected with the dual purpose construction and the location of the pumping station. These difficulties are as follows:
— low operating efficiency for pumping water in,
— pollution of irrigation water with drainage water, and
— high salinity of the irrigation water.

1. The operation of the dual purpose pumping station

When the pumping station was constructed, the capacity of the dual purpose pumps was adjusted to the estimated drainage capacity required since this was much greater than the estimated irrigation capacity. HENS (1950) assumed that the maximum discharge of the pumping station for drainage would be 40 mm per 24 hours, whereas for irrigation he considered that the capacity required would only be 0.64 litres/sec/ha (5.5 mm per 24 hours).
The capacities and power efficiencies for drainage and irrigation of the pumps installed, are shown on page 86. These figures, supplied by the manufacturer, show that the capacity of the pumps in the irrigation direction is 30 to 40% lower than in the discharge direction, and also that the power efficiency for pumping water in is 10% lower than for pumping water out.

So far as we have been able to ascertain the project plans did not include any estimates of the number of pumping hours required per annum for irrigation and drainage. Nor were any calculations made in order to determine the point of equilibrium of the profitability of a dual purpose pumping station and two separate pumping stations, with an increasing ratio of the number of irrigation operating hours to the number of drainage operating hours. Table 54 shows the number of operating hours per annum from 1954 to 1959 for pumping water in and out, as well as the hours in which sluicing by gravity was carried out via the sluiceways underneath the pumping station. The Table shows that the pumping station had to operate considerably more for irrigation than for drainage.
The operating hours only are shown as water output data are not available. The amounts are, of course, connected with the rainfall and the area served by the pumps.
(From 1954 to 1956 the annual rainfall was heavy to very heavy compared to the average, and from 1957 to 1959 light to very light. But during the wet

years as well, it was found that more water was pumped in than out, and it should also be borne in mind that in these years an additional 1,000 to 2,000 hectares of reclaimed land were being continually drained but not irrigated. As regards the land served by the pumping station, the following areas were sown and irrigated (main crop and second crop together): in 1954 1,000 ha, 1955 2,200 ha, 1956 5,000 ha, 1957 and 1958 7,300 ha, and 1959 7,900 ha. About 1,500 ha were drained by pumping in 1954, about 3,000 ha in 1955, about 4,500 ha in 1956 and about 5,000 ha of land from 1957 onward.)

TABLE 54 *Output of the Wageningen pumping station, in operating hours for pumping in and out and hours of sluicing out by gravity, from 1954–1959*

Year	Pumping in	Pumping out	Sluicing out
1954	800	900	400
1955	1600	700	1700
1956	3200	2500	1500
1957	4900	2300	1000
1958	5000	2600	1500
1959	4600	1600	1800

Hence the situation is that, although the pumps are constructed for a maximum discharge capacity per 24 hours, the annual discharge production is slight compared to the irrigation production. Irrespective of whether the maximum discharge capacity specified may be occasionally necessary for the timely discharge of heavy peak rainfalls, there is still the drawback that the bulk of the pumping production, which consists of pumping water in, has to be done at relatively low pumping efficiencies owing to the dual purpose system. In our opinion this development was not foreseen when the pumping station was designed, and it was, in fact, anticipated that the station would mainly have to operate for drainage, and not vice versa.
The two main reasons for this discrepancy between plan and reality are that an entirely different type of agriculture is being practised in the area than had been planned and that the irrigation requirements of mechanized rice-growing were underestimated.

The change in the type of agriculture has been considerable. There is no cultivation of the dry annual crops as specified in the basic plan in rotation with rice and for which the high drainage modulus was considered to be particularly necessary. In their stead rice is again cultivated as a second crop on a quarter of the area during the winter season. Besides, about twice as many hours of pumping are required for irrigating this second crop as the hours required per hectare for the main crop, this being due to the drier weather and the scattered location of the sown fields.
Moreover the leys planned for 1/6th of the area were not laid down so that this area also is being sown with paddy. In all 50% more rice is being grown in the polder than had been provided for in the plan, which, taking

into account the additional water consumed by the second paddy crop, means that as much as 80% more irrigation water is required.
A further consequence of the exclusive cultivation of rice has been the increasing use of gravity sluicing instead of pumping water out, since in rice-growing temporary high water levels in the drainage system are permissible up to a greater extent.

In order to illustrate the use of the pumping station, Figure 19 shows in diagrammatical form for the year 1958: the number of daily operating hours for pumping in and out, the number of daily sluicing hours (via the sluiceways below the pumping station) and the mean daily rainfall of 9 rain stations in the polder. The following cultivation calendar can be reconstructed from this diagram:

JANUARY. There is some irrigation of the 1,500 ha of second crop paddy. Despite the low rainfall there is a fair amount of sluicing during the first half of the month owing to the land being drained for fertilizing.
Drainage occurs almost entirely by sluicing.

FEBRUARY. Little irrigation; the ripening crop is gradually drained. Towards the end of the month it is only necessary to pump in water in order to keep the main irrigation canal at the proper level. All drainage is done by sluicing.

MARCH. At first there is little irrigation until the middle of the month; then a rapid increase occurs for tillage, and towards the end of the month also for sowing the main paddy crop.
Nearly all drainage is done by sluicing.

APRIL. A great deal of irrigation for both tillage and sowing. At the beginning of the month sluicing is still possible, but with the setting in of the long rainy season and the accompanying higher river water levels (cf. Table 55) it becomes increasingly necessary for the drainage-water to be pumped out.

MAY. A considerable amount of irrigation; gradually less than the previous month owing to the completion of rice sowing (5,900 ha) and the persistently heavy rainfall.
The irrigation water is used for reflooding after drainage for weed control and fertilizing, and also for making good seepage losses and evaporation.
Drainage is almost entirely by pumping and requires a great many operating hours.

JUNE. A considerable amount of irrigation for the same reasons as in May. The drainage operating hours are still high. Owing to high river water levels it is impossible to sluice.

JULY. Slowly decreasing irrigation. Also a slowly decreasing number of drainage operating hours. Some sluicing on to the river is again possible.

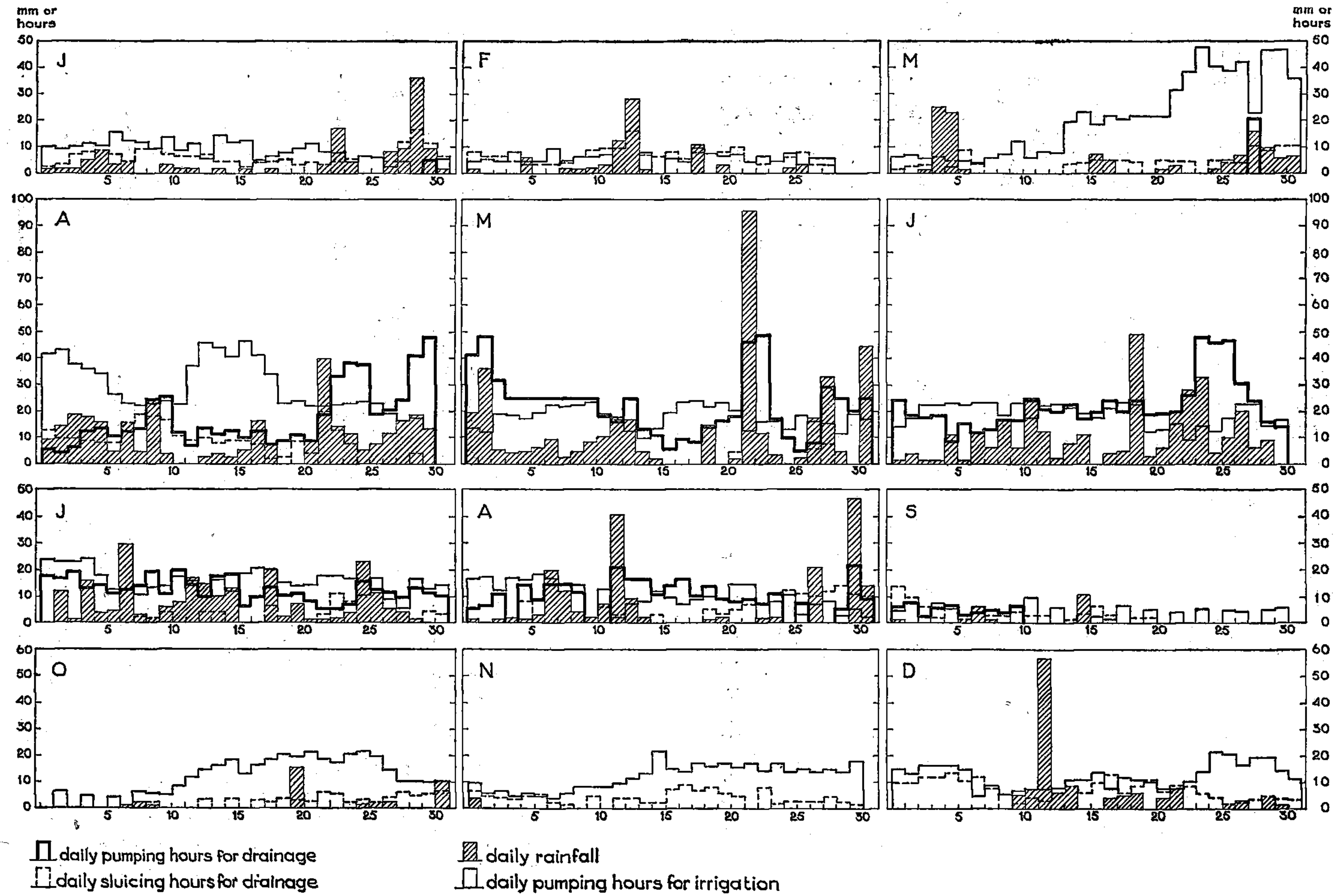
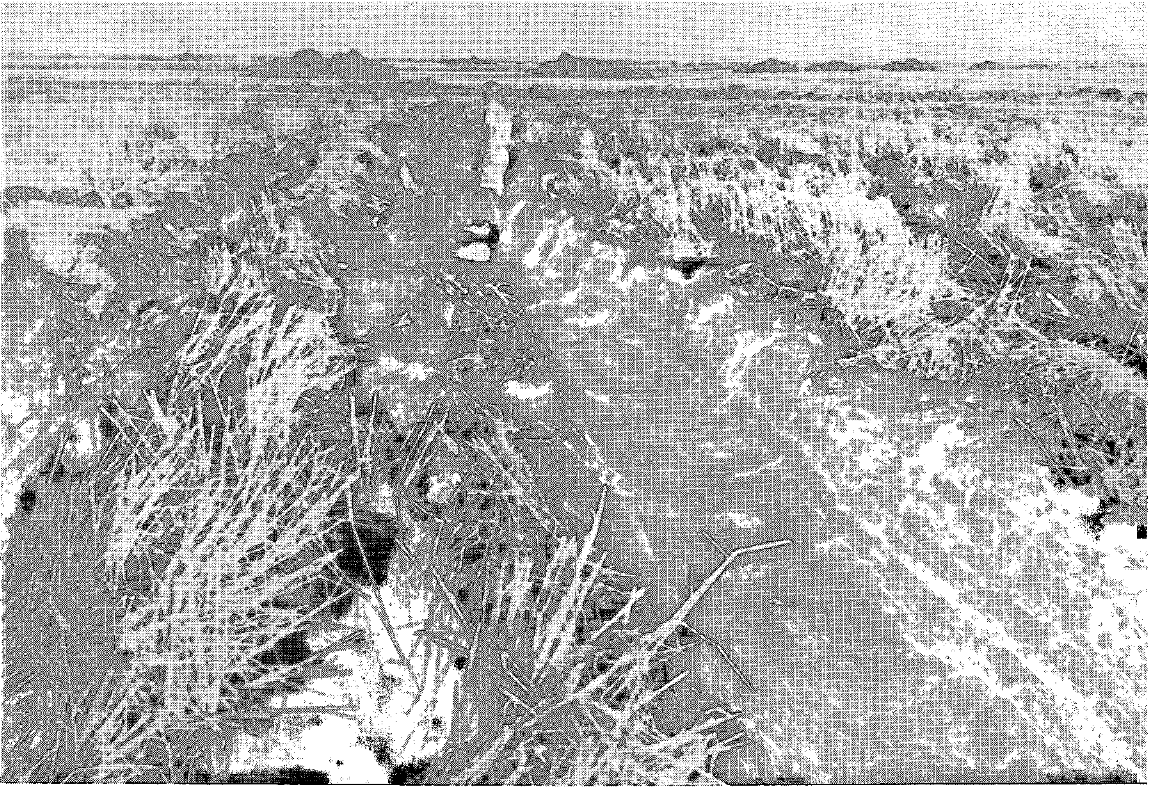
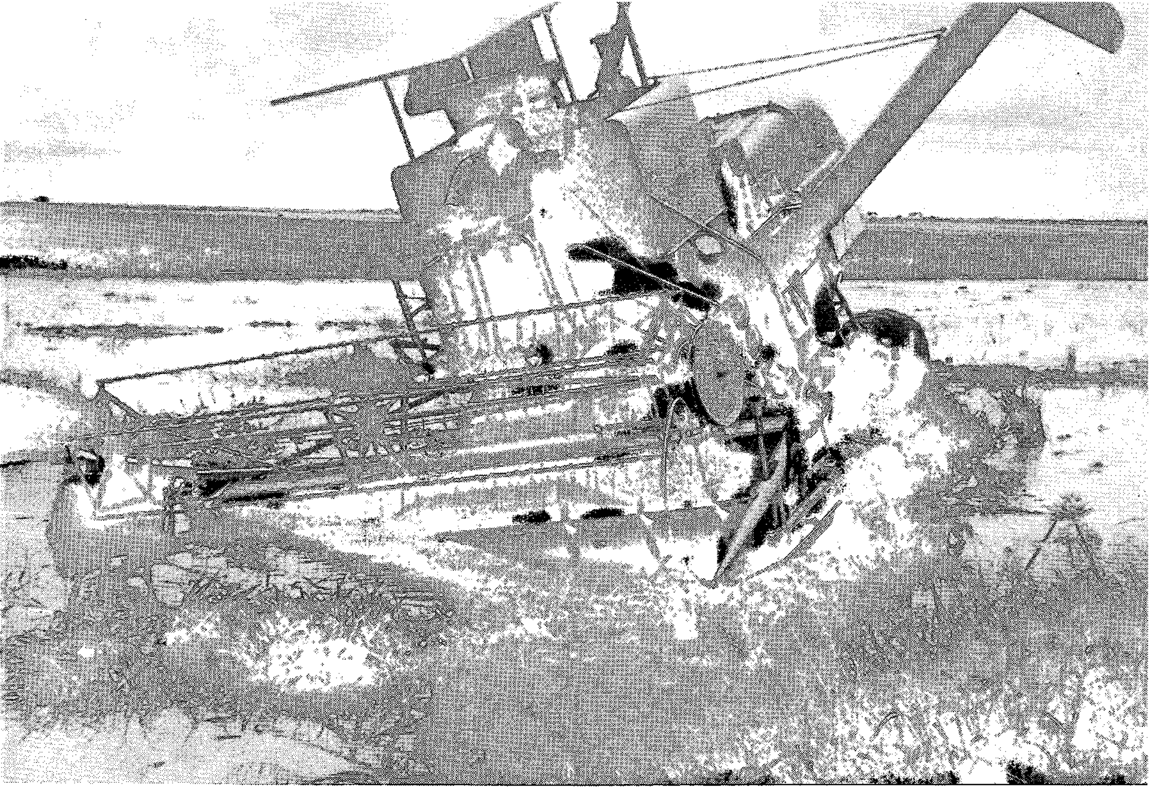


Fig. 19. *Survey of water control operations in the Wageningen polder in 1958.*



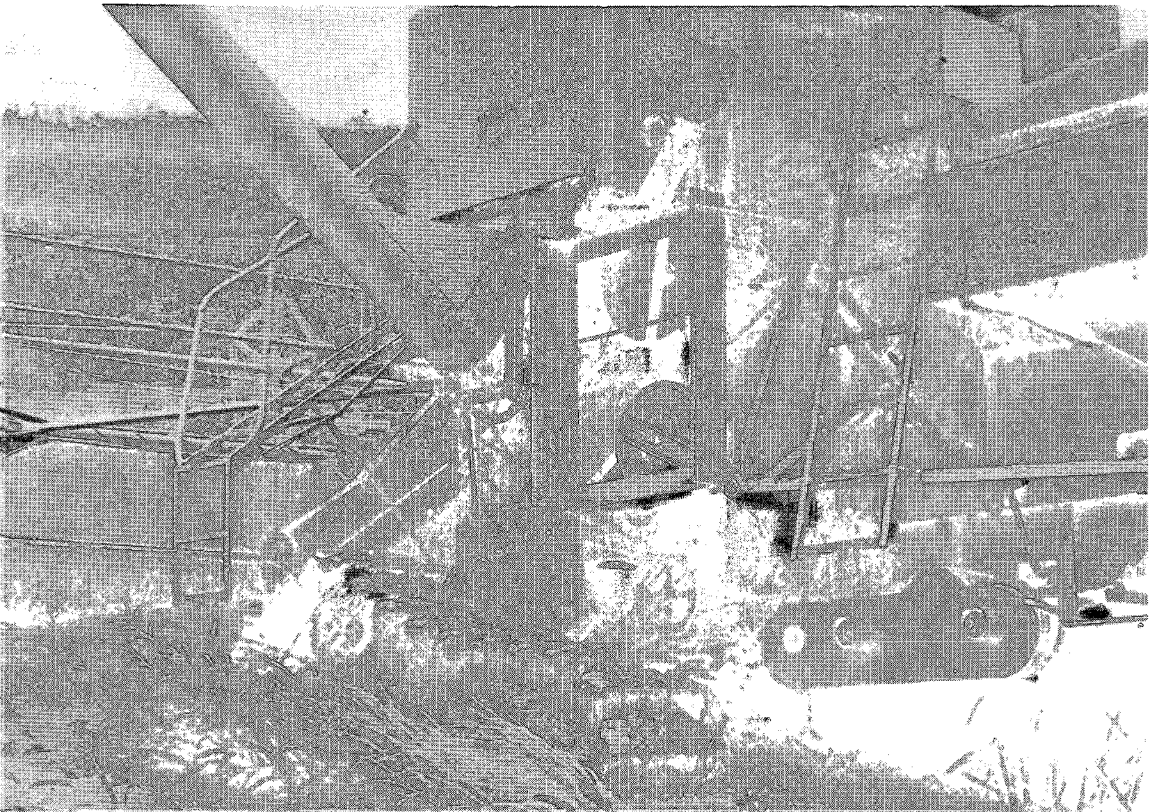
51. *Trail in rice-field of a mired down combine being pulled out by Al Evans winch.*

52. *Trail in the same rice-field of the "cable-propelled" winch-platform.*



53. *Trial runs with Claeys-combine; reversing from a bad spot, the machine tipped forward.*

54. *Trial runs with Claeys-combine; track has high floating capacity but little durability.*



AUGUST. The number of irrigation operating hours continues to fall.
The first fields are drained for the harvest. Owing to a number of heavy showers the pumps still have to operate for fairly long periods for drainage. Towards the end of the month large-scale sluicing is again possible.

SEPTEMBER. The harvest month par excellence.
The irrigation operating hours fall to the minimum figures required for maintaining the level of the main irrigation canal. All remaining fields are being drained.
Drainage is of minor importance as there is hardly any rain.

OCTOBER. About the 10th the irrigation operating hours begin to increase rapidly to a moderate level for tillage and subsequent sowing of the second paddy crop.
Drainage is entirely by sluicing; it is slight owing to the persistent drought.

NOVEMBER. By the beginning of November the sowing of 1,400 ha rice is completed and the irrigation water consumption falls; it rises again later in the month because of persistent drought and reflooding of areas drained for weed control and fertilizing.
Drainage is entirely by sluicing, and is only necessary for discharged irrigation water and seepage water.

DECEMBER. The comparatively high irrigation operating hours drop slightly in the second decade owing to a certain amount of rainfall and less reflooding, but increase again in the third decade mostly for reflooding after the second top-dressing. All drainage is done entirely by sluicing, even in the case of a 55 mm-rainfall on 12th December.

TABLE 55 *Mean river levels at ebb and mean suction lifts of the pumping station at Wageningen in 1958*
In metres

Months	Mean river levels at ebb (+Nickerie Survey Datum)	Mean suction lift at pumping in	Mean suction lift at pumping out
January	7.17	1.61 (253 h)	0.44 (4 h)
February	7.23	1.46 (145 h)	(— h)
March	7.13	1.76 (636 h)	1.88 (21 h)
April	7.48	1.53 (874 h)	0.71 (525 h)
May	7.83	1.21 (532 h)	0.90 (662 h)
June	7.70	1.36 (572 h)	0.78 (662 h)
July	7.54	1.47 (486 h)	0.72 (385 h)
August	7.49	1.55 (309 h)	0.72 (302 h)
September	7.27	1.63 (104 h)	0.72 (53 h)
October	7.21	1.78 (334 h)	(— h)
November	7.20	1.95 (361 h)	(— h)
December	7.14	1.87 (378 h)	0.48 (12 h)
Year	7.37	1.58 (5004 h)	0.79 (2624 h)

During the year 1958 specified the pumping station was working at top capacity in April, May and June, during which period a great deal of pumping was required for both irrigation and drainage. Figure 19 also shows an alternating occurrence (complementary effect) of irrigation and drainage. Naturally this has to be automatically reflected in the graph as soon as the dual purpose pumping station operates at full capacity. But also at lower operating rates it can be seen that with a heavy rainfall the pumping capacity is being used for pumping water out in particular, during which time the irrigation operating hours fall. Usually there is no harm in this, provided the main irrigation canal is maintained at a certain minimum level. The station works at full capacity when 60 to 70 pumping hours are done per 24 hours (3 pumps operating for 24 hours, less some idle hours for: maintenance, passing vessels through the lock, and periods of unfavourable pumping heads). It is not usual, nor was it found necessary, for more than two pumps to work in the same direction, as this would overload the suction and discharge bays during pumping out, as well as the inlet bay during pumping in. It is also doubtful whether the canals could cope with the mass of water from the three pumps. Actually, therefore, only two pumps can be counted on for the maximum discharge capacity, and in our opinion this weakens the argument on which the selected form of pumping station was based.

Another matter which is difficult to reconcile with the principle of maximum discharge capacity, is the manner in which the sluiceways are built underneath the pumping station (viz. in a single construction). Since they run partly via the pumping pipes (Fig. 16) it is impossible to sluice by gravity when the three pumps are in operation. It might have led to a considerable improvement if the sluiceways had been placed in front of the weed trap of the main drainage canal.

2. Irrigation water requirements

As stated earlier, during the construction of the project it was assumed that a maximum irrigation flow rate of 0.64 litres/sec/ha from the pumping station would be sufficient. This figure was based on experience gained in irrigating peasant rice-fields in Java. It is, however, far too low for the mechanized large-scale cultivation of rice as carried out in the Wageningen project, as we shall explain below. There was also too much dependence on the Javanese smallholding figures with regard to the total amount of irrigation water required for each rice crop. The following reasons can be listed why water consumption in the project should be higher:

— In order to prepare the seedbed by puddling a water sheet of about 25 cm (including the moistening of the soil) is applied. As this water is usually too turbid to sow in, it is subsequently drawn off and a second sheet of about 20 cm is supplied.

— The irrigation period is longer than in the case of smallholder rice growing, as direct sowing is practiced instead of transplanting.

— During the early stage of growth the water level in the paddy field has to be kept at a level of about 20 cm in order to control weed development.
— The fields are reflooded after being drained for chemical weed control and top-dressing (often twice) with ammonium sulphate.
— Further manipulations with the water level may be necessary for control of certain pests. On the Wageningen project this is done particularly intensively in order to control caterpillars in young crops. It seems probable that eventually more use will be made of water for this purpose. ADAIR (1955) mentions, for example, for ricefields in the U.S.A. 8 different diseases and pests which can be wholly or partly controlled by correct timing of irrigation and drainage.

The necessity of most of the points mentioned above is relative and it might be possible to manage with less water when its cost reaches a given high level. However, the maintenance of a sufficient level of water from sowing to about 2 months afterwards is quite unconditional. There has still been no close evaluation in the project of the benefits to be derived from some additional manipulation of the water compared to the drawbacks of limiting such manipulation or other possible solutions for these drawbacks. This matter should be given further consideration, as it should be quite possible to economize on water consumption.

It appears that the said refloodings are not in itself of very great importance to the rice crop (apart from their use for weed control and fertilizing).
From 1955 to 1956 onward trial fields were laid out at Wageningen, the number of fresh irrigations and drained periods being varied. The results observed are listed in Table 56. The rather extreme replenishment treatments were tested after no differences in yield had been noticed in other experiments in which one or two extra replenishments were given.

TABLE 56 *Yields of Dima with stagnant water and replenishment*
In 100 kg paddy/ha – 14% m.c.

	1955/56	1956	1957
Stagnant water continuously on the field for 100 days (in 1957 for 128 days)	20.8	39.4	27.8
Stagnant water continuously on the field for 125 days (in 1957 for 138 days)	20.9	39.1	27.1
Fresh water continuously flowing through for 125 days (in 1957 for 138 days)	24.3	40.7	27.5
Alternate dry and flooded weeks for 125 days (in 1957 for 138 days)	26.0	42.7	28.7

In none of the experiments the differences did reach a statistical significance ($p = 0.05$). In view of the fact that small additional yields have been a regular occurrence, it can, however, be stated that there is a tendency to increased yields with intensive replenishments. But the replenishments supplied would be so expensive, owing to the extra pumping hours they would represent, that replenishment would hardly seem to be profitable in view of the slight additional yields anticipated.

In the present cultivation schedule peak irrigation-flow is required during the period of tillage and sowing of the main crop, i.e. the second half of March and in April. By May the period of greatest activity is over again and moreover the rainfall then also affords some relief. By assuming the sowing period to be staggered over 6 weeks for 5,900 ha, a first 25 cm sheet of water for tillage and a second 20 cm for sowing, one arrives at a supply-rate of 1.23 litres/sec/ha. During this period the rain cannot be depended on, so that it should be possible for the irrigation system to provide this amount.
Extra flow is required to offset evaporation; 6 mm per 24 hr are suggested over half the area = 0.35 litres/sec/ha. To this must be added the seepage losses. Losses through (vertical) percolation on the fields are nil, but very considerable losses are caused by leaky dams, e.g. via drought-fissures, by overflowing of dams and by defective culverts.

The measurement of such losses is a difficult task. An attempt at measurement was made in December 1954 for a small area which had just been laid out. The estimated seepage losses were equivalent to a flow rate of 0.47 litres/sec/ha, not including, however, two extreme leaks which cost a further 0.5 litres/sec/ha. These figures caused some alarm at the time so that for this and other reasons the tertiary canal dams in particular, were reinforced and all culverts constructed with greater care. In the course of 1955 the state of affairs with the field culverts constructed before December 1954 became untenable, as one after the other was destroyed by undermining and subsequent erosion. It was even quite a common occurrence for the large culverts (of the main or secondary irrigation canals into the tertiary canals) to succumb and to cause a complete flood.
At that time the culverts consisted of 1 m concrete pipes, inserted in each other with a flange of only a few cm, the intention being to seal the seams with cement. Often this cement did not hold, or it was not applied all round, with the result that leaks therefrom rapidly started erosion, followed by subsidence, breaking open of the seams, and finally complete washing away of the pipes, overturning of the slide gate and collapse of the trench which had been excavated at the time for construction of the culvert and therefore had a looser soil-fill. The leak could, of course, start in a somewhat different way, e.g. owing to sinking or working loose of the culverts as a result of the vibration from tractors being driven over the dam. At first, it was refrained from rejecting the concrete pipes which had been prefabricated in large numbers. A great many were laid again on supporting planks, wedged between two wooden dam walls by means of iron draw rods, and in addition provided with a concrete ring to stop any transverse leak-stream. But in 1956 this

makeshift was abandoned and all concrete field culverts (about 2,000 in all) were successively replaced by wooden culverts made of one piece.

Thus, since the seepage measurements were made in December 1954 (it should be noted that they were taken over a scattered area sown with second crop), there has been some improvement in the polder, so that the leaks will now be less serious.

On the other hand for our estimate of the rate of flow we took into consideration the period of sowing the main crop, during which period there is more seepage than when the crop is developing in May and the succeeding months. During the sowing period always new leaks are being discovered, fissures in dams caused by drought have to close up again by swelling, and there are many differences in water levels due to the alternation of dry and flooded fields.

Adding together the 45 cm depth of water for sowing and tillage for 6 weeks, the daily evaporation of 6 mm over half the area, and the "normal" seepage found in December 1954, we find that the average flow rate required for the entire polder would be:

$1.23 + 0.35 + 0.47 = \sim 2$ litres/sec/ha.

If we assume that the tillage (puddling) water does not need to be replenished in every case and that the seepage losses can be kept low, it might be possible to reduce the minimum flow rate required to 1.5 litres/sec/ha. This is still considerably more than the 0.64 litres/sec/ha which it was thought could be applied when the project was planned.

In view of the slight slope in the irrigation canals and the small pressure head some "reserve" capacity of the pumping station is by no means a luxury. In practice it often happened during the peak periods of sowing that the flooding of a field took several days, a factor which may lead to poor emergence and prolific weed germination.

It should, however, be stated that the excessively low irrigation estimate has not led to water shortages until now, since:

— the capacity of the dual purpose pumping station was based on the much higher drainage requirements which resulted in a considerable reserve capacity for irrigation;

— the pumping station was moreover planned for a considerable larger area than has actually been developed;

— the irrigation canal system was given considerable greater dimensions for other reasons than water-supply rate.

In our opinion the principal consequence of the wrong estimate was that it contributed to the idea that irrigation was of minor importance compared to drainage for the construction requirements of the pumping station.

3. Irrigation water polluted by drain-water

One particular agricultural drawback of the dual purpose pumping-station is that a part of the drainage water is pumped into the irrigation system.

The pumping station is situated some 200 metres from the river to which it is connected by an open canal. Water is pumped both in and out via the same canal. But both the irrigation and drainage systems have a low reservoir capacity and a further drawback is that the polder area gradually slopes down to the north, so that the surface is about 50 cm lower in the north than in the south. It therefore often happens that water has to be pumped out (or sluiced) and pumped in at the same time in order to keep up a more or less constant water table in the polder. This means that large masses of silty drainage water pollute the irrigation system. Even if water were to be pumped in and out at different times, a remnant of drainage water would still first be pumped in from this junction canal, and since there is local eddying of the water when it is pumped in, silt sediments also are absorbed again.
The river-water itself is usually quite clear and free of silt at the point of intake, except for long periods of drought when it may become turbid and silty owing to low river-flow, but even in those periods this is considerably aggravated by the admixture of drainwater when it is pumped in.

The drawbacks to the project of this dirty irrigation water are as follows:
— It has a harmful effect on the emergence of rice sown in water. On the deeper parts of the fields in particular, the rice sprouts receive too little light in turbid water to enable them to grow through the water cover.
— If there is no risk of grass weeds a ricefield can be left dry after sowing until it is about a fortnight old. But it then has to be flooded to prevent drying out and weed development. At this stage muddy irrigation water dirties the young plants and hampers their growth. It has also been found that there is more algal growth in dirty water, the algae clinging to the young plants and pulling them down.
— Drainage water may contain a large number of snails which thus may find their way again into the irrigation system. This renders snail control in the fields more difficult, as fresh snails are constantly entering.
— The polluted water also contains weed seeds which are scattered over the entire polder in this way.
— It is known that *Sclerotium* fungi are spread by the water. Hence there is a risk that rice diseases cannot be localized, since they are spread by the water.
— The entire irrigation system will eventually silt up.
— The irrigation water is unsuitable as drinking or washing water. In periods of protracted drought there is an acute shortage of water in the polder. This is one reason why the rain-tubs of the houses should be enlarged.

On the author's instruction Miss HISSINK investigated in May 1957 the silt content of samples of water drawn from various points of the river. Fig. 20 illustrates some results of this investigation. The silt content appears to increase rapidly in a downstream direction and it reaches a particularly high peak in the junction canal between the river and the pumping station. The

setting in of the main rainy season, between 2nd and 13th May, effected a rapid reduction in the silt content.
At the time the silt content of freshly pumped-in irrigation water was also measured at set time intervals. On comparing the operating hours for pumping water in and out and the sluicing hours, it was found that the degree of pollution of the irrigation water was closely related to the times of pumping out or sluicing out.
During April, May, June and July 1957 the evaporation residues of the water from the irrigation canal were measured daily. During May these measurements fluctuated from 0.2 g to 1.6 g, and during June and July from 0.1 to 0.4 g per litre.

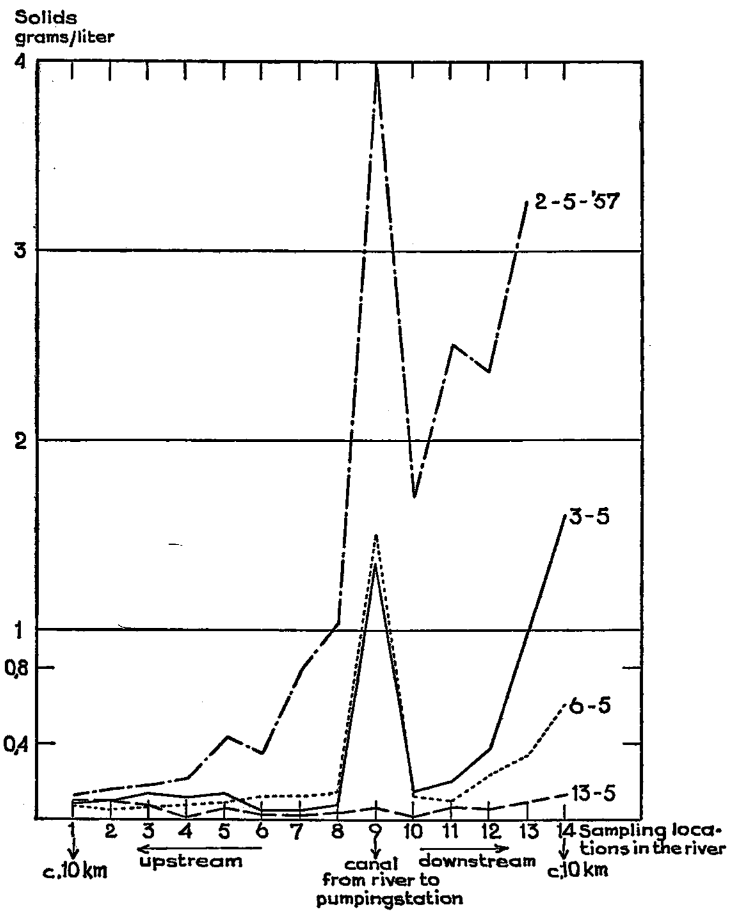


Fig. 20. *Silt content of the Nickerie river at the Wageningen project area.* Water samples taken at a depth of about 5 cm below the surface. Silt expressed in g evaporation residue per litre at 105° C.

Taking the dual purpose pumping station for granted, there are the following possible ways in which the drawbacks could be reduced:

— Improving the method of cultivation and possibly the soil and water properties on the fields, so that the drainage water contains less silt.

During the sowing period the drainage water is most polluted owing to the discharge of turbid, silty water from the puddled fields. The aim should be not to discharge this water from the fields until most of the silt has sunk to the bottom.

The siltiness due to puddling might also be reduced, by amelioration of soil structure or by adding coagulants to the water.

In evaluating the merits of the puddling cultivation method, its drawbacks, in particular the silt problem, should be given due attention.

— Adaption of rice cultivation to the polluted irrigation water. For this there should be: a better levelling of the fields than if clear irrigation water were available, a better seed-quality and higher seed-rates, and more efforts to control diseases and pests which are promoted by this polluted water.

— Improved separation of irrigation and drainage water by constructing a system of canals and locks by the pumping station on the river side, when the irrigation system would be given an upstream river connection and the drainage system a downstream connection.

— Complete separation of pumping in and out should the polder be extended to such an extent as to necessitate a new pumping station. The existing pumping installation should then be used for drainage only and not for irrigation (as proposed by OLDENBURGER ET AL., 1956), since in any case its hourly output and energy consumption per cu. metre of water output for pumping out is much more favourable than for pumping in. Moreover, owing to the occurrence of saline and silty river water during very dry periods, the location of the pumping station has proved to be less suitable for irrigation. Since an eastward extension of the polder area is to be preferred (for other reasons as well), in a new extension plan it would be logical to locate the new irrigation pumping station some 10 km upstream of the Nickerie river in the extreme south-east near the Koffiemakka creek, where in principle it should be capable of irrigating the entire polder system.

4. The salinity of the irrigation water

The anticipation that the Nickerie river at the point of intake would be sufficiently salt-free (see p. 69) has not materialized.

Especially during the dry years 1957, '58 and '59, repeatedly such high salt-contents were measured that pumping in had to be limited to prevent salinization of the polder area. It is apprehended that the salt water-line also moves considerably further upriver during low flow periods than was formerly the case, because of the withdrawal of large quantities of river-water by pumping.

The permissible salinity of irrigation water used for rice cultivation is a magnitude depending on numerous factors. We will not enter into a dis-

cussion of this complex subject. According to the Agricultural Experiment Station of Paramaribo, the Cl content of the irrigation-water should not exceed 300 mg/litre. It is understood that this advice only applies to conditions prevailing in Surinam.
From the beginning of the development of the project to 1957 the salt contents in the river opposite the pumping station were regular and low (20–30 mg Cl/litre). In May 1957, after a period of long drought, the salinity at 14 sample locations in the river was measured for ten about successive days. The samples were taken about 5 cm below the surface of the water and the Cl-content was determined by titration with $AgNO_3$.
Some 10 km upstream of the pumping station the Cl-content varied from 10–20 mg Cl/litre, but from 20–800 mg about 10 km downstream; the open supply canal from the river to the pumping station had 10–90 mg of Cl and the river itself 10–40 mg at the location of the pumping station. The relatively high Cl content in the supply canal is probably caused by admixture of aspirated deep river water having higher salt contents, although it may also be partly due to the drain water which is pumped out into the same canal. The Cl content of the drainage water may be higher owing to: brackish water brought up from the swamp north of the polder, desalinization of the polder lands and discharge of irrigation water with higher salt-content by evaporation.
After the long rainy season began in 1957, the salt contents fell rapidly to their normal values. During this year, however, rainfall continued to be on the low side and was succeeded by a further protracted period of drought from August onward.
On 11th November 1957 a salinity of 490 mg Cl/litre was measured in the river opposite the pumping station. On 12th and 13th November salinity measurements were made in ricefields in the polder; these measurements were found to vary from about 100 to 1450 mg Cl/litre. At the same time was examined the salinity in the irrigation canal, which varied from 150 to 440 mg Cl/litre.
Further salinity measurements in the river by the pumping station, for every 10 cm difference in water level, from 14th to 19th November, gave contents of from 40 to 1250 mg Cl/litre, with average minima at ebb-tides. For this reason it was decided to limit pumping-in hours to periods of low river-tides. But owing to this only a small amount of irrigation water was available, so that the increasing salt contents in the fields caused by evaporation could only be slowly corrected. From the beginning of December the Cl content of the irrigation water fell to below 100 mg Cl/litres as a result of the rainfall which had occurred in the meantime. The drainage water in the polder admittedly still had Cl contents of from 230 to 530 mg Cl on 4th December. So, as was expected owing to the drainage water being discharged into the pumping-in supply, the salt-water period was increased still further. Very high salt contents occurred again in April 1958, so that even the sowing schedule of the main season had to be changed consequently.

In none of the seasons mentioned could be observed any significant damage to the rice crop by salt concentration or drought (the latter being a result of the reduced supply). We cannot say, however, what the future will hold in this respect.
With the present scanty information it is not yet possible to determine to what extent it would have been better for the pumping station to have been located further upstream. Of course, the occurrence of high salt contents is to be regarded as an important drawback, which was not anticipated.

CHAPTER XIX

ORGANIZATION OF FARMING OPERATIONS

Agriculture in the general organization

During the initial years of the project from 1950 to 1956, the organization was dominated by construction work. From 1953 onward production began to increase, and after 1956 there was a rapid decrease in construction work owing to the completion of various sections thereof.
Since 1957 the project has been almost entirely in the production phase.
In schematical form, the project-organization consisted of the following main executive departments, from 1955 onward:
— civil engineering department, Wageningen;
— technical engineering department, Wageningen;
— reclamation department, Wageningen;
— agricultural production department, Wageningen;
— rice processing department, Wageningen;
— agricultural research department, two departments, of which the chief one is in the Prins Bernhard polder and the other at Wageningen;
— sales department, in the Netherlands.
Above these departments was the managing director, with at his disposal departments for secretariat, general and personal affairs, and the book-keeping department. Offices were also established at Paramaribo and The Hague.

Occasional difficulties arose about the division of the spheres of activity of the various executive departments, as well as regards their relationship to the management departments. During the existence of the project numerous changes have been made in this division, for example in connection with the above-mentioned transfer from the construction to the production phase. Staff changes were a further factor. Owing to the remote situation of the project area it was not easy to provide staff, so that it was occasionally necessary to adapt the organization of the establishment to the staff available.

The agricultural production department had no disturbing points of contact with the civil engineering department responsible for excavating the canals and the construction of building works, because the reclamation department occupied an intermediate position between them from the point of view of chronology and organization. No more with the sales department, which during production operated in conjunction with the rice-processing plant.

The allocation of work between the reclamation and agricultural production departments proved a fairly difficult matter. The chief task of the reclamation department was the digging of the field ditches with separating dams and clearing the fields of timber and levelling them. Since it was desirable for the reclamation and production departments to work in close conjunction, they both temporarily worked in the same area and had to make partial use of each other's equipment and staff. Up to about 1955 the fields were delivered by the reclamation department to the agricultural department in a ploughed condition; subsequently they were only delivered ripe for ploughing. Delivery before ploughing was preferable, one reason being the greater interest which agriculturists take in this kind of work in connection with the succeeding work of cultivation.

The allocation of work between the technical and agricultural production departments caused repeated difficulties in the matter of the responsibility of each department for the agricultural machinery.
It may be said that the technical department is responsible for maintenance and repairs, and the agricultural production department for the proper use of the machines, but this does not solve the problem of allocation of work. Initially the technical department has been responsible for the actual administration of the machines; afterwards the agricultural department was responsible for about two years, and since then the responsibility has again rested with the technical department.
In our opinion it would be to the benefit of farm management if the responsibility rested with the agricultural department, the technical department issuing strict instructions concerning maintenance and supervision.

The friction between the agricultural production and agricultural research departments chiefly related to:
— whether or not new research data should be made use of;
— the extent to which the production department should conduct experiments.
The situation in the Wageningen project was further complicated in that the most important research work was carried out in the P.B.P., some 40 km away from the project area. In this experimental polder the conditions for rice growing were not exactly the same as those prevailing at Wageningen, so that it was always necessary to test the research results still further.
The reason for the remote situation of the experimental farm was that no trial grounds were available in the project area up to 1953, and afterwards the situation remained unchanged, owing to the cost of moving as well as the advantage of being able to carry out research work in a quiet atmosphere.

During harvesting periods there had to be a fairly close contact between the rice processing and agricultural production departments, in order to ensure a regular supply of freshly harvested paddy. One unavoidable source of dissension between the two departments was that the definitive weight and quality measurements were made by the rice processing plant. In particular difficulties arose concerning the specific harvested weights from the individual fields, these data being important to the agricultural department.

The division of the area into farm units

From 1951 to 1956 a number of young Dutch farmers were engaged on the staff of the project, the intention being to lease them a farm.
When the leasing plan was indefinitely postponed, a number of these farmers left and the others remained project-employees and became mostly managers of farm-units.
During the first production year (1954) the land was still allocated on the basis of the intentioned size of farm to be issued (average 69 ha). In subsequent years the farm-units were increased to the following average areas: 102 ha in 1955, 221 ha in 1956, 375 ha in 1957 and 417 ha: 14 units with a variance from 200 to 650 ha, in 1958.
As during the initial stage it was not yet known what area a farm manager could match, the increases were made gradually and were not necessarily succeeded by forced dismissal of the farmers who had been engaged (most of whom regarded themselves as emigrants).
This transition period also provided an opportunity for gradually improving the ability of the farm managers as they passed from small to large units.

From the start it was aimed, to give the farm managers a reasonable amount of independence, in the first place because the work very largely depended on natural fluctuations, so many variations occurring that they could not all be covered by instructions. An equally important factor was that the greater measure of independence would lead to a greater sense of responsibility as well as more satisfaction in one's work. In the third place it should be pointed out that highly centralized farm management was technically infeasible owing to the poor quality of communications in the polder, particularly during rainy weather, when the area of 60 to 70 sq. km had to be reached either by boat or on foot.
The general binding instructions issued to farm managers were such as related to the smooth running of the organization, as regards staff, equipment, fuel, seed, other materials, and the use of cars and boats for passenger transport. They also related to work reports and farm accounts. As regards cultivation, approximate directives were given. Within these directives the farm managers were given wide scope, but often it was not taken advantage of (it probably gave them more peace of mind not to do so). The farm-units each had a separate accounting system, so that the expenditure and revenue of each unit was made known each year. The work performed by the managers was assessed on the basis of these accounts and given additional rewards in the form of bonuses.

In order to administer and supply the needs of this group of agricultural units a department-staff was employed, which from 1956–58 consisted of a head and assistants for farm inspection, machine inspection (familiarly known as the field service), seed, experimental fields and accounting.

Staff

During the period 1957–1958 the total number of staff engaged on the project was about 900.

At this time there were still some constructional operations, so that this number, minus 50 to 100, may be approximately regarded as the normal amount of production staff under the conditions prevailing.

Of these 900, some 120 were on monthly pay and about 700 day- and week-labourers, all of them more or less permanently employed; the remainder were casual workers.

During this period in the agricultural department there were about 30 salaried staff, of which about 20 were farm-managers. The number of regular workmen on the farms was about 200, or 1 man to 30 ha of land or to 37.5 ha of cropped area.

The number of casual workmen employed on the farms varied greatly according to the season, the average being about 1 man per 100 ha of land. For carrying out machine repairs on the farms, about 30 men were employed, or 1 per 200 ha of land.

The workmen employed on the farms, viz. drivers and manual workers, were almost exclusively Javanese and Hindustani from the smallholding districts of Surinam, chiefly from the Nickerie district.

They were accommodated in or near the farms where they worked.

Generally speaking the performance of these persons in mechanized rice-growing was very satisfactory. Most of them were trained as combine and tractor drivers. In view of the seasonal character of the various operations the drivers were also employed on manual work according to farm management requirements.

Mechanized operations were practically always performed on an hourly wage basis. Such manual work as sowing, spraying with knapsack sprayers, distributing fertilizer, ditching work, etc. was usually done on a job basis.

The organization of mechanized operations

A fairly important question in the organization of the agricultural establishment was, whether agricultural machinery should be used on the principle of a central hire establishment, or that equipment should be allocated permanently to each farm unit.

Since, owing to the original leasehold plan, a large number of houses and machine sheds had been built at different points of the polder, a decentralized organization was more or less inevitable with a view to their utilization. Apart from this it would have been desirable to decentralize the mechanized operations owing to the extent of the area, the bad road connections, the fact that the work in hand was dependent on weather conditions, and the comparative lack of mobility of the equipment, most of which was track-laying.

In practice this meant that most machines were permanently stationed at the farm units. In this situation, however, there were still two possible methods of organization, viz.:

to incorporate the machines administratively in a central machine inventory and to lease them per operating hour, or to entrust them entirely to the farm-unit manager, in which case, therefore, the actual cost of the machines would be charged to the farm-units concerned.
Both methods were employed at the Wageningen project. With the first method, staff of the technical department had a greater measure of control over the machines. But whereas they were better serviced by the lessors they were more neglected by the users. Generally speaking the machines were also easier to move so as to ensure their optimum use. This was of no great importance because the operations were similar on all farm-units. In addition the units were so large compared to the individual capacity of the machines in use, that even when the machines were permanently stationed at the farm-units it was possible to use them equally efficiently, with the proviso that instructions for mutual service were provided.
The establishment of a central machine inventory also resulted in more bureaucracy and might thus be an obstacle to the smooth running of the farming enterprise.
In our opinion the second method is preferable, some of the reasons being as follows:
— The farmer lived nearest to the machines and was the only one capable of exercising proper supervision over them.
— The farmer could be made entirely responsible for their proper handling. Moreover, he readily accepted this responsibility as it came under his sphere of influence.
— By charging the actual machine operating costs to the farm unit, and giving bonuses based on farming results, there was an incentive to keep such costs down. This applied both to the prevention of repairs and to the quality of such repairs, since there was an immediate response from the farmer who was directly interested in defects.
— The bona fide farmer preferred to make use of equipment permanently allocated to him immediately after purchase.

CHAPTER XX

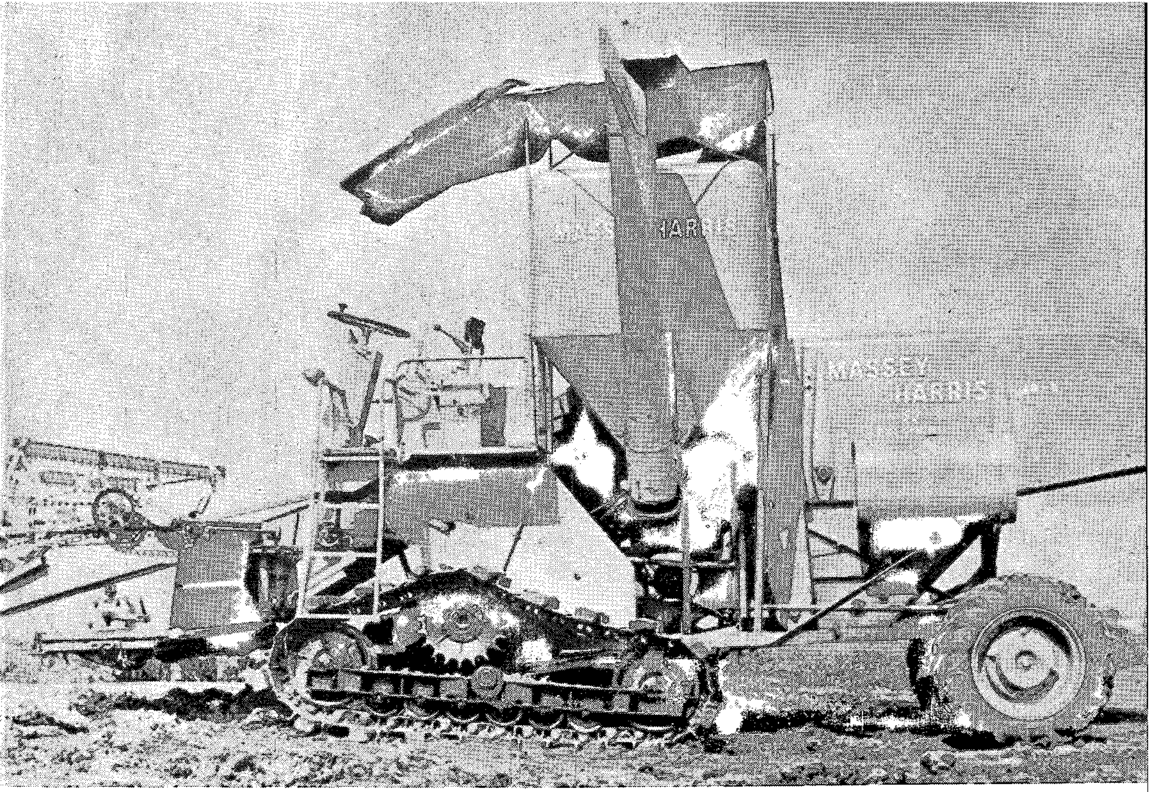
FARM ACCOUNTING

At the beginning of 1956 a detailed form of cost-price accounting was introduced, which started from the assumption that, in view of the small amount of experience available at the time, as much statistical material as possible should be assembled.
The costs per farm unit were divided into:
1. Field costs.
These are the costs which are noted separately for each field.
2. Farm management costs.
These are costs of a more general kind which do not directly relate to the fields, or where they have such a direct relation are very difficult to split up.
3. Machine costs.
For the costs of the self-propelled machines a separate account is kept for each machine. For the other machines a single implement account is kept for each farm. The machine costs are booked to the field costs and to the farm management costs at operating hour rates.

For all auxiliary and subsidiary matters relating to the agricultural department (seed production, repair services, stores, transports) and the other principal departments of the Wageningen project (rice-processing plant, technical department, etc.) the accounting system introduced was such that mutual services and supplies could be set off against each other in a reasonable way.

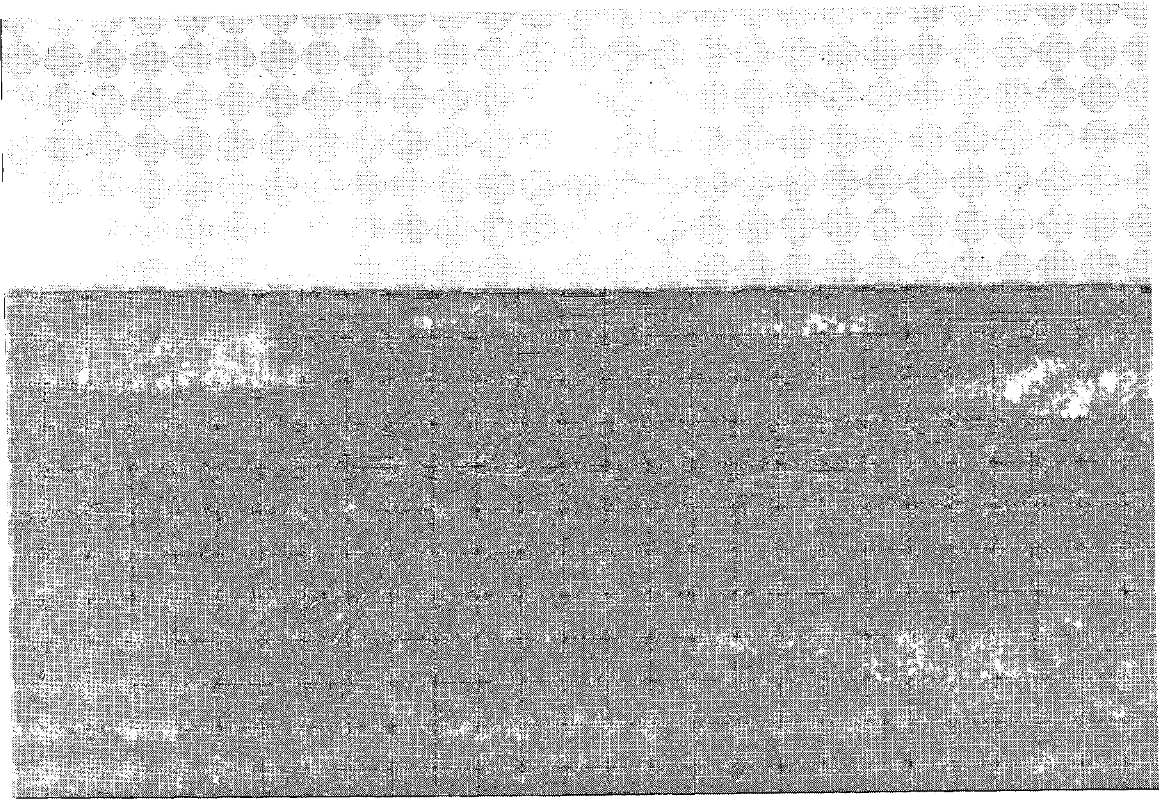
The field costs

The entries in respect of the various types of costs are made in 9 columns on cards kept for each separate field.
These columns are the following:
1. General costs. These are costs relating to the general maintenance of the field and which do not belong to any of the headings referred to below; for instance, land preparation by means of drastic levelling.
2. Operating hours for tillage. The usual tillage for rice growing, starting with the flattening of the stubble of the previous crop, expressed as the number of operating hours of the tractors multiplied by their rates per hour.
3. Seed. The number of kg of seed multiplied by the cost price calculated therefor.
4. Insecticides. The costs of the chemicals used for controlling diseases and pests.



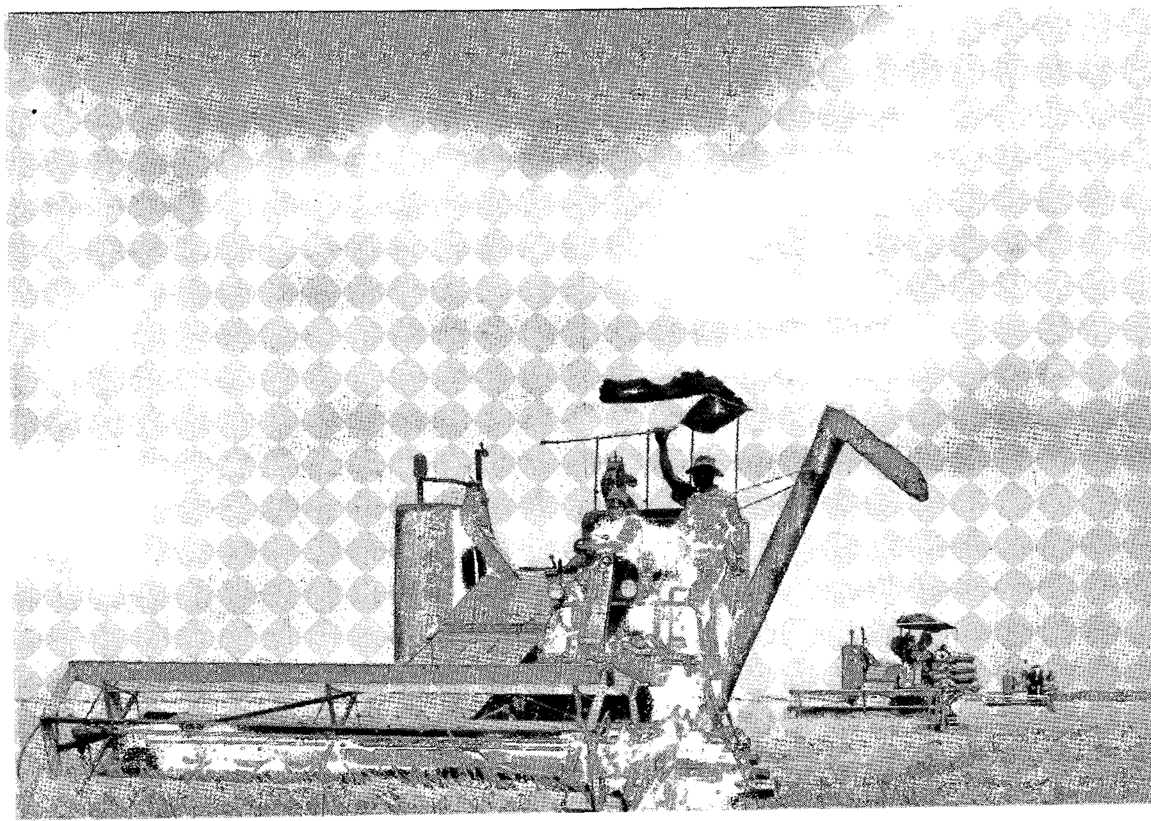
55. *Modified Massey Harris 90 combine with 6 roller track (and hardwood blocks bolted) en lieu of 3 rollers and 900 × 24 tyres en lieu of 750 × 18; the large rear wheels have slightly tilted the machine forward.*

56 *and* 57. *Standard 750 × 18 rear tyre of Massey Harris combine with bolted steel lugs and aircraft tyre 1500 × 16 mounted en lieu, reproduced at comparable sizes.*



58. *Stubble-field with wood-piles.*

59. *Combine-harvesting.*



5. Herbicides. The costs of the chemicals used for weed control.
6. Fertilizers. The cost of the ammonium sulphate used.
7. Operating hours for crop tending. The tractor costs charged to the field for all operations subsequent to land preparation up to and including harvesting, viz. for sowing, weed-, disease- and pest control, fertilizers and harvest transport.
8. Combine costs. The number of operating hours of the combines, multiplied by the rate per hour.
9. Implement costs. The number of operating hours on the field of the various non-self-propelled implements (ploughs, harrows, waggons, etc.), multiplied by the specific hourly rates therefor.

With regard to the above allocation of costs we would also mention the following:

a. A complete split-up of the costs of the respective operations was not aimed at. For instance, land preparation only includes the costs of the tractors, viz. not the implement costs or the drivers' costs. Again, only the cost of seed is included, and not the entire operation of sowing, etc. This is because such a detailed split-up of costs would lead to a disproportionate increase in accounting costs as compared to its value.

b. No wages or salaries are split up, for the same reason as mentioned above. A high rate of wages per field can usually be very well correlated to other items which are included in the field costs, and in our opinion a satisfactory comparison of costs is possible by applying to all fields in the same way this method of splitting up costs.

c. The choice of the various types of costs shown in the field accounts was determined both with a view to the comparatively easy accounting and, more in particular, the automatic provision of important agricultural data, viz. operating hours of tractors used for tillage and of the combines, seed and fertilizer quantities, by dividing the totals obtained by the standard rates applicable. This only applies when one accounting rate per column was applied for the said categories, which was usually the case.

As soon as wheeled tractors are used as well as caterpillar tractors, there are two rates applicable to tractors used for tillage. This was not the case when the accounting system was drawn up, although it did apply to various transport items, etc., which costs, however, were grouped under the subheading of operating hours for crop tending.

Farm unit costs

The farm unit costs are divided up into 7 columns.

1. Salaries, to which are added 70% additional expenses for staff sent out from the Netherlands and 10% for locally engaged staff.
2. Wages, to which are added 10% additional expenses.
3. Farm maintenance. This relates both to the maintenance of and depreciation on buildings, channels, ditches and field partitions. In order to prevent neglect reserve accounts were opened for each farm unit.

Every year Sf 10 per hectare are reserved for the upkeep of channels, ditches and culverts, with the consequence that large-scale repair works are also paid for out of these reserves.

4. Passenger transport. The numbers of kilometres travelled by car and boat are accounted for at the rates applicable. This specification is included on account of the fairly high cost of such transport and in order to prevent abuse.

5. Other transport. Those which cannot be booked to field-headings.

6. Deficits in machine accounts. This relates to entries made once or twice per annum after the machine accounts have been closed.

7. Field costs. The sum totals of the costs booked to the field accounts.

Hitherto the direct production costs of each farm unit have been accounted for, but excluding interest.

Machine costs

In these accounts the cost allocation is as follows:

1. fuel and lubricants.
2. repairs, subdivided into materials and wages + % increase for overhead.
3. overhaul reserves.
4. write-offs.

Where necessary, fuels and lubricants are kept separate, to permit a check on the consumption per operating hour.

Separating the repair costs into materials and wages affords a better insight into the effect of the repair organization on costs.

Overhaul costs are only kept separate from repair costs in the case of the tractors, the reason being that this overhaul only takes place every two to three years.

Via reserves this provides a more uniform picture of the operating costs, as it should be remembered that the project was begun with an entirely new set of machines. Without overhaul reserves operation would become gradually more expensive in course of time as a result of increasing repair costs.

One advantage of the reserves from the point of view of organization was that the tractors could be shifted more easily from one farm to the other without causing injustices.

In agriculture usually a system of writing off in stages is applied to tractors according to particular age classes (in operating hours), the largest amount being written off on the new machines at the beginning.

This method was not adopted for the tractors used on the project, because it was wished to stress the fact that the overhaul reserves should be financed far more rapidly than the depreciation reserves.

In the case of the combines the time interval in financing was less, so that the method of writing off in stages was applied. It was estimated that the combines could be used for about 5 years (2000 hours) before they required replacing, compared to a period of 10 years (10,000 hours) in the case of the caterpillar tractors.

In the latter case a fixed amount of Sf 1.50 an hour is calculated for depreciation per operating hour, for both 45–50 H.P. caterpillar tractors and 25–35 H.P. wheeled tractors. Despite the lower purchase price of the wheeled tractors the amount written off is the same, owing to the low total operating hours per annum resulting from their lesser usability.
In the case of the combines the depreciation is in stages: Sf 12.50 an hour for the first 500 hours, Sf 10 an hour for the 2nd 500 hours, Sf 7.50 an hour for the 3rd 500 hours, and Sf 5 an hour for the 4th 500 hours. After 2,000 hours the machine is written off altogether.
In the case of cars and motor-boats the depreciation is calculated per kilometre travelled. Finally, in the case of the non-self-propelled vehicles a fixed annual amount is written off which is generally 10% of the value when new.

Other cost accounts

In this section we confine our attention to the agricultural department.
General department. The costs of departmental staff in respect of salaries, wages, transport and office.
Experimental fields. The difference in cost price between the production of experimental fields and the average of the polder is determined at the end of the financial year and charged as experimental field costs.
Seed. The production costs of seed are listed in a separate account which is cleared again by crediting these costs to the farm units when the seed is issued.
The seed is purchased on this account at the current clearing price for consumption paddy, this price being an approximation of the agricultural cost price (excluding interest).
The chief seed processing costs are in respect of drying, cleaning and storage. Other important seed production costs are the salary of the overseer, the roguing of the areas planted with seed, and the transport of the harvested rough seed to the processing plants and the distribution of seed among the farms during the sowing season.
Machine inspection and repair. All these costs are booked to the machines in question on the farms.
The chief proper costs of this ancillary service are the salaries and wages of fitters and passenger transport.

The booking vouchers

The entries made under the accounting system are based on a number of fortnightly work-sheets relating to machines, staff and store supplies, as well as on internal clearing vouchers (from one department to another) for the supply of materials or services.
Various types of daily reports and supply vouchers, as well as notebooks of farm managers and overseers are used for compiling these work-sheets; this brings us to the very first stage of the accounting system.

A work-sheet is drawn up every fortnight for every self-propelled machine which has been in operation. On this is entered the amount of work done each day, expressed in terms of money according to the rate applicable, and in the case of the tractor sheets also the number of hours of operation of the implements used.
The booking advice with code numbers is then specified, viz. in the case of debit entries according to the various activities (tillage, etc.) and in the case of credits according to the machine accounts.
In order to limit the number of entries of the various machine work-sheets, the booking advices are combined under the same entry headings.
A fortnightly work-sheet is also drawn up for each workman, specifying the work performed each day, the number of hours and the amount earned. The workman is paid on this specification. Where necessary the booking advices are first compiled from the various work-sheets for the same headings.

As regards the accounting of the consumption of materials, we should distinguish two different categories of materials, viz. those which are immediately accounted for by quantity after delivery, or may be regarded as belonging to this category, and those which are accounted for out of farm-stores.
The first category of supplies can be immediately entered on the store sheets according to the operation entry headings.
In the case of machine repairs the debit is taken by the repair shop in the first instance, but the shop immediately transfers the costs to repair cards, and after the repair has been completed it transfers the entry to the customer, specifying the machine number, etc.
In the second category, materials supplied, even though they have been stored at some distance from the storekeeper, actually continue to be store materials from the accounting point of view until they have in fact been used up on the farm unit. The relevant booking vouchers are the fortnightly statements of farm materials received and issued. The chief farm stores are petrol, diesel oil, lubricants, ammonium sulphate, various insecticides and herbicides, and seed during the sowing seasons. To ensure smooth running of the farm these articles have to be stockpiled at the farm units in the polder. On the statements of materials received and issued, goods issued are specified according to the debit numbers concerned, viz. machine, field or farm accounts.

In the case of repair and construction work the ancillary services in question list the cost of materials required for each work order, and after the order has been completed they make out an account which includes a cover percentage for the overheads of these services.
For field repairs to agricultural machines the cover surcharge was usually 150% and for repairs or construction work in the central workshop 50 to 150%.

Of course these accounts also show the entry references, these mostly being debit entries of machine accounts.
Various forms of services rendered by one establishment to another, may, if they have not been cleared via work-sheets, be corrected by means of an account, provided the specification makes it possible to enter the costs according to the cost allocation system in use.
The booking coding. Each farm unit has a bookkeeping number, within this unit the fields are numbered from 1 to 000, and each field account has 9 columns. The three groups of figures next to each other and separated by dots identify the entry required.
For instance, 63.01.8 designates combine costs on field 1 of farm 63.
It has been found in practice that mistakes are occasionally made in the field numbering, so that it would probably be preferable not to number the fields in each farm from 1 to 000, but to use in the entries the permanent continuous numbering for the entire polder of all fields (from 1 to about 500). This would add one numeral to the coding.
On most work-sheets the farm number need only be mentioned once in the specification as it always remains the same.
The coding of farm accounts is similar. Instead of the field designation the numerals 00 are written; in this case there are only 7 columns.
In coding the machine accounts the inventory numbers are employed for the self-propelled machines and for the others the designation W.R. ("Werktuigrekening" = "Implement Account") with the farm number.

Possibilities of simplifying the system

The accounting method described above was applied in practice in 1956 and 1957 and generally speaking it led to satisfactory results.
From 1958 onward some simplification was made and this trend will possibly continue in the future since the method involves a good deal of clerical work.
The system lends itself admirably to simplification, e.g.:
— instead of splitting up the field costs on separate account cards for each field, it would be possible to keep a single field cost account for each farm unit;
— the number of columns in the field account can be reduced by combining types of costs which it is no longer required to keep separate;
— an obvious simplification would be to abolish the implement cost column in the field account, because these items are fairly small but entail much clerical work in adding up hours, owing to the different rates applied; the entire Implement Account could then be included in a column of the farm unit costs;
— the separate machine accounts may be combined, according to requirements, in a number of accounts per unit farm, e.g. for each series of machines of the same type.

The cost price accounts are necessary for gaining an insight into the financial and agricultural results. To a certain extent the information required for either purpose is the same. Most of the financial information provided is interesting from the agricultural point of view. On the other hand, for obtaining agricultural information more is required than can be reasonably supplied by financial accounts.

Also the high degree of accuracy which is properly expected from financial accounts need not apply to the accounting of agricultural data. For instance, to obtain an idea of the financial situation it is not necessary to add up the costs of each of the 500 fields separately every year. From the agricultural point of view it may be important to obtain such an idea, not so much for the individual consideration of the fields as in order to group them according to methods and then assess the averages.

With the combination of financial and agricultural bookkeeping employed in the project, there is a real danger that the quality of the entries may have to conform to an excessively high standard from the smallest separate item in field and machine accounts, with the result that the accounting system may become very extensive and costly.

For this reason we would prefer the above-mentioned agricultural cost-price accounts to be kept almost entirely outside the books. In that case most of the work could be done at the farm units with simple means and at a low cost.

We also imagine that if the individual and specified listing of machine and field costs have little or no value for assessing the financial trend of the farm, from the agricultural point of view it would be better to compile important sections thereof in some other way.

CHAPTER XXI

AGRICULTURAL PRODUCTION COSTS

In 1956 and 1957 the agricultural costs were listed according to the method described in the previous chapter.
Some of the results will be discussed in the present chapter.
With the use of these figures and other material a forecast was made of the possible cost price in the future. We have also made an approximate estimate of the profitability of growing a second crop.

Agricultural production costs in 1956 and 1957

In the first instance it must be stated that in 1956 and 1957 the costs were still greatly influenced by the reclamation conditions. For this reason they are not wholly representative of normal cultivation operations.
The first ploughing of new reclamation fields has been included in the said production costs. In principle it was only the clearance of remnants of vegetation in these fields that had been debited to the polder construction.
A second important reservation we have to make is that, owing to the adjustments made with increases for covering general and miscellaneous costs, it was assumed that the ancillary services (repair shops, stores, seed production, etc.) had no surpluses or deficits. This was not altogether true; for example, the workshops had deficits and the stores and seed production department surpluses. We cannot, however, account for these differences as relevant data are not available.
The chief increases were as follows:
on machine repairs, usually 150% on the wages included, and occasionally varying from 50 to 150%; in the case of miscellaneous store commodities, 2×25% on the invoice price for deliveries f.o.b. European or American ports and 25% on the invoice price for c.i.f. deliveries. In 1956 petrol and diesel oil was charged at Sf 0.20 and Sf 0.10 per litre respectively, and in 1957 at Sf 0.25 and Sf 0.15 per litre respectively.
In both years the delivery prices for seed were Sf 0.25 per kg for seed and Sf 0.14^5 per kg for ammonium sulphate.
The cost of salaries of staff assigned overseas from the Netherlands were calculated by adding 70% to the salary for covering the cost of leave periods, life insurances, savings funds, medical care, etc. The salaries of locally engaged staff were increased by 10%. In 1956 no increases were made to workmen's wages; in 1957 they were also increased by 10%.
A third shortcoming of the cost calculations shown below is that no interest

is charged for moneys invested, so that as a result the machine costs, to take an example, are too favourable in every case. In the case of the caterpillar tractors the interest may be estimated at about Sf 0.25 per operating hour and in the case of the combines about Sf 1.

In both years under review the cost calculations relate to a season year which closed after the main crop had been harvested in October.
In the closure period costs relating to the old and new year were kept strictly separate. For each field the new season commences with the flattening of the stubble.
In view of the cultivation conditions it would not be attractive to close the period on another date, for example on 31st December according to the calendar year. Owing to their mutual effect, from the agricultural point of view the best combination of a season year is second crop + next main crop, and not main crop + next second crop. It is also an advantage that both harvests fall in the same calendar year.

Table 57 shows the agricultural production costs per ha of area planted and per ton of paddy product, for the season years 1956 and 1957, these costs being divided up into three groups, viz. field costs, farm unit costs and other costs.
On comparing the costs per hectare of area planted in 1956 and 1957 we may make the following observations.
Re field costs. In 1957 the improved weather conditions enabled more work to be done on field amelioration. In 1957 more seed was used on the basis of experimental field results. The chemical control of weeds cost less owing to improved tillage and further use of sowing in water which was possible on a part of the area in which reclamation effects were no hindrance. There was a slight increase in the use of fertilizers.
The cost of mechanized crop-tending fell, as did also the combine costs owing to the fact that the harvest could be quickly gathered thanks to the dry weather in 1957.
A very sharp rise in implement costs occurred in 1957, owing to the fact that in this year most of the polder was ploughed with Solotrac ploughs which were subject to many breakages, in the former timber areas in particular. In addition a great deal of expensive levelling equipment was used.
Re farm unit costs. In 1957 there was a steep drop in the salary costs per hectare planted owing to the increase in land area per farm-unit compared to 1956. This led to some increase in passenger transport.
Re other costs. Staff costs fell in 1957 because an area about 50% larger was under production without proportionate increases in staff. The costs of the pumping station and buildings have little significance, being based on rough estimates.
For 1956 it was ascertained what amount of reserves and write-offs had been included in the average production costs per ha planted (Sf 335.90). In the case of tractor overhauls, the reserves were Sf 8 per ha planted, and in the

TABLE 57 *Farm production costs in 1956 and 1957, excluding interest*

Costs specification	Per hectare planted with rice		Per ton = 1,000 kg of paddy product	
	1956 (4144 ha)	1957 (6804 ha)	1956 (10716 tons) 2586 kg/ha	1957 (16004 tons) 2352 kg/ha
Field costs:				
General field amelioration . . .	Sf 1.00	Sf 5.10	Sf 0.40	Sf 2.10
Tractor-costs for tillage	„ 43.70	„ 43.60	„ 16.90	„ 18.60
Seed.	„ 17.10	„ 24.40	„ 6.60	„ 10.40
Insecticides.	„ 13.50	„ 14.80	„ 5.20	„ 6.30
Herbicides	„ 6.50	„ 2.70	„ 2.50	„ 1.10
Fertilizers	„ 9.30	„ 12.60	„ 3.60	„ 5.40
Tractor-costs for crop tending .	„ 6.00	„ 2.90	„ 2.30	„ 1.20
Combines	„ 54.80	„ 41.70	„ 21.20	„ 17.70
Implements.	„ 8.30	„ 20.50	„ 3.20	„ 8.70
Sub-total.	Sf 160.20	Sf 168.30	Sf 61.90	Sf 71.50
Farm unit costs:				
Salaries	Sf 42.70	Sf 28.10	Sf 16.50	Sf 12.00
Wages	„ 40.30	„ 44.10	„ 15.60	„ 18.70
Passenger transport	„ 3.10	„ 4.50	„ 1.20	„ 1.90
Maintenance, other transport, miscellaneous.	„ 16.60	„ 18.10	„ 6.40	„ 7.70
Deficits in machine accounts . .	„ 9.30	„ 9.60	„ 3.60	„ 4.10
Sub-total.	Sf 112.00	Sf 104.40	Sf 43.30	Sf 44.40
Total	Sf 272.20	Sf 272.70	Sf 105.20	Sf 115.90
Other costs:				
Agricultural dept. staff (salaries, wages, transport, office)	Sf 25.10	Sf 17.20	Sf 9.70	Sf 7.30
Experimental field costs	„ 6.00	„ 7.80	„ 2.30	„ 3.30
Pumping station (estimated) . .	„ 23.50	„ 25.80 (pumping station and buildings)	„ 9.30	„ 11.00 (pumping station and buildings)
Buildings (estimated)	„ 9.30		„ 3.50	
Sub-total.	Sf 63.90	Sf 50.80	Sf 24.80	Sf 21.60
Rounding-off differences	·/. 0.20	·/. —.—	·/. 0.10	·/. —.—
GRAND TOTAL	Sf 335.90	Sf 323.50	Sf 129.90	Sf 137.50

case of maintenance of ditches, culverts and tertiary lines, Sf 8.30 per ha planted. The write-offs were Sf 63.60 per ha planted for agricultural machines and Sf 12.90 per ha planted for pumping station and buildings. Hence the costs per ha planted, excluding reserves and write-offs, amounted to f 243.10 in 1956. (In 1957 the same accounting method was employed for reserves and write-offs as in 1956, so that the costs thereof will be of the same order).

Table 58 shows the field and farm unit costs in the season year 1956, of the unit with the highest and the unit with lowest costs.

The farm unit with the poorest results was located on recently reclaimed land in which heavy *koffie-mama* forest had grown (parcels Nos. 12 and 13, 1st series). The fields were densely covered with stacks of timber and the soil had a fairly thick pegasse cover. No second crop had been grown previous to the main crop.

TABLE 58 *Costs in 1956 of the farm unit with the lowest cost price and the farm unit with the highest cost price.*
(excluding the group "Other costs" shown in Table 57)

Costs specification	Per hectare planted		Per ton = 1,000 kg of paddy product	
	unit I with highest cost price, area planted 127 ha	unit II with lowest cost price, area planted 153 ha	unit I with highest cost price, average yield 2,191 kg/ha	unit II with lowest cost price, average yield 2,935 kg/ha
Field costs:				
General field amelioration . . .	Sf 0.20	Sf 0.30	Sf 0.10	Sf 0.10
Tractor-costs for tillage	„ 53.—	„ 36.70	„ 24.20	„ 12.50
Seed.	„ 18.20	„ 15.30	„ 8.30	„ 5.20
Insecticides.	„ 18.60	„ 15.60	„ 8.50	„ 5.30
Herbicides	„ 11.20	„ 5.—	„ 5.10	„ 1.70
Fertilizers	„ 1.80	„ 10.30	„ 0.80	„ 3.50
Tractor-costs for crop tending .	„ 6.40	„ 3.80	„ 2.90	„ 1.30
Combines	„ 59.20	„ 50.20	„ 27.—	„ 17.10
Implements.	„ 9.20	„ 5.60	„ 4.20	„ 1.90
Sub-total.	Sf 177.80	Sf 142.80	Sf 81.10	Sf 48.60
Farm unit costs:				
Salaries	Sf 62.90	Sf 49.90	Sf 28.70	Sf 17.00
Wages	„ 41.20	„ 29.40	„ 18.80	„ 10.00
Passenger transport	„ 0.20	„ 0.30	„ 0.10	„ 0.10
Maintenance, other transport, miscellaneous.	„ 18.40	„ 15.60	„ 8.40	„ 5.30
Deficits in machine accounts . .	„ 14.90	„ 2.30	„ 6.80	„ 0.80
Sub-total.	Sf 137.60	Sf 97.50	Sf 62.80	Sf 33.20
Rounding off differences	·/. 0.10	·/. 0.20	·/. —.—	·/. —.—
TOTAL	Sf 315.30	Sf 240.10	Sf 143.90	Sf 81.80

A large part of the area could not be ploughed for sowing. The entire area planted was sown on the mud, and about half of it could not be irrigated owing to the occurrence of floating pegasse.
Several corners of the land remained fallow, because the soil was too swampy to enable the weed vegetation to be smothered in the mud by means of machines. Three fields became overgrown with grass weeds and had to be weeded by hand. There was a good deal of bogging down of combines during harvesting.

The farm unit which obtained the best results was situated on grass-swamp land which had been reclaimed twelve months previously (parcels Nos. 41 and 42 in the 3rd series).

There were practically no stacks of timber in the field and the entire farm area had been ploughed with Solotrac ploughs, thereby eliminating pegasse nuisance. One field on this farm had yielded a good producing second crop previous to the main crop. Many difficulties were experienced during harvesting, although to a lesser extent than on the other farm.

As Table 58 shows, the total costs per hectare of area planted in farm unit II were 24% lower than in I. Of this 24%, 4% is unreal, being constituted by the higher salary charges per hectare on I resulting from the smaller area, so that the remainder is 20%. Typical differences between the two farm units are the high costs of I for tillage, weed control, combines, implements, wages and deficits in machine accounts, all of which resulted from the unfavourably nature of the terrain. On the other hand fertilizers cost more on the comparatively poorer soils of II.

As a result of the 24% lower ha costs and 34% higher ha production, the costs per 1,000 kg of product on farm unit II were 43% lower than on I.

This example shows clearly that during the first years the grass-swamp soils were better suited to rice production than the forest soils.

In 1955 one of the operational problems was to discover the optimum farm-unit size which could be worked by one employee-farm manager. Although this now seems a somewhat unreal problem, it was firmly held at the time that the area could not exceed 144 hectares (12 fields).

In Table 59 we give a cost comparison for farm units of various sizes in 1956 and 1957; it not only shows that increasing the area would have no harmful effect (production is higher), but that there would be a considerable saving in ha-costs.

TABLE 59 *Comparison of costs per ha planted on farm units of varying sizes in 1956 and 1957*
(excluding the group "other costs" shown in table 57)

Size of farm unit	1956			1957		
	Costs Sf/ha planted	Yield 100 kg/ha	Total area of the group	Costs Sf/ha planted	Yield 100 kg/ha	Total area of the group
2×72 ha. . . .	287.50	24.8	1618 (of which 5% 2nd crop)	305.90	21.7	179 (of which 20% 2nd crop)
4×72 ha. . . .	263.60	25.3	609 (10% 2nd crop)	288.80	21.0	2833 (20% 2nd crop)
5–10×72 ha . .	261.00	26.9	1917 (5% 2nd crop)	259.10	25.5	3792 (12% 2nd crop)

In this connection, however, we should mention that the differences found in favour of large farm units were also due to other causes than the farm size. This is because the large farm units were usually located on newly reclaimed land, most of which had had an original grass vegetation. On the other hand, the small farm units were usually situated on land which had been reclaimed a year or two previously and had had predominantly a forest cover.
The higher yields obtained on the larger farm units are the result of this difference in the land.
The difference in costs that was found was almost entirely due to the salary costs which, logically enough, were much lower on the large units. Excluding salaries, the costs per hectare planted in 1956 were: Sf 224.40 for 2×72 ha, Sf 219.80 for 4×72 ha, Sf 235.70 for 5–10×72 ha, and in 1957 Sf 252.80, Sf 253.70 and Sf 237.40 in the same order.
A further advantage of the larger farm units that might be adduced is the saving on equipment required, but owing to the method of depreciation per operating hour and the omission of the interest this is not reflected in the cost figures.
Notwithstanding these reservations, it may be concluded that the cost calculations did not show that there were any drawbacks attaching to larger farms.

Table 60 gives the total average machine costs per operating hour in 1956 and 1957. These actual machine costs show a fairly close correspondence with the rates per hour assumed beforehand. In these years, the rates per operating hour at which the machine accounts were transferred to the field and farm accounts, were: Sf 20 for combines, Sf 5 for 45–50 H.P. caterpillar tractors, Sf 3.50 for 25–35 H.P. wheeled tractors, Sf 4 for 50 H.P. wheeled tractors, for jeeps Sf 0.20 and Sf 0.25 per km, for outboard motors Sf 0.15–Sf 0.25 per km, and rates varying from Sf 0.50 to Sf 1.50 per hour for different implements.

After these rates have been transferred to the machine accounts, the remaining deficits constitute the item "Deficits on machine accounts" included under Farm unit costs (e.g. in Table 57).

In Table 61 the machine costs in 1956 have been split up according to the operating hour ages. It was found that the depreciation stages selected for the combines resulted in a satisfactory equilibrium in the costs per hour with respect to the age of the machines.
In the case of the caterpillar tractors the system of overhauls reserve applied also worked fairly well. The difficulty in this system is to determine what is an overhaul and what a normal repair. In view of the cost trend there are a few more repairs which should be classified as overhauls.

The advantages obtained by keeping separate cost accounts for each machine, were:
— the audit factor and the effect of the costs on bonus payments were an encouragement to staff to look after the machines well;

TABLE 60 *Average machine costs per operating hour or per kilometer in 1956 and 1957, excluding interest and drivers' wages, but including supervision of repairs and maintenance*

Machine	Hours or kilometres	Fuels and lubricants	Repairs	Deprecia-tion (rate)	Overhauls reserve (rate)	Total
Combines '56	11655 hrs	Sf 2.70	Sf 5.80	Sf 11.90	Sf —.—	Sf20.40/hr
'57	14515 hrs	„ 3.20	„ 5.50	„ 11.50	„ —.—	„ 20.20/hr
Caterpillar						
tractors '56	46465 hrs	„ 1.00	„ 1.40	„ 1.50	„ 0.90	„ 4.80/hr
'57	95617 hrs	„ 1.60	„ 1.20	„ 1.50	„ 0.90	„ 5.20/hr
Wheeled						
tractors '56	2425 hrs	„ 0.50	„ 0.80	„ 1.50	„ 0.70	„ 3.50/hr
'57	11223 hrs	„ 0.90	„ 0.80	„ 1.40	„ 0.70	„ 3.80/hr
Jeeps '56	40300 km	„ 0.05	„ 0.07	„ 0.09	„ —.—	„ 0.21/km
'57	99400 km	„ 0.06	„ 0.06	„ 0.09	„ —.—	„ 0.21/km
Outboard						
motors '56	119000 km	„ 0.09	„ 0.04	„ 0.03[5]	„ —.—	„ 0.16[5]/km
'57	132700 km	„ 0.13	„ 0.04	„ 0.03[5]	„ —.—	„ 0.20[5]/km

N.B. Fuels were higher in 1957 owing to price increases. In the case of combines the difference is small owing to the larger employment of diesel combines in 1957.
No deduction has been made in respect of the petrol taxes which the Government envisages refunding where the petrol is used for agricultural purposes.

TABLE 61 *Split-up of combine and tractor costs per operating hour in 1956 according to operating hour ages of the machines*
(Excluding interest and drivers' wages)

Age class (end of 1956)	Hours operated	Repairs	Fuels and lubricants	Deprecia-tion and overhauls reserve	Total
Combines:					
0–300	2462	Sf 5.—	Sf 2.70	Sf 12.50	Sf 20.20
301–600	5678	„ 5.50	„ 2.80	„ 12.40	„ 20.70
601–900	2450	„ 6.60	„ 2.70	„ 11.10	„ 20.40
901–1200	1065	„ 7.20	„ 2.60	„ 9.90	„ 19.70
Total	11655	Sf 5.80	Sf 2.70	Sf 11.90	Sf 20.40
45–50 H.P. Caterpillar tractors:					
0–2000	24310	Sf 1.30	Sf 1.—	Sf 2.40	Sf 4.70
2001–4000	22155	„ 1.60	„ 1.—	„ 2.40	„ 5.—
TOTAL	46465	Sf 1.40	Sf 1.—	Sf 2.40	Sf 4.80

— the systematic accounts system was a help to technicians in ascertaining when old machines should be replaced, in selecting the required types of machine and in assessing the quality of repairs carried out.
It was found that one of the most important conditions, of keeping a reliable system of cost accounts on the basis of operating hours, was that good operating hour or mileage meters should be fitted to the machines and a careful check kept to ensure their proper functioning.

Forecast of minimum operating costs

With regard to the figures given in Table 57 we can also supply the following comments on the future minimum operating costs of the project, assuming the area of the main crop to be 6000 ha and that of the second crop 1500 ha (and leaving changes in the level of wages and the like out of consideration).
Re field costs.
The combined items "General field amelioration" and "Tractor-costs for tillage" may drop from Sf 44.70 and Sf 48.70 respectively to about Sf 30.— (6 hours at Sf 5) when no extra tillage operations will be required anymore in connection with reclamation.
The item "Seed" is based on a seed cost price of Sf 0.25 per kg. This price need not be more than Sf 0.15 per kg, excluding the proper cost of breeding new varieties.
The items "Insecticides and Herbicides" as they were in 1957 cannot be given a lower estimate for the future either.
Fertilizer consumption will for the time being rise to 150 kg S.A./ha or Sf 22.
The item "Tractor-costs for crop-tending" is small and future estimates can remain at the figure found in 1957, viz. about Sf 3/ha.
The item "Combines" was Sf 41.70 in 1957, or an average of 2.1 operating hours per hectare. These costs may fall considerably owing to a smaller number of operating hours per hectare and better use of the combines.
Some of the factors involved in this are the improving carrying capacity of the fields, fewer lodging crops, increased skill of drivers and mechanics, and more efficient use of the machines on large farm areas.
Our best estimate for the future is Sf 30 per hectare of area planted.
The item "Implements" may be estimated at Sf 10 per hectare planted.
Re Farm unit costs.
As a result of further enlargement of farm units the salary costs may fall to Sf 20. Wages may also fall; although no very exact estimate can be given we venture to put the amount at Sf 30.
The item "Passenger transport" could be estimated at Sf 5.
"Maintenance" and "Miscellaneous items" at Sf 15 and "Deficits in machine accounts" at nil.
The last item is really a correction of machine-hour rates which were estimated at too low a figure.
Re "Other costs".

"Staff costs" may fall to Sf 10 per hectare and "Experimental field costs" to Sf 3.
We estimate the "Pumping station costs" at Sf 25 (provided no new areas are constructed) and the depreciation on buildings at Sf 7.
The item "Polder maintenance" is not shown in Table 57, the reason being, that in 1956–57 such maintenance as was required was charged to polder construction. Owing to lack of information, in this stage of the project a somewhat random estimate has to be made of these costs.
Having particular regard to the anticipated rapid accumulation of silt in the canals, we take the high estimate of Sf 10 per hectare.
In summary form, the estimates of minimum costs give the following pattern:

Field costs		
General field amelioration + tractor-costs for tillage	Sf 30.—	
Seed	,, 15.—	
Insecticides and herbicides	,, 18.—	
Fertilizers	,, 22.—	
Tractor-costs for crop-tending	,, 3.—	
Combine costs	,, 30.—	
Implements	,, 10.—	
		Sf 128.—
Farm unit costs		
Salaries	Sf 20.—	
Wages	,, 30.—	
Passenger transport	,, 5.—	
Maintenance and miscellaneous items	,, 15.—	
Deficits in machine accounts	,, —.—	
		Sf 70.—
Other costs		
Staff costs	Sf 10.—	
Experimental fields	,, 3.—	
Pumping station	,, 25.—	
Depreciation on buildings	,, 7.—	
Polder maintenance	,, 10.—	
		Sf 55.—
Total		Sf 253.—

In the case of the yields it is estimated that these may increase, with proper research and cultivation, to some 3200 kg/ha of area planted, so that it is considered possible that the farm price of paddy would be Sf 0.08 per kg delivered to the polder jetties, excluding interest and general project overheads.
Assuming that the total construction and lay-out costs of the agricultural

sector of the project required an amount of approximately Sf 20,000,000, without taking into account the comparatively small write-offs, the interest charges at 5% for a sown area of 7500 ha can be estimated at Sf 130 per hectare planted, or Sf 0.04 per kg of paddy produced.

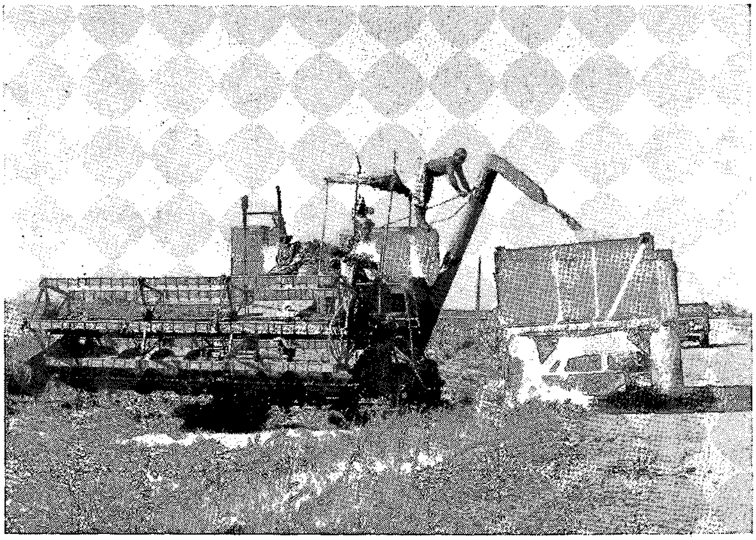
Profitability of the second-crop rice

The second-crop rice is very important for improving the profitability of the project since it enables production to be substantially increased within the scope of the existing means of production, viz. without, or with a slight increase only, in an important group of fixed costs.
With the use of the cost figures for 1956 shown in Table 57, in which year practically no second crop was grown, it is possible to split up the agricultural production costs approximately into fixed costs and costs varying according to the area of the second crop.
The "Field costs" group are mainly variable costs, although not entirely so. When the agricultural machines are able to operate for a greater number of hours per annum, the costs per operating hour will fall to some extent, viz., owing to relatively lesser wear and higher return from maintenance and repairs. Of the costs shown in Table 57 it is proposed to earmark as fixed costs: 10% of the tractor costs, 20% of the combine costs and 50% of the implement costs.
The groups "Farm unit costs" and "Other costs" are mainly fixed costs, with the exception of the item "Deficits in machine accounts" which is largely variable (the figure taken at 100%), and the items "Wages", 50% of which is estimated to be variable, and "Pumping station", for which the estimated variable figure is 20%.

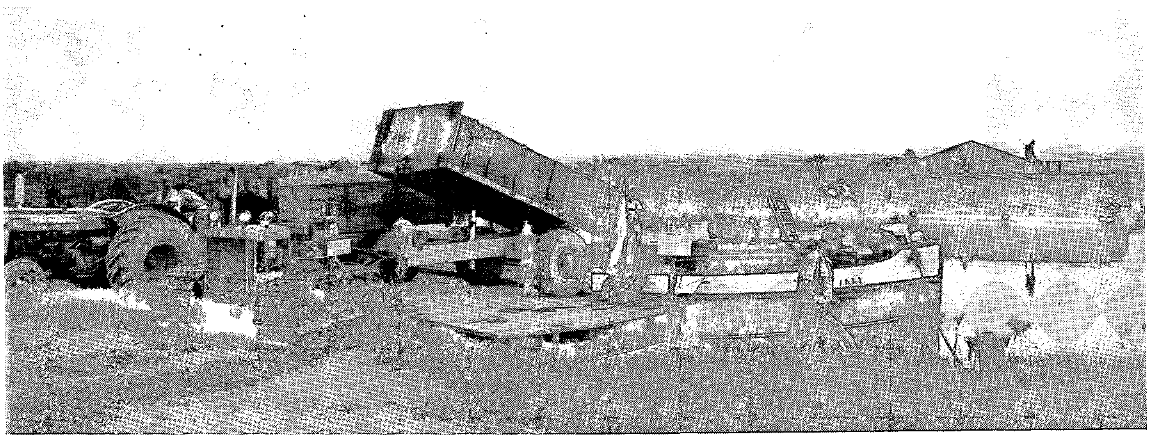
On the basis of these rough estimates Sf 174 variable costs were found out of a total of Sf 336 for 1956 (Table 57). Except for interest and overheads the ratio of fixed to variable costs is therefore approximately 1:1. When the cost figures for 1957 and the forecast figures are divided into fixed and variable costs the same ratio can be found, but with a slight shift towards higher variable costs on account of the cultivation of the second crop being included. When the 5% interest on the agricultural sector, amounting to Sf 20,000,000 for 6,000 ha, is added to the fixed costs, the ratio becomes 2:1. We can now assume that the marginal costs for the cultivation of the second crop also amount to Sf 174 per hectare.
According to the WITTE-JONGERLING Report (1959) the proceeds per ton of paddy less variable milling costs are about Sf 150.

The marginal second-crop yield would then be $\frac{174}{150}$ tons, but this should be increased with the lowering effect on production caused by the second crop on the immediately succeeding main crop. If we put this figure at 500 kg/ha the marginal second-crop yield becomes 1.66 tons/ha.

This marginal production is higher than the point of equilibrium for re-

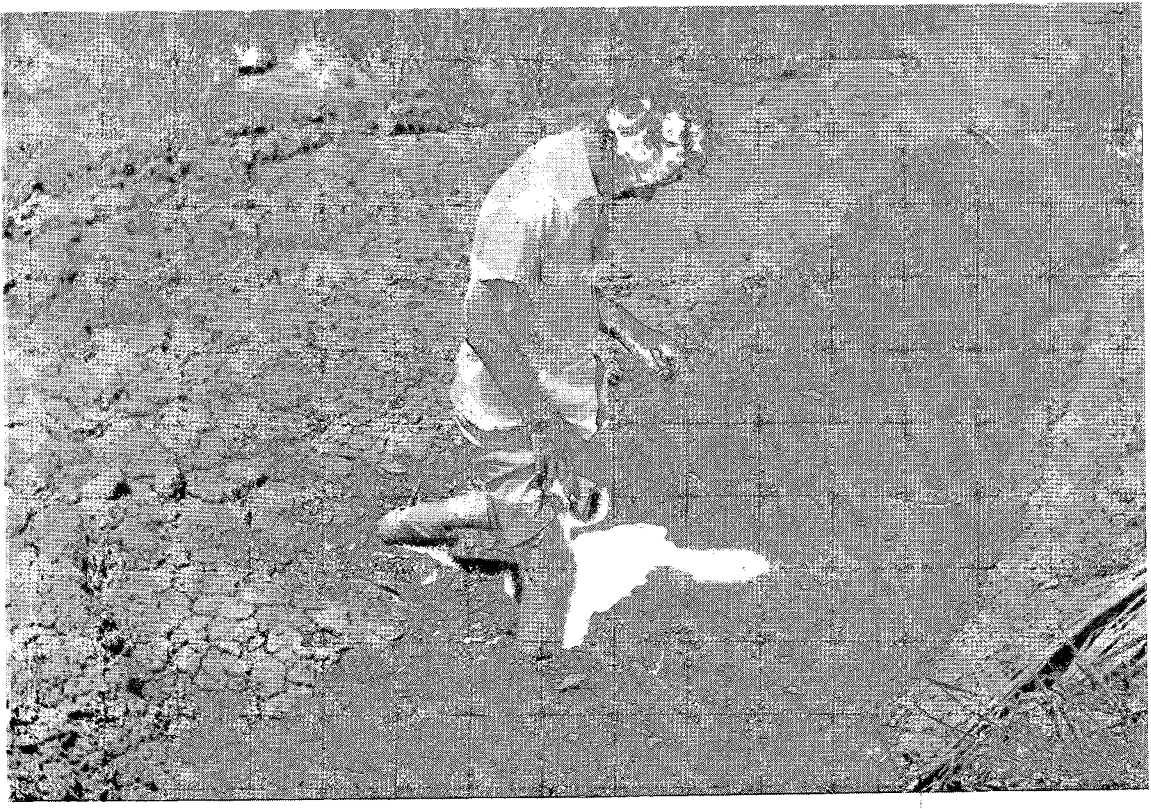


60. *Unloading tank in tipping-cart on field-end dam.*



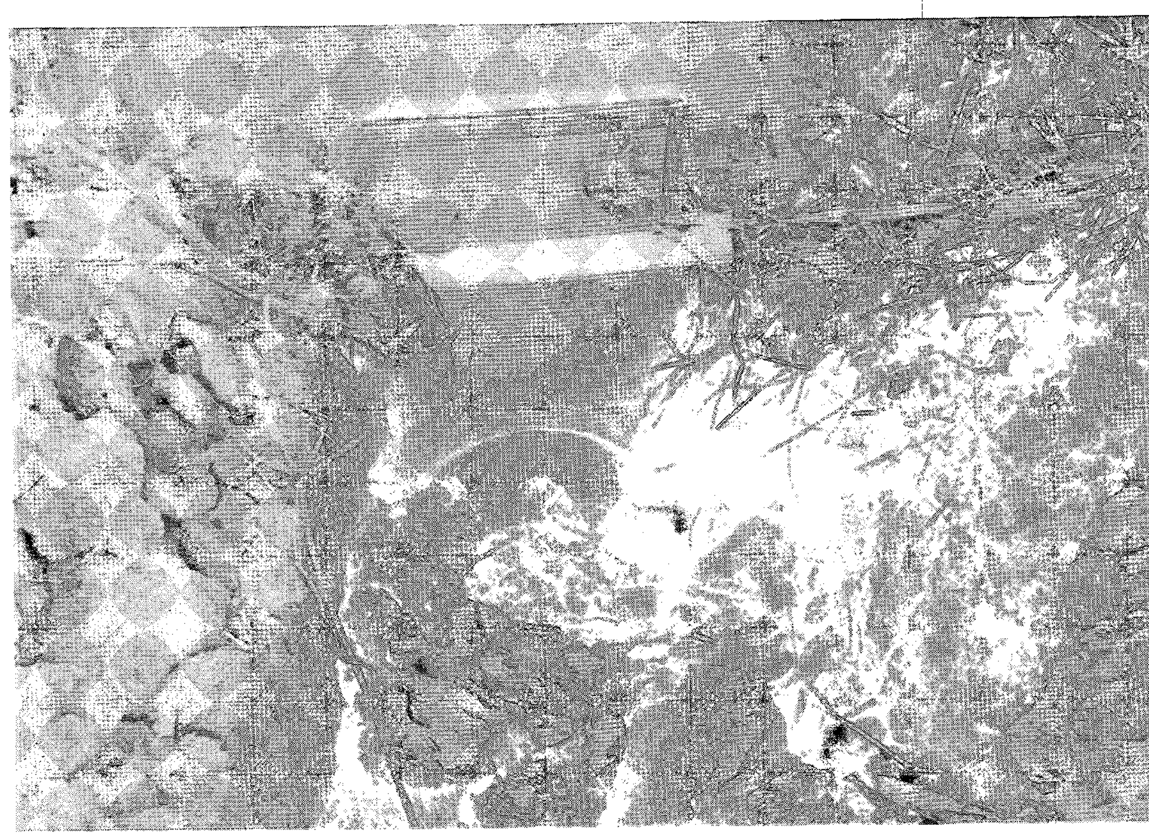
61. *Unloading tipping-carts in lighter at jetty in irrigation-canal. The jetty on the opposite side of the canal is being piled with bags harvested by bagger-combines.*

62. *Unloading the lighters by scoop elevator at the processing plant.*



63. *Rapid silting up of field ditches as a result of puddling.*

64. *Washing out of culverts is a common hazard.*



duction or increase in the cost prices (excluding interest). The $\frac{\text{variable costs}}{\text{fixed + variable costs}}$ ratio for the entire project can be calculated from the statistical material provided by the WITTE-JONGERLING Report.
For the 6,000 ha polder the ratio is 0.38 and for a 10,000 ha polder it may be estimated at 0.46.
Hence the point of equilibrium for 6,000 ha is reached when:
P second crop = P main crop × 0.38 + lowering of production.
When P main crop = 2.6 and lowering of production = 0.5, P second crop = 1.5.
When 5% interest on the total investment of Sf 32,000,000 is added to the costs, the variable costs/total costs ratio changes to 0.27 for 6,000 ha.
In this case there is a considerable fall in the point of equilibrium.

SUMMARY

The Wageningen project is a large mechanized rice estate of 6,000 hectares which was laid out in the coastal plain of Surinam during the period from 1949 to 1957 and financed by the Dutch Government.
Actually it was never intended to establish a large-scale undertaking: the original plan provided for allocation of the land to Dutch farmers, but as this scheme was found to be attended by several drawbacks the allocation was postponed and it was decided that the area should be provisionally operated as a large-scale undertaking by the semi-governmental establishment "De Stichting voor de Ontwikkeling van Machinale Landbouw in Suriname" ("Foundation for the Development of Mechanized Agriculture in Surinam") which was set up for the purpose of developing the project. Some important factors which led to the establishment of the project were: the increasing interest taken by the Netherlands in Surinam since the Second World War, the surplus of virgin land in Surinam, the suitability of this land for rice growing, the small population of Surinam which made mechanized cultivation a necessity, the world shortages of rice and the high market prices. Moreover the project is the realization of a great many proposals and plans submitted on this question since about 1920.
The area in question has a tropical rainy climate with a mean annual rainfall of about 2000 mm. Four seasons are distinguished on the basis of the rainfall, viz. the long rainy period from April to mid-August, followed by a long dry period to mid-December, a short rainy period lasting until February, and a short dry period until April.
The soil consists of impermeable, marine-fluviatile, heavy clay, deposited without lime. The clay fraction $< 2\,\mu$ comprises about 65%. In the natural state the clay is covered with a 0–40 cm layer of organic material, called pegasse.
When the plan was drawn up an agricultural system was designed in which rice was to be grown during the rainy "summer" season, and dry annual crops during the drier "winter" season; moreover, leys were to be put down on a part of the area. In practice this system proved unattractive, as the area in question was unsuitable for cattle raising and such dry crops as maize, soya, sorghum, etc., and in consequence rice was grown as a monoculture.

The polder was laid out in a rectilinear pattern of irrigation and drainage canals, forming parcels of land of a gross area of about 80 ha which were subdivided into six fields of an area of 600 × 200 m, each having its own irrigation and drainage.

A pumping station was built with a reversible direction of rotation of the pumps, so that it could be used for both irrigation and drainage.
A settlement known as the village of Wageningen was established beside the Nickerie river; it included a large number of dwellings and appropriate facilities, an up-to-date rice-processing unit consisting of a drying plant, silo and milling unit, and, of course, a power station and various workshops, etc.
The land reclamation operations comprised the clearance of the original vegetation and the levelling and ploughing of the virgin soil. Of prime importance in this reclamation work was the drainage which rendered the land accessible to tractors. Because of the impermeable soil most of this drainage had to be obtained by evapotranspiration of the original natural vegetation.
The forest vegetation was previously poisoned with sodium arsenite, and this considerably lightened the task of forest clearance by machinery. About half the 6000 ha area had a forest cover and the other half was grown over with herbaceous swamp plants. The cost of reclaiming the latter half was obviously much less.
Since the occurrence of much pegasse in the topsoil was found to be a drawback to the cultivation of rice, for instance, because a tilth of this kind (including the planting) tended to float during irrigation, much work was done during the reclamation stage to clear the pegasse either by burning or ploughing under.

A highly mechanized method of rice cultivation is employed in the project. Tillage is by machines, there is direct sowing only (i.e. no transplanting), weeds are controlled by sowing rice in water and by the use of herbicides, harvesting is by means of combines, and the produce is largely removed in bulk.
The main rice-growing season is from April (sowing) to September (harvest). The sowing period is staggered over about six weeks. The growing period of the varieties employed is about 140 days.
On about a quarter of the area a second crop of rice is grown in rotation, from October to March. A further extension of this additional crop would be desirable as it has the effect of increasing production without the need of extra investments. There are, however, some drawbacks in this connection, viz. lack of time owing to the accumulation of work, a yield-depressing effect of this second crop on the succeeding main crop (varying from 300 to 750 kg/ha from 1954 to 1958 as an annual average), and the greater harveat hazard of this second crop owing to the possibility of persistent rainfall.
A suitable green manure for the environment in question is *Crotalaria quinquefolia*. Owing to the initial high N-content of the reclamation land it is still only grown on a small scale.
Tillage consists of a varying combination of such dry-land operations as ploughing, harrowing and levelling, and wet cultivations (puddling), de-

pending on weather conditions. Puddling is employed as a standard practice and is regarded as essential for efficient adaptation to the rainy climate and the extremely heavy clay soils.
The varieties grown were all selected in Surinam during the past decade with particular reference to mechanized rice farming. They are varieties with a fairly stiff straw and long grains having a 1,000 grain weight of about 30 g. The chief ones are Dima, Nickerie and 80/5.
The only fertilizer used is ammonium sulphate which is applied as a top dressing when the paddy is from 40 to 60 days old. Urea may possibly be used as well in future.
The plantings on the project area have always experienced considerable trouble from various diseases and pests. They are noticeably worse than on the ricelands farmed by the smallholders. This may possibly be explained by the differences in methods of reclamation, area lay-out and cultivation. The chief diseases are *Helminthosporium oryzae* Breda de Haan, *Cercospora oryzae* Miyake and *Piricularia oryzae* Cav. The chief pests are snails (*Pomacea lineata* (Spix)), rats, seedling flies (*Hydrellia* sp.), jassids and delphacids, stink-bugs and stalk borers.
The drainage arrangements in the constructed polder, which are based on a run-off capacity of 70 mm rainfall per 24 hours, are satisfactory.
Some difficulties are experienced with the irrigation, the main ones being: – the pumping-station has a low efficiency for irrigation (because the operating conditions differ from those for which it was designed); – the river is sometimes too saline at the point of intake; – the irrigation water is frequently polluted with drainage water (because of the dual purpose design of the pumping station).
The chief problem of mechanized harvesting is the floatability of the combines on fields which are often wet and soft. The combines in use are accordingly fitted with extended and widened tracks and extra large rear wheels.

Rice farming is practised in a decentralized manner in the form of a number of farm units of sizes varying from 200 to 600 hectares. About one workman to 25 hectares is employed on the farms.
In order to obtain the maximum possible efficiency a specified cost-price accounting system has been introduced.
From 1954 to 1958 the total production has averaged 2600 kg/ha sown (paddy with 14% m.c.).
In 1956 the agricultural production costs, excluding management overheads and interest, were Sf 335.90 per ha planted (4144 ha), and in 1957 Sf 323.50 per ha planted (6804 ha). Owing to the unfavourable effect of initial difficulties and reclamation conditions these cost prices are not entirely representative of normal operation. A minimum future cost price is estimated at Sf 250/ha (excl. overhead and interest).
Up to now the project has been run at a loss. One contributory factor was the unexpected fall in the world market prices of rice in 1953–55.

SAMENVATTING

Het Wageningen Rijst-Project in Suriname

Ervaringen bij de Ontwikkeling van een Project voor Gemechaniseerde Rijstbouw in de Humide Tropen

Inleiding

Het Wageningen-project is een gemechaniseerd grootrijstbedrijf, dat werd aangelegd in de tropische kustmoerassen in het Westen van Suriname. Het project werd gefinancierd door de Nederlandse regering.
De uitvoering werd in handen gelegd van een semi-gouvernementele instelling, genaamd Stichting voor de Ontwikkeling van Machinale Landbouw in Suriname. Sedert het begin van de werkzaamheden in 1949 werd een polder van ca 6.000 ha ingericht en in cultuur gebracht, terwijl daarnaast een emplacement werd gebouwd met o.m. moderne installaties voor de opslag en verwerking van rijst.
De problemen, die zich voordeden bij de aanleg en het in cultuur brengen, zijn voor een groot deel niet specifiek voor Suriname, maar worden op analoge wijze ontmoet in andere tropische onder-ontwikkelde gebieden.

DEEL I

DE TOTSTANDKOMING VAN HET WAGENINGEN-PROJECT

In dit eerste deel worden behandeld: de omstandigheden die hebben geleid tot de oprichting van het Wageningen-project, de natuurlijke en de economische milieufactoren van het betrokken gebied, de keuze van het landbouwtype voor het project, en de aanleg van het project.

1. *Voorgeschiedenis*

Door verschillende omstandigheden, o.a. door een tekort aan goede en goedkope arbeidskrachten, ging het in de loop van de 19e eeuw snel bergafwaarts met de plantage-landbouw in Suriname. Vanaf het begin van deze eeuw begon zich echter een bevolkingslandbouw te ontwikkelen dank zij de vestiging van de geïmmigreerde Javaanse en Hindostaanse contractarbeiders als zelfstandige rijstbouwers, maar deze ontwikkeling was langzaam zodat gezocht werd naar mogelijkheden om de landbouwproduktie in een sneller tempo op te voeren.

Reeds omstreeks 1920 gingen de gedachten uit naar oprichting van gemechaniseerde rijstboerderijen, waarbij als overweging gold dat voor rijst geschikt te maken gronden in overvloed aanwezig waren en dat het tekort aan arbeidskrachten zou kunnen worden opgevangen door mechanisatie. Er van uitgaande dat de Surinaamse landbouwers nog te weinig ontwikkeld waren en ook niet over het benodigde kapitaal beschikten voor zulk een gemechaniseerde landbouw stelde men zich voor Nederlandse boeren te doen emigreren naar Suriname.

In de daarop volgende jaren kreeg deze gedachte geleidelijk meer vorm. Proefnemingen met gemechaniseerde rijstcultuur vielen gunstig uit en diverse rapporteurs, die Suriname bezochten, deden aanbevelingen voor de bevordering er van.

In 1949 tenslotte nam de Nederlandse regering het besluit, naar aanleiding van een advies van een commissie onder leiding van Prof. Ir. W. F. Eijsvoogel, om een rijstpolder van 5.000 ha in het Nickerie-district van Suriname te doen aanleggen, welke echter zou worden voorafgegaan door de aanleg van een proefpolder.

Met de aanleg van de proefpolder, Prins Bernhard polder genaamd, werd onmiddellijk begonnen en reeds datzelfde jaar werden de eerste proefvelden ingezaaid.

De voor de uitvoering van het grote 5.000 ha project (later Wageningen-project genaamd) in het leven geroepen Stichting begon, na een nadere uitwerking van de plannen, in 1951 op grote schaal met de aanlegwerkzaamheden.

2. *De bevolking en economische structuur van Suriname*

In 1950 werd de bevolking van Suriname geraamd op 220.000 zielen, bestaande uit 37% Creolen (afstammelingen van de negerslaven en van de eerste kolonisten), 30% Hindostanen, 17% Javanen, 10% Bosnegers en enkele procenten Indianen, Chinezen en Europeanen.
De grootste helft van de bevolking vindt haar bestaan in de landbouw, welke echter in 1947, volgens overigens vrij vage ramingen, nog geen 25% van het nationale produkt opleverde.
In 1956 bedroeg het in cultuur zijnde landbouwareaal, exclusief het Wageningen-project, 36.000 ha, waarvan 20.000 ha rijst en 4.000 ha grasland. Van de landbouwbedrijven is 50% kleiner dan 2 hectare en 95% kleiner dan 20 hectare.
De Surinaamse export bestond in 1958 voor 80% uit bauxiet, (in 1958 Sf 48 miljoen), voor 10% uit hout en voor 10% uit landbouwprodukten (waarvan de helft rijst van het Wageningen-project).
De bauxiet is via exportheffingen veruit de voornaamste inkomstenbron van het Surinaamse Gouvernement.

3. *Het klimaat*

De Nickerie-kustvlakte waarin het Wageningen-project is gelegen heeft, evenals geheel Suriname, een tropisch regenklimaat.
Op basis van de regenval worden per jaar 4 seizoenen onderscheiden: de grote regentijd van begin april tot medio augustus; de grote droge tijd van medio augustus tot medio december; de kleine regentijd van medio december tot begin februari en de kleine droge tijd van begin februari tot begin april.
De grote regen- en de grote droge tijd treden vrij regelmatig en duidelijk waarneembaar op, alhoewel de tijdstippen waarop ze beginnen en eindigen nogal kunnen uiteenlopen. De kleine regen- en de kleine droge tijd zijn echter zeer onregelmatig en beslist niet alle jaren duidelijk te onderscheiden.

De windrichting is, onder invloed van de N.O.-passaat, vrij constant tussen Noord en Oost. Door het optreden van land- en zeewinden treedt een dagelijkse gang op, zowel in richting als in kracht.
De windkracht is gering, slechts zelden komt zij boven 6° Beaufort. Stormachtig weer komt niet voor.
De gemiddelde jaartemperatuur bedraagt 27° C, met een maximum maandgemiddelde in september van 28° C en een minimum gemiddelde in januari van 26° C. De gemiddelde dagelijkse amplitude van de temperatuur bedraagt te Nw.-Nickerie 6° C.
De gemiddelde relatieve luchtvochtigheid is 80%, met een jaarschommeling van enkele procenten.
De zonneschijn is, gemeten in % van 7–17 uur, gemiddeld 57%, met maxima

in augustus, september, oktober van 67, 76 en 70% en minima in december-januari en mei van 46%.

De jaarregenval bedraagt gemiddeld te Nw.-Nickerie 1930 mm.
De gemiddelde maandregenvallen zijn er als volgt: januari 190 mm, februari 110, maart 110, april 170, mei 250, juni 320, juli 260, augustus 150, september 60, oktober 60, november 80 en december 170.
Zware buien kunnen over het gehele jaar verdeeld optreden, alhoewel het meest in de regenmaanden.
Het maximum van zware buien valt in de maand juni met eens per 5 jaar meer dan 90 mm regenval per etmaal, het minimum in september met circa eens per 5 jaar meer dan 40 mm per etmaal.
Behalve gedurende de maanden januari en februari treedt een maximum in de dagelijkse gang van de regenval op, dat zich van ± 11 uur in maart geleidelijk verplaatst tot ± 16 uur in augustus en september om vervolgens weer geleidelijk terug te lopen tot 13–14 uur in december.
Voorlopige waarnemingen in de Wageningen-polder duiden op het voorkomen van een reële buienspreiding binnen dit areaal.
Door de ligging van het polderproject dicht achter de kustlijn is het niet uitgesloten, dat binnen het polderareaal, vooral als verdere geprojecteerde uitbreidingen naar het Noorden worden gerealiseerd, significante klimaatsverschillen zullen optreden. Een zone van enkele kilometers achter de kustlijn heeft n.l. minder regen, meer wind en meer zonneschijn dan de meer landinwaarts gelegen gebieden.

4. *De bodem en de oorspronkelijke begroeiing*

De bodem van het Wageningen-project bestaat uit ondoorlatende, marine-fluviatiele, kalkloos afgezette, zware klei, met een vrij goed gehalte aan organische stof, in natuurlijke ligging overdekt door een *pegasse*-laag van 0–40 cm dikte.
Het gemiddelde bodemprofiel van de grond vóór de ontginning is eenvoudig en als volgt opgebouwd:

± 20 cm	min of meer verteerd organisch materiaal (de *pegasse*) op de klei rustend,
0– 10 cm	humeuze donkergekleurde klei,
10– 30 cm	grijze klei, met weinig vlekken (de gereduceerde zone),
30–100 cm	roestbruin tot geelbruin gevlekte grijze klei,
> 100 cm	egaal donkergrijze, zoute klei.

Het bodemtype is zeer uniform.
Het voornaamste degeneratieverschijnsel bij dit type gronden, de verzuring door opgesloten lagen organisch materiaal, z.g. katteklei-vorming, komt tot nu toe op het Wageningen-project slechts in onbetekenende mate voor.
De gronden bevatten oorspronkelijk vrij veel zout, zonder dat dit echter nadelige gevolgen van betekenis heeft voor de rijstcultuur.

De afwezigheid van grote chemische en physische grondverschillen doet de

invloeden van de topografie en de natuurlijke vegetatie meer op de voorgrond treden.
Het uitgekozen terrein is vrij vlak en leent zich uitstekend voor bassinbevloeiing van grote percelen, met een minimum aan egalisatiekosten.
De oorspronkelijke begroeiing heeft een belangrijke invloed op de aard van de bodem doordat zij het organisch materiaal (pegasse + org. stof van de humeuze klei) heeft gevormd, dat een wezenlijk onderdeel uitmaakt van de bouwvoor.
Ongeveer de helft van de polder was begroeid met een kruidachtige vegetatie (graszwamp) en de andere helft met open of gesloten bos.
De pegasse van de graszwampen was in het algemeen iets dunner dan die onder het bos, hetgeen zal samenhangen met de vele branden in deze graszwampen.
Met toenemende afstand tot de kust kan een successie van plantenassociaties worden waargenomen onder invloed van de afnemende zoutgehalten.

De grondanalysen ter verificatie van de landbouwkundige eigenschappen geven kort samengevat het volgende beeld:
— een lichtzure reactie in de bovengrond, die dieper in het profiel neutraal en zwak basisch wordt;
— een gemiddelde fractieverdeling van de bouwvoor van 65% $< 2\ \mu$, 28% van 2–20 μ, 4% van 2–50 μ en 0% $> 200\ \mu$;
— een matig tot goed gehalte aan voor de plant opneembare voedingsstoffen (basen, N, P);
— de klei bestaat vnl. uit het mineraal illiet;
— van de geadsorbeerde basen domineert het Mg^{++}.

De klei heeft voor de aanleg van kanalen en voor de fundering van zware constructies uitgesproken ongunstige mechanische eigenschappen.

5. *Het landbouwtype*

Het in te voeren landbouwsysteem werd voornamelijk bepaald door: de doelstelling van het project, het natuurlijke milieu, te weten bodem, klimaat en hydrologie, en het economische milieu, waaronder verstaan wordt de economische structuur van Suriname en de afzetmogelijkheden van produkten.
In het basisplan werd uitgegaan van verkoop of verpachting aan Nederlandse boeren van bedrijven van 72 ha, met 12 ha wisselweide en 60 ha sawahrijst in de grote regentijd, gevolgd door droge gewassen in het minder regenrijke winterseizoen.
Tijdens de uitvoering van het project bleek echter spoedig, dat dit onderdeel van het basisplan om de volgende redenen niet kon worden toegepast:
— bodem en klimaat zijn ongunstig voor veeteelt en droge gewassen, zodat economische produktie hiervan niet kon worden gerealiseerd; de gemechaniseerde rijstcultuur werd daarentegen een redelijk succes;
— de als gevolg hiervan uitgeoefende monocultuur van rijst brengt op 72 ha

te weinig op voor een Nederlandse boer; de bedrijfsgrootte zou daartoe 3 tot 6 maal zo groot moeten zijn;
— financiële, sociale en politieke overwegingen maken uitgifte van rijstboerderijen van een dergelijke omvang aan Nederlandse boeren echter weinig aantrekkelijk.

Voor de rijstcultuur zijn de omstandigheden ter plaatse gunstig. Dit blijkt in het bijzonder uit de resultaten van de bevolkingsrijstbouw die op soortgelijke gronden een gemiddelde produktie van bijna 3.000 kg padi (= ongepelde rijst) per hectare haalt.
Een nadere analyse toont, dat deze gunstige omstandigheden zowel gelden voor het klimaat, de bodem als de hydrologie, het laatste door de mogelijkheid irrigatiewater te onttrekken aan de Nickerie-rivier.

6. *De afzetmogelijkheden van (Surinaamse) rijst*

Bij de oprichting van het Wageningen-project bestond er een ernstig rijsttekort in de wereld. Gezien het verwachte chronische karakter hiervan werden de afzetmogelijkheden gunstig geacht. Suriname zelf had gemiddeld een produktieoverschot van rijst, zodat afzet in Nederland of op de wereldmarkt moest plaatsvinden.
Aanvankelijk werden besprekingen gevoerd om importpreferenties in Nederland te verkrijgen, doch het overleg in deze liep op niets uit.
In 1951 verrichtte het Nederlands Economisch Instituut te Rotterdam een onderzoek naar de afzetmogelijkheden van Surinaamse rijst. Het concludeerde dat deze afzetmogelijkheden tot 1965 gunstig waren door een te verwachten stijging van het prijsniveau op de wereldmarkt als gevolg van produktietekorten.
Zowel de wereldrijstproduktie als het prijsverloop op de wereldmarkt hebben zich echter sedertdien afwijkend gedragen van de prognosen.
De produktie is sneller toegenomen dan werd verwacht. Vraag en aanbod van rijst op de wereldmarkt zijn op een lager niveau (ca 5 miljoen ton) dan voor de oorlog (ca 9 miljoen ton) met elkaar in evenwicht gekomen.
Na een aanvankelijke prijsstijging van 1949–'52, trad tot 1956 een sterke prijsdaling op, zodat de prijzen in 1956, 20–30 % beneden die van 1948 lagen.
In de periode 1956 tot 1959 zijn de wereldmarktprijzen ongeveer gelijk gebleven bij een langzaam stijgende wereldomzet.
De daling van de wereldmarktprijzen was uiteraard voor het Wageningenproject een grote tegenvaller.

7. *De aanleg*

Het basisplan voor de aanleg van 5.000 ha werd in 1951 gewijzigd in een plan voor 15.000 ha. Tijdens de werkzaamheden aan het eerste gedeelte hiervan werd echter om verschillende redenen, waarvan wel de voornaamste was dat de kosten aanzienlijk boven de raming kwamen, toch weer besloten het project voorlopig te beperken tot 6.000 ha.

Het hoofdpatroon van de polder-*layout* vormde het stelsel van irrigatie- en drainagekanalen (fig. 12).
De afmetingen van de hoofd- en secundaire drainagekanalen werden gebaseerd op de afvoer van een regenval van 70 mm per etmaal. De tertiaire afvoerkanalen werden groter gegraven dan voor genoemde regenval nodig zou zijn geweest, teneinde de benodigde grond voor de rijdammen te verkrijgen. Bij de irrigatiekanalen speelden de eisen voor de benodigde debieten in het geheel geen rol, omdat met name de bevaarbaarheid of de benodigde grond voor de rijdammen, belangrijke grotere profielen vergden.
Door de aan- en afvoerkanalen werd het polderareaal verdeeld in een 80-tal rechthoekige percelen van bruto 80 ha. Deze percelen werden door dammen met sloten aan weerszijden onderverdeeld in 6 velden van 600 × 200 m, elk met onafhankelijke irrigatie en afwatering. (fig. 13 en 14). De sloten langs beide lange zijden van elke veld waren z.g. open sloten, d.w.z. sloten die naar de zijde van het veld niet bedamd waren, met aansluiting via afsluitbare duikers aan de ene zijde op de irrigatie en aan de andere zijde op de afvoer. Bij de inrichting van de velden werd rekening gehouden met de volgende punten: snelle aan- en afvoer van water, gemakkelijke toegankelijkheid voor landbouwmachines, machinaal onderhoud van dammen en sloten en aanpassing van de veldafmetingen aan de toe te passen machinale werkmethoden. Door de vrij vlakke ligging van het polderareaal behoefden de 12-ha velden niet verder in kleinere irrigatievakken onderverdeeld te worden.
Langs de hoofd- en secundaire irrigatiekanalen werden in diverse groeperingen de woonhuizen voor het personeel en de machineloodsen neergezet. Voorin de polder, in de 1e en 2e reeks, werd hierbij nog in kleine *units* gebouwd, gebaseerd op het oorspronkelijke plan boerderijen van 72 ha te verpachten. In de overige reeksen waar later werd gebouwd vond een concentratie van de bebouwing tot grotere *units* plaats. Vanwege de hoge kosten die aan de aanvoer van wegverhardingsmateriaal over grote afstanden zijn verbonden, werd afgezien van de aanleg van een net van "all-weather" wegen door de gehele polder. In verband hiermede werd besloten het transport van materialen en produkten alsmede het personenvervoer bij ongunstige weersomstandigheden te doen geschieden per boot via de hoofd- en secundaire irrigatiekanalen, welke dan ook speciaal voor dit doel waren ingericht.
Het voor de polder gebouwde pompgemaal heeft 3 schuinliggende, elektrisch aangedreven schroefpompen met omkeerbare draairichting en verstelbare waaierschoepen, welke pompen met behulp van een kleppen- en schuivenstelsel in de pompkanalen, zowel voor inmaling als uitmaling gebruikt kunnen worden (fig. 16). Voor de uitmaling werd de draairichting met de hoogste capaciteit (ca. 800 m^3/min/pomp, bij 1 m opvoerhoogte en 315 pk) en het beste krachtsrendement gekozen.
Het rijstverwerkingsbedrijf omvat o.m. een padidrooginstallatie, met een capaciteit van ca. 600 ton padi/etmaal voor droging van 20% op 14% vocht, een in beton uitgevoerde silo voor ca. 13.500 ton padi, en een modern ge-

outilleerde rijstpellerij met een capaciteit voor verwerking tot cargo (het normale halffabrikaat, dat door Wageningen wordt geëxporteerd) van circa 250 ton/etmaal.

8. *De ontginning*

Na het gereedkomen van de kanalen en sloten werd aangevangen met de ontginning van de terreinen, bestaande uit het opruimen van de oorspronkelijke begroeiing en het prepareren van de gronden voor de eerste rijstgewassen door ploegen en egaliseren.
Van overheersend belang bij de gehele ontginning was de ontwatering en opstijving van de terreinen teneinde ze berijdbaar te maken voor de machines. Droog-weer-perioden zijn hiervoor noodzakelijk, omdat de ontwatering van de grond in feite slechts in voldoende mate kan plaatsvinden door evapotranspiratie van de natuurlijke vegetatie. Droog weer is ook essentieel om het hout en het andere organische materiaal door branden effectief te kunnen opruimen. Voor deze ontginning konden goede, aan de omstandigheden aangepaste werkmethoden worden ontwikkeld.

Bij het cultuurrijpmaken waren twee soorten terreinen te onderscheiden: het bos- en het graszwamp.
De ontginningsmethode van het boszwamp was in het kort als volgt:
1. *Bosvergiftiging*. De bomen werden stuk voor stuk geringd en de ringen werden besmeerd met Na-arseniet.
2. *Platrijden van het bos*. Na 1–2 jaar werd het afgestorven, gedeeltelijk in elkaar gezakte bos, met *bulldozers* of door de methode van *chainclearing* platgereden en vervolgens gewalst met *brushcutters*.
3. *Het branden*. Enkele dagen na het platrijden werd zo intensief mogelijk gebrand.
4. *Het schuiven*. Direct hierop aansluitend werd het resterende hout met lichte bulldozers gesprokkeld en op hopen of rillen gebracht, waarna opnieuw werd gebrand. Voorzover nog nodig werd ook het teveel aan pegasse meegeschoven. De rillen werden vervolgens verder opgerold tot hopen.
5. *Het ploegen*. Gewoonlijk nog tussen de hopen werd met Solotrac-ploegen een goed kleihoudende bouwvoor geploegd.
6. *Verbouw van het eerste rijstgewas*. Aangezien de droge tijden gewoonlijk van beperkte duur zijn, moest het eerste rijstgewas worden verbouwd in terreinen met houthopen.
7. *Het opruimen van de houtresten*. Na het rijstgewas werden de houthopen verder bij elkaar geschoven en opnieuw gebrand. Tenslotte werden de restanten, vnl. aarde en houtpulp, met lichte bulldozers over het terrein uitgesmeerd. De laatste houtresten werden met de hand gesprokkeld.
8. *Het egaliseren*. De ruwe egalisatie van de oneffenheden op korte afstand kon direct hierna met *landplanes* plaatsvinden.
De grote egalisatie met *carry-scrapers* moest enkele jaren wachten met het oog op de stabilisatie van het terrein na het verteren van de pegasse. Deze

definitieve egalisatie, welke momenteel nog in uitvoering is, bleek maar op een deel van de velden nodig te zijn.

De ontginning van de graszwamparealen was uiteraard aanzienlijk eenvoudiger dan die van het bos. Ten behoeve van de inzaai van de eerste rijstgewassen kon dan worden volstaan met het platrijden en branden van de kruidachtige begroeiing, gevolgd door ploegen met Solotracs, waarbij de pegasse goed moest worden ondergewerkt. Deze werkzaamheden vergden, vooral als goed gebrand kon worden, nauwelijks meer inspanning dan het klaarmaken van een met onkruiden begroeide, normale sawah. Ook de daarna te verrichten egalisatie was op de graszwampterreinen minder omvangrijk dan op de bosterreinen.
De kosten, excl. rente en overhead, voor het opruimen van de begroeiing bedroegen voor terreinen met 50–100 % bos gemiddeld ca Sf 190 per hectare, met 20–50 % bos ca Sf 130/ha en met 0–20 % bos ca Sf 50/ha.

Bij de eerste rijstaanplantingen trad op de bosgronden gewoonlijk een weelderiger groei op dan op de graszwampgronden, hetgeen meermalen resulteerde in schimmel-aantasting, slechte vruchtzetting en dus lagere produkties.
Correctie vond plaats door bij de ontginning meer aandacht te besteden aan het opruimen van de N-rijke pegasse en daarnaast door aanpassing van de cultuurmethode (o.m. via de varieteitenkeuze).
Het opruimen van de pegasse bleek bovendien in het algemeen gewenst, omdat de rijstaanplant met veel pegasse aan de oppervlakte van het veld na irrigatie ging drijven, hetgeen leidde tot een slechte ontwikkeling van het gewas.

Bij sortering van de opbrengsten van het project naar ontginningsjaren en naar type van oorspronkelijke begroeiing blijkt, dat deze factoren niet de voornaamste oorzaak gevormd hebben van de zich voordoende produktieverschillen. Deze moet n.l. gezocht worden in het optreden van ziekten en plagen welke tot op zekere hoogte weliswaar weer verband houden met de ontginning. Typerend is b.v. de bijna elk jaar gedurende het tweede-gewasseizoen optredende grotere rattenschade in de voormalige bosgebieden dan in de graszwampgebieden.

9. *De aanlegkosten*

Tot 1 januari 1958 werd Nf 64.000.000 in het Wageningen project geïnvesteerd.
Dit bedrag is viermaal zo groot als de bij de oprichting in 1949 gemaakte kostenraming.
De voornaamste reden van dit grote verschil is dat een geheel ander en kostbaarder project werd aangelegd dan in 1949 voor ogen stond.

DEEL II

DE GEMECHANISEERDE RIJSTBOUW OP HET WAGENINGEN-PROJECT

In dit tweede deel worden behandeld de verschillende aspecten van de op het project toegepaste methoden van gemechaniseerde rijstcultuur.

10. *Het cultuurschema*

De belangrijkste onderdelen van het cultuurplan zijn de grondbewerkings-, zaai- en oogsttijden, de verbouw van een of twee rijstgewassen per jaar en de braakmethoden. De zaai- en oogsttijden worden o.m. bepaald door: de jaarlijkse gang van de regenval, de groeiduur van de rijstvarieteiten, de gewenste arbeidsspreiding en de wenselijkheid oogst en grondbewerking bij droog weer te doen plaatsvinden.

Globaal wordt op het project het volgende schema toegepast:

hoofdgewas	inzaai	van 1 april –15 mei
	oogst	van 20 augustus– 5 oktober
tweede gewas	inzaai	van 15 oktober –15 november
	oogst	van 1 maart – 1 april.

Volgens dit schema vallen de oogst van het hoofdgewas en de grondbewerking voor het daarna volgende tweede gewas in de grote droge tijd en de oogst van het tweede gewas en de grondbewerking ten behoeve van het hoofdgewas in de kleine droge tijd. Gezien de geringe zekerheid van de kleine droge tijd en de wenselijkheid van arbeidsspreiding verdient het evenwel aanbeveling, een gedeelte van de tijdens het tweede gewas seizoen braakliggende arealen reeds in de grote droge tijd, dus 4–5 maanden vóór de inzaai te ploegen.

De verbouw van twee rijstgewassen per jaar (hoofdgewas en tweede gewas) vindt plaats op ongeveer een kwart van het areaal. De redenen waarom geen groter oppervlak met tweede gewas wordt ingezaaid zijn:

— een opbrengstverminderende invloed van het tweede gewas op de daaropvolgende hoofdaanplant;

— tijdgebrek door opeenhoping van werkzaamheden;

— de wenselijkheid van braakperioden voor de nieuwe ontginningsgronden ten behoeve van houtruimen, egalisatie en opstijving van de grond.

De optredende opbrengstreductie van het hoofdgewas na tweede gewas is de hoofdfactor. Gedurende de jaren 1954–'58 varieerde deze reductie in jaargemiddelden van 300–750 kg padi per ha.

De waarschijnlijke oorzaken hiervan waren: ontoereikende grondbewerking

door de natte conditie van de pas afgeoogste velden, achteruitgang van de grond door het ontbreken van een rust- c.q. uitdrogingsperiode, en overdracht van ziekten en plagen.
Vermindering van de nadelen van de tweede gewascultuur, teneinde verdere uitbreiding hiervan te verwezenlijken, vormt een van de belangrijkste research objecten van het project. Op deze wijze kan immers een grotere produktie worden verkregen zonder uitbreidingsinvesteringen van het produktie-apparaat.
Een nadere analyse van de produktiemogelijkheden van het tweede-gewasseizoen ten opzichte van die van het hoofdseizoen toont, afgezien van de wederzijdse beïnvloeding aan, dat deze in wezen maar in enkele opzichten ongunstiger zijn. Het oogstrisico is b.v. groter, doordat er in maart meer kans op regen bestaat dan in september. Dit risicoverschil is echter minder groot dan op het eerste gezicht lijkt, omdat in maart een groter percentage van de regen 's nachts valt en dus relatief minder verlet geeft bij het maaidorsen. Bovendien mag aangenomen worden dat de velden in het tweede gewasseizoen gemiddeld een grotere draagkracht hebben als gevolg van een goede droge grondbewerking in de grote droge tijd.
Een tweede nadeel van het tweede-gewasseizoen wordt gevormd door de grotere behoefte aan irrigatiewater vanwege de mindere regenval tijdens de groeiperiode.
Tot nu toe zijn de resultaten met het tweede gewas op het project vrij bevredigend geweest waarbij in aanmerking moet worden genomen dat de beperking tot 1/4 van het areaal hiertoe kan hebben bijgedragen, waardoor o.a. steeds enige terreinselectie kon plaatsvinden en bij de oogst veel meer *combines* per eenheid areaal konden worden ingezet dan bij de hoofdoogst.

Ten aanzien van de braakmethoden werd op Wageningen nog weinig ervaring opgedaan, ten eerste omdat tot voor kort de braakperioden zoveel mogelijk werden gebruikt voor afwerking van de ontginning en ten tweede omdat alle maatregelen tot opvoering van de vruchtbaarheid van de grond gedurende de braakperioden vermeden werden in verband met de initiële geilheid van de grond.
In de Prins Bernhard polder werden op dit gebied belangrijke onderzoekingen verricht. Geconstateerd werd dat groenbemesting en daarnaast natte braak belangrijke opbrengstverhogende factoren vormen. Een bruikbare groenbemester voor het gegeven milieu werd gevonden in de *Crotalaria quinquefolia*. De natte braak bestond uit een inundatie gedurende b.v. 3 maanden. Hierbij werd herhaaldelijk een effect geconstateerd dat gelijk gesteld kon worden met ca 100 kg ZA overbemesting per hectare.

11. *De grondbewerking.*

Het grondbewerkingssysteem, dat voor het project is ontwikkeld, bestaat uit een, naar gelang de omstandigheden wisselende, combinatie van „droge"

bewerkingen, zoals ploegen, eggen en egaliseren, en „natte" of modderbewerkingen. Het essentiële verschil tussen beiden is, dat bij de droge bewerkingen het vochtgehalte van de met de werktuigen in aanraking komende grond beneden het kleeftraject moet liggen en bij de natte bewerkingen er boven.
De voordelen van dit voor de rijstcultuur typische grondbewerkingssysteem zijn de volgende:
— Bij het in Suriname tijdens de grondbewerkingsseizoenen veel voorkomende regenweer kan de grondbewerking zo nodig worden voortgezet op natte velden, zodat men dus niet meer geheel afhankelijk is van de weersomstandigheden.

— Bij gunstig droog weer zouden met uitsluitend droge bewerkingen veel draaiuren nodig zijn om de kluiten van de zware klei voldoende fijn te krijgen. Door het veld na het ploegen en 1 of 2× eggen onder water te zetten en daarna een lichte modderbewerking uit te voeren vallen de kluiten gemakkelijk uiteen en wordt snel een mooi fijn modderzaaibed verkregen. Ook het onkruid wordt op deze wijze beter weggewerkt.
— De inzaai kan volgens een vast tijdschema plaatsvinden en zij kan bovendien tot vrij diep in de grote regentijd worden voortgezet. Dit laatste is van belang met het oog op de arbeidsspreiding en het vallen van de hoofdoogst in de grote droge tijd.
— Zonder de toepassingsmogelijkheid van natte grondbewerking zou de cultuur van tweede gewas rijst veel minder aantrekkelijk zijn, omdat juist na de oogst hiervan de velden dikwijls te nat zijn voor droge bewerkingen ten behoeve van de direct daaropvolgende inzaai van het hoofdgewas in april of mei.

Voor een goed begrip moeten ook enkele bezwaren resp. beperkingen van het „modderen" worden vermeld:
— Het is gewenst, dat het veld vóór elk gewas tenminste droog geploegd wordt. Bij uitsluitend modderbewerkingen zijn de opbrengsten namelijk meestal aan de lage kant.
— In het bijzonder de rupsen van de tractoren vertonen een grotere slijtage in het agressieve modderwater dan bij droge bewerkingen.
— De structuur van de grond gaat achteruit. Dit punt zou belangrijk zijn indien behalve rijst ook andere gewassen werden verbouwd, hetgeen tot heden niet het geval is.
— De draagkracht van de grond vermindert enigszins.

Bij de schematische beschrijving van de tot heden gevolgde werkwijzen kan een onderscheid gemaakt worden tussen maagdelijk ontginningsland en langer in cultuur zijnde terreinen.
De eerstgenoemde arealen hadden meestal veel pegasse aan de oppervlakte en werden daarom tot 15 à 20 cm diep geploegd met zware eenschaarploegen (Ransomes Solotrac) teneinde deze pegasse goed onder te werken. Voor de slechting van de forse ploegbalken werden dan zware dubbele

schijveneggen met gekartelde schijven (Rome A-16"-26") gebruikt. De reeds langer in cultuur zijnde velden werden meestal geploegd met schijvenploegen (International No. 98, 5 schijven) en geëgd met dubbele schijveneggen (Ransomes Baronet of Baron) of met verstek schijveneggen (Rome, div. typen).
Het verder zaaiklaar maken was voor beide typen terreinen ongeveer hetzelfde. Bij gunstig droog weer werden de daarvoor in aanmerking komende ongelijke velden eerst nog geëgaliseerd met "landplanes" (Marvin, typen Junior en Standard). Daarna werd 5–15 cm water op het veld gebracht en volgde als laatste bewerking voor het zaaiklaarmaken een modderbewerking met een z.g. modderrol + plank. Deze modderrol is een in een trekframe geplaatste open cylinder van ± 1 m diam., bestaande uit twee ± 3,5 m uit elkaar geplaatste ijzeren wielen, verbonden door een aantal ribben van smalspoorijzer. De plank sleept aan staalkabels of kettingen achter de rol.
Als het veld door regenval te nat was voor droge bewerkingen en als het zaaischema langer wachten niet toeliet werden de droge bewerkingen vervangen door suppletoire modderbewerkingen. Vooral als er veel onkruid was, werd hiervoor dikwijls de *weedcutter* (Marden, type T 5) gebruikt.
Voor de groei van het rijstgewas bleek het weinig uit te maken of nat c.q. droog was bewerkt, met uitzondering van het droog ploegen, dat niet op ongeveer gelijkwaardige wijze door modderbewerkingen kon worden geremplaceerd. Het kwam evenwel toch vrij dikwijls voor, dat velden noodgedwongen ongeploegd uitsluitend door modderen zaaiklaar werden gemaakt. Het resultaat was dan een lagere opbrengst. Sedert 1958 worden op het project proeven genomen met aangedreven spitmachines (proto type in ontwikkeling bij Mulder, Kampen), welke mogelijk een verbetering kunnen brengen in de grondbewerking omdat daarmede nog onder zeer natte veldomstandigheden kan worden doorgewerkt.
Vooral bij de ontginningsvelden deed zich nogal eens de situatie voor, dat de draagkracht van de grond na het ploegen zeer gering was geworden. Indien ook hier in verband met het zaaischema het wachten op uitdroging en opstijving onmogelijk was, werd getracht door lichte modderbewerkingen (b.v. alleen met een sleepplank achter de trekker) de geploegde akker voldoende fijn en onkruidvrij te krijgen. In het uiterste geval werd rechtstreeks op de ploegsnede gezaaid.

Als trekkracht voor de grondbewerking werden vrijwel uitsluitend rupstrekkers van 40–50 pk (International TD9 en Caterpillar D4) gebruikt. Wieltrekkers van een vergelijkbaar vermogen waren op de dikwijls natte, zware kleigrond weinig efficient.

12. *De rijstvarieteiten en de zaadwinning*

Het rijstvarieteiten sortiment, dat op het project wordt gezaaid, bestaat geheel uit nieuwe varieteiten, die sedert 1950 speciaal voor de gemechaniseerde cultuur werden geselecteerd door het Landbouwproefstation (varieteit Dima) en door het Proefstation van de Stichting in de Prins Bernhard polder (varieteiten Nickerie, 80/5 en 80/7). Vergeleken met Skrivimankoti, het voornaamste rijstras van kleine landbouwers in Suriname, hebben de nieuwe varieteiten een aanzienlijk grotere legervastheid, geringere seizoengevoeligheid, betere reactie op N-bemesting en betere korrel-kwaliteit. Ze zijn echter minder geschikt voor overplanten, een van de redenen waarom zij in de bevolkingsrijstbouw weinig belangstelling ontmoeten.

In de periode 1954–'58 werd op het project de varieteit Dima het meest gezaaid, daarnaast successievelijk No. 80/5, Nickerie en No. 80/7. De tekortkomingen van Dima zijn gevoeligheid voor *Helminthosporium* en te geile groei op vruchtbare gronden.

80/5, Nickerie en 80/7 hebben genoemde bezwaren in mindere mate, maar deze hebben andere gebreken. 80/5 en 80/7 zijn gevoeliger voor *Cercospora* en *Piricularia;* Nickerie is dit ook hoewel iets minder, maar heeft bovendien een minder goede korrelkwaliteit dan Dima.

De gemiddelde produkties over de jaren 1954–'58 waren: van Dima: 32.8 qt/ha op proefvelden en 25.5. qt/ha op het praktijkareaal, van 80/5: 34.1 resp. 25.4 (relatief lage opbrengst op praktijkareaal ten opzichte van proefvelden door standplaatsfactoren), van Nickerie: 33.8 resp. 27.2 en van 80/7: 32.7 resp. 26.2.

Op grond van produktiewaarnemingen in de Prins Bernhard polder wordt verwacht, dat na een wat langere cultuurperiode van de Wageningse gronden, Dima hogere produkties zal halen dan de andere genoemde varieteiten.

De jaarlijks benodigde hoeveelheid zaaizaad voor 6.000 ha hoofdaanplant en 1.500 ha tweede gewas zou à raison van 100 kg/ha 750 ton bedragen. In 1957 en 1958 werd echter per jaar meer dan 1.000 ton gewonnen. De reden hiervan is, dat steeds een reserve moet worden aangehouden voor eventueel overzaaien, voor bederf van opgeslagen partijen en voor een niet voorziene, noodzakelijk blijkende verschuiving in de samenstelling van het in te zaaien rassensortiment.

Het merendeel van het benodigde zaad wordt gewonnen tijdens het hoofdseizoen. Gedurende het tweede gewas-seizoen worden de voor het daarop volgende hoofdgewas ter beschikking staande zaadkwantums van de verschillende varieteiten naar behoefte aangevuld. De tweede-gewascultuur maakt dus een efficienter zaadvoorziening mogelijk.

De belangrijkste punten, waarop bij de zaaizaadproduktie wordt gelet zijn: rode rijst, varieteiten-vermenging, ziekten en kiemkracht. De rode-rijst infectie van het Wageningen-areaal vond plaats via van elders aangevoerd zaaizaad.

13. *De inzaai*

De waterregeling vormt het voornaamste element bij de zaaimethode. De meest bevredigende en derhalve meest toegepaste methode is de zogenaamde zaai in water. Hierbij wordt gezaaid op nagenoeg waterpas liggende velden

in een waterlaag van ca 15 cm, die ook na de zaai op ongeveer dezelfde hoogte continu op het veld wordt gehouden tot het rijstgewas ten minste 4–5 weken oud is. Deze werkwijze wordt voornamelijk toegepast omdat de aanplant dan praktisch onkruidvrij opgroeit.
Bijkomende voordelen zijn: regelmatige opkomst en geen of weinig schade door vogels, ratten en rupsen.
Direct voorafgaande aan het zaaien wordt het zaad voorgekiemd door 18–24 u. weken onder water, gevolgd door 18–24 u. kiemen op het droge. Door het voorkiemen wordt de opkomst beter en krijgt het rijstzaad een extra voorsprong op het onkruid.
Het zaaien geschiedt zowel machinaal als met de hand, in beide gevallen breedwerpig. Machinale zaai is meestal regelmatiger.
Een belangrijke voorwaarde voor het in water zaaien is een intensieve bestrijding van de rijstkiemen-etende waterslakken.
Als eèn nadeel van het zaaien in water kan nog worden beschouwd de wel eens door de golfslag veroorzaakte uitspoeling van jonge kiemplantjes. In Suriname is dit bezwaar evenwel niet zo groot vanwege de geringe windkracht. Het is in dit verband toch nuttig als de velden met de lange zijden dwars op de richting van de heersende krachtige winden worden aangelegd.
Diverse omstandigheden kunnen de toepassing van de methode van het in water zaaien op het project beletten. De voornaamste hiervan vormden weinig gerijpte, vers ontgonnen gronden. De rijstkiemen bleken op dergelijke terreinen onder water niet te groeien ten gevolge van het gereduceerde milieu. Als de kieming daarentegen op natte modder, dus bij toetreding van lucht plaatsvond, was de groei normaal.
De invloed van de zaaidatum op de produktie van het rijstgewas is gering. Ook de zaadhoeveelheid is vrij onbelangrijk. Een zaadgift van circa 100 kg/ha is gebruikelijk.
Bij slechte opkomst moet niet lichtvaardig besloten worden tot overzaaien. Het is n.l. beslist zeer moeilijk om het eerste zaaisel volledig door grondbewerkingen te vernietigen, hetgeen noodzakelijk is teneinde een op twee data afrijpende aanplant te voorkomen. Het uitstoelingsvermogen van rijst is zeer groot, zodat ook een zeer dunne stand zich nog goed kan herstellen.

14. *De onkruidbestrijding*

Een zo goed als absolute preventieve onkruidbestrijding wordt verkregen door toepassing van de methode van het zaaien in water. Geen van de ter plaatse voorkomende belangrijke onkruiden heeft n.l. hetzelfde vermogen als rijst om onder een laag water te kiemen en naar de oppervlakte te groeien. Nu komt het echter vrij veel voor, dat deze methode niet gevolgd kan worden, b.v. op pas ontgonnen terrein of op natte akkers na tweede gewas, wanneer het rijstzaad onder water niet wil groeien.
Onder dergelijke omstandigheden moeten de periode van droogstand steeds zo kort mogelijk worden gehouden, teneinde de onkruidontwikkeling af te remmen.

Voorzover de preventieve bestrijding met een permanente waterlaag op het veld niet zou slagen, is het nog mogelijk vrijwel alle niet tot de Gramineae behorende onkruiden chemisch te bestrijden. Bij onverhoopte ontwikkeling van grasonkruiden in een aanplant zou handwieden de enige oplossing zijn, maar dit is onder de omstandigheden van het project onbegonnen werk.
Het voornaamste grasonkruid is *Ischaemum rugosum* Gaertn. Oorspronkelijk werd dit gras niet op de terreinen van het project aangetroffen. Zeer waarschijnlijk vond de infectie hiermede voornamelijk plaats door van elders aangevoerd rijstzaad.

De voornaamste, niet tot de grassen behorende onkruiden zijn: *Sphaenoclea zeylanica* Gaertn., *Aeschynomene sensitiva* Sw., *Jussieua* spp. en *Cyperus articulatus* L. Hierbij wordt opgemerkt, dat de besproken onkruidflora betrekking heeft op de condities tijdens en vlak na de ontginning. Wijziging hiervan kan worden verwacht als de terreinen langer in cultuur zijn.
Het onkruid *Sph. zeylanica* trad in de eerste jaren niet op en werd waarschijnlijk, evenals *I. rugosum*, van elders in Suriname geïntroduceerd.
De chemische bestrijding van deze onkruiden werd voornamelijk uitgevoerd met mengsels van 2,4-D en 2,4-5-T, in hoeveelheden van 1,0–1,5 zuuraequivalent op 20–30 liter water/ha, op een leeftijd van het rijstgewas van 5–7 weken. Gedurende één seizoen (in 1955) werd het spuitwerk uitgevoerd met een helicopter; in alle overige seizoenen met rugspuiten, met of zonder hulpmotor.
Aangezien de onkruidbestrijding bij het zaaien in water slechts op een beperkte oppervlakte (in 1957 en 1958 op 20–25% van het totale areaal) en bovendien per veld alleen pleksgewijs behoeft te worden uitgevoerd, is inschakeling van vliegtuigen voor dit werk niet efficiënt.

15. *De bemesting*

Tot nu toe is alleen een gunstig effect geconstateerd met groenbemesters en stikstof, dus niet met fosfaat, kali of kalk.
Als N-meststoffen bleken uitsluitend die op basis van ammoniak in aanmerking te komen, welke dan als overbemesting moesten worden toegediend. Nitraat-meststoffen hadden vrijwel geen uitwerking en hetzelfde kan gezegd worden van elke N-kunstmest indien deze reeds werd toegediend vóór de inzaai.
Op de jonge gronden van het project trad nogal eens een onverwacht weelderige groei van het rijstgewas op, op grond waarvan weinig groenbemesting werd toegepast. Overbemesting met N wel, omdat de bemestingsbehoefte dan kon worden afgestemd op de feitelijke ontwikkeling van het gewas zelf.
Als meststof werd vrijwel uitsluitend zwavelzure ammoniak gebruikt. De mogelijkheden van ureum-applicaties zijn reeds enige jaren in onderzoek. Zwavelzure ammoniak heeft het nadeel van de in de grond achterblijvende sulfaatrest en daarnaast van de grotere vrachtkosten t.o.v. ureum, dat een 2× zo hoog N-gehalte heeft.

Het voornaamste onderzoek op het gebied van de N-bemesting werd verricht in de Prins Bernhard polder. Als beste bemestingstijden werden daar gevonden: ca 8 weken na de zaai bij giften tot 150 kg za/ha en ca 7 resp. 10 weken na de zaai bij toediening van hogere giften in twee keren. Terwijl in de Prins Bernhard polder bij 200 kg za/ha gemiddeld een meeropbrengst werd verkregen van bijna 1.000 kg padi/ha, was dit resultaat op Wageningen tot en met 1958 gemiddeld minder dan de helft daarvan.

16. *Ziekten en plagen*

Het is opvallend, dat het Wageningen-project meer hinder ondervindt van ziekten en plagen dan de rijstarealen van de kleinlandbouwers in overig Suriname.

Ter verklaring van dit verschil kan het volgende aangevoerd worden:

— De rigoureuze machinale ontginning gaf een verstoring van het biologisch evenwicht.

— De Wageningen-polder is aangelegd als een strakke, aaneengesloten uitgestrektheid van rijstvelden, terwijl de bevolkingsarealen bestaan uit een groot aantal kleine rijstveldjes, die afgewisseld worden met erven, bosjes en andere cultures.

Dit laatste landschap vormt een beter milieu voor vogels en andere natuurlijke vijanden van insectenplagen, en het houdt door de aanwezigheid van natuurlijke barrières een snelle verspreiding van een plaag tegen.

— De van de bevolkingsrijstbouw afwijkende cultuurmethode, die op het project wordt toegepast, leidt om verschillende redenen tot een frequenter optreden van ziekten en plagen:

a. de veredelde rijstvarieteiten hebben een grotere gevoeligheid;

b. de teelt van tweede gewas rijst heeft tot gevolg dat continu rijst te velde staat, hetgeen de vermenigvuldiging van enkele ziekten en plagen mogelijkerwijs in de hand zou kunnen werken;

c. door de rechtstreekse uitzaai inplaats van het door de bevolking toegepaste overplanten wordt het rijstgewas in haar gevoeligste jeugdperiode meer aan plagen blootgesteld;

d. de toepassing van insecticiden in het algemeen en speciaal van "blanket applications" kan tot een grotere frequentie van plagen leiden door verstoringen in de populaties van natuurlijke vijanden;

— Het voor het project ontworpen irrigatie- en drainage-stelsel heeft tot gevolg dat een deel van het drain-water weer in de irrigatie wordt gepompt, hetgeen in sommige gevallen een snelle infectieverspreiding kan teweegbrengen.

De voornaamste ziekten zijn: *Cercospora oryzae* Miyake en *Piricularia oryzae* Cav. bij de rijstvarieteiten Nickerie en 80/5; *Helminthosporium oryzae* Breda de Haan bij de varieteit Dima.

De schade door ziekten veroorzaakt is soms vrij aanzienlijk. Bruikbare rechtstreekse bestrijdingsmethoden van optredende aantastingen in het veld zijn niet bekend.

Als algemene voorzorgsmaatregel wordt het rijstzaad behandeld met kwik ontsmetter. Resistentie-selectie lijkt echter voor de ziektenbestrijding nog de beste perspectieven te bieden.

De voorkomende plagen zijn talrijk en vergen elk jaar grote uitgaven voor hun bestrijding:

— *Slakken* (*Pomacea lineata* (Spix)). Deze, in het water levende huisjes-slakken, volwassen 3–5 cm groot, kunnen reeds bij weinig opvallende populaties een geheel zaaisel van een in water gezaaid veld binnen enkele dagen na het zaaien volledig vernietigen door het afzuigen van de rijststengelkiemen. Als gevolg van het algemeen voorkomen van de slakken en de moeilijke waarneembaarheid ervan, werden in de praktijk alle velden bij het zaaien tegen slakken behandeld met kopersulfaat of HCH. Vanwege de hoge vaste bestrijdingskosten kunnen de slakken als de belangrijkste op het project voorkomende plaag worden beschouwd.

De slakkenbestrijding vertoont verschillende bijzondere aspecten; een daarvan is, dat het delta-isomeer van HCH een minstens met het gamma-isomeer vergelijkbare molluscicidewerking blijkt te bezitten.

— *Ratten.* Ratten deden vooral schade aan de tweede gewas-aanplanten. Bestrijding geschiedt door het plaatsen van met cumarine-rodenticide gemengd padi-aas op de dammen rond de velden, onder circa 30 cm grote houten dakjes. Bij een zware rattenplaag begin 1957 bleek deze bestrijding niet afdoende. Er werd toen eveneens met redelijk succes overgegaan tot meer rechtstreekse vangmethoden zoals: het vangen met honden, het uitgraven van rattenhaarden, en het verjagen en vervolgens doodslaan van ratten door de damkanten langs rijstvelden te walsen met *brushcutters* (merk: Marden).

— *Vogels.* De vogelschade is beperkt. Vermeldenswaard zijn de *wiesie-wiesie* eendjes (*Dendrocygna autumnalis discolor* Sclater & Salvin), die in grote vluchten 's nachts kunnen neerstrijken op pasgezaaide rijstvelden en dan vooral in de ondiepe gedeelten schade aanrichten. Bestrijding geschiedt door verjaging, en door schieten.

— *Bibitvliegjes* (*Hydrellia* sp.) De larven van dit insect mineren het blad van de enkele weken oude rijstaanplant. De aantasting is alleen van betekenis op de laatgezaaide velden van de hoofdseizoen-aanplant. Zonder bestrijding kan gemakkelijk de gehele aanplant te gronde gaan, vooral wanneer in water is gezaaid, omdat dan het gemineerde op het water liggende blad snel wegrot. Dieldrin is een uitstekend bestrijdingsmiddel.

— *Rupsen.* Veel voorkomend zijn *Laphygma frugiperda* (J. E. Smith) en *Mocis latipes* (Guen.)

In een jonge padi aanplant is opvoering van de waterstand in het veld de aangewezen bestrijding aangezien de plantdelen onder water beschermd zijn en de rupsen op het water afdrijven naar de veldranden.

Aantasting in oudere padi wordt bestreden met DDT, Toxapheen e.d.

— *Jassiden en delphaciden.* Van de aangetroffen soorten zijn de voornaamste de jasside *Draeculacephala clypeata* Osb. en de delphacide *Sogata oryzicola* Muir.

Deze insecten komen in het rijstgewas voor vanaf enkele weken na de zaai tot tegen de afrijping. Ze kunnen zeer schadelijk zijn en omdat ze zich verscholen onder het gewas ophouden zijn ze moeilijk te bestrijden. *S. oryzicola* is vector van de *hoja blanca*-virusziekte, een rijstziekte die wel in Suriname is waargenomen maar nog niet op het Wageningen-project.
Jassiden werden tot heden met afwisselend succes bestreden met DDT en delphaciden met HCH. Het onderzoek naar betere chemische bestrijdingsmiddelen vindt nog voortgang.
— *Wantsen*. De belangrijkste zijn de zwartbruine bladwants *Tibraca limbativentris* Stål, die vrij goed bestreden kan worden met dieldrin, en de kleinere geelbruin getekende arenwants (*Oebalus poecilus* (Dall.), die zich gemakkelijk laat bestrijden, o.a. met HCH.
— *Boorders*. Van de twee voorkomende stengelboorders *Diatraea saccharalis* (F.) en *Scirpophaga albinella* Cram., is de *Diatraea* tot nu toe het meest schadelijk gebleken. Zij treedt reeds tijdens het uitstoelingsstadium van de padi op in pleksgewijze concentraties en veroorzaakt dan dode stengelharten of voze pluimen. *Scirpophaga* treedt echter eerst tijdens het afrijpingsstadium in belangrijke mate op met geleidelijke toeneming bij latere zaaidata tot infecties van 50% van het aantal stengels in de laatst gezaaide velden. Door het late optreden van *Scirpophaga* blijft de schade beperkt tot een minder goede korrelzetting en meer legering van het gewas.
Effectieve en economisch aanvaardbare methoden voor de bestrijding van boorders zijn nog niet ontwikkeld.

Als equipment voor de toediening van insecticiden zijn op het project motordusters (Wervelwind), rugspuiten (Saval) en motorrugvernevelaars (KWH) in gebruik. De motordusters worden gebruikt voor de massale applicaties van goedkope poeder-chemicaliën en ook wel bij grote urgentie; voor de duurdere middelen zijn om economische redenen de rugapparaten te prefereren.

17. *De oogst*

Bij de bespreking van dit onderwerp treden vier aspecten naar voren, n.l.: de conditie van het gewas, de draagkracht van het veld, het maaidorsen en het transport van de geoogste padi.
De gewenste conditie van het gewas voor de oogst wordt bepaald door zijn geschiktheid voor het maaidorsen en zijn maximale opbrengst, mede in kwalitatief opzicht.
De op het project aangeplante varieteiten, zoals Dima, Nickerie en 80/5, hebben onder normale cultuuromstandigheden een uitmuntende legervastheid. Gedurende de ontginningsperiode, waarover deze studie handelt, waren de velden echter nog zeer moerig, zodat dikwijls ernstige legering optrad in te weelderig opgroeiende gewassen; vooral de Dima varieteit bleek daar gevoelig voor.
Bij de vaststelling van de oogstrijpheid spelen de volgende punten een rol: de

mate van volgroeid zijn van de aar, de mate van afdorsen, het vochtgehalte en het percentage *suncracks.*
Met het voortschrijden van de afrijping neemt het aantal rijpe graankorrels toe, evenals de afdorsbaarheid, terwijl het vochtgehalte daalt, maar op een gegeven moment begint het percentage *suncracks* – dit zijn krimpscheurtjes in de korrels onder invloed van afwisselende bevochtiging en droging – snel toe te nemen. *Suncracks* verminderen de kwaliteit van de padi omdat zij leiden tot meer breuk bij het pellen.
Er is dus sprake van een compromis bij de rijpheidsbepaling. Onder de omstandigheden op het project is het rijstgewas *combine*-rijp bij een vochtgehalte van 19–21%. Het geoogste graan heeft dan nog vrij veel groenige korrels.

Gedurende de eerste produktiejaren vormde de onvoldoende draagkracht van de velden de voornaamste moeilijkheid bij de oogst. Een groot deel van het areaal werd van 1954–'56 bij aanhoudend regenweer in cultuur gebracht en bleef als gevolg daarvan nog lang een natte en zachte bodem houden met geringe draagkracht voor *combines.* Daarentegen werden op de in 1957 ontgonnen gronden, welke door evapotranspiratie tijdens langdurige droogte goed uitgedroogd waren, weinig moeilijkheden ondervonden.
Verbetering van de bodemdraagkracht werd nagestreefd door:
— beperking van de rijstcultuur tot één gewas per jaar;
— egalisatie en opruimen van de houthopen;
— begreppeling in de braakperioden;
— vroegtijdige droogzetting van de te oogsten velden.
Normaliter werden de padi-velden 2 à 3 weken vóór de oogst drooggezet. Voor zachte velden werd dit vervroegd tot 4 à 5 weken, in welk geval de dan nog groene rijstaanplant door grotere evapotranspiratie extra bijdroeg tot de opstijving van de sawahgrond.

Als maaidorsers waren in 1958 op het project in gebruik 31 Massey Harris No. 27 (aangeschaft in 1951), 12 Massey Harris No. 90 (d.d. 1956) en 9 Claeys MZ (dd. 1957), alle op rupsen, met eigen aandrijving en met 12–14 voet snijbreedte.
1 MH 27, 6 MH 90 en 9 Claeys waren met een graantank uitgerust, de overige met een afzakinrichting.
De MH-combines bleken niet zonder meer geschikt voor de zachte terreinen. In de machinewerkplaats op het project werden daarom de rupsen verlengd met 1 of 2 rollen (35–70 cm) en tevens verbreed door montage van houten blokken op de trackplaten. Bij verscheidene machines werd bovendien de draagas van de rupsen naar achteren verplaatst. De stuurwielen met bandenmaat 750 × 18 werden vervangen door 900 × 24. De platforms van de machines met afzakinrichting werden naar voren uitgebreid, in verband waarmede (bij de MH 27) de chauffeursplaats met bedieningsorganen werd overgeplaatst van de zijkant van de machine naar voren boven de opvoervijzel. Door al deze constructieveranderingen werd de bodemdruk van de

tracks teruggebracht van ongeveer 0,4 tot 0,2 kg/cm² terwijl tevens de druk op de stuurwielen werd verlaagd.
De Claeys-combines werden door de fabriek geleverd met lange tracks en grote stuurwielen. Ook de gewichtsverdeling was gunstiger doordat vrijwel geen gewichtsdruk op de stuurwielen kwam. Na het monteren van houten verbredingsblokken op de tracks waren deze machines zonder meer bedrijfsklaar. Andere voordelen van de Claeys waren de grotere stroverwerkingscapaciteit van het dorsmechanisme en de, onafhankelijk van de maaitafelstand, hydraulisch verstelbare *pick-up-reel*, alsmede de uitrusting met dieselmotor, tegenover de semi-vast op de maaitafel gemonteerde *pick-up-reel* en de uitrusting met benzinemotor bij de M.H. Bovendien was de Claeys door de lagere zeevracht vanuit Europa goedkoper dan de M.H.
Daartegenover stond, dat de kwaliteit van constructie en verwerkt materiaal van de Massey Harris machines in vele opzichten superieur was.

In de eerste produktiejaren 1954–55 van Wageningen werd de oogst uitsluitend afgevoerd in zakken. Daarna werd gedeeltelijk op *bulk*-vervoer overgeschakeld.
De voordelen van bulk zijn o.a.: aanzienlijke personeelsbesparing in de piekperiode van personeelsbehoefte, minder tijdverlies van de combines en afschaffing van zakken. Voor de afvoer van de bulkpadi van het veld naar het schip in het irrigatiekanaal zijn 2-wielige kipwagens in gebruik met een laadvermogen van 6 à 7 m³, 1500 × 16 banden en hydraulische pompen, die met de hand bediend worden.
De 2-wielige wagens zijn gemakkelijk wendbaar op de smalle dammen en bij het plaatsen op de kleine steigers voor rechtstreekse storting in de lichters. Gemiddeld zijn de velden te zacht om er met de wagens in te rijden, zodat het rijdend lossen van oogstende combines niet wordt toegepast. Zowel voor bulk als voor zakken-afvoer rijden de combines 600 m-strekkingen en lossen dan in de op de dammen langs de tertiaire leidingen geplaatste wagens. Het bulkvervoer is een uitnemende werkwijze in het kader van de op het project plaatsvindende grootlandbouw. Het is dan ook de bedoeling om bij de successievelijke vervanging van versleten combine-materiaal geheel op bulk over te gaan.

18. *Aspecten van de waterhuishouding*

De afwateringsvoorzieningen van de aangelegde polder zijn goed. Daarentegen laat de inrichting van het irrigatiestelsel te wensen over.
Deze situatie is onder meer het gevolg van de wijziging in het cultuurplan, waarop de polderaanleg aanvankelijk werd gebaseerd en dat zowel de cultuur van droge eenjarige gewassen als van sawahrijst inhield. Speciaal voor de droge gewassen werd n.l. de afwateringscapaciteit gebaseerd op de afvoer van 70 mm regenval van het veld per etmaal, hetgeen een zeer hoge eis kan worden genoemd. Indien in het basisplan conform de feitelijke situatie alleen sawahrijstcultuur zou zijn opgenomen zou ongetwijfeld een lagere afvoer-

capaciteit zijn aangehouden. Overigens zou dit ten onrechte zijn geweest, want ook de gemechaniseerde rijstbouw stelt in dit opzicht bijzonder hoge eisen, en de toegepaste capaciteit is niet overdreven gebleken.

Wat de irrigatie betreft werd uitgegaan van het lage maximum suppletiecijfer van 0.64 l/sec/ha (5,5 mm per etmaal). Dit cijfer berustte op ervaringen in de Javaanse bevolkingsrijstcultuur. Het is echter gebleken dat voor de gemechaniseerde rijstcultuur op het project 2 à 3 × zoveel irrigatiedebiet nodig is, hetgeen men overigens ook wel had kunnen voorzien wanneer men zich gerealiseerd had welke consequenties de verschillen tussen de cultuurmethode van de kleinlandbouw met overplanten en de gemechaniseerde grootcultuur hebben voor het waterverbruik.
Door min of meer toevallige omstandigheden heeft de te lage raming geen capaciteits-tekorten tot gevolg gehad. Het irrigatiekanalennet is n.l. ten behoeve van de scheepvaart en voor het verkrijgen van voldoende grond voor dammen veel ruimer uitgevoerd. En omdat voor de afwatering en de irrigatie dezelfde pompen (met omkeerbare draairichting) worden gebruikt wordt hierbij de capaciteit bepaald door de veel grotere maximale afvoerdebieten.
De lage raming van het irrigatiedebiet heeft echter tezamen met de eerdergenoemde wijziging van het cultuurplan wel geleid tot een minder economische gemaalexploitatie. De pompen van het gemaal zijn opgesteld voor maximaal rendement in de uitmaalrichting. Voor inmalen zijn het debiet en het krachtrendement veel lager.
Maar in de praktijk blijkt dat 2 tot 3 × zoveel uren ingemalen als uitgemalen moet worden (wellicht was het omgekeerde verwacht).

De irrigatie-inrichting van het project heeft nog andere tekortkomingen. Gedurende de drie achtereenvolgende jaren 1957 t/m 1959 was gedurende zekere perioden van het jaar en met name ook gedeeltelijk tijdens de zaaitijden, het water van de Nickerie-rivier ter hoogte van het gemaal te zout voor inmaling, zodat achteraf bezien veel te zeggen was geweest voor een meer stroomopwaarts gelegen inmaal-locatie. Doordat voorts dezelfde pompen in- en uitmalen is het nadeel ontstaan dat een deel van het drainwater weer als irrigatiewater wordt ingemalen. Deze vervuiling van het irrigatiewater heeft allerlei ongewenste gevolgen zoals: het volslibben van de irrigatiekanalen, een slechte groei van de pasgezaaide padi in het troebele water en een groter gevaar van verspreiding van onkruiden, ziekten en plagen.

19. *De organisatie*

Geschematiseerd was de organisatie van het project (De Stichting voor de Ontwikkeling van Machinale Landbouw in Suriname) sedert 1955 als volgt opgebouwd:
— Het bestuur, bestaande uit een Raad van Commissarissen die regelmatig te Den Haag bijeenkomt.
— De directie, bestaande uit een directeur met tot zijn beschikking staande

hoofdbureaus te Wageningen (Sur.) voor algemene zaken, personeel en boekhouding en kleinere kantoren te Paramaribo en Den Haag.
— 7 executieve hoofdafdelingen, nl. de civieltechnische afd., de technische afd., en de afdelingen ontginning, landbouwexploitatie en rijstverwerking, allen te Wageningen (Sur.), de afd. landbouwkundig onderzoek te Wageningen en in de Prins Bernhard polder en de afd. verkoop te Den Haag.

De organisatievorm van de landbouwexploitatie is enigermate historisch gegroeid. Voor het project werden van 1951–'56 een aantal jonge Nederlandse boeren als employé's aangetrokken met de bedoeling dat deze binnen ca 3 jaren een boerderij (van 72 ha) zouden kunnen pachten of kopen. Toen deze uitgifte niet kon doorgaan bleven de meeste van deze jonge boeren als bedrijfsleider verder werken. Het vrijwillige verloop van dit bedrijfsleiderspersoneel liep parallel met de geleidelijke empirische vergroting van het per bedrijfsleider ter beschikking te stellen areaal. De gemiddelde grootte van de bedrijfseenheden liep van 70 ha in 1954 geleidelijk op tot 417 ha in 1958.
De totale personeelsbezetting van Wageningen omvatte in 1957–'58 gemiddeld circa 900 man, waarvan ca 120 maandgelders, ca 700 dag- en weekgelders en ca 80 losse arbeidskrachten.
In de afd. landbouwexploitatie werkten toen ca 30 maandgelders (waarvan 20 landbouwbedrijfsleiders of aspiranten), ca 200 vaste arbeiders (dag- en weekgelders op de landbouwbedrijfs-*units*), ca 30 hulpmonteurs (dag- en weekgelders bij de velddienst van het machinepark) en gemiddeld ca 60 losse arbeiders.
De trekkerchauffeurs en veldarbeiders zijn vrijwel uitsluitend Javanen en Hindostanen. De inschakeling van deze mensen voor de machinale rijstbouw slaagde buiten verwachting goed. De werkzaamheden met machines worden gewoonlijk tegen uurloon uitgevoerd; zuivere handarbeid zoveel mogelijk op basis van aangenomen werk, dus tegen stukloon.
De inzet van het machinepark geschiedde dusdanig, dat de landbouwbedrijfsleiders dezelfde machines zoveel mogelijk permanent op hun bedrijfseenheid kregen gestationneerd.

20. *De landbouwboekhouding.*

Sedert 1956 is een kostprijsadministratie in gebruik die als volgt is opgebouwd:
— Veldkosten. Dit zijn kosten, die per veld van 12 ha of naar verkiezing per groep van velden, worden bijgehouden. De veldkostenrekeningen bevatten 9 kolommen n.l. voor algemene kosten, grondbewerkingsdraaiuren, zaaizaad, insecticiden, herbiciden, meststoffen, verplegingsdraaiuren, maaidorseruren, werktuigkosten.
— Boerderij-bedrijfskosten. Dit zijn meer algemene kosten, of kosten die niet of moeilijk op veldrekeningen kunnen worden ondergebracht, en die derhalve per bedrijfseenheid worden geadministreerd. De rekeningen be-

vatten 7 kolommen n.l. voor salarissen, lonen, algemeen onderhoud, personentransporten, overige transporten, tekorten op machinerekeningen en (eventueel) getotaliseerde veldkosten.

— Algemene landbouwkosten. Dit zijn algemene kosten die niet meer door de individuele bedrijfseenheid beïnvloed worden of zich niet meer lenen voor splitsing per bedrijfseenheid. De voornaamste zijn: kosten van de afdelingsstaf, proefvelden, pompgemaal, onderhoud polder en afschrijving gebouwen.

De werkelijke machinekosten, bestaande uit brandstoffen, smeermiddelen, onderhoud, reparaties en afschrijvingen worden per machine met eigen aandrijving (of per bepaalde groep van machines) en per bedrijfseenheid voor overige werktuigen, op rekeningen verzameld. Deze rekeningen worden voor de verrichte draaiuren tegen vaste uurtarieven gecrediteerd en de veldrekeningen e.d. waarvoor het machinale werk is geschied, gedebiteerd.

Voor alle andere afdelingen van het project, benevens voor de hulpbedrijven van de landbouw (b.v. ten behoeve van zaaizaadproduktie en machinereparaties) zijn zodanige administratieve regelingen getroffen dat wederzijdse leveringen kunnen worden verrekend en dat een beeld wordt verkregen van de exploitatiekosten per afdeling.

Het systeem is een combinatie van landbouwkundige statistiek en van financiële administratie en voldoet in de praktijk redelijk goed. Het hoofdbezwaar is uiteraard de bewerkelijkheid, die echter naar behoefte verminderd kan worden door beperking van het aantal rekeningen en van het aantal kostenkolommen.

Zolang op het project uitsluitend rijst in groot-cultuur wordt verbouwd, is de methode aantrekkelijk, omdat door de uniformiteit van de gevolgde werkwijze de kostensortering eenvoudig is en omdat uit de kosten- en opbrengstenvergelijkingen door het beperkt aantal variabele factoren op vrij gemakkelijke wijze conclusies kunnen worden getrokken.

21. *De landbouwexploitatiekosten*

In 1956 bedroegen de landbouwproduktiekosten, exclusief directie overhead en rente Sf 335.90/ha aanplant (over 4144 ha) en Sf 129.90/ton padi (over 10716 ton), en in 1957 resp. Sf 323.50/ha aanplant (over 6804 ha) en Sf 137.50/ton padi (over 16004 ton).

In 1956 was in de kosten per ha een bedrag van Sf 93.10 opgenomen voor afschrijvingen en reserveringen.

Deze kostprijzen zijn niet geheel representatief voor een normale exploitatie omdat zij nog ongunstig beïnvloed worden door de ontginningsomstandigheden.

Onder voorbehoud dat zich geen bijzondere omstandigheden voordoen kan de prognose voor de minimum kostprijzen worden gesteld op Sf 253/ha aanplant (voor 6.000+1.500 ha) en Sf 80.—/ton padi (bij een opbrengstgemiddelde van 3200 kg/ha aanplant), excl. rente en overhead.

Op basis van verzamelde kosten kan de marginale produktie per hectare als gevolg van produktieverhoging door tweede gewas, worden gesteld op 1,66 ton padi, mits de opbrengst minus variabele pelkosten Sf 0.15/kg padi en de produktiedrukking van dit tweede gewas op het daaropvolgende gewas niet meer dan 0.5 ton/ha bedraagt. Is de produktiedrukking hoger dan moet de marginale produktie per hectare conform verhoogd worden.

APPENDIX

The Lay-out of the Rice Processing Plant at Wageningen and the Manufacturing Methods used

drafted by E. O. C. K. Schramm,
rice-processing expert of the Stichting Machinale Landbouw.

(With reference to this technical description, it should be noted that the installations were mainly delivered by Messrs Kampnagel of Hamburg.
Where this is not the case, the firm's name is mentioned separately.)

The paddy brought by lighters from the polder to the processing plant is unloaded at a cleaning building by a scoop elevator having a capacity of 30 tons/hr. Parallel with this elevator there works a pneumatic conveyor having a capacity of 10 tons/hr which is specially used for emptying the corners inaccessible to the scoop elevator.
By this means the lighter can be practically emptied at the moment the supply of grain to the scoop elevator stops. The lighter can then be shifted directly, and a new one with paddy moored under the elevator.
In the pre-cleaning building there is a Scalperator (Carter Co.) which removes the coarsest dirt from the paddy and attains a rate of 30–40 tons/hr, depending on the degree of pollution of the paddy. After this the paddy is weighed.
The weighed paddy then passes via chain conveyors to the drying and silo buildings. These two buildings are combined, as the first row of compartments of the silo—small compartments of 60 and 90 tons, are partly used for the drying process.
The paddy first passes over two driers each having a capacity of 20 tons, which in the first instance reduce the moisture content by about 3–4%.
The paddy then enters the compartments of the silo for a rest period of about 12 hours, after which it passes over the third drier and after a further rest period, finally over the fourth drier.
After drying (to about 14% m.c.) the paddy is passed over a Silo-Scalperator (Carter Co.) where the dust and chaff released are removed, so that the paddy can be stored clean.
After this the paddy first passes over an automatic weighbridge so that its weight can be determined, before it is stored in the silo.

The silo consists of: 48 compartments, 4.85 × 4.85 in cross-section, and 20 m high (excluding the funnel), with a capacity of about 250 tons (at a rate of 525 kg/cu.m), 12 compartments of 90 tons, and 4 compartments of 60 tons. Each silo compartment has four connections underneath for air supply, and an air aspiration connection at the top. In this way it is possible to force air through the paddy.

After drying in the compartments the paddy still has too high a temperature, so that, in order to obtain a good storage temperature it is then cooled by means of mobile cooling units connected to the compartment air supply which force air of about 7° C. through the paddy. During this cooling the paddy looses about 0.4% m.c.
For temperature control of the paddy, a Hot-Spot installation is built in with measuring points at metre intervals up the compartments.

The milling building stands next to the silo and the paddy can be transported via elevator and chain conveyors from one of the compartments, or from several compartments together, to the milling unit, again via a weighbridge. After being weighed the paddy passes over two "Combinets" (Kalker Trieurfabr.). These are pre-cleaning machines with an eccentric vibrating screen and two air supply ducts. With these machines the paddy is cleaned, weed seed, fine brokens, dust and chaff etc. being removed.
These machines also grade the paddy by air to specific gravity.
The light paddy, 20–30%, passes via the chain conveyors back again to the silo for a separate processing. The heavy paddy, 70–80%, passes via an Iron-separator to the Hulling machines. These are two stones coated with a layer of emery, the lower one rotating and the upper one being stationary. The product issuing from here passes over two chaff "Combinets" (Kalker) where it is separated into: 1. hulled rice with paddy, 2. chaff, and 3. bran, where most of the germs are also present. The bran is used for cattle fodder and the chaff as fuel for a steam engine, of 800 h.p. with open exhaust, or 1000 h.p. with a condensation system. The Hulling machines produce about 10–12 tons paddy per hr. The weight of the chaff is about 20%, i.e. 2000–2400 kg/hr, with which it is possible to raise this 800 h.p. to 1000 h.p.
After the two chaff Combinets the product, viz. shelled rice with paddy, first passes over a Duo-separator (Carter Co.) in order to remove the chaff which had not been removed in the chaff Combinet.
This facilitates the work of the following machines, – the Paddy-separators. The Paddy-separators are assembled in two sections, the first section roughly separating shelled rice and paddy.
The paddy is returned to the Hulling machine, and the shelled rice, which still has a certain percentage of paddy, is passed to the following section of Paddy-separators where clean shelled rice is separated from the few percent of paddy mixed with some shelled rice.
This sorted paddy with shelled rice passes over the Rubberroller hulling machine and is then returned to the production system again via conveyors.
The clean shelled rice from the Paddy separators is now ready for further processing. The plant is adapted for producing both cargo and white consumer rice. The capacity for cargo production is as great as the paddy processing on the Hulling machines, viz. 10–12 tons paddy/hr., while the white rice production capacity is about a third of this.
However, provisions have been made to extend these installations in future to a capacity of 12 tons paddy/hr.

In cargo processing the shelled rice passes over a Trieur-installation (Kalker) in order to sort out a part of the brokens, after which the product is ready. The cargo is delivered with a maximum of 5% brokens, and a maximum of 2% paddy.

White rice is produced as follows: the shelled rice passes over a first Pearling Cone where a part of the cuticle is scoured off, and then passes over a Millerator (Carter Co.). This is installed in order to suck off any small pieces of chaff which may still remain, and in order to cool down the product by spreading it out on the winnowing screens, and in the aspiration duct. From this Millerator the product passes once more to a Pearling Cone and then again over a Millerator which once more supplies aspiration.
From the Millerator the product, now completely white, arrives at the Polishing machine in order to clean off loose remnants of cuticle still remaining in and on the rice, after which the grading of this product can begin. Grading is done by a combination of Trieurs in which the product is successively passed over Trieurs which sort out the large whole grains, ¼ brokens, ½ brokens and the ¾ brokens and small grains.
These different gradings can be kept apart but, if necessary, can also be combined to make consumer rice with specified proportions of whole rice and brokens.

The processed product, both cargo and white consumer rice, is weighed with automatic bagging weighbridges and the sacks are sown up by machine. They then arrive via conveyors at the packing shed where they are temporarily stored if they are not shipped directly. The packing shed is connected to the main jetty via a conveyor, enabling ocean-going vessels to be loaded at a rate of 50–100 tons/hr.

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