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RELATIONSHIP BETWEEN FARM LAND STRUCTURE AND MACHINE EFFICIENCY

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ABSTRACT

Effective machine capacity is affected by the physical and geometrical conditions of the fields. In the small and scattered farmland structure field efficiency is greatly influenced by plot geometry. In this paper, a method for estimating field efficiency and effective machine capacity was developed. The developed method was applied to Korean paddy cultivation.

Various time elements related to farm operations for small and scattered plots are discussed in this paper. Available working time is divided into two parts, viz. the preparation time for machine operation and actual working time. Two kinds of machine efficiencies, namely, Machine Efficiency 1, applicable on a single large plot or a set of well consolidated plots; and Machine Efficiency 2, applicable on small and scattered multiple plots, are considered. Basic assumptions made and steps followed to construct the model are discussed. Effective capacity of each machine based on different plot geometries are calculated by the model. Machine efficiency on a single plot increases with increase in the dimension of longer side of the plot. Low speed, low theoretical capacity machines have higher machine efficiency which is only slightly influenced by plot geometry. As plot geometry is improved, the machine efficiency of high speed, high capacity machines increases rapidly. The effects of short side length and plot size on machine efficiency on a single plot depend on the type of farm operation. For a particular plot shape, as plot size increases, machine efficiency on multiple plots increases rapidly. The effect of consolidation on machine efficiency is highly significant if the plot size is small and/or machine size is large.

Key Word: Korea, Agriculture, Efficiency, Structure

INTRODUCTION

Estimation of effective machine capacity and machinery operation cost for different plot geometry are very important for selecting farm machinery. Effective machine capacity is affected not only by the theoretical machine capacity but also by physical and geometrical conditions of the fields (Renoll, 1972, 1979; Hunt, 1979; Hanna et al., 1979; Ullah and Kofoed, 1987; Ullah et al., 1989).

LIST OF SYMBOLS

CSFT	Coefficient of supportive function time (decimal)
Ew	Effective swath coverage (decimal)
FAC1	Number of turns on headline
MC1	Effective capacity of farm machinery on a single plot or consolidated farm land (ha/h)
MC2	Effective capacity of farm machinery on multiple plots (ha/h)
ME1	Machine efficiency on a single plot or consolidated farm land (decimal)
ME2	Machine efficiency on a multiple plots or small and scattered farm land (decimal)
N_1	Number of persons for cutting paddy
NST	Nursery supply time (h/ha)
PLS	Plot size (ha)
S1	Short side length of a plot (m)
S2	Long side length of a plot (m)
Sm	Paddy cutting speed per person (min/m^2)
Sp	Speed of travel (km/h)
Te	Effective operating time (= Th/Ew)(h)
TFC	Theoretical field capacity (ha/h)
Th	Theoretical operating time (h)
TMC	Theoretical machine capacity (ha/h)
Ts	Supportive function time (h)
Tt	Total turning time (h)
TT	Total number of turns
Ttp	Time for travelling and implement resetting before or after operation (h)
W	Rated width of implement (m)
WD1	Cutting width at the corner of plot (m)
WD2	Cutting width along the side of plot (m)

For converting theoretical machine capacity to effective machine capacity field efficiency is used. But the concept of field efficiency as defined therein hardly applies to small and scattered farmland structure wherein field efficiency is greatly influenced by plot geometry. Also, travelling and implement resetting time constitute a considerable portion of working hours per day.

If theoretical machine capacity, turning time for a turn, supportive operational time and average distance among plots are known, machine efficiency and effective capacity for the different plot geometry could be predicted. In this paper, a method for estimating field efficiency and effective machine capacity was developed and applied to Korean paddy cultivation.

FARM MACHINE CAPACITY

Theoretical machine capacity, as defined in this paper, differs from theoretical field capacity based on full-rated operational width. The reason is that machine capacities used in this model were based on effective implement width given by National Agricultural Material Inspection Office (NAMIO, 1987). Eqn. 1 and 2 show the difference in theoretical machine capacity and theoretical field capacity.

$$TMC = \frac{Sp \times W \times Ew}{10} \tag{1}$$

$$TFC = \frac{Sp \times W}{10} \tag{2}$$

Machine Efficiency

For calculation of field efficiency (E_f), following equation was used (Hanna, 1979 and Hunt, 1979).

$$E_f = 100 \times \left(\frac{Th}{Te + Tt + Ts}\right) \tag{3}$$

When the plot size is so large that a machine need not have to move from one plot to another in a day, the concept of field efficiency explained in Eqn. 3 is applicable. In fact, in many developing countries plots are small and scattered. Various time elements related to farm operations, used in this study, (Fig. 1) are described below:

- (i) Machine preparation time at farm household
- (ii) Travel time to and from the field
- (iii) Implement resetting time before and after operation
- (iv) Effective field time
- (v) Turning time
- (vi) Supportive function time, e.g., loading or unloading time and machine adjustment time

Available working time is divided into two parts, namely, the preparation time for machine operation, and actual working time. Preparation time for operation includes machine preparation time at the farm household, travel time from farm household to the first plot and machine preparation time before starting operations on the first plot. Actual working time starts from the point of beginning of intended activity on the first plot to returning to household and placing the machine into shelter.

Operation Time Type 1 refers to the sum of the time elements from item (iv) to item (vi) for a given plot. **Operation Time Type 2** covers operation time type 1 plus implement resetting time after operation, travelling time to next plot and implement resetting time before starting operations on the next plot.

In this paper, two kinds of machine efficiencies, namely, **Machine Efficiency 1 (ME1)** and **Machine Efficiency 2 (ME2)** are considered. ME1 is based on operation time type 1 while ME2 is based on operation time type 2 (Eqns. 3 and 4). The ME1 is applicable on a single large plot or a set of well consolidated plots. The ME2 is applicable on small and scattered multiple plots.

$$ME1 = \frac{Te}{Te + Tt + Ts} \qquad (4)$$

$$ME2 = \frac{Te}{Te + Tt + Ts + Ttp} \qquad (5)$$

Data on turning time and supportive function time were adopted from NAMIO (1987-1989), Renoll (1972) and AMI (1980, 85, 89).

Effective Capacity

On a single plot or consolidated farm land ME1 is used to calculate the capacity of a farm machine .

$$MC1 = TMC \times ME1 \qquad (6)$$

Capacity of farm machine on the multiple plots is calculated by using ME2.

$$MC2 = TMC \times ME2 \qquad (7)$$

COMPUTER MODELLING

Basic Assumptions

(i) The size and theoretical capacity of each machine are based on current manufacturing technology in Korea.
(ii) Farmers will continue to follow the present field pattern as given below:
- tillage and transplanting: continuous turn strips at each end
- harvesting: circuitous rounded corner

Steps of Modelling

(A) The following relationships were determined by developing simple input-output sub-models for standard conditions.

(i) Machine size and theoretical machine capacity (Source: NAMIO, 1987-1989).

(ii) Machine size and effective width of operation for various implements (Source: NAMIO, 1987-1989).

(iii) Turning time and supportive function time (Source: NAMIO, 1987-1989; Renoll, 1972; and AMI, 1980, 85, 89).

(B) Calculation of machine efficiency based on the plot geometry: ME1 and ME2 of each machine size were calculated using equations from 4 to 13. The difference between the two is assumed to be due to the effect of land consolidation.

For calculation of machine efficiency, effective field time (Te) is calculated as

$$Te = \frac{PLS}{TMC} \tag{8}$$

Total turning time (Tt) is computed by the relation

$$Tt = TT \times Turning\ time\ per\ turn \tag{9}$$

The total number of turns (TT) is calculated as

$$TT = \left(\frac{Short\ \ Side\ \ Length}{W \times Ew} - 1\right) + FAC1 \tag{10}$$

Supportive function time is determined by using Eqns. 11, 12 and 13.

(i) **For field operations** with power tiller and tractor

$$Ts = (Te + Tt) \times CSFT \tag{11}$$

(ii) **For transplanting:** Nursery loading time

$$Ts = PLS \times NST \tag{12}$$

(iii) **For harvesting:**
Paddy cutting time for combine or binder operation

$$Ts = [2 \times (S1 + S2 - WD1) \times WD2 + 4 \times WD1^2]\ x\ \frac{Sm}{N_l \times 60} \tag{13}$$

It is assumed that in case of machine operation, crops on the edges of the plot are cut by manpower. In case of combine two persons cut paddy ($N_l = 2$); while in case of a binder, one person cuts paddy ($N_l = 1$).

(C) Calculation of effective machine capacity: Effective machine capacity on the given plot geometries are calculated by using Eqn. 6 or 7.

RESULTS AND DISCUSSIONS

(i) The relationships between the plot geometry and machine efficiency on a single plot (ME1) are shown in Figs. 2 and 3. As shown in the figures, machine efficiency on a single plot increases with the increase in the dimension of the longer side of the plot (Fig. 2). This is due to the lower ratio of the time required for one turn to the time required for one trip operation in the case of larger long side of the plot. The marginal rate of increase of this ratio with long side length increases at a decreasing rate. Thus it may be said that as long side is extended, the rate of increase in the machine efficiency on a single plot decreases.

(ii) To determine the effects of short side length of a plot and plot size, machine efficiency on a single plot based on different short side lengths such as 20, 40 and 60 m were further analyzed. Fig. 3 indicates that the effects of short side length and plot size on machine efficiency on a single plot depend on the type of farm operations. In case of power tiller and tractor in which the field pattern are usually continuous turn trips at each end of the plot, the machine efficiency depends mainly on the long side length. Similar is the case with transplanters.

In the case of the binder and combine where the field pattern is continuous rounded corner, the effect of short side length is significant. If the plot shape is square then the paddy cutting time (supportive function time) decreases, while the machine turning time increases. The machine efficiency also increases with increasing size of the plot of a particular shape, because the ratio between the paddy cutting time and the effective field time is decreased.

(iii) Following conclusions can be drawn from Figs. 2 and 3: *(a)* Low speed, low theoretical capacity machines (power tiller with rotary) and/or machines equipped with wide implements (transplanter) have higher machine efficiency which is influenced by plot geometry only slightly. *(b)* As plot geometry is improved, the machine efficiency of high speed, high capacity machine (combine) and/or machines equipped with narrow implements (tractor with plow) increases rapidly. These can be explained by the following three reasons: *(a)* A machine equipped with wide implements requires relatively less number of turns for farm operation on a given plot. *(b)* For a machine having low speed and/or low capacity, the ratio of turning time to total required time for farm operation is lower than that for a machine having high speed and/or high capacity. *(c)* As plot geometry is improved, in the latter case the ratio is more rapidly increased than in the former.

(iv) Machine efficiency on multiple plots (ME2) represents overall machine efficiency including travelling and implement resetting time. It is a function of effective field time, operation type 1, and travelling and implement resetting time (Fig. 1).

Fig. 4 illustrates the effects of consolidation on machine efficiency of transplanters. It indicates that on a particular plot shape, as plot size increases, machine efficiency on multiple plots increases rapidly. This is mainly due to reduction in travelling and resetting time while moving from one plot to another. When all the plots are together as consolidated holding, this plot to plot travel and resetting time is almost negligible. The increase in machine efficiency resulting from consolidation of small plots is significantly higher than that resulting from the consolidation of large plots. In case of large size machines, the resultant increase in machine efficiency due to consolidation is highly significant.

CONCLUSIONS

(i) Machine efficiency on single plot increase with increases in plot size. The machine efficiency increases significantly with increase in length of a plot. However, the effect of the width of the plot on machine efficiency depends on the type of farm operation.

(ii) For a particular shape, as plot size increases, machine efficiency on multiple plots increases rapidly. The effect of consolidation on machine efficiency is highly significant if the plot size is small or machine size is large.

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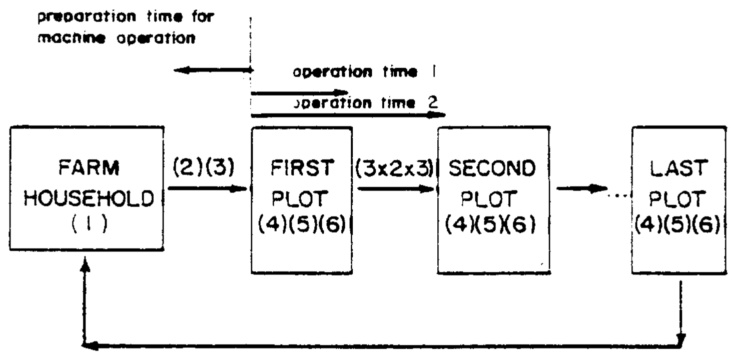


Fig. 1: Time elements for small and scattered plots of a farm land

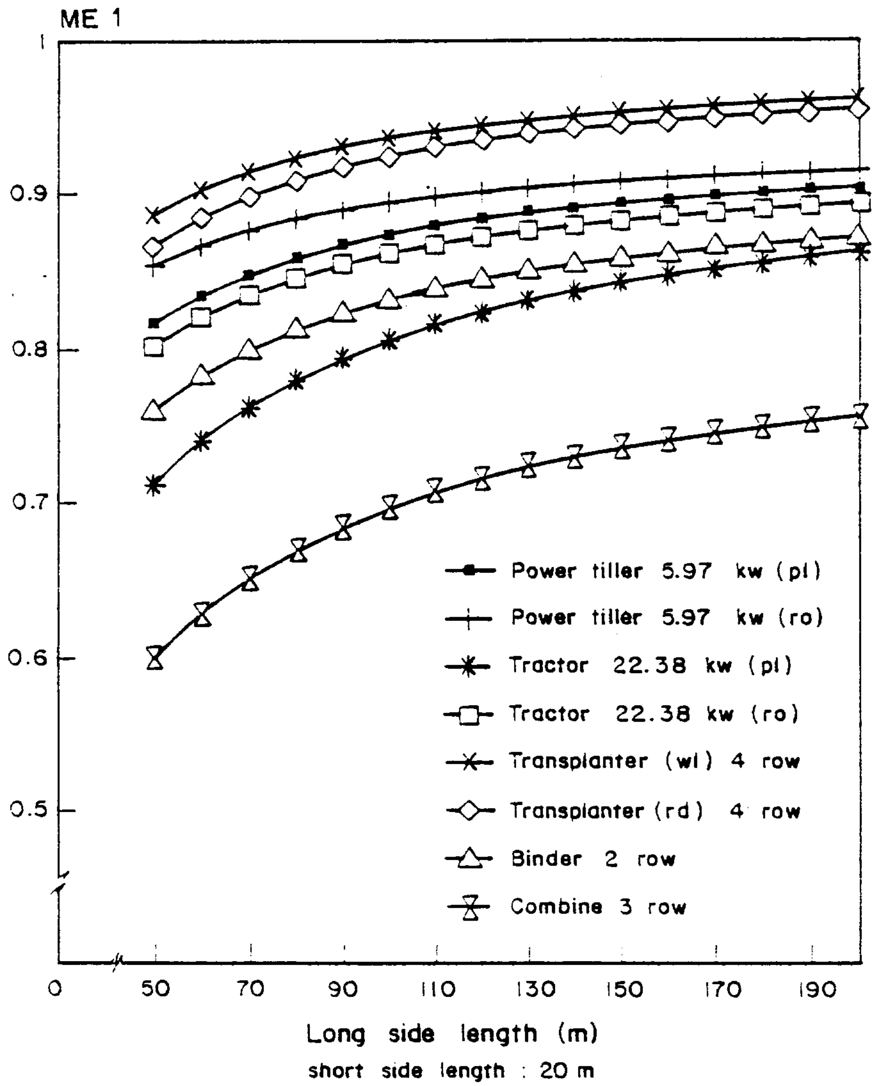
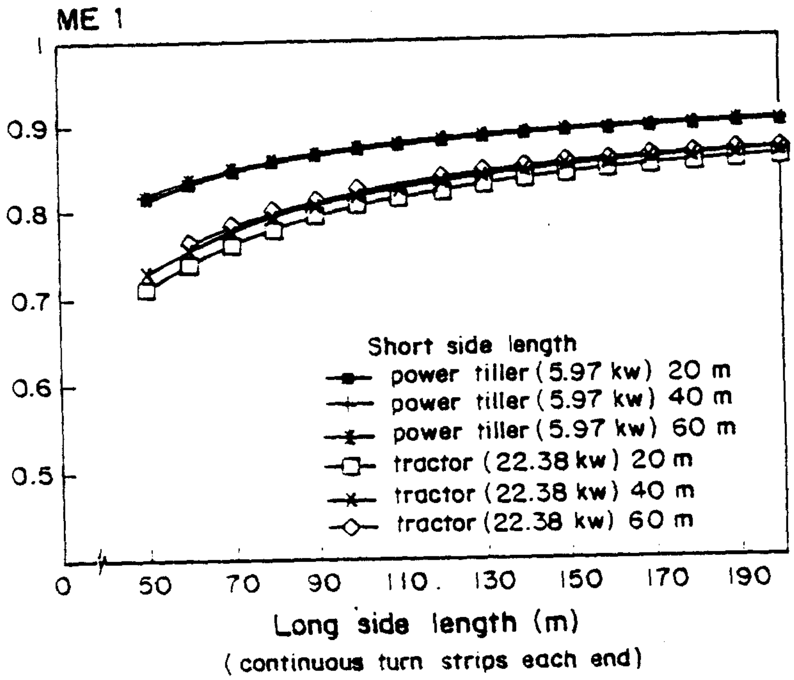


Fig. 2: Machine efficiency and long side length



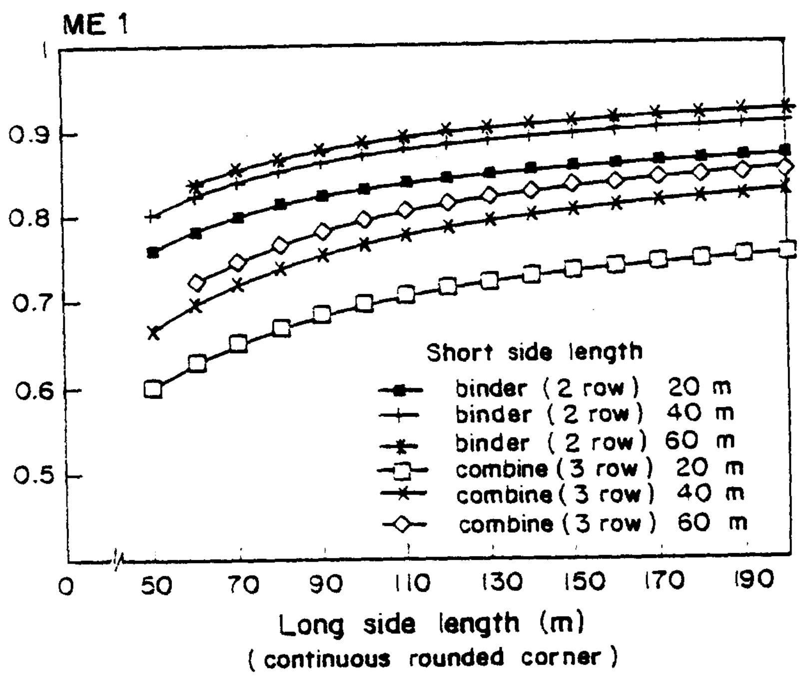


Fig. 3: Effects of short side length on machine efficiency

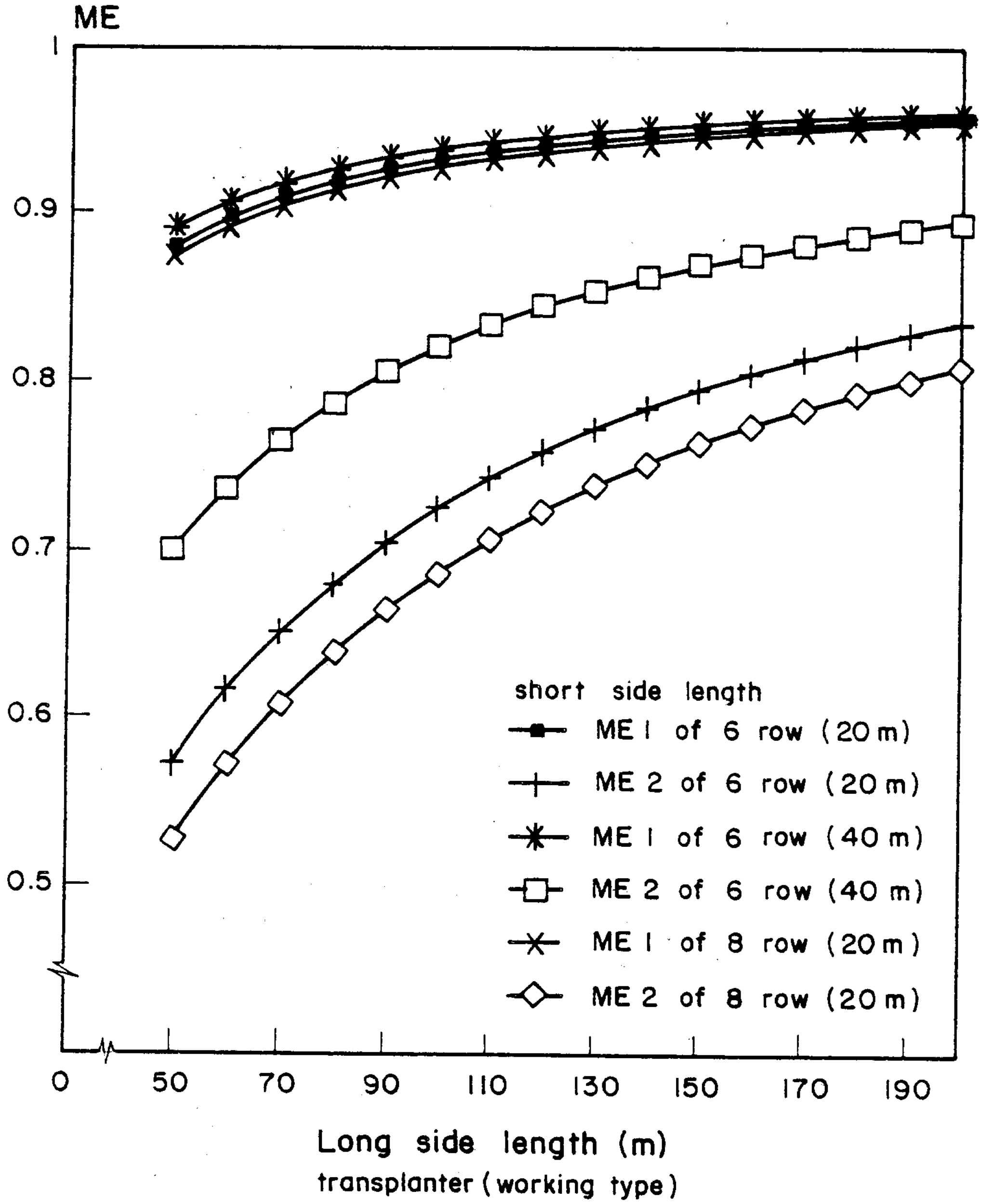


Fig. 4: Effects of plot geometry on ME1 and ME2