13. LAND READJUSTMENT FOR FARM MECHANIZATION IN PADDY FIELD

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Preface

In promoting mechanization in paddy field, field conditions must be first fitted for the use of farm machinery.

In Japan, irrigation and drainage facilities were so simple for a dual-purpose use; field lots were less than 0.1 ha and farm roads were only about 1 meter wide until about 1945.

Then power tiller took place of animal plowing, in accordance with which farms were standardized to be 0.1 to 0.2 ha and farm roads to be about 2 meters wide, from 1945 to 1960, and some irrigation and drainage systems developed.

Since 1960, as a result of a remarkable social and economic development the importance of labor productivity in agriculture has been emphasized, and farming in paddy field has been mechanized on a large scale with a progress of farming.

Land readjustments have proceeded as follows; the realization of large farm lots became more than 0.3 ha in area and farm roads more than 4 meters in width; the perfect separation between irrigation and drainage; the subsurface drainage as well as the subsoil improvement for reinforcement of bearing capacity.

At present, these processes have brought out the planning standard of land consolidation in paddy field, on the basis of middle and large scale mechanization. Recently, land consolidation projects covering about 60 thousands ha (average of working expenses is 1.5 to 2 million yen/ha) are put in execution every year.

Now, for further discussion, I would present some details of land consolidation in paddy field based on the latest mechanization of large scale in Japan.

Field conditions needed for farm mechanization

To mechanize farming on a large scale and to stabilize maximum rice yield, it is necessary to meet the following field conditions:

(1) Readjustment of field lots

To promote the working efficiency of machine, it is desirable that each farm lot to be readjusted, is larger than 30 m × 100 m (=0.3 ha), as conventional one is too small and its form is not uniform.

(2) Improvement of farm road

Main farm roads of 6 to 7 meters in width for bringing machine to field and their branches of 4 to 5 meters in width leading to each field lot should be well distributed along field lots.

(3) Improvement of irrigation and drainage facilities

After fundamental irrigation and drainage facilities such as irrigation water sources for whole paddy field and main canals for irrigation or drainage, water gates and drain pumps are well prepared, branch canals for irrigation or drainage should be appropriately distributed along each field lot so as to freely control water according to the

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operation of machine and the management of cultivation.

(4) Subsoil improvement

Soil and subsoil of paddy field should have a sufficient bearing capacity so as to permit a large size machine with heavy load. In case of clayey soil of poor drainage, it is particularly important to carry out subsoil improvements such as underdrainage or subsoil breaking.

Besides, it is essential to take a measure to solve difficulties in levelling surface as recently field plots have been increasing in area.

Land readjustment

(1) Definition of farmland blocks

Farmland blocks are classified and defined in Japan as follows:

a) Field lot: Lot surrounded by roads, irrigation and drainage canals of fixed borders. The term farmland block generally means field lot.

b) Field block: Block made up of a group of several field lots arranged in a row. It is surrounded by such permanent and fundamental facilities as roads or irrigation and drainage canals.

c) Farm block: Block surrounded by farm roads or main and branch canals. Each farm block, in general, consists of two adjacent field blocks separated from each other by a drainage canal.

(2) Disposition of farm roads and canals

In readjusting farm lots, irrigation and drainage canals are disposed first; then, according to this, farm roads and farmland blocks are arranged. Drainage ditches are disposed at right angles with contours in order to diminish cross-sectional area of flow and to minimize construction costs.

The short side of each field lot is to be disposed at right angles with contours in order to minimize soil to be removed in land grading. That is, drainage ditches are arranged along the short side of each field lot, and branch canals are fixed to connect main canal with ditches effectively.

The mutual arrangement of roads and ditches surrounding each field block is to be decided with consideration of perfect separation between irrigation and drainage canals, free water management in each field lot, convenience in approaching each field lot from roads, necessity of subgrade solidification of roads, and suitability of repeated use of water. It is also necessary to minimize the area occupied by farm roads, canals, and borders.

Table 1 shows the relation between the size of farmland block and the percentage of occupied area. As farmland block expands, the latter decreases.

(3) Form and area of farmland blocks

In Figure 1, the long side (a) of field block is limited principally by allowable length of irrigation ditch along the long side. When irrigation ditches branching from irrigation branch canal are too long, irrigation water is not well distributed to each field lot. 300 to 600 meters is a generally desirable length. A field lot is equivalent to each of 15 to 16 divisions of a field block.

The form and the area of a field lot depend on (1) operation effciency of machine; (2) gradient of land; (3) convenience in operating irrigation and drainage system; (4) situation of land possession and possibility of its consolidation.

These four are the main factors to determine (1) a lower limit of the long side (b) and of the short side (c); (2) an upper limit of the short side (c); (3) an upper limit of the long side (b); (4) an upper limit of an area of field lot.

Table 1. Relation of field lot shape to occupation area by road, ditch and border

Short side length	Long side length	Area of field lot	Percentage of occupation area of road, ditch and border
20m	50m	0.1 ha	13.2%
25	80	0.2	9.5
20	100	0.2	9.5
30	100	0.3	7.8
40	100	0.4	7.0
50	100	0.5	6.5

Note: Conditions used for calculation as follows:
Farm road width = 4 m
Total width of irrigation and drainage ditch = 5 m
Drainage branch canal width = 1.5 m
Border width = 0.5 m
By Dr. Shinzawa and Dr. Koide

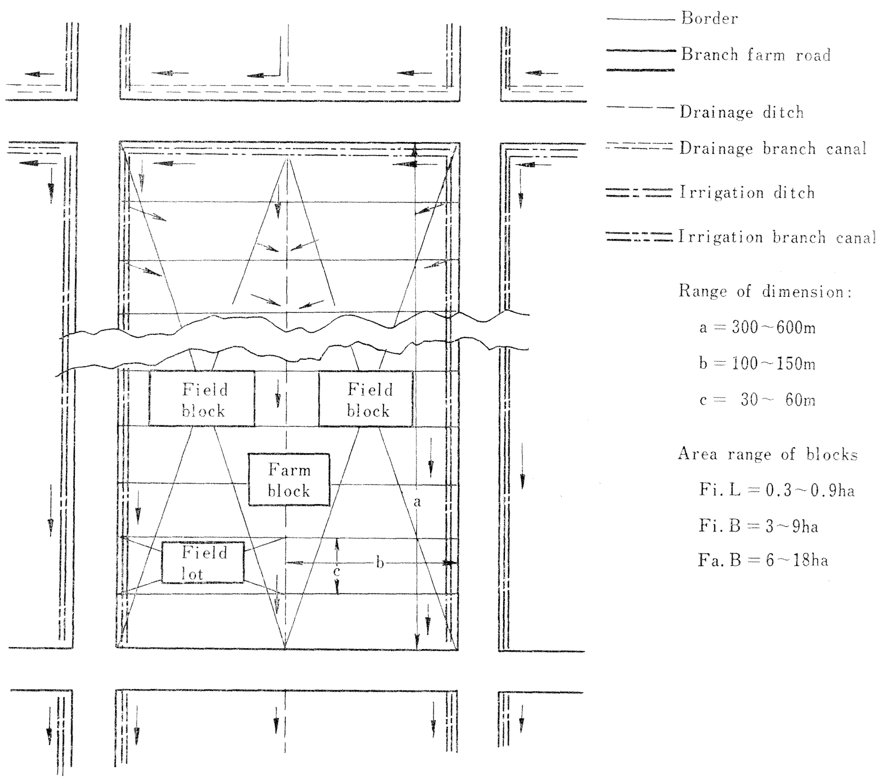
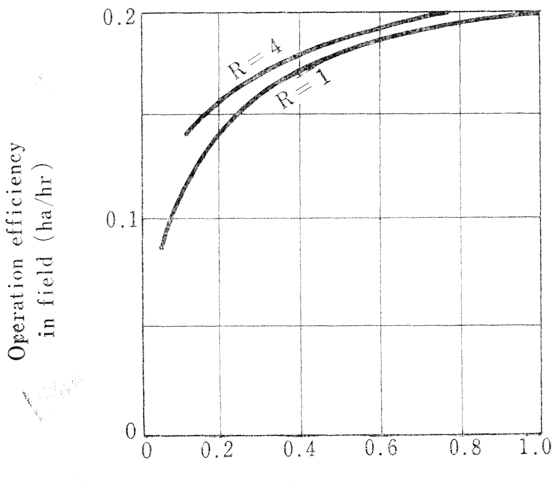


Fig. 1. Definition of farmland blocks in paddy field.

1) Operation efficiency of machine:

Operation efficiency of machine concerns cultivating grading, harrowing, fertilizing, seeding and weeding with tractor, pest controlling, and harvesting with combine. Operation efficiency is seriously affected by the form and the area of farmland blocks. So, a field lot is to be decided according to operation efficiency mainly of important and time-consuming works in field, which is mainly fixed by machine turning, butt processing, material supplying and carrying, and subsoil conditioning.

The operation efficiency of machine generally becomes higher in proportion to a farmland area and a ratio of the long side to the short side. This relation is clearly shown in the rotary cultivation with a 30 to 40 ps wheel tractor as in Fig. 2; when the area exceeds 0.3 ha, the efficiency increases a little, while it remarkably decreases in the area under 0.3 ha. As the long side—short side ratio increases, the efficiency increases.



Note: R……Ratio of b to c length (See Fig. 1)

Fig. 2. Relation of field lot area to operation efficiency in field.

When the long side (b) is above 100 meters, the efficiency increases in proportion to its length. On the other hand, it is desirable that the short side (c) is a little more than 30 meters and is not excessively beyond this from the standpoint of the convenience of machine turning.

Though distributing operation of agricultural chemicals, unlike the other ones, limits the length of long and short sides, the efficiency (present max. effective range: 80 meters) of distributing machines will be developed in future.

2) Land inclination:

Generally, it is the most economical to locate the long side (b) in parallel with contours and the short side (c) at right angles with them. Gradient and undulation of land are the factors to limit the short side (c) mainly because land grading costs are affected by (c).

As regards a land inclination, the short side (c) can be freely decided when land is less than 1/500 in gradient: But, in case of 1/50, a land inclination is the most important factor to limit the short side. It is desirable that the level difference of neighboring paddy fields is within 0.3 meters and it must be kept within 1 meter even in case of a steep-sloped land.

Land grading costs occupy usually about 40% of the total costs of land readjustment project. And in general this percentage increases in proportion to the degree of land inclination as well as the length of the short side (c).

3) Operation of irrigation and drainage systems:

Water of paddy field should be controlled freely in each field block in individual farming, and in each farm block in large-scale farming or group farming. So, as shown in Figure 1, the maximum length of the long side (b) of field lot is often limited by the easiness of water control. As the technique of rice cultivation has advanced the importance of water management has come to be highly recognized.

Not only standing water in paddy field but also ground water table should be controlled rapidly. Especially to consolidate land durability, to allow optimum percolation and to improve soil, rapid drainage of surface water in paddy field and a fast lowering of ground water table are considered to be very important. Then, the excessive length of the long side (b) would make it difficult to level the surface of paddy field and to drain the surface water. It is not good for cultivation management that the long side (b) exceeds 100 meters, especially in clayey soil paddy field of poor drainage.

4) Scale of farm management:

The area of field lot is restricted not only by the above-mentioned natural or technical conditions but also by the scale of farm management (farming area).

In Japan, a farm is approximately one hectare in area. So, in many cases a block of more than 0.3 ha is difficult to be established owing to little possibility of substitution or consolidation of farm land, even though judging from the other conditions, it is appropriate. However, where large-scale management or group cultivation can be carried out this management condition is not a factor to decide the area of field lot.

From the facts mentioned above, the present standard field lot in Japan can be shown as in Table 2.

Table 2. Standard shape and area of field lot.

(Unit: kg/cm²)

Land slope	Drainage condition	Short side length	Long side length	Field lot area
Flat zone (1/500)	Well-drained paddy field	30—60 m	100—150 m	0.3—0.9 ha
	Ill-drained paddy field	30—60	100	0.3—0.6
Gentle slope zone (1/500–1/50)	Well-drained paddy field	30	100—150	0.3—0.45
	Ill-drained paddy field	30	100	0.3
Rapid slope zone (1/50)		20—30	100	0.2—0.3

Readjustment of farm roads

(1) Classification of farm road

The farm road now available in Japan is classified according to the kind, name

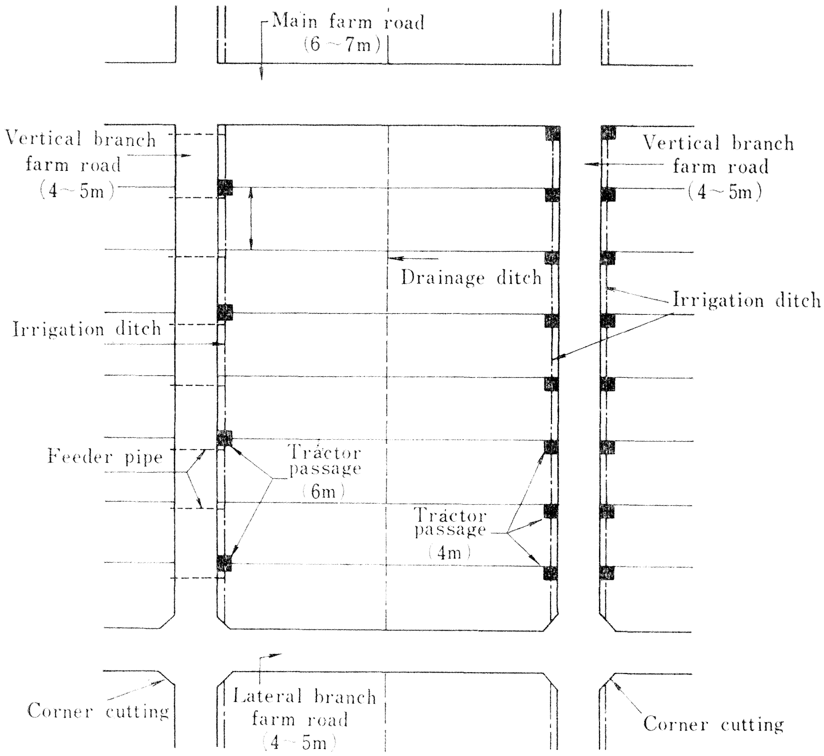


Fig 3. Each part related to farm road.

and function as follows (Figure 3):

1) Main farm road: Main road to connect different communities or different field blocks with one another as well as a community with a district of field blocks or general roads with field blocks.

2) Vertical branch farm road: A branch farm road which abuts on the short side of each field lot and connects each field lot with main farm road.

3) Lateral branch farm road: A farm road which connects the vertical ones laterally for the purpose of communication.

4) Small farm road: Provisional small road for special farm works in forming wide infield-borded or ditch-side-border.

(2) Width and height

Farm road must have both a width enough to pass vehicles or farm machines and a width of shoulder on both sides. Each standard width is as follows:

Main farm road: 6 to 7 meters (which enables two trucks to pass each other).

Branch farm road: 4 to 5 meters (which enables a combined harvester-thresher to pass).

In addition, the width of farm road enough to pass main vehicles or farming machines is listed for reference as follows:

Motorcar	1.9 m
Truck (of 5 t)	2.4 m
Tractor (of 40 ps class)	2.0 m
Trailer	1.9 m

Combined harvester-thresher (3 m in reaping width) .... 3.5 m
Speed duster (of tractor system) .... 1.9 m

A farm road higher than field surface is convenient for maintenance, but a lower road is more profitable for passing machine between road and field, ventilating crop population, and its lower construction costs. The standard should be fixed as follows:

Main farm road .... 50 cm (height from field surface)
Branch farm road .... 30 cm (height from field surface)

(3) Intersection and tractor passage

At the intersection of two branch farm roads, 1.5 meters of the corners are cut off for turning vehicles. It is not necessary where two main roads or a main road and a branch road intersect each other.

The tractor passage for getting in and out of a field lot should be built on either every lot or every two lots. The irrigation ditches along farm road are made of concrete hume pipes. To pass a combined harvester-thresher the width of passage should be 4 meters when it is built on every field lot or 6 meters when on every two lots. The gradient should be less than 18°.

(4) Pavement of farm road

In many cases, farm road is paved with gravel or crushed stone to cut down the construction costs. Its standard thickness is 10 to 15 centimeters. All the paving materials are not applied at a time so as to repeat paving several times. Particularly important main farm roads have been paved recently.

Readjustmen t of irrigation and drainage

It is general in Japan to readjust irrigation and drainage systems on the occasion of land readjustment.

(1) Irrigation canals and ditches

Water requirement of 20 to 30 mm/day (2.3 to 3.5 l/sec/ha) in depth is regarded as standard irrigation water for paddy field. And the water requirement for preparation of paddy field needed early in the irrigation period is regarded as the designed duty of water to fix the section of irrigation canal.

Irrigation ditches abutting on each field lot are distributed either by open channel or by pipe line.

Open channel was generally cut into the earth. Concrete lining or flumes have come to be applied in many cases, so the maintenance of water channel has become easier.

Pipe line was not common because of its higher construction costs, but it is coming into general use all over the country owing to such merits as easier maintenance, less occupation areas, water saving and no destruction of machine passage.

(2) Drainage canals or ditches

The drainage discharge required in fixing the section of drainage canals or ditches in paddy field is designed to drain away daily rainfall within a day in case of single-crop paddy field. The designed rainfall is estimated with consideration of such a heavy rainfall as occurs once in 10 years.

Drainage canals or ditches belong in principle to open channel type. In case the soil is apt to break, it is reinforced with fence revetment or stone wall revetment.

The sufficient depth would be approximately 40 to 50 centimeters under the surface so far as the drainage of rainwater is concerned. However, about 1 meter is required with the consideration of the underground drainage for increasing a bearing capacity in non-irrigation period, or optimum percolation in the irrigation period.

(3) Underdrainage

It is necessary to construct underdrainage in an ill-drained paddy field whose soil has insufficient bearing capacity or whose ground water table is not sufficiently lowered in non-irrigation period. The necessity of underdrainage depends on whether the ground water level lowers to 50 centimeters below surface within a few days after rainfall or not.

The underdrains are laid at the depth of 0.6 to 1.2 meters after examining soil conditions such as permeability of subsoil layers and development of cracks. The standard interval is 5 to 10 meters in case of clayey soils, and about 10 to 20 meters in case of sandy soils.

Earthen or plastic pipes are laid in ditches dug out with trencher, and are wrapped with rice hulls for an effective underdrainage. In addition, heavy clayey soil needs subsoil improvement such as mole drains or subsoil breaking because only underdrainage cannot be sufficiently effective in such soil.

Subsoil improvement

In order to introduce a large-scale machine into paddy field and to obtain a stable maximum yield, subsoil improvement is required as well as land readjustment.

(1) Surface soil removing

In land readjustment to recompose small blocks into large ones, land is graded for leveling the field surface.

When more than 15 centimeters of soil is taken off, the fertile surface soil is once removed and then put back again after subsoil adjustment.

As surface soil removing makes readjustment works expensive, so it is desirable to avoid it. But when subsoil fertility is remarkably low, or subsoil is sand, gravel or peat, etc. surface soil removing is indispensable.

(2) Improvement of soil permeability

High permeability is desirable for machine passage in drainage. But too high permeability is undesirable because it increases the quantity of percolation and needs the excessive duty of water.

Consequently, a proper soil permeability coefficient is between 10^{-4} to 10^{-5} cm/sec in soil layers of lowest percolation.

In the paddy field of higher permeability, it is necessary to prevent percolation by means of soil dressing or subsoil compacting, while in the clayey soil its lower permeability needs to be increased by means of underdrainage and subsoil improvements such as mole drain and subsoil breaking.

(3) Bearing capacity of soil

Bearing capacity of soil needed for passing machine in paddy field varies largely according to the type of machine, wheel, attachment and machine works.

There are several methods of indicating and measuring a bearing capacity. The result of various examinations up to now is shown in Table 3, by the simplest indication of cone index and soil resistance in kg/cm^2 which are obtained by static penetration test by the use of cone penetrometer with 6.45 cm^2 of cone area and 30 degrees of point angle. Table 3 can be regarded as indicating standard values to judge the limit of machine passage. In improving soil layers, it is aimed at to produce a subsoil condition maintaining these standard values.

(4) Land leveling grade

When block is enlarged it becomes more difficult to keep paddy field surface in a well leveled condition, and this causes difficulty in operating machine such as rice planter and in promoting uniform management of cultivation. So, in land leveling works following a readjustment the leveling accuracy of paddy field surface should be within the limit of ± 5 centimeters. In addition, it is desirable to make the drain side of block, as a whole, lower than the irrigation canal side. The leveling accuracy of ± 5

Table 3. Judgement of trafficability by cone index

(Unit: kg/cm^2)

Judgement of trafficability	Tractor (cultivating)		Combine
	Rubber wheel	Rubber wheel with girdle	Semi crawler
Easy	4	3	3
More or less difficult	3—4	2—3	2—3
Difficult	2—3	1—2	1—2
Impossible	2	1	1

centimeters is just a limit for construction machines such as bulldozer and a higher accuracy should be ensured by repeating leveling works by hand. The experiences so far have shown that a more or less incomplete leveling at the construction works can be appropriately improved on enough to manage the cultivation within a few years.

Discussion

S. Vivekanandan, Ceylon: In your present program of middle and large scale mechanization, which involves consolidation at a heavy working expense of 1.5–2 million yens per hectare, what part of this expense is contributed by the farmers and what part does the Government bear? Could you also comment on the percentage of the total farming population that is benefited by such schemes?

Answer: The cost of farm land consolidation works is to be shared as shown in the following table:

	The Rate of Share	Reference
The Government	40—50%	50% for the field lot of 0.3 hector or over and 40% for that of 0.3 hectare below.
The Prefectures	20—30%	The rate varies according to the financial condition of each Prefecture.
The farmers	20—30%	The farmers are provided with such financial aids as long term loans, three year deferred payments, fifteen yearly payments and 5.5 per cent interest.

The amount of the yearly payment which the farmers pay, including water charges and so on, is usually within 40,000 yens per hectare. Not only farm land consolidation but the project to improve the living envnronment of farmers has been under examination in recent years.

As for the percentage which you asked the comment on, I am sure that nearly all the rice-growing farmers are benefited.

M. Aoki, Japan: What could the Authority resort to in case some farmers would not agree to the farm land consolidation project? What about the legal basis?

Answer: We have the Land Improvement Law as a legal basis of farm land consolidation; by the consent of more than two thirds of farmers concerned, the Authority has force to compel the rest farmers to accept the project. But in fact there are very few cases of resort to the Law; the absolute majority agrees in most cases.