1. Introduction
Recently, there has been a demand for equipment to use in the conversion of fields into multi-purpose ones beyond the purpose of the paddy field. In Saga, we have developed the technique of the high ridge, the mole drain, and the complete chaff underdrain as the field drainage measure for the heavy clay soil paddy field on low flat land. In addition, we hope to have a substantially improved drainage system.

In this report, we describe the local drainage plan in Saga and introduce the new technique which crushes the hard soil and makes it permeable.

2. The Local Drainage Plan
Although the Saga plain is a large flat area, it has few water sources because of the lack of mountains. Therefore, we built creeks which function in irrigation and drainage and as reservoirs. However, we have a problem. Since first the creeks are filled with water, they are very hard to drain. The aims of land improvement works at the lower part of the Chikugo River are taking clean water rationally and eliminating the damage caused by draught, floods, and so on.

The methods are constructing canals for irrigation and drainage improving the soil. Both the national and Saga Prefectural governments are involved.

The main drainage canals, which handle local drainage, serve the same functions as creeks with adjustments in the water level. We always try to keep the water level 0.1 m lower than paddy level and to avoid water shortage and flooding.

3. The Effect of Drainage
Farm land in this area is hard to drain because the stratum of field soil becomes thinner and thinner; the stratum of the hard soil is found by using large tractors, rice planters, and chemical fertilizer. We introduce as an example the land improvement technical examination which we have developed at Saga agricultural experiment station.

The main aims of this examination are: (1) a way to make the soil permeable by plowing deeply; (2) a method of adding the fertilizer to the bottom of the field; (3) a way to work on paddy whose soil is made by crushing the plowsole. We
developed a synthetic land improvement technique with these aims. The soil in
the test field has small, gray grains; and its stiffness level is 23~24 (by Yamana-
ka's stiffness meter). Between 9 cm to 20 cm, there are two stratum: one is
made by mechanical work and the other, by house power. The groundwater lies
90—100 cm under the surface of the paddy field. We crush and dig the plowsole
at 25 cm, 15 cm, and 10 cm depths and divide it into three test sections. During
the test period, we planted and grew three crops.

\begin{table}
\centering
\begin{tabular}{cccccc}
\hline
 & 88 summer & 88 winter & 89 summer & 89 winter & 90 summer & 90 winter \\
Soybean & Barley & Rice (direct seeding culture) & Barley & Rice (transplanting) & Barley \\
\hline
\end{tabular}
\caption{Crop rotation schedule}
\end{table}

As shown in Table 1, changes are not apparent in the sections 10 cm and 15 cm
depth, but the soil becomes permeable at 25 cm deep. When we grew the barley in
winter 1990, we investigated the drainage. We show the drainage discharge and
strength of the underdrainage in Figure 1. It is clear that the drainage effect is
good at 25 cm deep.

Next, in the field where the plowsole layer is crushed, bearing capacity and
permeability is the problem. The bearing capacity is the important element for
paddy field farming using a large machines and extending the field.

In planting program of this experiment, the bearing capacity tended to increase
with accumulation of Fe and Mn at 17~25 cm deep in 25 cm deep section.

As shown in Table 2, the bearing capacity (cone index) in summer 1990 was
more than 2.0 kg/cm² for 10 cm-, 15 cm-, and 25 cm-deep sections at puddling. It
was no problem to drive a tractor (wheel type 45 ps) or a seated-type rice
transplanter (15~20 cm raised seedlings transplanted in 5 rows).

\begin{table}
\centering
\begin{tabular}{cccc}
\hline
Division & Upper (5~10 cm deep) & Lower (25~30 cm deep) \\
Before plowing & 6.5×10^{-5} & 1.3×10^{-6} \\
After plowing & 3.9×10^{-3} & 6.6×10^{-6} \\
10 cm section & 1.3×10^{-2} & 8.2×10^{-6} \\
15 cm section & 1.7×10^{-4} & 8.7×10^{-5} \\
25 cm section & & \\
\hline
\end{tabular}
\caption{Saturated hydraulic conductivity of soil before and after plowing (cm/sec)}
\end{table}

\begin{table}
\centering
\begin{tabular}{cccc}
\hline
Depth & 10 cm section & 15 cm section & 25 cm section \\
10 cm deep & 0.5 & 0.5 & 0.2 \\
20 cm deep & 2.6 & 2.1 & 1.1 \\
25 cm deep & 6.6 & 3.7 & 2.4 \\
30 cm deep & 5.5 & 5.1 & 4.3 \\
Average & 3.8 & 2.9 & 2.0 \\
\hline
\end{tabular}
\caption{Bearing capacity in puddling period (kg/cm³)}
\end{table}
Figure 1 Drainage intensity of underdrainage

The water requirement on the paddy field also presented no problem; it was within the optimum water requirement rate for the flat land of Saga (16–25 mm/day).

This experiment shows that it is effective to crush the bearing capacity for field drainage improvement.

4. Conclusion

Technical improvement is more and more necessary for the future development of paddy-field farming. New techniques are needed for controlling irrigation, drainage, and soil conditions. To have better paddy fields, we need to have good drainage systems for clayey paddy field soil.

In the paddy field, we should have “water way” in anyway and find the ways to irrigate and drain. To open a “waterway,” we use the technique of crushing B-horizon (alluvial horizon). In addition, it is necessary to develop new drainage technique and ways of soil management.

The techniques are effective only when regional irrigation and drainage facilities are maintained.