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RELATIONSHIP BETWEEN FARM LAND STRUCTURE AND MACHINE OPERATION IN KOREA

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ABSTRACT

The shortage of agricultural labour due to industrial growth has greatly induced the mechanization in Korean agriculture. However small and scattered land holdings have been the main constraints in the process of mechanization. This paper describes the interrelationships of farm land structure, machinery selection and machinery operation areas. The sandy silt loam irrigated paddy land having single crop a year was selected as a target area for this study. Machine operation cost is greatly influenced by operation period, plot geometry and operation area. On the improved geometry plots, optimal machine size increases slowly with increase in operation area. Operable area increases due to increased effective machine capacity on better geometry plot. The difference between the effects of operation period and plot geometry is that in the former case, the cost reduction is caused by delay in increase of machine size, whereas in the latter case timeliness cost is reduced by increased effective capacity. The effect of farmland consolidation is greater on small plots than that on big plots. Increasing wage rates have induced the adoption of more labor saving machinery. Bigger labor saving machines require enlargement of operation area and larger plots through improvement in farm land structure. Machine cost on poor plot geometry increases more rapidly than that on the good plot geometry and as operation area increases machine cost reduces significantly.

It is concluded that the development of agricultural mechanization in Korea will depend on the improvement in farm land structure and enlargement of operation area.

Key Word : Korea, Agriculture, Structure, Operation

INTRODUCTION

In the process of industrialization in Korea, farm population has decreased from 16.1 million (53.4%) in 1967 to 7.5 million (16.9%) in 1990. The decrease in agricultural labor has induced a rapid increase in agricultural wage. As a result, adoption of labor saving technology such as farm mechanization was accelerated. Problems of Korean agriculture are rooted in inefficient farmland structure such as small holding size (average holding size is 1.2 ha) consisting of small and scattered plots, e.g for 60% of paddy land, the plot size is less than 0.2 ha.

LIST OF SYMBOLS

ACB	Additional cost of binder use (won/ha)
AMO	Additional cost for machine above-average-use (won/h)
AWT	Actual working time per year (h)
MC1	Capacity of machine on a given plot (ha/h)
CNB	Cost of nursery boxes (won)
EWH	Expected working hours per year (h/year)
FCR	Fuel consumption rate (l/h)
FP	Price of fuel (won/l)
H	Working hours per day (h/day)
i	Interest rate (%)
INS	Insurance rate (%)
K	Timeliness coefficient (decimal/day)
n	Working life of machine (year)
nb	Working life of nursery boxes (6 years)
NM	Number of machines operated (machine)
nt	Number of times to be divided
OA	Operation area (ha)
OCR	Oil consumption rate (l/h)
OP	Price of oil (won/l)
PNB	Price of a nursery box (670 won)
PP	Purchase price (won)
PS	Price of string (1.0 won/m)
RL	Required labor per machine (man/machine)
RLD	Required labour for setting up paddy bundles for drying
RMFM	Repair and maintenance factor as % of purchase price/hr
RNB	Required number of nursery boxes per ha (28 box/ha)
ROP	Required operation period (days)
RS	Required length of string (1,200 m/ha)
s	Salvage value factor (decimal)
Sc	Schedule of operation
Sh	*Shelter charge rate (%)*
TEWH	Total expected working hours for the machine life (h)
TLC	Timeliness cost (won)
TRL	Total required labor for machine operation (man-day)
U	Fractional utilizations of total time (decimal)
V	Value of crop (won/kg)
VC	Variable cost (won)
Wage	Wage of labor for machine operation (Won/h)
Y	Potential crop yield (kg/ha)

This paper describes a model to investigate the interrelationships between farm land structure, machinery selection and machinery operation areas. Through the application of the model to Korean paddy production system, policy implications are drawn. The sandy silt loamy irrigated paddy land having single crop a year was selected as a target area for this study. As agriculture is influenced by the agro-climatic conditions, in this study paddy land of Korea is categorized into three agrozones namely; North (north of Han river), Middle (south of Han river and north of Dae-Jun city), and South (south of Dae-Jun city).

FARM LAND STRUCTURE AND MACHINE OPERATION MODEL

The structure of this model has been described in detail by Ahn (1992). The model can help in understanding how problems, associated with agricultural mechanization in Korea; such as poor farmland structure, high wages and small holding size; are related to machine operation. The model comprised of the endogenous and exogenous variables which affect the machine operation cost. Among the exogenous variables, plot geometry, machine size and operation area are assumed as controllable, and the other factors such as weather and biological factors are assumed as uncontrollable.

Scope and Limitations of the Model

(i) The model incorporates land preparation, paddy transplanting and harvesting operations only.
(ii) The model construction is based on the current level of machinery manufacturing technology in Korea.
(iii)Farmers will continue to follow the present field patterns as given below:
- tillage and transplanting: continuous turn strips at each end
- harvesting: circuitous rounded corner

Stages of Modelling

(A) The following relationships were determined by developing simple input-output sub-models for standard conditions (Source: NAMIO, 1987-1989).

(i) Machine size and theoretical machine capacity
(ii) Machine size and effective width of operation for various implements
(iii) Machine size and machine purchase price
(iv) Machine size and fuel consumption rate

(B) Calculation of farm machinery efficiency and effective machine capacity (Source: Ahn, 1992)

(C) Calculation of machinery associated cost, required operation period and required labor hours for each machine operation on different plot geometry for different agrozones having different agro-climate conditions as given below:

Fixed cost

$$FC = PP\,[\frac{(1-s)i(1+i)^n}{(1+i)^n - 1} + si + INS + Sh] \tag{1}$$

Variable costs

$$VC = \frac{OA}{MC1}[RL \times Wage + FCR \times FP + OCR \times OP + PP \times RMFM] \tag{2}$$

Cost of nursery boxes for transplanting

$$CNB = \frac{RNB \times PNB \times OA}{nb} \tag{3}$$

The additional cost of binder use (including the cost of string for binding paddy by reaper binder and the cost of labor for setting up paddy bundles for sun drying)

$$ACB = RLD \times Wage \times OA + RS \times PS \times OA \tag{4}$$

Machine above-average-use cost

$$AMO = (AWT - EWH) \times \frac{PP}{TEWH} \tag{5}$$

If AWT < EWH then AMO equals to 0.

Timeliness cost

Timeliness cost can be estimated using a formula derived by Hunt (1979) as:

$$TLC = \frac{(K)\times(Y)\times(V)\times(OA)^2}{(Sc)\times(nt)\times(U)\times(H)\times(MC1)} \tag{6}$$

Required operation period (ROP)

$$ROP = \frac{OA}{MC1 \times U \times H} \tag{7}$$

Total required labour (TRL)

$$TRL = ROP \times RL \times NM \tag{8}$$

(D) Determination of optimal machinery combination for whole system: To find optimal machinery combinations, the dependence of each machine operation is considered. In the case of the operations which must be carried out simultaneously, performance of one machine influences the other machine. Therefore, for selection of machinery, required period or labor-hours for a sequential farm operations are considered. Among the machine combinations which satisfy available operation periods (Table 1) and labor hours constraints, the least cost machine combination is selected as an optimal machine combination.

RESULTS AND DISCUSSION

Effect of Operation Period on Machine Operation

The relationship between available operation period and economic machine operation area is illustrated in Fig. 1. Cost curve (tc) represents the total cost per ha. Line OM represents the machine capacity. Line P represents the available operation period for a farm machine. The maximum operable area of a machine is determined by the point at which the operation period line and machine capacity line meet. The economic machine operation area is the area corresponding to the lowest cost per ha point on the cost curve (tc) within the maximum operable area. For longer period P_l, the maximum operable area is A2 while most economic operation area is A1 with cost/ha as Ec1. In case of shorter operation period P_n, the maximum operable area is A3 with cost/ha as Ec2.

In the agrozones where operation period is short if the operation area is increased then machine size has to be increased rapidly to complete the operation in short time.

Effect of Plot Geometry on Machine Operation

The relationship between plot geometry and machine operation is illustrated in Fig. 2. On a better plot geometry, effective machine capacity increases. Decrease in variable and timeliness cost caused by decrease in operation period moves the cost curve downward. Decrease in timeliness cost also moves the cost curve rightwards. As a result, the operation cost per ha curve shifts downward and to the right. Therefore, improvement in plot geometry results in (a) an increase in effective machine capacity, (b) an enlargement of economic operation area and (c) reduction of machinery cost per ha.

The effect of improvement in plot geometry is very similar to the effect of operation period. Both are related to maximum operable area. The main difference is that the effects of operation period is not related to change in effective machine capacity, while plot geometry is related. As a result, if operation area is small, operation period does not affect operation cost per ha while improvement in plot geometry always results in the reduction in variable and timeliness cost per ha.

Optimal Machinery System

Based on different combinations of operation period, plot geometry, operation area and machine price, the optimal mechanization patterns such as optimal machine type and size, machine operation area, and cost per ha were investigated. The machine price, in this study, is classified into following three cases: (i) no subsidy; (ii) loan with low interest rate (6-8.5%) as in the case of private ownership; and (iii) 50% subsidy and loan with low interest rate (5%) as in the case of cooperative ownership.

To clarify the effect of plot geometry on machine operation cost, two types of plot geometry of 100 x 20m and 100 x 40m were investigated. Due to different operation periods available in northern, southern and middle part of Korea (Table 1), economic operation area and cost per ha for three regions are different as shown in Table 2. Due to very short period in north the operation areas are significantly smaller than those for south and middle part of Korea. Consequently the operation cost per ha in north are significantly higher than those in south and middle part of Korea.

Fig. 3 illustrates the effects of plot geometry and operation area on tractor size and cost of operation. If the tractor operation area exceeds 7 ha, the cost reduction effect from the improvement in plot geometry is highly significant. The reason is that the cost is reduced not only by the decrease in timeliness cost due to increased effective machine capacity but also by the decrease in the fixed cost due to delay in change of optimal machine size. Also from Fig. 3 it is clear that the smaller the plots, the greater is the consolidation effect. This is because of larger ratio of travelling and implement resetting time to actual working time on smaller plots. As operation area increases to optimal operation area, the cost reduction effect of improvement in farmland structure is greater.

The effect of operation area on optimal tractor size and operation cost for three zones is shown in Fig. 4. As the operation area is directly proportional to operational period, this figure clearly illustrates the effect of available operation period on the size of equipment and its associated costs. In north with short operation period, the tractor size is significantly bigger than that for middle and south part of Korea for the operational area of 10 ha and above.

CONCLUSIONS

(i) Operation period influences the operable area, as a consequence when the operation period is short, large machine size is required to complete farm operation within short optimal periods resulting in increased machine operation cost. In the region where machine operation period is long, maximum operable area of a machine is larger and the machine cost per ha is lower.

(ii) On a large plot with good geometry, effective machine capacity increases which reduces machine operation cost and increases operable area of the machine.

(iii) Increase in machine operation area decreases the fixed cost per unit area basis.

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Table 1: Available working days for various farm operations (Source: RDA, 1988)

Machine type	*North*	*Middle*	*South*
Tractor/Power tiller (Land preparation)	22	32	74
Transplanter	11	16	37
Binder	21	26	31
Combine	21	26	31

Table 2: Effect of plot geometry and operation period on machine operation
(No subsidy case)

Plot geometry	*Region*	*Power tiller*		*Tractor*		*Transpl-anter*		*Transpl-anter*		*Binder*		*Combine*	
		5.97 kW		*22.38 kW*		*wl,4 row*		*rd,4 row*		*2 row*		*3 row*	
		Ea	*Ec*	*Ea*	*Ec*	*Ea*	*Ec*	*Ea*	*Ec*	*Ea*	*Ec*	*Ea*	*Ec*
100 x 20m	North	7	223	16	260	10	165	16	212	4	281	13	304
	Middle	10	171	22	186	16	128	25	156	7	212	16	256
	South	10	174	37	175	16	129	28	157	7	215	19	255
100 x 40m	North	7	216	16	251	10	157	16	201	4	268	16	272
	Middle	10	166	25	172	16	122	28	148	7	203	19	224
	South	10	169	37	166	16	124	28	150	7	206	22	225

Ea-Economic operation area (ha); Ec-Cost per ha for Es (1000 won)

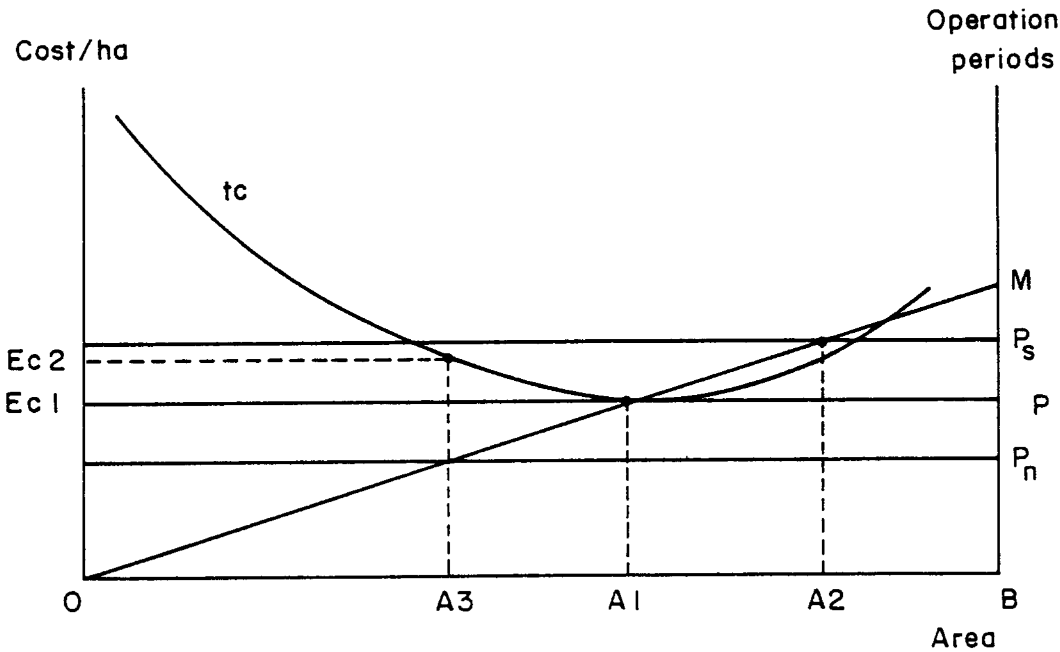


Fig. 1: Operation period and economic operation area

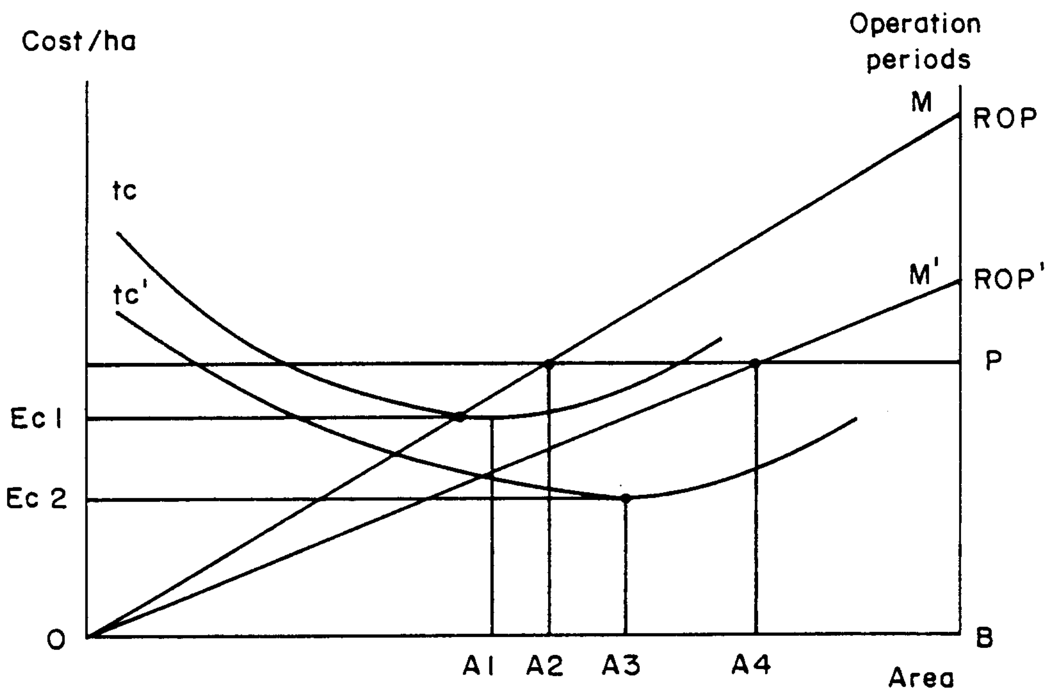
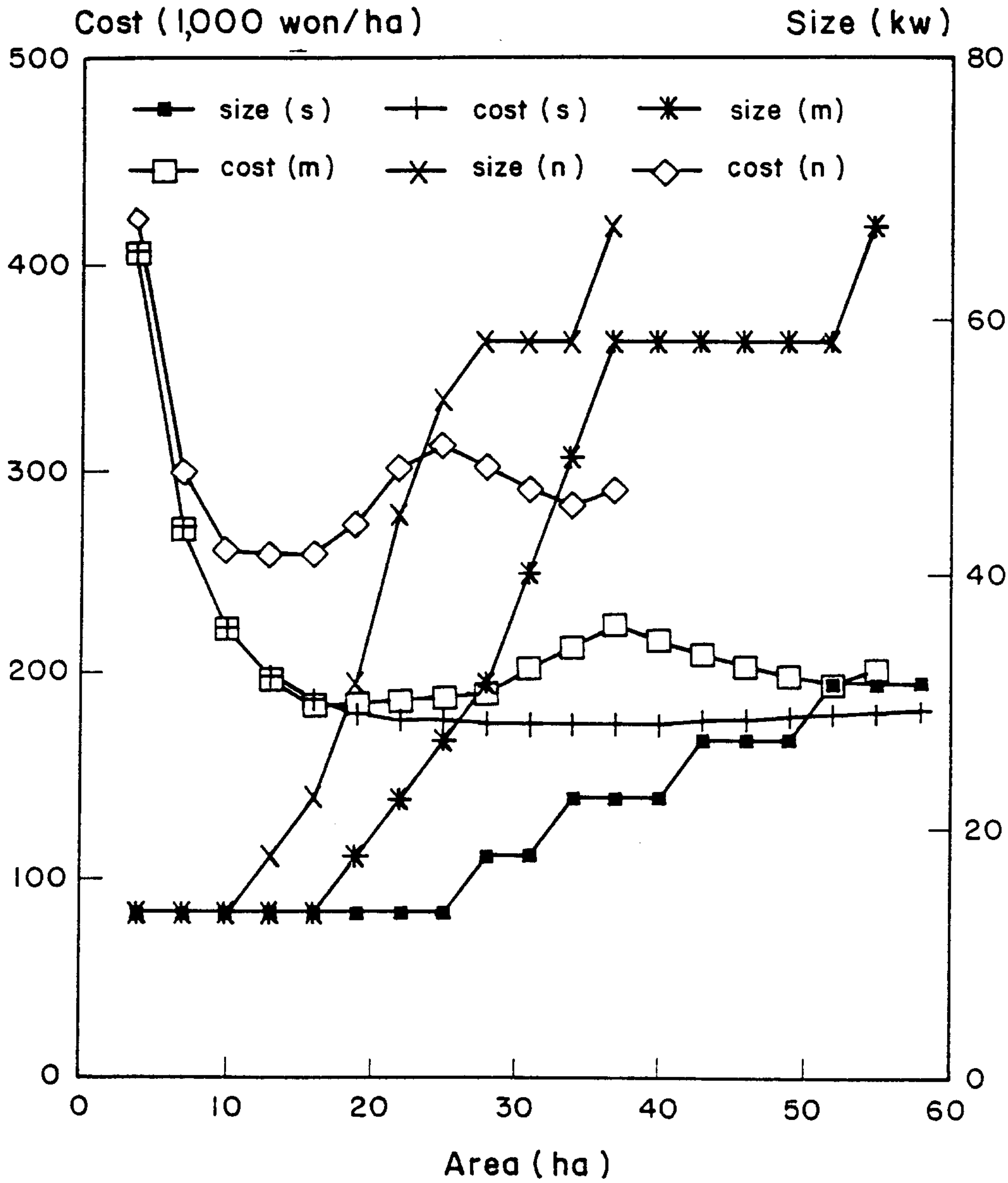


Fig. 2: Effect of plot geometry on machine cost



Plot geometry : 100x20
s : south, m : middle, n : north

Fig. 3: Effect of plot geometry on tractor operation

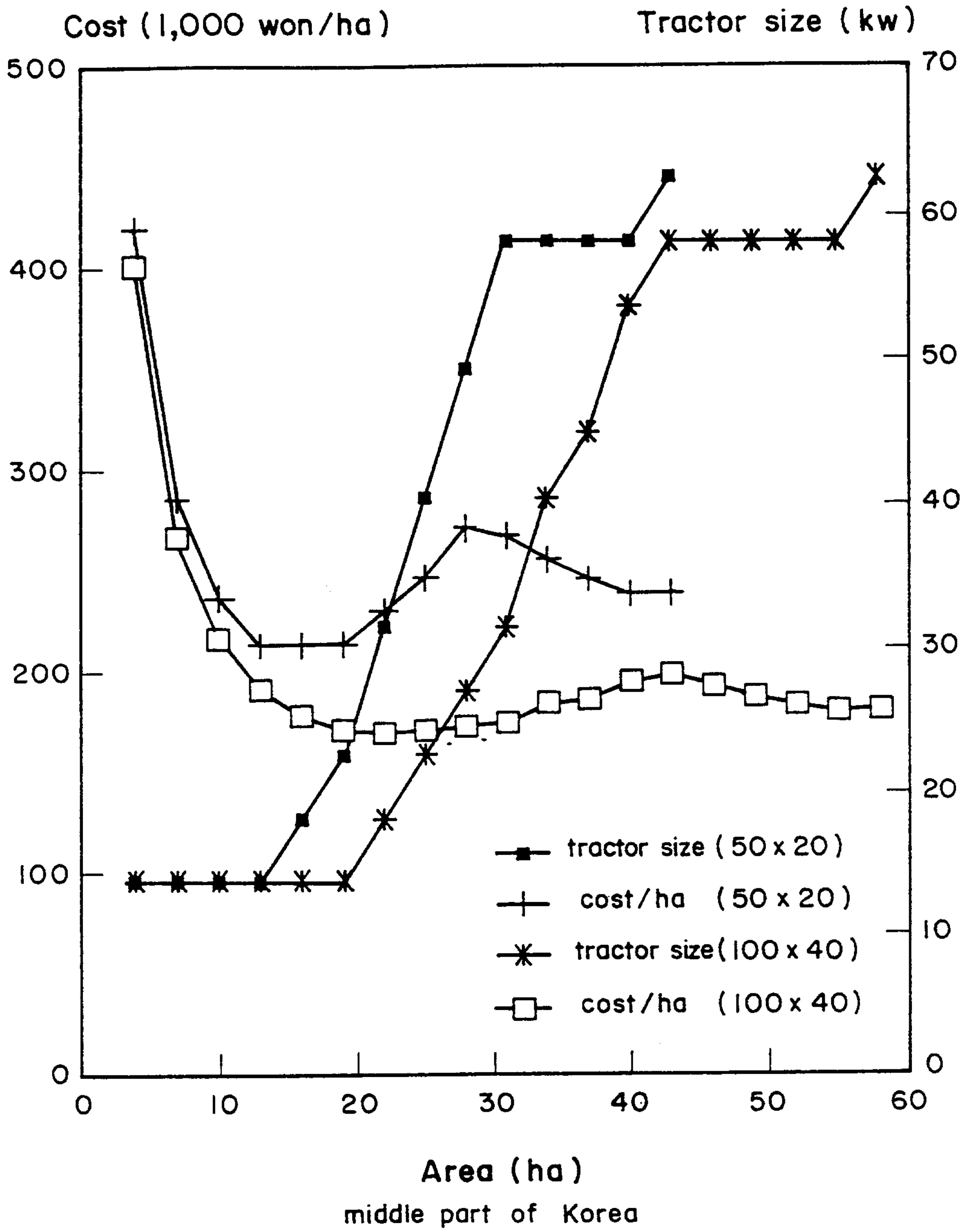


Fig. 4: Effect operation area on optimal tractor size and cost