J. Fac. Agr. Hokkaido Univ., Vol. 66, Pt. 1 : 69~77 (1994)

IMPLICATIONS OF HEAVILY MECHANIZED FARMING ON FIELD OPERATION

—— Case Study for Experimental Farm of Hokkaido University ——

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(Received May 19, 1993)

Introduction

Hokkaido Agriculture showed great success during the last three decades. There has been a large production due to higher chemical, capital and energy inputs into agriculture[1]. With an increase in agricultural machinery, heavy duty operations such as plowing, subsoiling and harvesting could be carried out at higher speeds and under safer and more comfortable operating conditions, even in muddy field conditions. However, this achievement was partially offset by increasing energy costs, off-farm inputs and damage to field environment. The concept of LISA (low input sustainable agriculture) arose from concern about soil compaction, soil erosion and water pollution in conventional agriculture[2][3].

In order to clarify both positive and negative effects of conventional agriculture, which is characterized as highly mechanized and with chemical inputs, it is important to analyze the implication of agricultural tractors and implements on field performance over a longer period. Recently, a very useful data base was produced by experimental farms of Hokkaido University[4]. This data base supplies informations on field operation performance in the farm over a period of 35 years. In this report, the effect of an increase in size of tractors and implements on field performance was analyzed and useful information was derived for the consideration of alternative agriculture.

Analyzed Data Base[4)-6)]

A unique and very beneficial data base was produced by the experimental farms of Hokkaido University. The data were collected over a period of 35 years, beginning in 1956. This data base covers all the important information

related to field operation and practice. It would be a very good source for the investigation of agricultural machinery or management in Hokkaido. All information about field operations for all holding tractors and implements for every commodity is covered. In this report, the tendency of size increase of agricultural tractors and implements was analyzed and it's effects on the field operation performance were clarified.

Results and Discussion

1. Change in the size of tractors

Figure 1 shows the change in total mass for tractors. Figure 2 shows the summation of engine volume for tractors. Before 1972, small tractors were

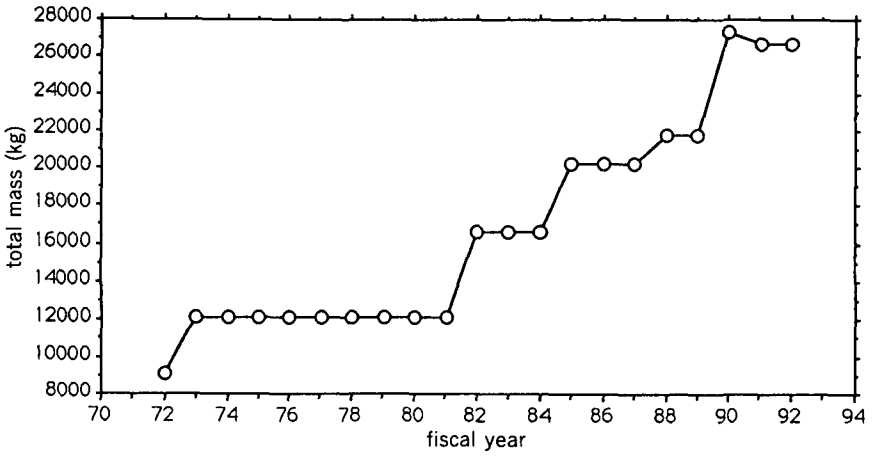

Fig. 1 Total mass of tractors

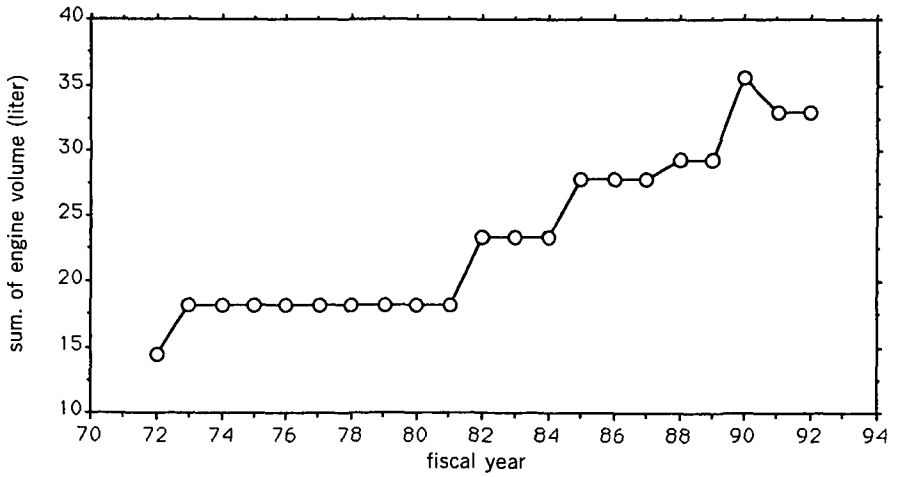

Fig. 2 Summation of engine volume of tractors

mainly used while middle class tractors were mainly used from 1972 to 1980. The number of large in size tractors gradually increased after 1981 and after 1990 most of the tractors were large size. The total area was around 80 ha for the 35 year period. Almost 70% of the total holding area has been used for grass production. Other commodities are dent corn, beans, potato, beet, corn and wheat. More detailed reports have recently been published by Kawai et al. and Sato et al.[4]

2. Performance of field operation

The average of total operation rate (ha/hr) shows large fluctuations but continues to increase gradually (Figure 3). The changes in field performance for three different operations were analyzed in this section.

1) Performance of harvesting

Figure 4 shows the change in operation rate (area / time) for forage harvest-

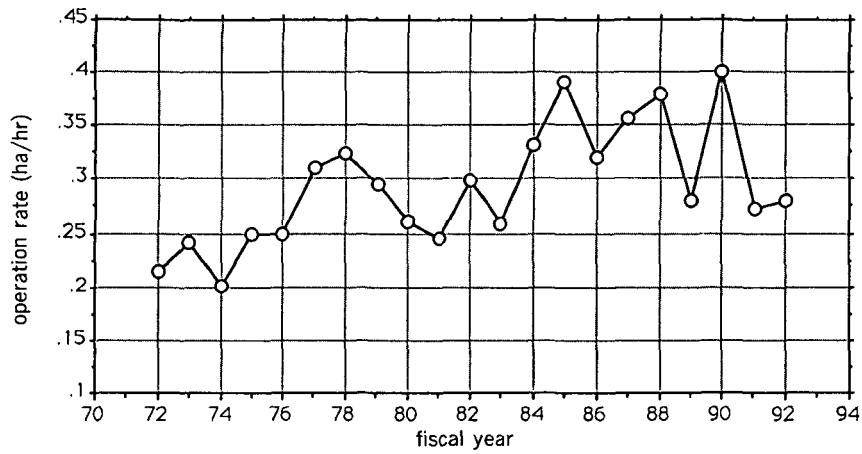

Fig. 3 Change of total operation rate

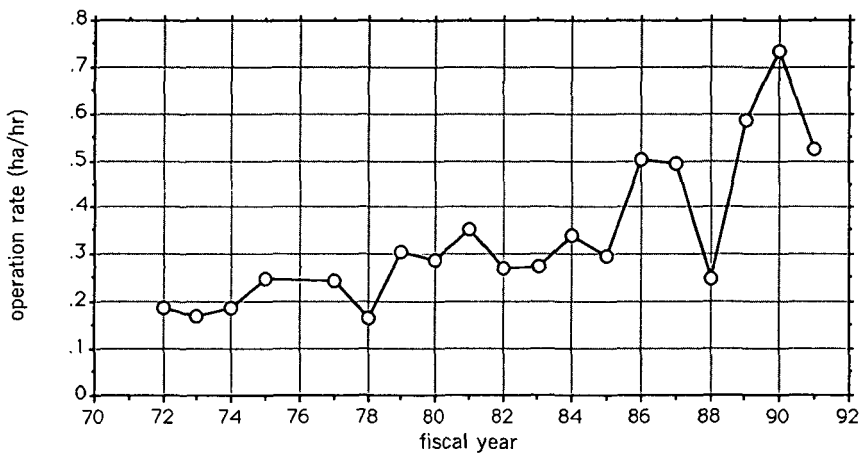

Fig. 4 Change of operation rate for farage harvesting

ing. The rate was around 0.2 ha/hr from 1970 to 1975, but rose to approximately 0.7 ha/hr in 1990. The forage harvesting rate in 1990 was three times higher than the 1970's due to an increase in tractor size. As a large forage harvester demands both high power and draft force, the operation rate of forage harvesting was improved effectively by large and high power tractors.

2) Performance of rotary tillage

Figure 5 shows the change in operation rate (ha/hr) for rotary tillage. The rate fluctuates between 0.05 and 0.10 ha/hr over the period. Both the operating depth and the operation speed have been limitations in rotary tillage performance. The limitation of operating depth was solved by a unique concept of an up-cut rotary system by Sibusawa. However, the limitation of operating speed remains a big problem. The operation rate can only be improved by an increase

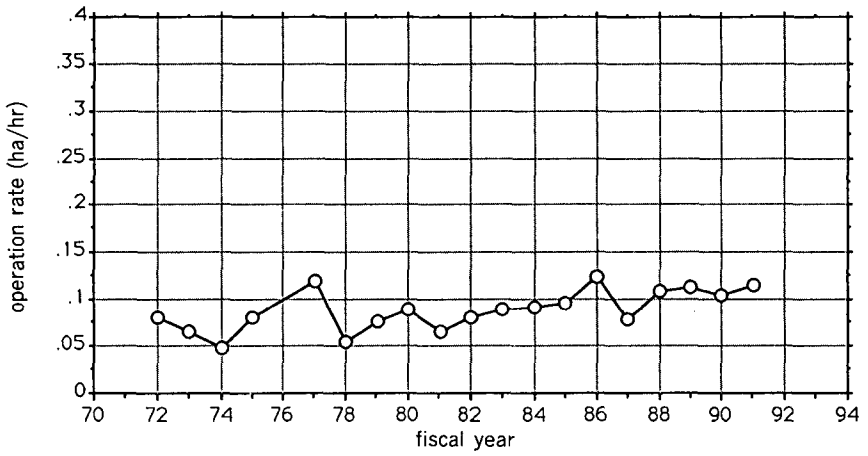

Fig. 5 Change of operation rate for rotary tillage

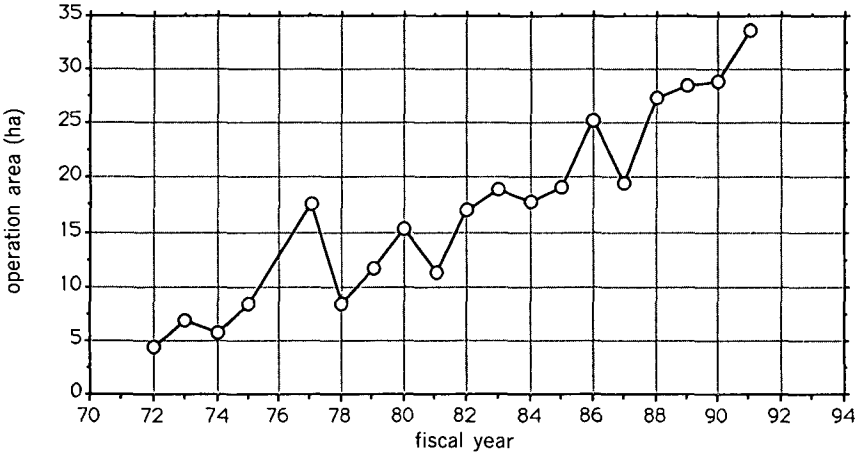

Fig. 6 Change of operation area for rotary tillage

in operating width. On the other hand, the operating area has increased rapidly, as shown in Figure 6. The operating area of rotary tillage in 1991 was 8 times larger than in 1972. This is due to an increase in the number and power of holding tractors. As about 20 ha of the field needs rotary tillage, this indicates that more than 70% of the field has been tilled twice or more in the 1990's. This means that the soil has been highly disturbed and compacted by the use of high powered tractors.

3) Performance of mechanical weed control

In the field, the conventional (chisel) cultivator and the rotary cultivator have been used for mechanical weed control. The former cultivator can be operated by a small tractor, but the latter requires a middle or large size tractor to drive the rotary tillage equipment. Figure 7 and Figure 8 show the changes in opera-

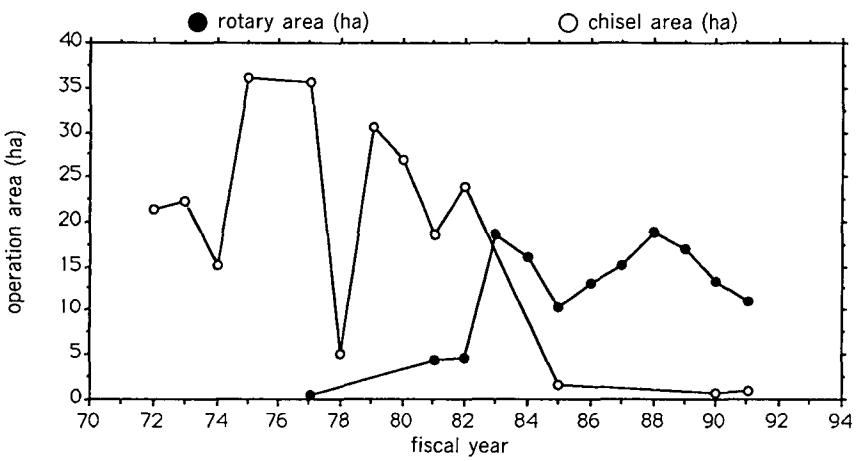

Fig. 7 Changes of operation area for rotary cultivator and chisel cultivator

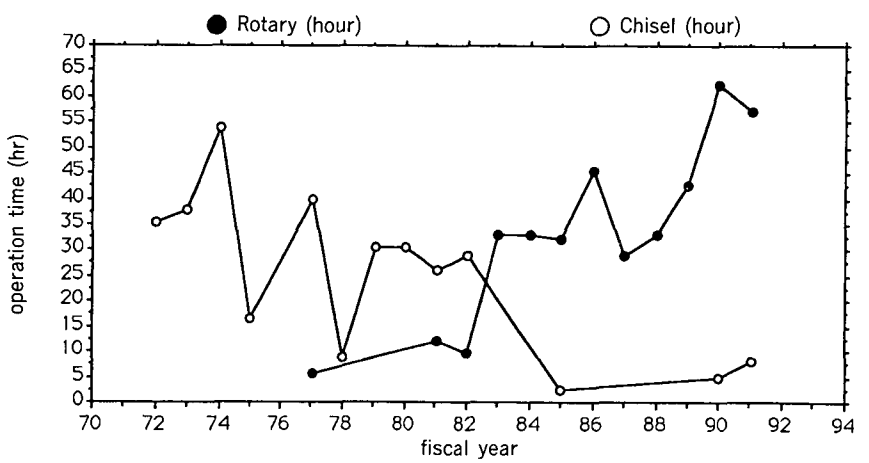

Fig. 8 Changes of operation time for rotary cultivator and chisel cultivator

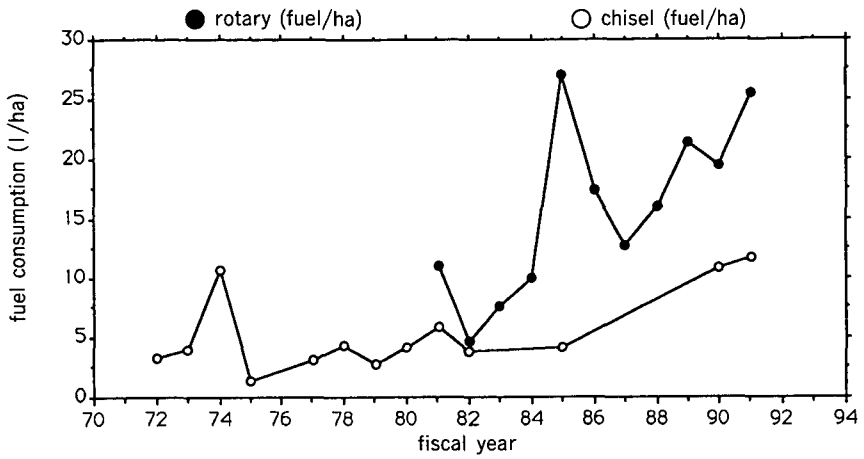

Fig. 9 Changes of fuel consumption for rotary cultivator and chisel cultivator

tion area and operation times, respectively, for the rotary cultivator and chisel cultivator. Before 1973, only chisel cultivators were used. After 1980, rotary cultivators began to replace the chisel types. The operation area of the rotary cultivator was almost half that of the chisel type cultivator. This means that at least two operations were needed for the chisel type cultivator and only one operation was for the rotary cultivator. The operation rate of the rotary cultivator is less than the chisel cultivator, but, the quality of weed control using the rotary type is much higher than that of the chisel type. The fuel consumption per area (liter / ha) for the rotary type and the chisel type are compared in Figure 9. The rotary type consumes twice as much fuel as the chisel type.

3. Increasing mass as a source of soil compaction

With an increase in tractors'mass, the average mass charged on the field has been increasing. The average mass is defined by equation 1) and 2).

$$M_a = \frac{\sum_{i=1}^{n} M_i A_i}{\sum_{i=1}^{n} A_i} \qquad 1)$$

$$M_t = \frac{\sum_{i=1}^{n} M_i T_i}{\sum_{i=1}^{n} T_i} \qquad 2)$$

The changes in time averaged mass and the area averaged mass over a 20 years period are shown in Figure 10. Both M_a and M_t were less than 2000 kg before 1970, as small tractors were mainly used. During the period of middle class tractors from 1972 to 1982, M_a and M_t were within the range of 2200 kg to 2400 kg. From 1984, M_a and M_t gradually increased and reached around 2600 kg following an increase in the number of large size tractors. After 1990, M_a

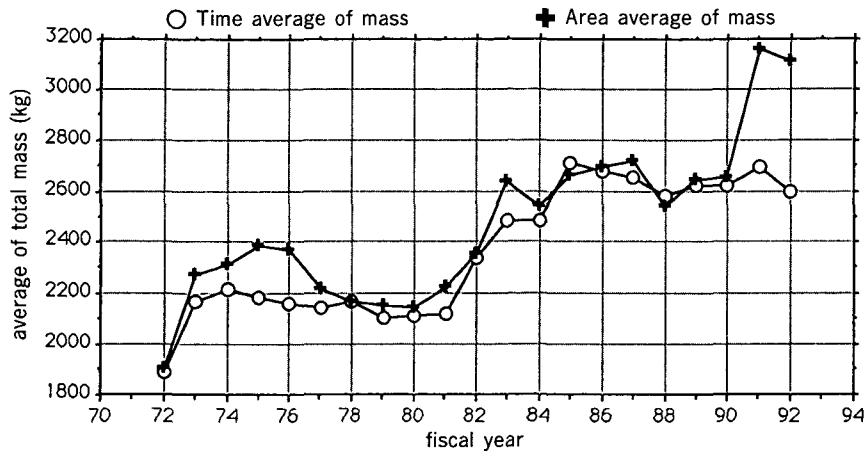

Fig. 10 Changes of time averaged and area averaged mass

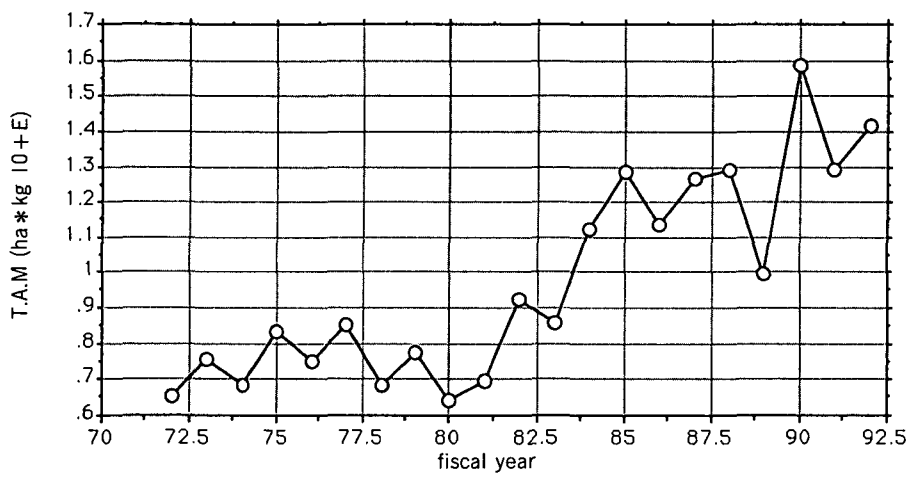

Fig. 11 Change of total product of area and mass ($T.A.M$) of holding tractors

increased to over 3000 kg. The M_a and M_t in the 1990's are 80% and 50% higher than the figures for 1972, respectively. This resulted into a source of soil compaction[7)8)].

The total product of operation area and mass ($T.A.M$) can be considered as an indicator for soil compaction. $T.A.M$ is defined as follows :

$$T.A.M = \sum_{i=1}^{n} M_i T_i \qquad 3)$$

The change in $T.A.M$ is shown in Figure 11. $T.A.M.$ was around 800000 ha*kg before 1980 and gradually increased to reach 1600000 ha*kg in 1990. This corresponds to the increase in the size and number of tractors.

Soil compaction often leads to infiltration problems, increased input energy, more fertilizer use and other problems for sustainable agriculture. The effect of tractor size on soil compaction should be investigated for each commodity using the data base. New technologies should also be developed in order to reduce the size of tractors while maintaining field performance[9]. Maintaining field performance is important as it is impossible for farmers to return to the past low level of mechanized farming.

Conclusions

1. The effects of the increase in size of agricultural machinery on field performance were analyzed using a recently supplied data base. This data base was produced by the Experimental Farms of Hokkaido University and covers all information about field operation performance on the farms over a 35 years period.
2. With an increase in tractors'mass, the average mass loaded on the field has increased. The area averaged mass M_a and time averaged mass M_t in the 1990's are 80% and 50% higher than the figures for 1972, respectively. This increase in average mass has led to soil compaction.
3. The forage harvesting rate in 1990 was three times higher than in the 1970's due to an increase in tractor size. The operating area of rotary tillage in 1991 was 8 time larger than that in 1972. As rotary tillage is carried out for approximately a 20 ha area, this means that more than 70% of the field has been tilled twice or more by rotary tillers in the 1990's. Rotary cultivators replace the chisel types from the mid-1980's. The quality of weed control for the rotary type is much higher that for the chisel type, as the former can easily mix soil and weeds.
4. It is clear that field performance has improved with an increase in tractor and implement size. On the other hand, frequency and energy to disturb the field soil through rotary tillage and soil compaction have also increased. The effect of such disturbance to the field environment by heavy mechanization is an area for future analysis.

Acknowledgement

The author (KS) wish to thank Mr. Konno and Mr. Wakazawa for their useful discussions.

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