A Need for the Drainage of Paddy Fields to Enable Farm Mechanization for Double-Cropping of Rice in the Muda Irrigation Project

-A joint study by the Muda Agricultural Development Authority, Malaysia, and the Tropical Agriculture Research Center, Japan-

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Double-cropping of rice covering about 100,000 ha of paddy has been successfully carried out in the Muda Irrigation Project area since 1970 and presently, it is planned to carry out a program of mechanization particularly during periods of peak labour demand so that all farm activities be made to conform to acceptable planting schedules. It may be noted that the practice of double-cropping of rice in the Muda area makes it necessary to undertake farm operations, such as land preparations and harvesting in the midst of the wet seasons. However, under present drainage conditions there are indications that the use of heavy farm machinery is becoming more and more difficult on the predominantly heavy marine clays of the area.

A twin approach is suggested to overcome this problem: firstly, land improvement through land consolidation or otherwise with the emphasis on improved terminal irrigation and drainage facilities at farm level and secondly the development of machinery to suit local conditions.

This paper will deal with the need for improving on-farm irrigation and drainage facitlities that may aid in the farm mechanization of double-cropping of rice in the Muda area.

Decrease of soil bearing capacity due to double-cropping

Previous to the introduction of double-cropping in the Muda area, the ploughing of paddy fields has been carried out mainly by four-wheeled tractors, on a contract basis. However, with the introduction of double cropping in the area, it was recognized that the soil bearing capacity of the paddy fields was generally decreasing in many areas, making the use of large four-wheeled tractors and combines quite difficult. In 1972, that is the third year after the introduction of double-cropping, a survey of the soil bearing capacity was carried out on selected farmers' fields on a 1 mile grid on about 50,000 ha of the northern region of the Muda area. The survey compared the ploughing operation in these fields before and after the introduction of double-cropping of rice. As given in Table 1, four-wheeled tractors were used over 99% of the total area at the time of single cropping, whereas the area that permitted the use of four-wheeled tractor was reduced

Table 1. Field condition related to plowing before and after the introduction of double cropping of rice, as expressed by kinds of machinery used for plowing

Time	Field condition		Ratio
	Off season	Main season	
Single cropping of rice	Fallow	Machinery use impossible	0.4
		Power tiller	0.8
		4-wheel tractor	98.8
	Total		100.0
Double cropping of rice	Machinery use impossible	Machinery use impossible	0.7
	Power tiller	Machinery use impossible	0.4
	Power tiller	Power tiller	21.6
	4-wheel tractor	Power tiller	46.3
	4-wheel tractor	4-wheel tractor	31.0
	Total		100.0

Note : Difference between the main season and off season is due to the difference of field condition. For example, in area of 46.3% of the total paddy fields tractor can be used in off season but only tiller in main season.

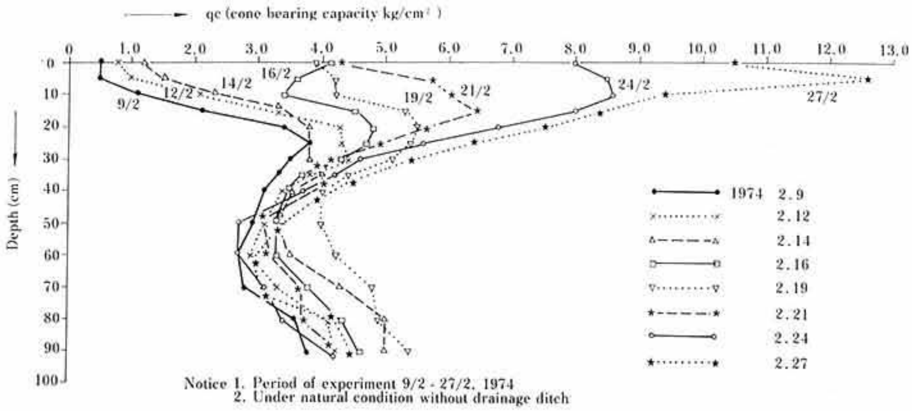

Fig. 1. Changes of qc in a course of soil drying.

to 77% in the off season (Feb.–July) and only 31% in the main season (Aug.–Jan.) in 1972.

Characteristics of change in soil bearing capacity

By taking advantage of a long spell of drought in the dry season of early 1974, an experiment was carried out to examine the physical change in soil characteristics by measuring the soil bearing capacity, which bears a close relationship to traficability of tractors. An experimental field in the Telok Chengai Experimental Farm was irrigated to fully saturate the soil. The soil was kept submerged under water for 3 to 4 days then drained. Changes in soil bearing capacity of the drying soil due to the extremely dry conditions were measured using a cone-penetrometer (6.45 cm² of bottom area).

From the results given in Fig. 1, the following conclusions can be drawn.

1) The soil surface layer showed large variation in hardness, due to the wetting and

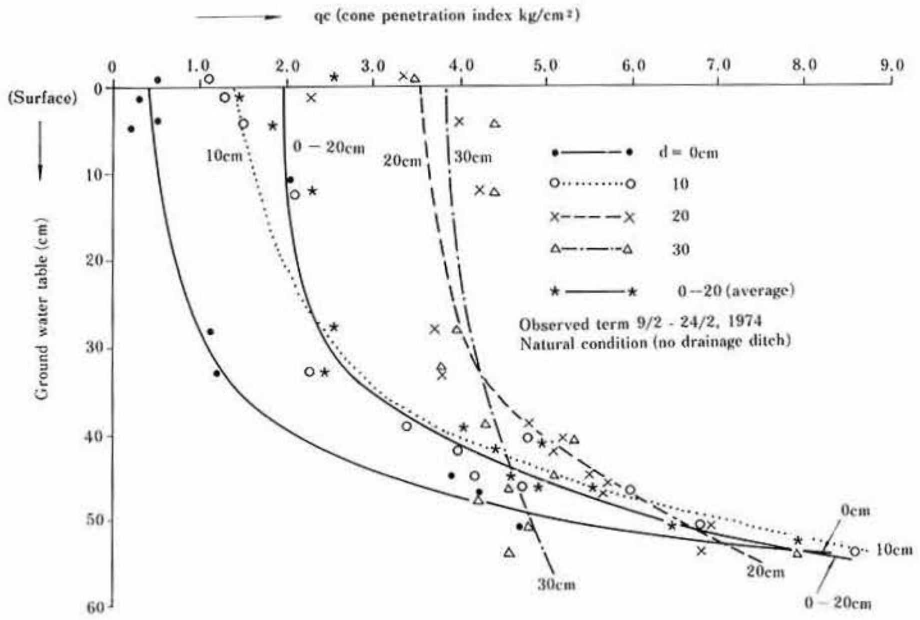

Fig. 2. Relationship between ground water table and cone penetration index at different depth

drying of soil.

2) Variation in soil hardness took place only in the surface layer. The soil layer deeper than 30 cm depth showed almost constant hardness, irrespective of soil moisture content.

3) The soil layer showing large variation in hardness corresponds to the so called "plough sole" or "hard pan" layer, which is directly related to farm operations such as ploughing.

Therefore it can be concluded that soil hardness is dependent on the extent to which the soil dries (as expressed by decreased soil moisture content). As the lowering of ground water level is associated with the drying of soil above it, it would be convenient to use the lowering of ground water level as an indicator of soil hardness. Fig. 2 shows the relationship between ground water level and qc (cone penetration index) at depth 0 (surface), 10, 20 and 30 cm. The average cone penetration index for the soil layer 0 to 20 cm depth is also shown as this is the layer where qc and the trafficability of tractors bears a close relationship.

In Fig. 2, it can be seen that in the shallow soil layers at 0, 10 and 20 cm depth, qc increases with the lowering of ground water level but qc at 30 cm depth does not vary as much and is almost constant, and does not seem to be influenced by ground water level. This seems to be the case even for shallow layers of soil up to about 20 cm where qc only increases very little until the ground water level goes down to 30 cm below the surface. When the ground water table is lowered below 30 cm, there is a marked increase in qc for shallow layers of soil.

The soil moisture tension of the shallow layers when the ground water level is at 30 cm is between 1.5 to 2.0 pF. Incidentally the curves shown in Fig. 2 are at the dynamic inflection point when the ground water level is also at 30 cm thus indicating a theoretical basis for the remarkable increasae of qc when the ground water level is below 30 cm depth.

Since soil hardness required for trafficability of tractors is when qc is between 3.0 to 4.0 kg/cm^2 for the 0–20 cm soil layer, it can be a general standard to lower ground water level to 30 to 40 cm depth. The only way to increase soil hardness is to lower the ground water level by providing adequate drainage channels and remove surface water as rapidly as possible.

Need for Drainage

1) Destruction of the hard pan

As described above in the Muda area there generally exists a subsoil layer which is hard enough to support heavy machines provided its hardness is not greatly reduced by submergence. This layer is found at a depth of about 20 cm in Telok Chengai, as shown in Fig. 1, but in some places, it is deeper than 20 cm reflecting on the past history of drainage performances or drying of soil.

However, the feasibility of farm operations with heavy machines working on submerged fields, depend on the hardpan located at a depth of 20 to 30 cm. It is likely that the use of such machinery under submerged conditions will destroy this layer resulting in the creation of a deep and loose layer which will not be able to take such heavy machines again. There are already indication of this happening in some areas.

In order to avoid such an outcome, not only the travelling mechanism of machines should be improved (to lower the bearing capacity) but also actual farm operations under submerged conditions should be carefully re-examined and studied on a long term basis. At the same time it is necessary to improve drainage in the paddy fields.

2) Prospects of improving soil conditions for mechanization

Although it is true that the soil in the Muda area is a heavy marine clay and it is difficult to predict its behaviour, it is however more manageable than some newly reclaimed marine clay found in similar areas in Japan. For example, in the Hachirogata Polder Land, which is a typical agricultural engineering project, the muddy soil (hedoro) when it was first reclaimed showed 250–300% water content ratio, 0.30–0.35 apparent specific gravity and a void ratio of 7 (volume of soil particles 1 : 7 of water volume). This is an extremely loose clay found nowhere else in Japan. At present, after 10 years of land drainage, the water content ratio is still 50–100% and apparent specific gravity is about 0.8.

On the other hand, the marine clays in Muda area give a water content ratio of 60% even when saturated and the specific gravity ranges from 1.0 to 1.3 indicating that the soil is fairly dependable as far as its physical properties are concerned.

In spite of the extremely poor soil conditions in the Hachirogata Polder Land, mechanized farming using heavy machines has been successfully carried out in a very short period. This has been achieved by the construction of extensive drainage works.

3) Importance of surface drainage and use of the dry season

In the Muda Irrigation Project, cropping schedules have been so adjusted to avoid harvesting in the major wet season (September to November) so that harvesting of the off-season crop and puddling and transplanting of the main season crop fall within a period from July to August, which can be called the minor dry season. However, drying of the soil during this period is difficult which in turn creates a problem for operations.

Using the rainfall record for the past three years at Telok Chengai (measured by Muda DID) the monthly frequencies of continuous dry days (including days with less than 0.2 inches of rainfall, which is regarded as ineffective) were calculated and plotted in Fig. 3. The columns shown shaded in Fig. 3 express the frequencies of occurrence of indicated days of continuous dry weather, and those without shading express frequencies of occurrence of continuous dry weather longer than the indicated number of days. For example, in July the probability of occurrence of continuous dry weather for 9 days is 0.7,

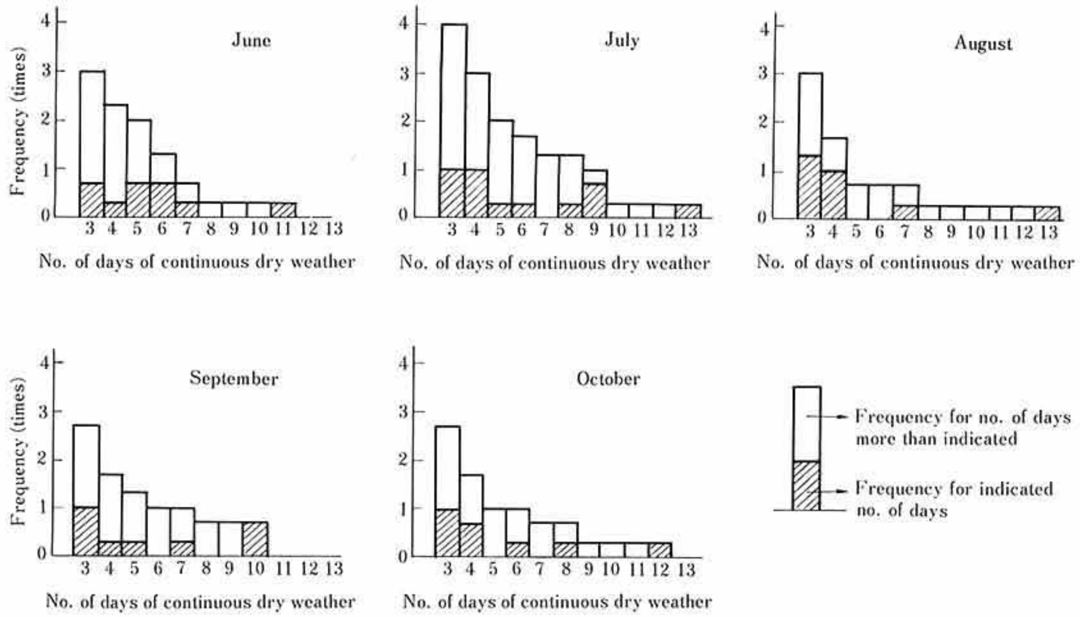

Fig. 3. Monthly frequency of continuous dry weather (Average from 1971 to 1973 at Telok Chengai)

and that for continuous dry weather for more than 9 days, including that of 9 days is 1.0. This would mean that continuous dry weather for more than 9 days can be expected to occur at least once in a month of July. Similarly, dry weather for more than 3 days can be expected to occur four times. In this particular case it is clearly shown that there are unexpected long spells of dry weather even in the wet season. Although the analysis is for a short period, this technique could be used by taking rainfall stations with many years of record to arrive at a more accurate probability analysis.

This concept of continuous dry weather could be used to advantage for carrying out farm operations. However, this can only be carried out with rapid removal of surface water by an effective drainage system. For example, it will take about 7 days before a surface water layer of 50 mm evaporates away, assuming daily evapotranspiration of 7 mm and only after that actual soil drying can take place. Although from the analysis continuous dry weather for more than 7 days can be expected to occur once in July, it is practically impossible to dry out the soil surface layer with a 50 mm layer of water on it. However, it is possible to remove most of the surface water layer by the introduction of on-farm drainage ditches. The remaining water in lower portions of the field after surface drainage has taken place can be assumed to be at the most about 20 mm based on experimental data in Japan. These remaining surface water in the form of surface puddles can be removed by evaporation in about 3 days of dry weather. In actual cases it may be impossible to remove all surface water from the lower portions of a plot with deeper water depth but repeated dry weather can create improved soil conditions, such as the formations of cracks which causes soil to dry in a shorter period by accelerating surface run-off of remaining water into surface drains.

It is common practice in Japan to carry out drainage at the ripening stage, mid term drainage and intermittent irrigation which induces the soil to crack resulting in increasing soil bearing capacity. Incorporating extensive drainage ditches at farm level should therefore be an essential feature of on-farm development so as to increase the bearing capacity of soils.

Conclusion

In this paper, it is emphasized that an efficient drainage system is a prerequisite to enable mechanization for double-cropping of rice using heavy machines in the Muda area. However, drainage alone is not the only factor for successful mechanization. Increased drainage may induce the rapid exhaustion of soil organic matter and increase irrigation requirements. Any change in soil organic content may require drastic changes in the traditional cultural practices while increased irrigation requirements may possibly necessitate a review of the overall irrigation water resources plan.

Studies on irrigation engineering or on agricultural machinery alone may not be enough. It is felt that proper on-farm development possibly with land consolidation, conforming to actual condition existing in the Muda area together with an integrated approach including cultural methods, fertilizer application, varietal improvement and farm management is a necessity for the development of this agricultural area.

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