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Criteria for Determining Working Area and Operating Cost for Long-Term Lease of Agricultural Machinery

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Abstract

Purpose: This research suggests a method of establishing criteria for working area and operating cost for a long-term lease of agricultural machinery. **Methods:** Eight crops were selected—three food crops and five open-field vegetables—and agricultural machines used for sowing, transplanting, and cultivation in dry-field farming were analyzed. **Results:** The break-even acreage for agricultural machinery under a long-term lease was found to differ by agricultural machine, ranging from 1.0 to 5.8 ha. In terms of arable land area, the break-even acreages for harvesting machinery and transplanters were 15.6 to 26.1 ha and 6.1 to 8.6 ha, respectively. The working area lessees should secure was divided into two cases: (1) 2.0 to 11.6 ha when leasing individual agricultural machines (sowing and transplanting) for a long-term period, and (2) more than 10 ha when farmers who cultivate beans, potatoes, garlic, onions, and so on lease sowing and transplanting machines as a set. When agricultural machinery was leased for a long term, the operating cost and working time were reduced by 27.6 to 74.4% and 2.5 to 21.6%, respectively, indicating considerable effect. **Conclusions:** A long-term lease project needs to be promoted to overcome the limitation of short-term leases of agricultural machinery. The local government should lead this project and facilitate the mechanization of dry-field farming. The department in charge of agricultural machinery lease projects needs to set the working area to cover the rate and maintenance cost for farmers who lease agricultural machinery for the long term.

Keywords: Agricultural machinery, Arable land area under burden, Break-even point, Long-term lease, Operating cost, Working area

Introduction

Unlike in rice farming (98%), the level of mechanization in dry-land farming in Korea has only reached 56% (RDA, 2014a). The low mechanization rate in dry-land farming can be explained by the diverse crops, scattered arable land, and small-scale cultivation (85 to 95% of farmhouses have less than 0.3 ha), which makes it difficult for farmers to purchase agricultural machinery (Statistics Korea, 2014).

To cope with this, the Korean government has since 2003 been pushing ahead with a project to allow farmers to lease and use agricultural machinery. This short-term lease project (1–3 days) operated by agricultural machinery rental business centers in 143 cities and countries involved agricultural machines with poor uptake that were used less frequently.

However, a short-term lease of agricultural machinery has some limitations in that it requires employees to manage the project and involves high cost for maintenance control. Therefore, it is necessary to develop a long-term (more than one year) lease project to promote the use of agricultural machinery and offer good service to lessors who are not limited by time and place and have no burden of labor and equipment. It is also necessary to establish new criteria to select lessors for the leasing project. Potential examples are as follows: (1) lessors who personally

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perform farming and maintain agricultural machines, (2) lessors who have the financial ability to pay the rental fee, and (3) lessors who have a certain size of working area. It should be noted that an appropriate operating cost should be suggested, considering that the use of agricultural machinery is not fully established. If lessees that do not have enough working area are selected for a long-term lease, this will result in a low utilization rate, as it will be difficult for the lessee to earn back the rental fee.

In Japan, the Ministry of Agriculture, Forestry and Fisheries has been encouraging the lease project since the 1980s and has developed supporting systems, for example, the farmhouse and farming system, the joint organization of agricultural machinery, and hybrid farmhouse management (Japanese Association of Agricultural Mechanization, 1998).

In the United States, manufacturers and dealers of agricultural machinery have been involved in renting high-priced machinery such as tractors and combines. There are two classifications of long-term leases in the United States: (1) operating leases in which lessors are in charge of maintenance and repair and can cancel mid-term, and (2) a finance lease in which lessees are in charge of maintenance and repair, but cannot cancel mid-term (NCFMEC, 2014).

In Germany, Maschinenringe (MR—the Bank of Agricultural Machinery) has had a leasing project since 1950. This project includes a brokerage for outsourcing farm work, a group purchasing business, and diverse farm support systems such as non-farm income and labor consultation (Ministry of Agriculture and Forestry, 2003).

This study was conducted to establish new criteria for working area and operating cost to effectively promote the long-term lease of agricultural machinery.

Materials and Methods

Calculation of break-even point and arable land area under burden

Break-even acreage for agricultural machinery leasing

In order for lessees to lease agricultural machines for a long time without economic loss, a working area of land over the break-even point should be secured. The calculation of the break-even point (BEP) for acreage was made after dividing the annual fixed cost (FC) of agricultural machinery by the value obtained from subtracting the variable cost (VC) from a custom rate using Equation 1 (RDA, 1993). Eight crops were selected in this study: three food crops (beans, sweet potatoes, potatoes) and five open-field vegetables (white radish, Chinese cabbage, chili peppers, garlic, and onions), which are the main cultivars of the area. In this study, the focus was agricultural machines for sowing-transplanting and cultivation in poorly mechanized dry-field farming.

$$BEP = \frac{FC}{CR - VC} \tag{1}$$

where, *BEP : Break-even point for acreage (ha/year)*
FC : Fixed cost (won/year)
CR : Custom rate (won/ha)
VC : Variable cost (won/ha)

Annual fixed cost

The annual fixed cost consists of depreciation, repair cost, and interest. Depreciation was estimated using the straight-line method using Equation 2. The initial purchasing price (P_i) was based on the "agricultural machine price" (KAMICO, 2015), and the salvage value (P_s) was derived from the "finance support guideline for used agricultural machinery in the Guidelines on the Agricultural Livestock Project" (MAFRA and KAMICO, 2015). In addition, the lifetime (L) of leased agricultural machinery was based on "life years of leased agricultural machinery in the agricultural machinery rental business operating guide" (RDA, 2011).

$$D_s = \frac{P_i - P_s}{L} \tag{2}$$

where, D_s *: Depreciation (won/year)*
P_i *: Initial purchase price (won)*
P_s *: Salvage value (won)*
L *: Lifetime (years)*

Interest (I) on the investment in agricultural machinery was calculated using Equation 3. Depreciation was estimated through the straight-line method. Here, the interest rate (i) was 2%.

$$I = \frac{P_i + P_s}{2} \times 2 \tag{3}$$

where, *I : Interest cost*
i : Interest rate

Annual repair cost (R_c) was obtained by multiplying the initial purchase price of leased agricultural machinery by the repair rate using Equation 4 (Jung, 1988). The repair rate (r) used in Equation 4 was 6%, which was suggested by the economic analysis method used by the Rural Development Administration.

$$R_c = P_i \times r \quad (4)$$

where, R_c: *Repair cost (won/year)*
r : *Repair rate*

Custom rate per hectare

A custom rate per hectare for the initial stage of mechanization was calculated by multiplying labor input hours per task times farm wage for harvest work. The labor input hour per task was based on the "labor input hours per crop growth stage" (RDA, 2013b). Farm wage was obtained from the National Statistical Office (Statistics Korea. 2014).

Variable cost per hectare

The variable cost of agricultural machinery is the cost incurred proportional to hours of use and calculated using Equation 5 (Jung, 1988). In the case of farm machinery, a fixed cost was applied for the power source. Fuel cost was calculated using Equation 6 (Jung, 1988). Work efficiency (C) was obtained from the "agricultural machinery performance test yearbook" (FACT, 2014). Fuel consumption (F) was based on data from "fuel consumption chart per machine standard hours" (NH, 2014). Fuel price (f) was based on the average cost of tax-free oil for farming. Lubricant cost (O) represents 15% of the total fuel cost applied. Labor cost (L_c) includes wages for assistant workers in addition to drivers in case of necessity. Drivers' wages are 1.4 times more than the wage for an average male. In addition, the fixed power source cost (T) is 0 for self-propelled machines.

$$VC = F_c + O + L_c + T \quad (5)$$

where, VC : *Variable cost (won/ha)*
F_c : *Fuel cost (won/ha)*
O : *Lubricant cost (15% of fuel cost)*
L_c : *Labor cost (won/ha)*
T : *Fixed cost of power source (won/ha; in the case of self-propelled machines, T = 0)*

Table 1. Suggested value to use in calculating break-even acreage for various farm machines

Crop	Machine	Model	P_i (1,000 won)	R_s (%)	L (year)	C (ha/h)	F (ℓ/h)	L_h (h/ha)	
								m	f
Soy-bean	seeder	HG800A	3,640	5	6	0.48	11.0	12	16
	bean cutter	M1-GS	9,000	10	5	0.13	1.2	23	38
	bean thresher	SWB5000	2,000	10	5	0.21	-	8	11
Sweet potato	power transplanter	TSP-1	15,000	10	6	0.06	1.0	52	115
	harvester	DR-1400CA	5,100	5	6	0.30	11.0	16	104
Potato	power seeder	ASK-2	12,000	10	7	0.12	-	19	44
	harvester	DR-1400AT	5,400	5	6	0.17	11.0	24	144
White radish	seeder	JPHS	4,000	5	6	0.41	11.0	32	48
Chinese cabbage	power transplanter	SKP-100W-KR	16,200	10	6	0.06	1.0	43	99
Chili	power transplanter	TVP-1	13,000	10	6	0.07	1.2	62	80
Garlic	seeder	JK-GPS10T	16,500	5	6	0.11	11.0	82	279
	harvester	DRGH-1400	3,800	5	6	0.30	11.0	12	63
Onion	power transplanter	OP-4-KR	31,000	10	6	0.07	1.4	33	245
	harvester	BG-1400GN	4,900	5	6	0.29	11.0	24	96
Common value	P_i: Initial purchase price, R_s: Rate of salvage ($P_s = P_i \times R_s$), L: Lifetime, C: Work efficiency, F: Fuel consumption, Lh: Labor input hours Interest rate (i): 2% , Repair rate (r): 6% Farm wage: male (F_{w1}) 97,000 won/day; female (F_{w2}) 64,000 won/day Fixed cost of power source (T): 27,900 won/h (tractor 44 kW) Fuel price (f): Gasoline 1,023 won/ℓ, diesel 1,071 won/ℓ								

$$F_c = C + F + f \quad (6)$$

where, F_c : *Fuel cost (won/ha)*
C : *Work efficiency (h/ha)*
F : *Fuel consumption (ℓ/h)*
f : *Fuel price (won/ℓ)*

All data used to calculate the break-even acreage are listed in Table 1.

Arable land area under burden

Under the given conditions of operating time and weather when the performance of agricultural machines can be maximized, an arable land area under burden was calculated using Equation 7 (Jung, 1988). Field efficiency (A_e) was obtained from the "agricultural machinery performance test yearbook" (FACT, 2014) and, as suggested by the manufacturers, takes into account machine width, speed, field capacity, and so on. In addition, daily hours of use (U), work rate (E_u), and effort days (E_d) were based on criteria suggested by "the agricultural mechanization trend and primary research direction" (RDA, 1993). The number of workable days (D) was obtained from a report titled "major crop farming order table" (RDA, 1995).

$$A = A_e \times U \times E_u \times E_d \times D \quad (7)$$

where, A : *Arable land area under burden (ha)*
A_e: *Field efficiency (ha/h)*
U : *Daily hours of use (h)*
E_u: *Work rate*
E_d: *Effort days*
D : *Number of workable days (days)*

All data used to calculate the arable land area under burden are listed in Table 2.

Determination of secured working area and operating cost

Secured working area for lessees

Agricultural operations must be carried out beyond a certain point in order for lessees to cover rental rate and repair cost. When considering the small cultivation scale of farmhouses in domestic cases, it is deemed difficult for each farmhouse to lease agricultural machinery. Accordingly, the leased machinery is considered to be used communally by a number of farmhouses. The working area of the lessees was set to be over the break-even acreage and under the arable land area under burden.

break-even point acreage ≤ working area ≤ arable land area under burden

Calculation of operating cost

Most farm work has been performed by laborers; some farm work, including sowing, transplanting, and harvesting is in the early stage of using agricultural machinery. In addition, an operating cost of agricultural machinery has

Table 2. Suggested value to use in calculating arable land area under burden for various farm machines

Crop	Operation	Machine (power source)	Model	A_e (ha/h)	E_u	E_d	D (day)
Soybean	sowing	seeder (tractor)	HG800A	0.47	0.75	0.86	20
	cutting	soybean cutter	M1-GS	0.13	0.72	0.72	30
	threshing	soybean thresher	SWB5000	0.21	0.72	0.72	30
Sweet potato	trans-planting	power transplanter	TSP-1	0.06	0.75	0.86	30
	harvest	harvester (tractor)	DR-1400CA	0.30	0.72	0.72	20
Potato	sowing	power seeder	ASK-2	0.12	0.75	0.86	20
	harvest	harvester (tractor)	DR-1400AT	0.17	0.72	0.72	20
White radish	sowing	seeder (tractor)	JPHS	0.40	0.75	0.86	20
Chinese cabbage	trans-planting	power transplanter	SKP-100W-KR	0.06	0.75	0.86	20
Chili	trans-planting	power transplanter	TVP-1	0.07	0.75	0.86	20
Garlic	sowing	seeder (tractor)	JK-GPS10T	0.11	0.75	0.86	20
	harvest	harvester (tractor)	DRGH-1400	0.30	0.72	0.72	20
Onion	trans-planting	power transplanter	OP-4-KR	0.07	0.75	0.86	30
	harvest	harvester (tractor)	BG-1400GN	0.29	0.75	0.72	20

not been determined thus far. Operating cost (C_h) is based on the cost of machine use, which is the sum of fixed cost divided by annual working area (A_a) and variable cost using the expression in Equation 8 (Jung, 1988). The annual working area (A_a) was based on the standard working area, and tractors were included as a variable cost, as a cost per hectare of a tractor use for the power source (VC_2).

$$C_h = \frac{FC}{A_a} + VC(= VC_1 + VC_2) \quad (8)$$

where, C_h : *Operating cost (won/ha)*
FC : *Fixed cost (won/year)*
A_a : *Annual working area (ha/year)*
VC_1 : *Variable cost of self-propelled machinery or working machinery (won/ha)*
VC_2 : *Variable cost of power source of working machinery (won/ha)*

Results and Discussion

Break-even acreage and arable land area under burden

Farmers who lease agricultural machinery must ensure that there is no economic loss when the machinery is not in use. That is, a minimum working area over the break-even acreage must be secured to cover the lease and repair costs of agricultural machinery. If farmers manage an area less than the break-even acreage after leasing the agricultural machinery, this undermines the efficiency of government-led lease projects and creates economic loss.

The break-even acreage of agricultural machinery under long-term lease is listed in Table 3. The calculated break-even acreage of agricultural machinery ranges from 1.0 ha to 5.8 ha depending on the machine type. In addition, the break-even acreage for sowing and transplanting (high-priced machines) were relatively higher than for other tasks.

One of the traits of farm work is an optimal time. The arable land area under burden is defined as the area in which farmers use agricultural machinery during the best time. The calculated arable land area under burden is listed in Table 3. The arable land area under burden is based on a single unit of agricultural machinery leased in a large-scale working area.

The arable land area under burden varied greatly between machines, influenced by work efficiency. As a result, a harvesting machine has a high range of arable land area under burden, ranging from 15.6 ha to 26.1 ha. In the case of a transplanter, which has relatively low work efficiency, the arable land area was 6.1 ha to 8.6 ha.

The break-even acreage and arable land area under burden calculated in this study can vary depending on optimal number of working days and the capability of agricultural machinery in the crop-growing area. Therefore, it is desirable to calculate the break-even acreage and

Table 3. Break-even point (BEP) for acreage and arable land under burden (A) of individual agricultural machines under a long-term lease

Crop	Operation	Machine (power source)	Model	BEP (ha)	A (ha)
Soy-bean	sowing	seeder (tractor)	HG800A	4.0	48.5
	cutting	soybean cutter	M1-GS	5.2	15.6
	threshing	soybean thresher	SWB5000	4.8	26.1
Sweet potato	trans-planting	power transplanter	TSP-1	3.1	8.6
	harvest	harvester (tractor)	DR-1400CA	1.3	25.1
Potato	sowing	power seeder	ASK-2	5.8	12.4
	harvest	harvester (tractor)	DR-1400AT	1.0	14.1
White radish	sowing	seeder (tractor)	JPHS	1.3	41.3
Chinese cabbage	trans-planting	power transplanter	SKP-100W-KR	3.6	6.1
Chili	trans-planting	power transplanter	TVP-1	2.8	6.9
Garlic	sowing	seeder (tractor)	JK-GPS10T	1.3	11.4
	harvest	harvester (tractor)	DRGH-1400	1.7	24.9
Onion	trans-planting	power transplanter	OP-4-KR	3.4	11.1
	harvest	harvester (tractor)	BG-1400GN	1.2	24.1

Table 4. Secured working area for long-term lessees of agricultural machinery

Crop	Operation	Machine	BEP	A	Working area	
					Individual machinery	Individual crop
Soybean	sowing	seeder (tractor)	4.0	48.5	8.0[a)]	10.4[c)]
	cutting	soybean cutter	5.2	15.6	10.4[a)]	
	threshing	soybean thresher	4.8	26.1	9.6[a)]	
Sweet potato	trans-planting	power transplanter	3.1	8.6	7.7[b)]	7.7[c)]
	harvest	harvester (tractor)	1.3	25.1	2.6[a)]	
Potato	sowing	power seeder	5.8	12.4	11.6[a)]	11.6[c)]
	harvest	harvester (tractor)	1.0	14.1	2.0[a)]	
White radish	sowing	seeder (tractor)	1.3	41.3	2.6[a)]	2.6
Chinese cabbage	trans-planting	power transplanter	3.6	6.1	5.5[b)]	5.5
Chili	trans-planting	power transplanter	2.8	6.9	5.6[a)]	5.6
Garlic	sowing	seeder (tractor)	1.3	11.4	10.3[b)]	10.3[c)]
	harvest	harvester (tractor)	1.7	24.9	3.4[a)]	
Onion	trans-planting	power transplanter	3.4	11.1	10.0[b)]	10.0[c)]
	harvest	harvester (tractor)	1.2	24.1	2.4[a)]	

[a)]Twice the break-even acreage.
[b)]90% of arable land area under burden.
[c)]The highest working area of an individual crop.

arable land area taking local government and agricultural machinery rental office policies into account.

Secured working area and operating cost for lessees of agricultural machinery

The working area on which lessees use agricultural machinery must be greater than the break-even acreage and less than the arable land area under burden. When the working area is closer to the break-even acreage, the operating costs increase, and the efficiency of agricultural machinery decreases. If lessees of agricultural machinery are required to secure a working area close to the arable land area under burden, the application rate by farmers who have small-scale farmlands will decrease, which will cause a setback in promoting the use of agricultural machinery. In addition, it is necessary to determine the proper working area for the long-term lease of agricultural machinery as part of the lease administration.

In this study, the working area that lessees of agricultural machinery should secure is set using the following method. First, the area lessees should secure is determined to be two times higher than the break-even acreage. However, in the case of seeders and transplanters for some crops, a small working area leads to a high cost, so it should be adjusted to 90% of the arable land area under burden (considering an excess rate of 10%).

As a result, the working areas for lessees using long-term leases of agricultural machinery ranged from 2.0 to 11.6 ha, influenced by machine price and work efficiency. In the case of upland crops, agricultural machinery should be provided as one set to promote the use of agricultural machinery for sowing, transplanting, and harvesting. It was revealed that lessees cultivating soybeans, potatoes, garlic, and onions have to secure working areas greater than 10 ha (Table 4).

Operating cost and its effect on agricultural machinery leasing

The operating cost for leased agricultural machinery is the cost of operating the machinery. The cost of operating machinery here considers the standard area of each crop (as listed in Table 4) to be the area worked annually using leased agricultural machinery; the calculation is shown in Table 5. That is, it is the minimum operating cost to ensure an accurate rental rate for agricultural machinery including repair cost and labor cost. When considering the operating cost in rural areas and expanded working areas, the calculated operating cost can be higher than those in Table 5. This study revealed that the operating cost of transplanting machines for six crops (except for

Table 5. Operating cost and effect of agricultural machinery on a long-term lease

Crop	Operation	Operating cost (thousand won/ha)			Operating hours (h/ha)		
		Machine work (a)	Custom work (b)	a/b × 100 (%)	Machine work (c)	Custom work (d)	c/d × 100 (%)
Soybean	trans-planting	203	273	74.4	2.1	28	7.5
	harvest	494	768	64.3	12.8	80	16.0
Sweet potato	trans-planting	901	1,550	58.1	36.0	167	21.6
	harvest	371	1,027	36.1	6.6	120	5.5
Potato	sowing	344	550	62.5	8.3	59	14.1
	harvest	503	1,444	34.8	12.0	168	7.1
White radish	sowing	493	772	63.9	2.4	80	3.0
Chinese cabbage	trans-planting	959	1,313	73.0	17.0	142	12.0
Chili	trans-planting	887	1,391	63.8	30.0	142	21.1
Garlic	sowing	892	3,227	27.6	9.0	361	2.5
	harvest	304	650	46.8	6.6	75	8.8
Onion	trans-planting	1,057	2,362	44.8	28.0	278	10.1
	harvest	342	1,060	32.3	7.0	120	5.8

Power source of working machinery: tractor 44 kW (fixed cost: 27,900 won/h, annual use: 181 hours, number of persisting years: 8, persistence rate: 30%, coefficient of repair cost: 6%, interest: 2%)

sweet potatoes and soybeans) ranged from 887 to 1,057 thousand won, a relatively high range. Conversely, the operating cost for sowing and harvesting work was less than 500 thousand won. As a result, the operating cost and operating hours for each agricultural machine were reduced by 27.6 to 74.4% and 2.5 to 21.6%, respectively, compared to the cost and hours of performing the tasks using manual labor.

Conclusions

This study suggested new criteria or determining the operating cost and working area for lessees of agricultural machinery to promote the long-term leasing of agricultural machinery in dry-field farming.

(1) The break-even acreage for long-term leasing of agricultural machinery was found to differ by machine type, ranging from 1.0 to 5.8 ha. In addition, the arable land areas under burden for harvesting and transplanter (with low work efficiency) machines were 15.6 to 26.1 ha and 6.1 to 8.6 ha, respectively.

(2) The working area lessees should secure was divided into two cases: (1) 2.0 to 11.6 ha when leasing individual agricultural machines (sowing and transplanting) for a long-term period, and (2) more than 10 ha when farmers cultivating beans, potatoes, garlic, onions, and so on lease sowing and transplanting machines as one set.

(3) The operating cost of transplanting machines for six crops (except for sweet potatoes and soybeans) ranged from 887 to 1,057 thousand won, a relatively high range. Conversely, the cost of sowing and harvesting work was less than 500 thousand won. As a result, the operating cost and operating hours for agricultural machines were reduced by 27.6 to 74.4% and 2.5 to 21.6%, respectively, compared to the cost and hours of performing the tasks using manual labor.

(4) A long-term leasing project needs to be promoted by local government to overcome the limitations of short-term leasing of agricultural machinery and facilitate the mechanization of dry-field farming. The department in charge of agricultural machinery leasing projects needs to set an appropriate standard area to cover repair and maintenance costs for farmers who use a long-term leasing service for agricultural machinery.

Conflict of Interest

The authors have no conflicting financial or other interests.

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