트랙터 耕耘碎土費用分析模型에 關한 硏究

Development of A Model For Estimating The Cost of Tractor Tillage Operation

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摘 要

本 論文은 트랙터를 利用한 耕耘碎土作業費用을 算出하기 위한 模型을 開發하고 이 模型을 實用化하기 위해 必要한 資料를 分析함과 同時에 이를 適用하여 트랙터를 利用한 耕耘碎土費用을 計算하는데 있었다.

또 지난 21年間의 氣象觀測記錄에서 分析한 트랙터耕耘碎土作業可能日數 및 其他 不變値들을 利用하여 트랙터規格, 地域別 트랙터耕耘碎土作業의 負擔面積을 計算하였다.

또 트랙터耕耘碎土作業費用 計算에 必要한 모든 變數들의 時系列分析을 實施하여 慣行耕耘碎土作業費用과의 損益分岐年度를 計算할수 있도록 하였다.

本 論文에서 誘導한 耕耘碎土費用 算出模型을 利用하여 地域別, 作業條件別로 트랙터耕耘碎土作業費用을 計算하였으며 그分析結果는 다음과 같다.

1. 트랙터耕耘碎土作業의 年間負擔面積은 다음 一般式을 利用하여 計算할 수 있다.

$$A=\frac{1}{10}e_f e_u e_d\ SWUD.$$

2. 地域別, 季節別 트랙터耕耘碎土作業, 可能日數를 分析한 結果 旬間作業 可能日數는 地域, 月, 季節에 따라 差異가 있으며 大略 6～9日의 範圍였다.

3. 本論文에서 誘導한 다음과 같은 트랙터 耕耘碎土費用算出模型은 定義된 파라미터에 適當한 값을 주므로서 어떠한 作付體系나 어떠한 作業條件에도 適用이 可能하다.

$$H(t)=\frac{FC_P\%P_P(t)}{A(1+\beta)}+\frac{10\alpha}{S_P W_P e_{fP} e_{uP}}\Big[(F_P+O_P)K(t)+L(t)+T(t)\Big]+\frac{FC_R\%P_R(t)}{A(1+\beta)}+\frac{10}{S_R W_R e_{fR} e_{uR}}\{(F_R+O_R)K(t)+L(t)+T(t)\}$$

$$T(t)=\frac{FC_T\%P_T(t)}{(1+\gamma)\left(\frac{10\alpha A}{S_P W_P e_{fP} e_{uP}}+\frac{10(1+\beta)A}{S_R W_R e_{fR} e_{uR}}\right)}$$

4. 本 論文에서 誘導한 트랙터耕耘碎土費用 算出模型을 使用해서 慣行耕耘碎土作業費用과의 損益分岐年度를 推定할 수 있으며 트랙터의 經濟的인 利用年度를 決定하는데 매우 有用하게 使用될 수 있다.

損益分岐年度 分析結果 南部의 二耗作地域에서는 트랙터를 利用한 耕耘碎土作業이 어느程度는 妥當하지만 北部와 中部地域에서는 當分間은 經濟的으로 不利하다.

5. 트랙터를 利用한 耕耘碎土作業費用은 年間負擔面積 또는 年間稼動日數에 따라 큰 差異가 있는 反面 트랙터規格에 따른 差異는 前者에 比해 작다. 따라서 트랙터를 選定할 때에는 트랙터利用費用보다는 負擔面積, 農路, 利用組織等과 같은 技術的인 要因들을 充分히 檢討하는것이 바람직하다.

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I. INTRODUCTION

It is necessary that in selecting farm machinery not only technical but also economical evaluations be seriously taken into consideration. The farm machinery must have suitable enough capacities that they can come into full operation within the optimum cropping time and can produce the maximum income of cultivation out of the minimum machine operating costs. Therefore, with the technical evaluation taken as the necessary condition, the economical evaluation should be regarded as the sufficient condition.

When farm machinery that have been developed in foreign countries are introduced to a developing country like Korea, where farm mechanization is in its initial stage, the most urgent thing is to analyze the essential and sufficient conditions on the present scene of mechanized farming and to inspect whether the imported farm machinery are fit for the conditions. However mere application of foreign evaluation methods to farming in Korea serves, as we see, to bring about complicated problems because there are wide differences in farming and cropping conditions between the exporting countries and our nation.

In order to wipe out the technological and economical differences and eliminate the loopholes in the program of importing farm machinery, optimum evaluation methods should be developed so as to meet the needs of the farming environment, the farming structure, and the farming methods in this country. However, no work on analyzing the cost of using tractors on farms in Korea has been done so far.

The objectives of this study were:

1) to develop a model for analyzing the cost of using tractors in plowing-rotavating operations, which may be the major operational use along with various tractor attachments.

2) to analyze the basic materials necessary for cost estimation such as the number of good workable days, machine performance rates, and annual coverage area of machines for different conditions and area.

3) to illustrate the application of a model for a specific condition.

To make practical use of the model, the needed materials and data were surveyed and analyzed. From the results of the field surveys, the conventional plowing-rotavating cost equation was formulated and in the process it was possible for the present investigator to estimate the break-even year of the machine costs when compared with the costs by a conventional method.

II. REVIEW OF LITERATURE

In analyzing tractor costs, it is common for tractor costs to be divided into two categories: fixed and variable costs. Fixed costs are independent of operational use, while the variable costs depend upon the hours in use.

However, it is not always clear to which category some of the specific costs belong. Generally, the costs of depreciation, the interest on investment, insurance and shelter costs are included in the fixed costs and the costs of repair and maintenance, labor charge, fuel, and lubrication are included in the variable costs.

Chancellor (3) classified the annual tractor costs into three categories: fixed costs, energy costs, and time costs. He defined costs as follows;

"Fixed costs are the costs that the owner must meet if the tractor is put in a shed and not used at all such as interest, taxes, insurance, housing, and only the portion of depreciation associated with obsolesence and time deterioration. Energy costs are the ones which are directly proportional to the amount of work done by tractors regardless of their size such as fuel, lubricants, repairs and maintenance and the portion of the depreciation associated with wearing due to use. Time costs are directly proportional to the numbers of hours the tractor operates, regardless of tractor size".

Kisu and other authors (7) classified tractor costs according to the general cost classification method, but the costs of taxes, insurance, and housing were excluded from the cost calculation. Depreciation may vary according to the computing methods. Among the various methods the straight-line is generally accepted because of its simplicity in computing. The annual interest charge to be included as the opportunity cost is the product of the annual interest rate and the average investment during the machine life (2) (4) (5) (16) (17).

Some authors (4) (5) (6) (7) combined the costs of depreciation, interest on investment, taxes, housing, and insurance into a single percentage of the purchase price and regarded them as part of the annual fixed cost percentage.

The repair and maintenance cost is very important because it determines the time for replacement of a machine. The expression of repair costs by percentage in the purchase price is commonly used (17). The former work indicated that the total repair costs of the machine during the service life varies from 70 per cent to 120 percent of the purchase price (4) (5) (7). This wide variation may be attributed mainly to the variable characteristics of the cost itself and, in addition, to the different basis of its estimation.

Operating cost of tractors vary according to their size and annual use. Jones (5) concluded from the results of his study on the operating cost of tractors that: (1) The larger the tractor, the greater the hourly operating costs, (2) The fixed costs remain relatively constant, regardless of the total hours of annual use, (3) The operating costs vary directly as the total hours of annual use, (4) Depreciation and fuel are the most important cost items in tractor operation, (5) The greater the annual use in hours, the lower the total operating costs per hour, (6) The cost per horsepower-hour remains relatively constant regardless of the size of the tractor, but under any conditions is greatest for low annual use and lowest for a high annual use.

Farm machinery selection must be based on the anticipated machine performance and operating cost. In other words, a machine that can complete an operation within an optimum time and minimize the operating costs is desired.

Hunt (4) indicated that in machinery selection the most pertinent variable is the machine size or capacity and expressed all of the factors that have to do with the machine cost as a function of implement width. He indicated that all of the repair and maintenance, fuel and lubrication costs were proportional to the annual use or annual coverage. Then he dropped these costs out of consideration in selecting machinery. He considered the inability of an implement to complete an operation within an optimum time as an hourly charge against the implement. He developed the optimum width equation, in which the timeliness factor K was additionally included in the least-cost-width equaion. K values so defined were specified separately for different farming operations.

Kisu (7) expressed all of the factors having to do with the tractor operating costs as a function of tractor engine horsepower P and developed a tractor operating cost equation by using tractor price coefficient α, fuel coefficient β, annual use in hour x, and hourly labor cost l.

$$Y_a=\left[\left\{\frac{2}{\left(13-\frac{10}{P}\right)\left(1-\frac{x}{2400}\right)x}+\frac{0.028}{x}\right\}\alpha P^{3/4}+\beta P+l\right]\cdot\left(\frac{9}{P}+1\right)$$

in which Y_a=tractor operating cost per 10 are.

He examined his model in various types of tractors and recommended that it be used for selecting tractors.

Chancellor (3) expressed annual tractor cost Z, as a function of rated power-take-off horsepower H. The minimum cost horsepower H^* was derived by taking the derivative of the cost function with respect to H. He then modified the expression of H^* by taking into account the loss of yield due to untimely operation. The optimum horsepower equation is given as follows;

$$H=\sqrt{\frac{LW(C+LD)}{AK}}$$

where, A=ratio of fixed charges to initial tractor cost,

K=initial cost of tractor per rated horsepower,

L=land area worked per year,

W= rated hp-hrs required per year for each unit of land,

C= operating costs which are proportional to time of operation

D= average penalty in cost per area-working hr for the delay between the time a cultural operation is started on a given farm and the time it is completed.

The concepts of the-least-cost width and optimum width of a machinery as outlined above may be too general to apply them directly to the farming in Korea. The cost of operating tractors or their implements must be estimated by including factors pecular to our farming situation. No work in this field has been done so far.

III. DEVELOPMENT OF MODEL

1. Definition of Parameters

The parameters used in this study are defined as follows.

Plow-Rotavator Ratio In the case of conventional paddy preparation in spring, complete plowing is generally followed by harrowing. Because of the efiectiveness of tractor rotavating, the soil prepared by tractor rotavation may be used to plow the paddy only once in several years. To accomodate this condition the plow-rotavatoring ratio α is defined as the ratio of the plowing area in a year to the coverage area of tractor rotavating. Thus, it can be expressed as

$$\alpha=\frac{A_P}{A} \text{ or } A_P=\alpha A \qquad (1)$$

where A=tractor coverage area (ha)

A_P=partial area of annual coverage for plowing followed by rotavating (ha)

$A_P=\alpha A$	$A(1-\alpha)$	(in Spring)

Fig. (1) Definition of Parameter α

Cropping Rate Parameter The double-cropping, rice-barley rotation is usually practiced in the southern and central parts, while it is rarely practiced in the northern area in Korea. The difference of these cropping methods could alter considerably the operational pattern of tractors. To accomodate this condition in the model to be developed, the cropping-rate parameter is defined here as the area engaged for double-cropping in the entire tractor coverage area:

$$\beta=\frac{A_b}{A} \text{ or } A_b=\beta A \quad (0\leq\beta\leq 1) \qquad (2)$$

where A_b is the portion of area used for double-cropping in the entire tractor coverage area.

$A_b=\beta A$	$A(1-\beta)$	(in Autumn)

Fig. (2) Definition of Parameter β

Multi-function parameter The annual total number of operating hours of a tractor could be increased by attaching as many implements as possible. This practice in turn could reduce the fixed costs of tractor. However, the portion of tractor operating hours besides its use for tillage operation may be quite variable according to farming and other conditions in which a tractor is used. To accomodate these variable conditions, a new parameter was introduced in this study. The multi-function parameter γ is defined here as the ratio of total annual operating hours for miscellaneous work done by a tractor as prime power to the total annual operating hours of tractors used for tillage operation (plowing and rotavating), which can be expressed as:

$$\gamma=\frac{T_m}{T_{Pr}} \text{ or } T_m=\gamma T_{Pr} \qquad (3)$$

where: T_{Pr}=total annual operating hours of a tractor for tillage operation,

T_m=total annual operating hours of a tractor used for miscellaneous work (manure spreading, seeding, spraying and transportation, etc.)

2. Assumptions made in developing a model

In developing a model for estimating the costs of tractor tillage operation, the following assumptions were made:

(1) We can anticipate some differences in the costs of soil preparation by a tractor between spring and fall due to difference in physical soil condition, operational seasons, and daily working hours. However, as a matter of convenience, it is assumed that the rotavating cost per hectare in spring is the same as in autumn.

(2) The purchase price of a farm tractor and implements, fuel and lubricant, labor charge, and conventional tillage operation cost may vary year by year with certain trends.

(3) The conventional tillage operation cost change has the same trend as the cost of agricultural labor charge does.

3. Development of the cost function of tractor tillage operation

The annual cost of maintenance and operation of a farm tractor is made up of fixed costs and variable costs; the former consist of depreciation cost, interest on investment, housing, and insurance, while the latter consist of fuel and lubricant costs, and labor charges.

Repair cost can be expressed by percentage of the machine purchase price and, for the sake of convenience, is included in the fixed costs even though it has been conceptionally treated in general as a part of the variable costs.

All the components of fixed costs are expressed by percentage of the purchase price. On this basis, the annual operating cost of a machine can be approximated by:

$$AC=FC\%P+\frac{10A}{SWe_f e_u}(F+O+L+T) \quad (4)$$

where: AC=the annual operating cost of a machine (Won/Year).

$FC\%$=annual fixed cost percentage,

P=purchase price of an implement (Won),

A=coverage of an implement in hectare,

S=forward speed of an implement in km/hr.,

W= effective width of an implement in m.,

e_f=field efficiency,

e_u=labor efficiency,

F and O=fuel and lubrication costs per hour,

L= hourly labor charge,

T=hourly fixed cost of a tractor.

The hourly fixed cost of a tractor can be computed by the following equation.

$$T=\frac{FC_T\%\ P_T}{T_e} \quad (5)$$

where: $FG\%$=annual fixed cost percentage of tractor,

P=purchase price of tractor,

T_e=total annual use of tractor in hours (hr/year).

T_e represents the total annual number of operating hours by employing a tractor as the prime force of all the implements: plow, rotavator, fertilizer, seeder, trailer, etc. The total annual number of operating hours of a tractor can be computed by summing up the needed hours for plowing-rotavating (that are the tractor's main usage) and the hours for other miscellaneous works. Therefore, by introducing the multi-function parameter, T_e can be expressed as:

$$T_e=(1+\gamma)\left(\frac{10\alpha A}{S_P W_P e_{fI} e_{uP}}+\frac{10(1+\beta)A}{S_R W_R e_{fR} e_{uR}}\right) \quad (6)$$

When equations (5) and (6) are combined, the hourly fixed cost of a tractor is:

$$T=\frac{FC\%P_T}{(1+\gamma)\left(\frac{10\alpha A}{S_P W_P e_{fP} e_{uT}}+\frac{10(1+\beta)A}{S_R W_R e_{fR} e_{uR}}\right)} \quad (7)$$

To convert the annual machine cost into the cost per hectare, the equation (4) should be divided by the annual coverage area of a machine, which gives:

$$H=\frac{AC}{A}=\frac{FC\%P}{A}+\frac{10}{SWe_f e_u}(F+O+L+T) \quad (8)$$

where: H is the cost of operating an implement with tractor prime power, Won per hectare.

If the defined parameters, the assumptions made, and equation (8) are combined, the equation for estimating the cost of tillage operation per hectare is given as follows:

$$H=\frac{FC_P\%P_P}{A(1+\beta)}+\frac{\alpha}{S_P W_P e_{fP} e_{uP}(1+\beta)}(F_P+O_P+L+T)+\frac{FC_R\%P_R}{A(1+\beta)}+\frac{10}{S_R W_R e_{fR} e_{uR}}(F_R+O_R+L+T) \quad (9)$$

In equation (9), all the factors which could vary year by year should be expressed as the function of year (t).

$$H(t)=\frac{FC_P\%P_P(t)}{A(1+\beta)}+\frac{10\alpha}{S_P W_P e_{fP} e_{uP}}[(F_P+O_P)K(t)+L(t)+T(t)]+\frac{FC_R\%P_R(t)}{A(1+\beta)}+\frac{10}{S_R W_R e_{fR} e_{uR}}[(F_R+O_R)K(t)+L(t)+T(t)] \quad (10)$$

$$T(t)=\frac{FC_T\%\ P_T(t)}{(1+\gamma)\left(\frac{10\alpha A}{S_P W_P e_{fI} e_{uP}}+\frac{10(1+\beta)A}{S_R W_R e_{fR} e_{uR}}\right)} \quad (11)$$

Where: $P_P(t)$, $P_R(t)$, $P_r(t)$=purchase price of plow, rotavator, and tractor in t year, respectively,

$K(t)$=the rate of change of fuel and lubricant costs in t year,

$L(t)$=labor cost function in t year,

$T(t)$=fixed costs of a tractor in t year.

If machine operation cost $H(t)$ per hectare in a given year is to be estimated by using equation (10) and (11), the appropriate values for all the factors should be employed.

IV. APPLICATION OF THE MODEL

1. Factor analysis affecting the coverage in tractor tillage operation.

(1) General equation of the coverage in tractor tillage operation.

There are a number of factors involved in determining the area that a tractor operation can be accomplished within an available working duration. The major factors affecting the coverage are field capacity of implements and total workable span of hours within the period. However, there are a number of factors that can limit the available working time, which in turn reduces the size of machinery coverage. To estimate the average tillage coverage by a tractor, it may be necessary to analyze and relate its factors.

From consideration of field capacity of tillage machinery and all the factors affecting the workable span of hours, a general equation for estimating the average coverage may be given by:

$$A=\frac{1}{10}e_f e_u e_d \text{ SWUD} \qquad (12)$$

where: A=annual coverage of tillage operation by a tractor (ha)

S=forward speed in km/hr,

W=effective width of an implement in meter,

U=daily workable hours

D= workable days in the operation duration (day)

e_f=field efficiency (decimal)

e_u=labor efficiency (decimal)

e_d=percentage of days being good for tractor tillage operation (decimal)

In the equation (12), (SW) refers to the theoretical field capacity, $(e_f SW)$ to the effective field capacity, and $(e_u U)$ to the actual workable hours in a day. Therefore, $(e_f SW)$ $(e_u U)$ represents the actual machine capacity in hectares per day.

(2) Machine capacity and field and labor efficiencies

The rate at which a machine cover a field while performing its intended function is the function of the rated width of the machine, the speed of travel, and the amount of field time lost during the operation. The maximum permissible forward speed and the width of an implement are related to such factors as the condition of field, the amount of power available, and the nature of the operation. The forward speed and effective width generally used for different tractors are summarized in Table (2) to make them use of the cost analysis to be followed.

Field efficiency is the ratio of effective field to theoratical field capacity, expressed as percent. It includes the effects of time lost in the field and of failure to utilize the full with of the machine. A turn at the ends or a corner of a field represents a loss of time that is often of considerable importance, especially for small and short fields. The field efficiencies for different sizes of field and different ratios of width to length are shown in Table (1) (17).

Farm land in Korea is generally very small in size. If the tillage operation with high capacity tractors is attempted in this small-scaled farm land, there must be inevitably frequent servicing and travelling to and from the field as well as field time lost due to major adjustments and repairs.

These time losses may be very great if a tractor is large in size and at the same time the pieces belonging to an individual farm are far apart. Therefore, the labor efficiency (e_u) is included in this study to accomodate this condition. Bateman (1) studied the labor efficiency, the definition of which is directly adoptable to this study. However, the study of the labor efficiency for different conditions is not available at present and thus arbitrarily chosen as given in Appendix Table (3).

(3) Daily working hour

An 8-hour workday is generally accepted in other industries all the year round. But in farm work it is impossible to make a clearcut timetable, because the machine operation is dependent upon seasonal and weather conditions that affect cropping functions.

Table (1). Dimensions of tillage implements for different sizes of tractors used in cost analysis.

Tractor size	Implements	Size	Forward Speed (km/hr)	Effective Width (m)
25HP	Plow	12″×2	4.5	0.57
	Rotavator	1.2m	1.6	1.15
35HP	Plow	14″×2	4.5	0.68
	Rotavator	1.6m	2.0	1.58
45HP	Plow	14″×3	4.5	1.00
	Rotavator	1.8m	2.0	1.76

Table (2). Field efficiencies for different sizes of field and different ratios of width to length 1/.

Field sizes & shapes				Field efficiency (%)	
Width (m)	Length (m)	Area (a)	Ratio	Bottom plow mounted	Rotavator mounted
20	50	10	2.50	47	50
	75	15	3.75	58	60
	100	20	5.00	65	67
	200	40	10.00	82	80
25	40	10	1.60	45	50
	80	20	3.20	63	66
	100	25	4.00	69	71
	200	50	8.00	84	83
30	50	15	1.67	53	59
	80	24	2.67	66	69
	100	30	3.33	71	74
	200	60	6.67	85	85
40	50	20	1.25	56	64
	75	30	1.88	67	73
	100	40	2.50	73	78
	200	80	5.00	86	88
50	50	25	1.00	58	67
	80	40	1.60	69	77
	100	50	2.00	74	81
	200	100	4.00	86	89

1/ Refer to literature (17).

If the daytime between the sunrise and the sunset is the workable span, the daily workable hours in spring and autumn naturally differ from each other. In some farming operations, it may be possible to operate a machine continuously and extend the machine operation into the night by exchanging its driver. However, it is common practice in machine schedules to determine daily workable hours from a realistic basis.

Accordingly, in this study, it was assumed that the workable span of hours in a day may be between the sunrise and the sunset. In addition, three

Table (3). The daily operating hours of farm machinery by month and by 10-day period.

Month \ Ten-day period	First 10-day period	Mid 10-day period	Last 10-day period
April	8.47	11.10	10.33
May	9.61	11.11	11.27
June	11.49	11.49	11.45
October	8.39	8.45	7.58
November	7.29	7.10	6.85

hours within the workable span were reserved: one hour for breakfast, one for lunch, and one for leisure time. In the process, the daytime hours between the sunrise and the sunset with three hours reserved are regarded as the actual hours of machine operation. The actual daily operating hours of machinery analyzed on these basis are given in the Table (3).

(4) Workable days and percentage of days being good for tillage operation.

The working duration for tillage operation both in spring and fall depends upon the cropping system and regional and climatic conditions. Lengthening the working duration may result in increasing the operational hours of machinery and thus in reducing the fixed cost of machinery use. However, this duration must be determined so as to avoid relative economical loss due to untimely tillage operation.

Figure (3) (4) (5) shows the cropping systems for three different regions determined from the available informations and some survey data. The duration of the spring tillage operation in some

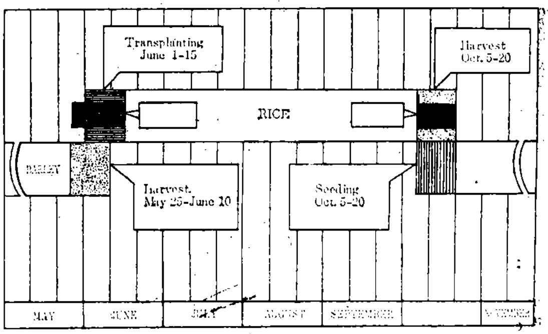


Fig. (4). CROPPING SYSTEM OF RICE AND BARLEY IN CENTRAL REGION.

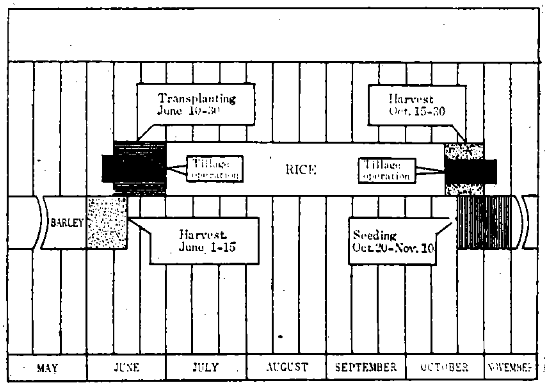


Fig. (5). CROPPING SYSTEM OF RICE AND BARLEY IN SOUTHERN REGION.

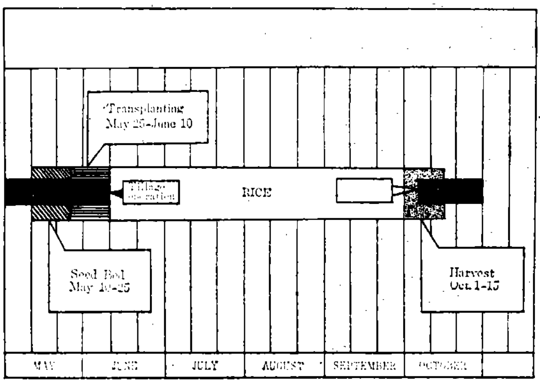


Fig. (3). CROPPING SYSTEM OF RIGE IN NORTHERN REGION.

southern regions, for example, is from June 5 to June 25. It will be assumed in this study that operating duration specified in the cropping system are the available days for tillage operation and that, if the operation is actually done within the period, no differences in yield are expected.

It may be noted that all the days within the available working period could not be used for tillage operation because of bad weather condition, mainly due to rainfall.

To predict the number of days being good for tractor tillage operation within the available duration, the record of rainfall classified by 10-day period and by regions were analyzed. Twenty-one years records were available for this study. Daily rainfall less than 10mm was considered to give no effect on tillage operation. The comulative frequency distribution of such days and days without rainfall at all were analyzed and some of the analysis are illustrated in Fig. (6) to (11).

From this analysis, it can be seen that the frequency of occurrance for workable days are quite different between months. The days being good for tillage operation used for machinery scheduling in a given region and 10-day period of a month were specified at the 66% probability level. In other words, the number of days during 10-days period corresponding to the 66% occurrance of days with less than 10mm in rainfall were defined as days being

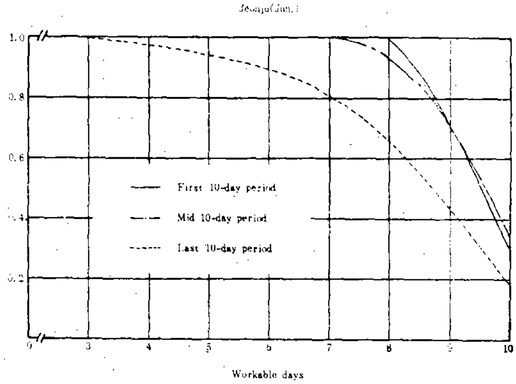
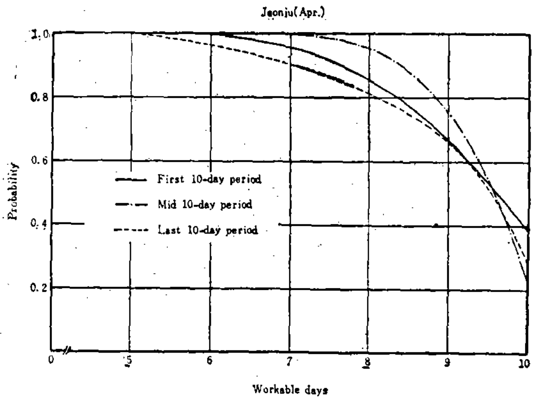


Fig. (8). The cumulative distribution of weather being good for tractor tillage operation. (Jeonju, June)



Fig, (6). The cumulative distribution of weather being good for tractor tillage operation. (Jeonju, April)

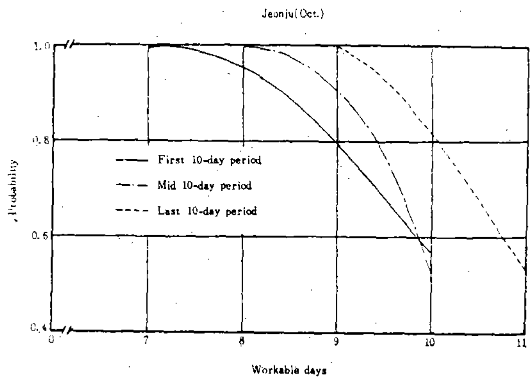


Fig. (9). The cumulative distribution of weather being good for tractor tillage operation. (Jeonju, October)

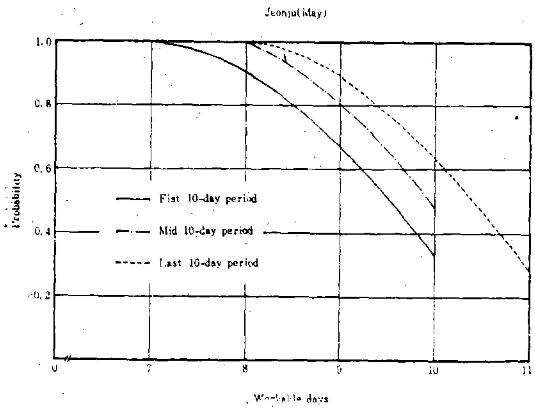


Fig. (7). The cumulative distribution of weather being good for tractor tillage operation. (Jeonju, May)

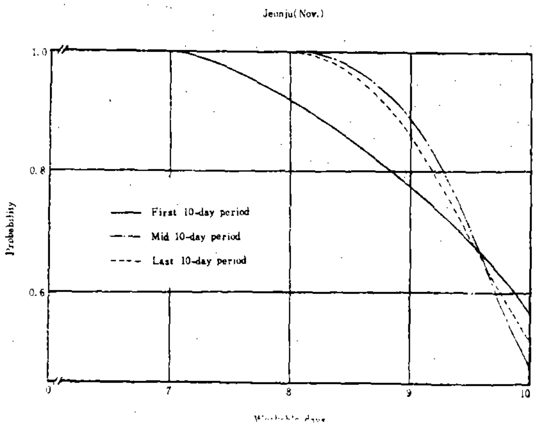


Fig. (10). The cumulative distribution of weather being good for tractor tillage operation.

Table (4). Percentage of probable days being good for tillage operation by month and by region.

Month	Districts	First 10-day period	Mid 10-day period	Last 10-day period
April	Seoul	83.9	83.5	83.9
	Jeonju	80.2	81.9	80.2
	Gwangju	78.6	81.3	75.7
	Daegu	85.2	85.2	80.2
	Busan	80.2	76.4	75.2
May	Seoul	84.1	90.1	84.6
	Jeonju	80.2	84.5	82.8
	Gwangju	76.9	85.2	82.8
	Daegu	83.6	87.4	91.1
	Busan	77.8	80.2	77.3
June	Seoul	82.1	82.4	81.2
	Jeonju	81.3	81.4	70.3
	Gwangju	80.2	78.3	68.3
	Daegu	83.8	82.7	71.6
	Busan	78.6	81.1	70.3
October	Seoul	68.5	70.2	73.8
	Jeonju	73.6	65.4	69.3
	Gwangju	85.2	80.1	91.9
	Daegu	90.8	85.9	91.8
	Busan	90.1	85.2	87.7
November	Seoul	65.6	61.2	56.2
	Jeonju	60.3	58.2	60.3
	Gwangju	85.2	90.8	87.3
	Daegu	88.8	88.8	91.3
	Busan	90.1	85.7	88.3

good for tillage operation. The days so defined were expressed as percentage. The result of analysis are summarized in Table (4). The value in the table, say 80.0, represents that 8 days within 10 days duration are expected to be good for tillage operation with 66 per cent confidence level.

2. The cost of invariable terms

In the cost function of tractor tillage operation, there were involved a number of cost terms which are assumably invariable year by year.

The terms included in the annual fixed cost percentage are ones which belong to the invariable term. The straight-line method was used to determine the annual depreciation, the cost of which was expressed as the percentage of machinery purchase price. For this analysis, the appropriate value of machine life and the salvage of the machinery were taken from reference (4).

The annual interest rate applied in this study was

Table (5). Annual fixed cost percentage of tractors and their tillage implements.

Machine \ Cost	Depreciation	Interest on investment	Repair cost	Sum
Tractor	0.09P (9%)	0.05P (5%)	0.07P (7%)	0.21P (21%)
Plow	0.09P (9%)	0.05P (5%)	0.04P (4%)	0.18P (18%)
Rotavator	0.113P (11.3%)	0.05P (5%)	0.063P (6.3%)	0.225P (22.5%)

9 per cent for all the machinery, which corresponds to the interest rate for which the Government Authorities has adopted by the Farm Mechanization Fund.

Repair cost was also regarded as a fixed cost in this study and expressed as percentage of machinery purchase price. Annual rates of repair and maintenance cost were taken from the reference (17).

The fixed costs as expressed above along with total annual fixed cost percentage for different machinery are summarized in Table (5).

3. Determination of variable cost functions

Purchase price of machinery, $P(t)$ The future purchasing price of a tractor and its implements can be predicted reasonably according to the changing trend of farm machinery price that has been shown so far. From the recent work done by NACF the equation for estimating the purchase price $P(t)$ of farm machinery in t year was related by the straight-line as follows (refer to Fig. 11):

$$P(t)=Po\ (1+0.083t) \tag{13}$$

where: Po=the purchase price of a farm machinery in the reference year

Fuel and lubricant cost function $K(t)$ In the similar, fuel and lubricant costs in t year are given by

$$K(t)=0.25t \tag{14}$$

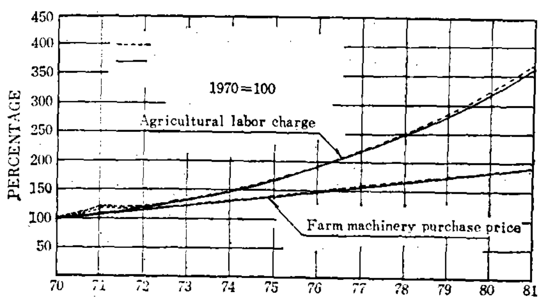


Fig. (11). Formulation of prediction equations for labor charge and farm machinery purchase price.

Labor charge function The equation of the labor charge can also be expressed from its changing trend in the past. However, it was shown that the changing rate of labor charge did not follow the straight-line, but gave a quadratic form. Therefore, it was attempted to represent the relation between the labor charge and year as the second-degree polynominal. Based on data given by NACF 1/ labor cost function is approximately as

$$L(t)=118+10t+1.5t^2 \tag{15}$$

where: $L(t)$=the farm labor charge in t year

4. The cost function of the conventional tillage operation

The conventional cost of tillage operation varies a little in accordance with region and season. Since the conventional tillage operation consists of human and animal powers, the changing trend of the cost of conventional tillage operation was assumed to be about the same rate as the labor charge. Based on this assumption, the equation for estimating the conventional tillage operation was formulated as follows:

$$G(t)=A+Bt+Ct^2 \tag{16}$$

where: A, B and C are constants to be estimated.

The cost in the reference year (1970), which corresponds to the constant A in the Equation (16), was taken as 9,000 won per hectare. The constants B and C can be determined from the results of analysis on the trend equation of labor charge as given in Equation (15). Thus, the conventional tillage-operation cost in t year is estimated by the following equation.

$$G(t)=9,000+689t+132t^2 \tag{17}$$

The equation shall be used in comparing the cost of tillage operation performed by a tractor.

5. Analysis of the costs of tillage operation

(1) The cost of tractor tillage operation

The costs of tillage operation can be solved by putting the necessary input data as defined in the preceding sections into the Equation (10) and (11). As a large number of calcnlations were required to solve the equation, a electronic computer at the Office of Rural Development in Suweon was employed. Some of the important cases obtained from the analysis are summarized in Appendix Table (1-A), through (1-C). For illustration, the costs of tillage operation for different tractors for are also plotted and shown in Figure (12).

The followings are some of the important conclusions that can be drawn from the analysis:

First, it appears that there may be some differences in the cost of tillage operation among tractors when they are used in the approximately same annual operating hours. 35-HP tractor gives the least cost and the second least cost goes to 45-HP tractors, difference of the cost being very small. The result coincides with one that studied by Kisu (7).

Second, one of the most sensitive factors to the cost of tractor operation for a fixed purchase price seems to be the annual operating hours or the machine coverage. Therefore, it may be necessary to take some measures so as to increase the annual operating hours of a tractor, if tractor farming is to be introduced in early days to come into Korea. One of the measures available, as the present investigator sees, may be the lengthening of tillage operating duration by altering the cropping system.

Third, the cost of tractor tillage operation is much higher in the central region than in the southern region if the rice-barley double cropping is to be attempted. It may be because duration of tillage operation in the central region is shorter than in the southern region.

(2) Analysis of the break-even year

It is desirable to know when the cost of tractor tillage correpsonds to the cost of conventional method. If tractor tillage operation will not be economical, farmers will not adopted the new technology. Therefore, the break-even year of the cost of using machinery as compared with conventional one can be used as one basis for deciding the time when tractors can be introduced into farming. Of course, such factors as labor and land productivities are also to be taken into consideration.

The break-even year can be determined by the year t to which the following relation is held.

$$H(t)=G(t) \qquad (18)$$

where: $H(t)$ and $G(t)$, as defined early in Equation (10) and (17), are the cost function of tractor tillage and conventional method, respectively.

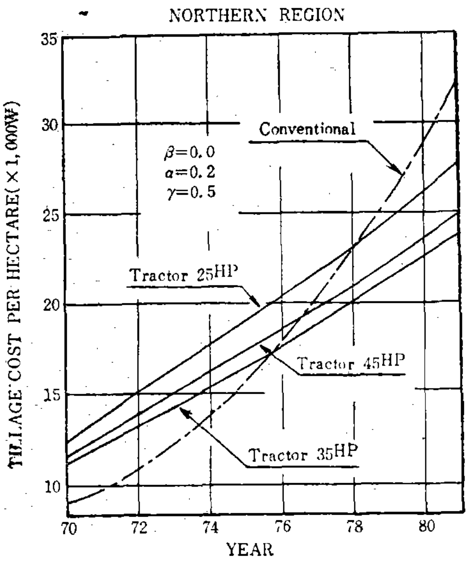


Fig. (12). The comparison of the cost of tillage operation for different tractors and conventional method.

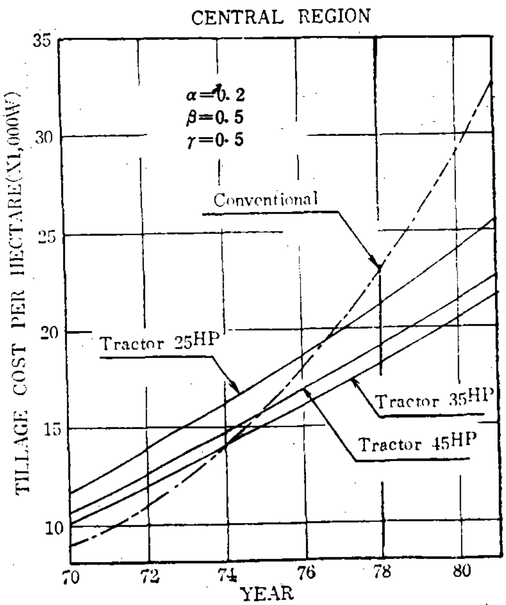


Fig. (13). The comparison of the cost of tillage operation for different tractors and conventional method.

The break-even years for different regions and different farming conditions were analyzed by using computer programming and are summarized in Appendix Table (2). Figures (12) and (13) illustrate the break-even year for different sizes of tractors.

From the analysis of the break-even year, the following are to be especially noticed:

First, tractor farming in the southern region may be feasible at present under the condition of double cropping and with effective use of tractors.

Second, tractor tillage operation in northern and central regions as a whole may not be economically feasible at the present time, unless operating hours except the tillage operation are kept considerably small.

Third, if the predicted costs for all the variable terms are nearly correct through years to come, it is expected that tractor farming shall be feasible within a few years. However, financial support by the Govern at Authorities may be necessary if tractor farming is immediately to be adopted.

V. SUMMARY AND CONCLUSION

This thesis reports on the development of a model and application of it to specific combinations of variables. The model relates the cost of tractor tillage operation to machine capacities, annual coverage and regional cropping systems, probable good days for days for field work and all components of fixed and variable costs.

In the process, the parameters which can accomodate variable conditions of cropping rate, plowing-rotavating ratio and the degree of multi-function of tractor use, were defined and specified for a specific use.

The probability distribution of days good for tillage operation were analyzed by using the records during past twenty-one years. Based on the workable days determined from weather probability and using other pertinent variables, average seasonal coverages of tractor tillage operation were analyzed. From the time-series analysis of all the variable factors involved in the costs of tillage operation, it was possible to decide the break-even year of machinery costs of tillage operation when compared with the costs by a conventional method.

Because a large number of calculations are required to solve the equation which defines the model, the tractor operating costs for different regions and operating conditions were analyzed for practical use.

Keeping in mind the need for refinement of input data, it is possible to draw some conclusions from the results obtained.

1. It is possible to estimate the annual coverage of tractor tillage operation by using the general equation.

$$A=\frac{1}{10}e_f e_u e_d \text{ SWUD}$$

2. It is possible to predict the probable days that are good for tractor tillage operation in different regions and seasons. The analyses indicate that the probable workable days range from 6 to 9 days within 10-day period.

3. The cost function of tractor tillage operation derived in this study, as given in the following, is applicable to any specific farming and operating conditions of tractors by giving the appropriate values in the parameters defined.

$$H(t)=\frac{FC_P\%\ P_P(t)}{A(1+\beta)}+\frac{10\alpha}{S_P W_{P} e_{fP} e_{uP}}[(F_P+O_P]K(t)+L(t)+T(t)]+\frac{FC_R\% P_R(t)}{A(1+\beta)}+\frac{10}{S_R W_R e_{fR} e_{uR}}[(F_R+O_R]K(t)+L(t)+T(t)]$$

$$T(t)=\frac{FC_T\%\ P_T(t)}{(1+\gamma)\left(\frac{10\alpha A}{S_P W_{P} e_{fP} e_{uP}}+\frac{10(1+\beta)A}{S_R W_{fR} e_{uR}}\right)}$$

4. From the model developed it is also possible to predict the break-even year of the cost of tractor tillage opeartion as compared with the cost of conventional method. This is of special importance in determining when the tractor farming is economicaly feasible. The analysis of the break-even years shows that tractor farming in the southern region is conditionally feasible while, in the northern and central regions, tractor farming may not be feasible by some years to come.

5. The cost of tractor tillage operation is most sensitive to the annual coverage or annual operating hours but affected a little by the size of tractors. Therefore, it may be desirable to select a tractor

and its implement based upon technologically feasible conditions such as the size of land, farm road, and the organization of tractor use.

Appendix Table (1). The cost of tractor tillage operation in 1973 computed from the developed model.

(A) Northern region:

Parameters β	α	γ	Tractor size (HP)	Fixed cost (Won)	Variable cost (Won)	Sum (Won)	Annual use in hours
0.0	0.2	0.5	25	5,249	11,289	16,538	407
			35	3,901	10,457	14,358	431
			45	4,394	10,677	15,071	412
		1.0	25	5,249	9,248	14,497	543
			35	3,901	8,432	12,333	574
			45	4,394	8,593	12,987	550
	0.4	0.5	25	5,249	11,695	16,944	460
			35	3,901	10,853	14,754	507
			45	4,394	11,005	15,399	470
		1.0	25	5,249	9,654	14,903	614
			35	3,901	8,828	12,729	676
			45	4,394	8,921	13,316	627

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Parameters β	α	γ	Tractor size (HP)	Fixed cost (Won)	Variable cost (Won)	Sum (Won)	Annual use in hours
0.0	0.2	0.5	25	7,024	14,050	21,074	304
			35	5,220	13,197	18,417	322
			45	5,880	13,496	19,376	303
		1.0	25	7,024	11,318	18,342	406
			35	5,220	10,486	15,706	429
			45	5.880	10,707	16,587	411
	0.4	0.5	25	7,024	14,456	21,480	344
			35	5,220	13,593	18,813	379
			45	5,880	13,824	19,704	351
		1.0	25	7,024	11,725	18,749	459
			35	5,220	10,882	16,102	505
			45	5,880	11,035	16,915	468
0.5	0.2	0.5	25	4,682	10,272	14,954	437
			35	3,480	9,451	12,931	454
			45	3,920	9,668	13,588	440
		1.0	25	4,682	8,451	13,133	582
			35	3,480	7,644	11,124	606
			45	3.920	7,809	11,729	587

0.4		0.5	25	4,682	10,543	15,225	476
			35	3,480	9,715	13,195	511
			45	3,920	9,887	13,807	484
		1.0	25	4,682	8,722	13,404	635
			35	3,480	7,908	11,388	682
			45	3,920	8,028	11,948	645

(C) Southern region:

Parameter			Tractor size (HP)	Fixed cost (Won)	Variable cost (Won)	Sum (Won)	Annual use in hours
β	α	γ					
0.5	0.2	0.5	25	3,886	9,033	12,919	526
			35	2,888	8,221	11,109	547
			45	3,253	8,403	11,656	531
		1.0	25	3,886	7,522	11,408	702
			35	2,888	6,722	9,610	730
			45	3,253	6,860	10,113	708
	0.4	0.5	25	3,886	9,304	13,190	574
			35	2,888	8,485	11,373	616
			45	3,253	8,622	11,875	583
		1.0	25	3,886	7,793	11,679	765
			35	2,888	6,986	9,874	821
			45	3,253	7,079	10,332	777
1.0	0.2	0.5	25	2,914	7,454	10,368	686
			35	2,166	6,656	8,822	707
			45	2,440	6,805	9,245	690
		1.0	25	2,914	6,321	9,235	915
			35	2,166	5,531	7,697	943
			45	2,440	5,648	8,088	920
	0.4	0.5	25	2,914	7,657	10,571	734
			35	2,166	6,854	9,020	776
			45	2,440	6,969	9,409	742
		1.0	25	2,914	6,524	9,438	978
			35	2,166	5,729	7,895	1,034
			45	2,440	5,812	8,252	990

Appendix Table (2-A). Break-even year of the cost of tractor tillage when compared with conventional tillage.

Region	Parameters β	α	γ	Tractor size (HP)	Break-even year
Northern	0.0	0.4	0.5	25	1979
				35	1976
				45	1977
			1.0	25	1977
				35	1973
				45	1975
		0.4	0.5	25	1979
				35	1977
				45	1978
			1.0	25	1978
				35	1974
				45	1975

Appendix Table (2-B). Break-even year of the cost of tractor tillage when compared with conventional tillage.

Region	Parameters β	α	γ	Tractor size (HP)	Break-even year
Central	0.0	0.2	0.5	25	after 1981
				35	1980
				45	1981
			1.0	25	1980
				35	1978
				45	1979
		0.4	0.5	25	after 1981
				35	1981
				45	1981
			1.0	25	1981
				35	1978
				45	1979
	0.5	0.2	0.5	25	1977
				35	1975
				45	1975
			1.0	25	1975
				35	1970
				45	1975
		0.4	0.5	25	1978
				35	1975
				45	1976
			1.0	25	1976
				35	before1970
				45	1973

Appendix Table (3). The coverage of rotavating operation for different tractors.

Tractor (HP)	Region	e_f	S_R	W_R	e_u	e_d	U	D	Coverage (Hactare)
25	North.	0.74	1.6	1.15	0.75	0.840	10.35	25	22.20
	Centr.					0.803	11.45	17	15.96
	South.					0.786	11.45	20	18.38
35	North.	0.74	2.0	1.58	0.69	0.840	10.35	25	35.07
	Centr.					0.803	11.45	17	25.22
	South.					0.786	11.45	20	29.04
45	North.	0.74	2.0	1.76	0.64	0.840	10.35	25	36.24
	Centr.					0.803	11.45	17	26.06
	South.					0.786	11.45	20	30.01

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