中華農業研究 (Jour. Agric. Res. China) 37(4) : 458~469 (1988)

Working Patterns, Capacity, and Cost of Rice Combine[1]

Chia-chung Chen[2]

Abstract: A series of working locus equations are established to study the effect of the working patterns on efficiency and capacity of rice combine. As the field area was less than 0. 4ha, circuitous method was better. At the range of 0. 4—0. 5ha, either pattern could be adopted. Continuous pattern was good for larger area.

Operating capacity and the machinery price are the major deteriming factors for working cost. Large combines will be more economical for long-term development.

INTRODUCTION

Harvesting is the most important farm working for rice production. In 1986, about 90% of the rice paddies were harvested by machinery. Because of the prevalence of the "custom work" system prevails the machinery-owner works for himself and neighbour s. The typically work hours per year for rice combines was so high that the depreciati on period was reduced. In order to improve the working capacitie and reduce the oper ating cost, it is necessary to study the relations of the working patterns and efficiency of rice combine. The operating cost also need to be studied.

Different working patterns for big farm eruipment in USA were described by Hunt (1979). Many researches of farm machinery cost had been presented (Hassan et al., 1978; Renoll, 1981). The study of working patterns of harvest machinery in Japan only included two-row riding type combines (Shimizu and Fukayaama, 1971).

In this study of working capacity, the working patterns were formulated as a series of locus equations. The related parameters were investigated and substituted into these equations to find the working efficiency of three types of combines. The cost of rice combine are divided into fixed and variable cost. Five types of machinery were studied and compared.

MODEL DEVELOPMENT

I. Working patterns and capacity

1. Contribution No. 1440 from the Taiwan Agricultural Research Institute, Taiwan, Republic of China. This paper was partially revised and condensed from the papar that presented at the 1988 Intern ational summer meeting of the ASAE. (ASAE paper No. 88—5009) .

2. Associate Researcher, Department of Agricultural Machinery, Taiwan Agricultural Research Institute, Wu-feng, Taichung, Taiwan, 41301, ROC.

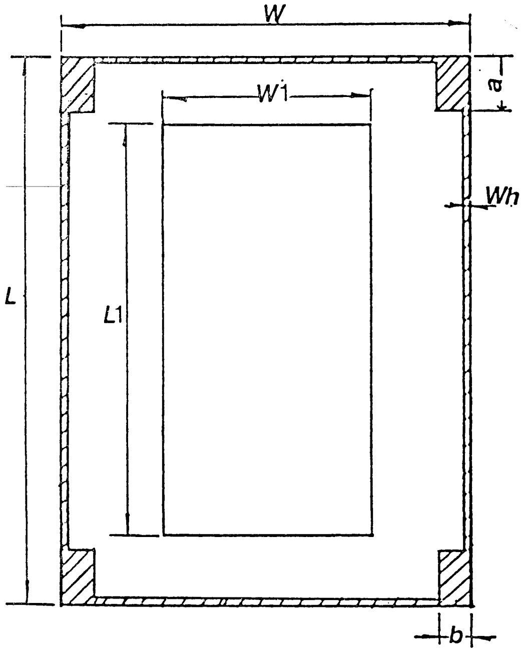

Fig. 1. The standard shape of paddy field and headland

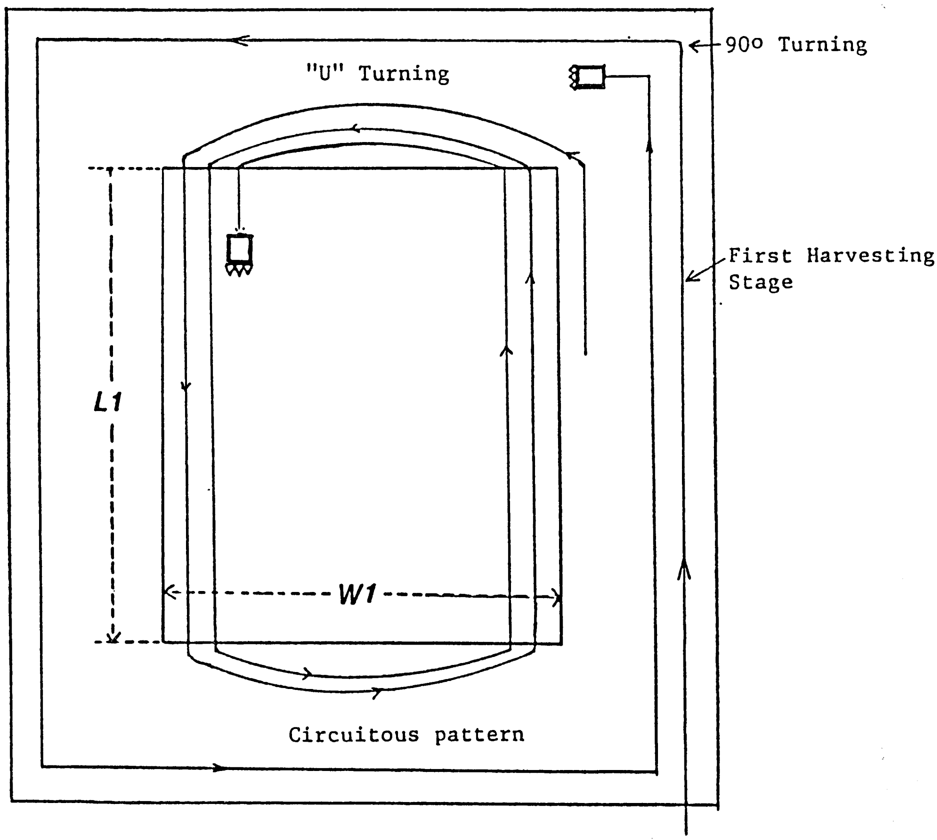

Fig. 2. The first harvesting stage and circuitous pattern

To effectively utilize the paddy field, no unprocessed land was left for headland. Before using combines, the fields needed to be reaped by hand at four corners and around four sides to provide enough turn strips for machinery (showed in Fig. 1). All reaped grains were threshed by the thresher of combine.

A. Working methods

The first harvest stage was worked around the field side to obtain enough headland for next operating work (Fig. 2). Each corner took a time to turn a 90° corner. The second stage were divided into two different patterns.

a. Circuitous pattern

As the residual field width (W1) was below 20 meters, the combine kept on operating that circulating around the working area as shown in Fig. 2. The field length for harvesting was fixed at L1.

If W1 was greater than 20 meters, the residual working field was divided into several subregions that width are within the range of 10—12 meters. The subregions were operated by inner-circular or outer-circular patterns (Fig. 3). As the combine finished one long side working, it turned along a "U" type path to next start point.

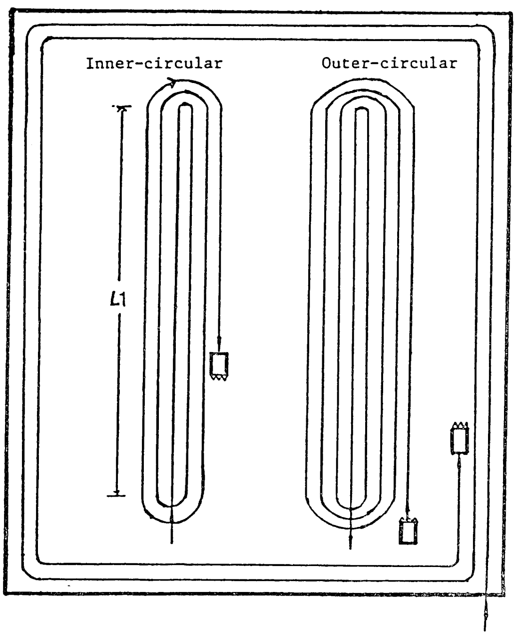

Fig. 3. Two types of circuitous pattern

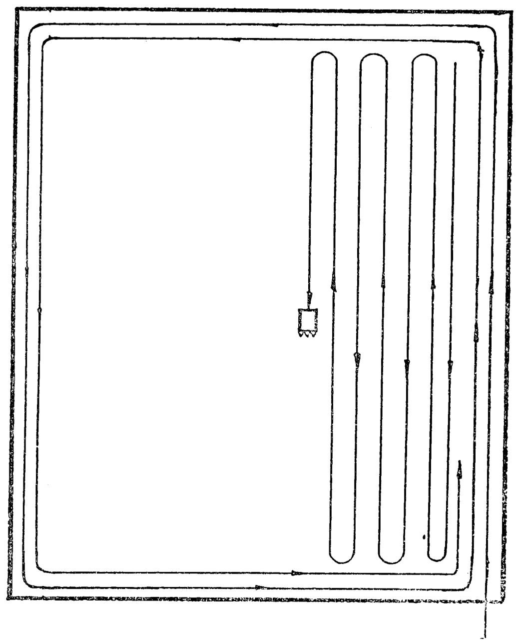

Fig. 4. The continuous pattern

b. Continuous pattern

This pattern is shown in Fig. 4. After the first stage work, combine harvested rice by continuous pattern. Each time required the 180° turninng at a limit distance.

B. The analysis of required time

a. Headland area and operation time

The headland area, AH (m^2), could be calculated as following :

$$AH = 4ab + 2Wh^*(L + W - 2a - 2b) \quad \cdots\cdots (1)$$

Where a = length of headland (m)
b = width of headland (m)
Wh = width of the manual reaped around four sides (m)
W = width of paddy field (m)
L = Length of paddy field (m)

The manual reaped time for headland was TH (sec),

$$TH = AH*Cm \cdots\cdots (2)$$

Where Cm = manual capacity of reaping by hand (sec/m^2)

The required time to thresh the grains was TS (sec),

$$TS = AH*Sm \cdots\cdots (3)$$

Where Sm = operating capacity for thresher to thresh the grains that reaped by hand (sed/m^2)

b. The operating time for the first stage.

The travelling paths of the rice combine at the first stage are listed as Table 1. The total travelling pathes was Pt (m),

Table 1. The travelling pathes of rice combine at the first stage

No. of Circular	Long side	Short side
1	2L—w	2W—3w
2	2L—5w	2W—7w
3	2L—9w	2W—11w
4	2L—13w	2W—15w
———	———	———
n	2L—(4n—3)w	2W—(4n—1)w
Total	2nL—(2n*n—n)w	2nW—(2n*n+n)w

$$Pt = 2*N1*(L+W) - 4*w*N1^2 \cdots\cdots (4)$$

Where N1 = require circular number for the first stage
w = effective operating width (m)

The required operating time for this stage was T1 (sec),

$$T1 = \frac{2*N1*(L+W) - 4*N1*N1*w}{S} + 4*N1*Tf \cdots\cdots (5)$$

Where S = the operating velocity for combine (m/sec)
Tf = the time to turn a 90° corner (sec)

c. The working time for circuitous pattern

As W1 is less than 20m, the required times for rotation N2,

$$N2 = W1/w \cdots\cdots (6)$$

The required operating time for this stage was T2 (sec).

$$T2 = \frac{L1}{S} \times N2 + \Sigma Tui \cdots\cdots (7)$$

Where Tui=require turning time for "U" type rotation (sec),

If W1 is greater than 20m, some subregions of equal width (Ws1) and the smallest subregion (width was Ws2) composed of the residuca field.

$$W1 = K \times Ws1 + Ws2 \cdots\cdots (8)$$

Where K=the number subregions in which had same width, Therefore,

$$N3 = K \times \frac{Ws1}{w} + \frac{Ws2}{w} = K \times i + j \cdots\cdots (9)$$

The requierd time for this stage was T3 (sec),

$$T3 = \frac{L1}{S} \times N3 + K \times \sum^{i} Tui + \sum^{j} Tu2 \cdots\cdots (10)$$

d. The working time for continuous

In this pattern, the total required rotation times could be expressed as,

$$N4 = W1/w \cdots\cdots (11)$$

The total operating time for this stage was T4 (sec),

$$T4 = (\frac{L1}{S} + Tr) \times N4 \cdots\cdots (12)$$

Where Tr=the time for turning of 180° (sec)

C. The operating efficiency and operating capacity

The total working time for whole field operation was T1.

a. Circuitous pattern, W1<20m

$$Ta = TH + TS + T1 + T2 \cdots\cdots (13)$$

b. Circuitous pattern, W1>20m

$$Tb = TH + TS + T1 + T3 \cdots\cdots (14)$$

c. Continuous pattern,

$$Tc = TH + TS + T1 + T4 \cdots\cdots (15)$$

The theoretical total working time is Te (sec),

$$Te = \frac{Area}{S \times w} = \frac{L \times W}{S \times w} \cdots\cdots (16)$$

The operating efficiency was e,

$$e = \frac{Te}{Ti} \cdots\cdots (17)$$

The field operating capacity was C (ha/hr),

$$C = 0.36 \times e \times S \times w \cdots\cdots (18)$$

II. Cost analysis

In this study, Operating cost were divided into fixed and variable cost

A. Fixed cost

Fixed costs included the depreciation and interest on investment. Tax, insurance, and shelter costs were not considered for rice combine.

a. Depreciation

The straight-line method was adopted to estimate the depreciation costs. The annual depreciation charge was D (NT$/yr),

$$D=(Pc-Ps)/N \cdots\cdots (19)$$

Where Pc = purchase price (NT$)

PS = salvage value (NT$)

N = estimated economic years of life (yr)

b. Interest

The interest cost for per years is I (NT$/yr),

$$I=(\frac{Pc+Ps}{2})\times i \cdots\cdots (20)$$

Where i = the annual interest rate and was 8.5% in Taiwan.

B. Variable costs

Variable costs included repairs, fuel and lubricant consumption, and labor.

a. Repairs cost

Owing to the rapidly renew periods for rice combine, the concept of accumulated repair cost was not suitable. A simple method to estimate the repair cost was to adopt the idea of total repair coefficient (Cr). Cr was the ratio of the total repair cost from purchased to worn-out to the purchase price.

The repairs cost per year can be calculated as R (NT$/yr),

$$R=Pc\times Cr/N \cdots\cdots (21)$$

b. Fuel and lubricant cost

The fuel consumption coefficient, K, was expressed as :

$$K=2.7\ NT\$/hp-hr \cdots\cdots (22)$$

The estimated cost of fuel was F (NT$/yr),

$$F=K\times Hp\times H \cdots\cdots (23)$$

Where Hp = the horsepower of combine (hp)

H = the annual working hourse (hr/yr)

The lubrication consumption cost was assumed to be as a portion of the oil cost. The lubricant oils costs was O,

$$O=r\times F \cdots\cdots (24)$$

Where r = the average ratio value for oil cost

c. Labors cost

The annual labors cost were determined as L (NT$/yr),

$$L=Lc\times H\times PM \cdots\cdots (25)$$

Where Lc = the hourly wage (NT$/hr)

H = annual operating hours (hr/yr)

PM = the required labors, two persons for combine

C. Annual operating cost

The annual operating cost (Ct) was,

$$Ct=D+I+R+F+O+L$$

$$=\frac{0.9\times Pc}{N}+0.04675\times Pc+\frac{Cr\times Pc}{N}+(1+r)\times K\times Hp\times H+Lc\times H\times PM \cdots\cdots (26)$$

The operating capacity, Fc (ha/hr), was,

$$Fc = Ta/H \cdots\cdots (27)$$

Where Ta = the total annual working areas (ha)

H = the total annual operating hours (hr)

The total economic working years was N (yr),

$$N = \frac{Th}{H} = \frac{Th \times Fc}{Ta} \cdots\cdots (28)$$

Where Th = the total economic working hours (hr)

Let Ca was the annual operating cost per hectare, combined Eq. 26, 27, and 28.

$$Ca = \frac{Ct}{Ta} = \frac{(Pc-Ps)}{Fc \times Th} + 0.04675 \times \frac{Pc}{Ta} + \frac{Pc \times Cr}{Fc \times Th} + \frac{(1+r) \times K \times Hp}{Fc} + \frac{Lc \times PM}{Fc} \cdots\cdots (29)$$

MODEL PARAMETERS

A. Working patterns and capacity

The parameters of working capacity for rice combine were collected in time studies of rice harvesting. The observers recorded the following data for three types of comb ines :

Turning time, Tr, Ta, and Tf

Unloading time

Reaped area and required time by hands

Grains threshed time

Total harvesting time

These data were used to calculate the effective field efficiency. The average value are listed in Table 2.

Table 2. The parameters of operating capacity of rice combines

Item	YS—1300	TC—1800	MC—2450
w (m)	0.75	1.05	1.45
S (m/sec)	0.67	0.79	0.85
a (m)	2.0	5.0	5.0
b (m)	2.0	4.0	4.0
Wh (m)	0.3	0.3	0.0
Tf (sec)	12.6	13.4	12.3
Tr (sec)	15.0	12.0	11.0
Sm (sec/m*m)	6.4	5.2	4.85
Cm (sec/m*m)	84.0	84.0	84.0
N1	8.0	6.0	5.0

B. Operating cost

The specifiations for operating costs of combine were collected througn personal interviews of custom operators and field investigation.

Information gathered by the interviewers included :

Annual working area and hourly use

Custom rate and operater's wage

Fuel and lubricant oil requirements

Spare parts and repair costs

Purchase and salvage price

Operating capacity

The information of five types of combines are listed in Table 3.

Table 3. The parameters of operating costs of rice combine

Item	YS—1300	MC—1700	TC—2200	MC—2250	TC—3500
Hp (hp)	13	15	21	24	32
w (m)	0.75	1.02	1.30	1.35	1.35
C (ha/hr)	0.126	0.162	0.188	0.237	0.342
Nc (N.T.$)	265,000	390,000	580,000	670,000	970,000

RESULTS AND DISCUSSIONS

A. Operating patterns and capacity

From the investigative results, Tu value was found to be a function of turning distance.

The total time for "U" turning was ΣTui. For threr types of combine, ΣTui were found to be the function of width of subregions (Ws),

1. YS−1300

$$\Sigma Tui = 24.6 + 34.4 \times Ws + 5.56 \times Ws \times Ws \quad (30)$$

2. TC−1800

$$\Sigma Tui = 39.0 + 25.9 \times Ws + 2.44 \times Ws \times Ws \quad (31)$$

3. MC−2450

$$\Sigma Tui = 9.84 + 33.4 \times Ws + 2.01 \times Ws \times Ws \quad (32)$$

Combining all information, the working efficiency of three types of combine for two methods are shown in Fig. 5.

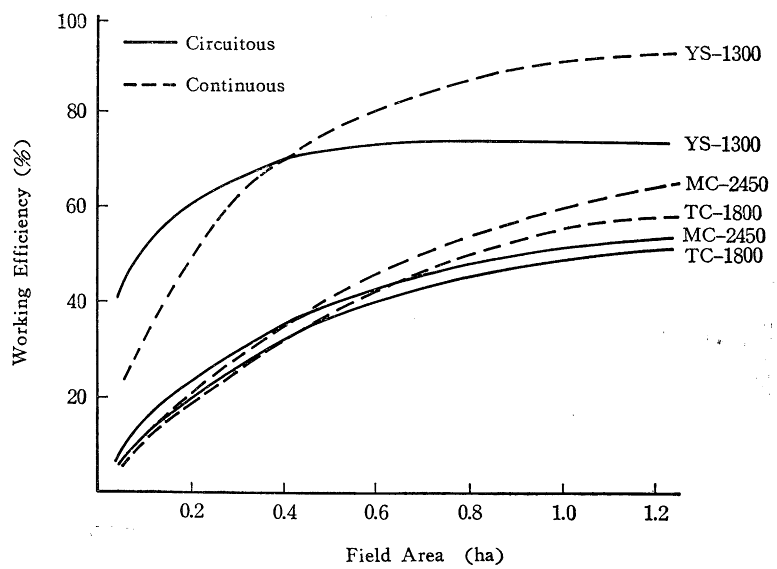

Fig. 5. The working efficiency vs field area

YS-1300, the smallest type, had the largest working efficiency. The reasons could be explained that small machinery required small area of headland and was more easy for turning. As the field area below 0.4 ha, the working efficiency of circultous patterns was higher than those of continuous patterns and the results was contrary to larger area.

MC-2450 had the similar areas of headland with TC-1800. The turning time for Tf, Tu, and Tr were also similar. Owing to faster operating speed and wider operating width, it had the higher efficiency.

The operating capacity for these combines are shown in Fig. 6. The smallest com bine, YS-1300, although had the highest efficiency, revealed the lowest capacity due to its low operating speed and narrow operating width. Above the 0.5ha, it apporached the limitation of 0.12ha/hr. In spite of the same working efficiency, MC-2400 showed a significant improvement on working capacity.

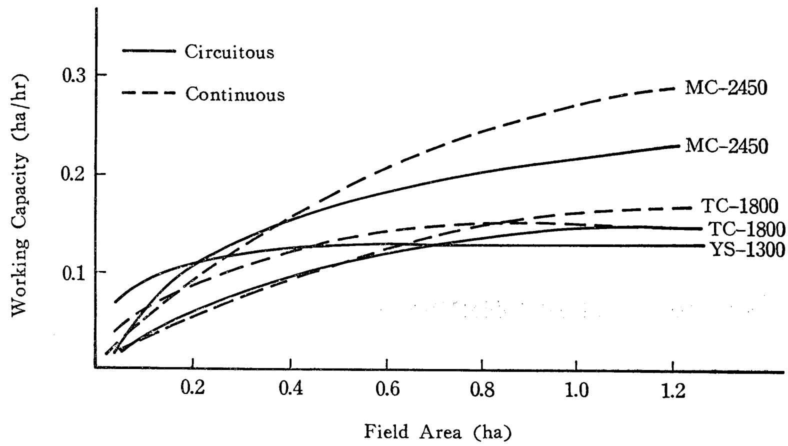

Fig. 6. The working capacity vs field area

Field area showed the similar effect on the working capacity for three types of co mbines. As the area was below 0.4ha, circultous patterns was the better method. At 0.4—0.5 ha, either patterns could be adopted. For larger area above 0.5 ha, continuous pattern was worth recommending.

B. Operating cost

From the investigative results, Ps=0.1Pc, Th=1500hr, Cr=0.5, r=0.3, Lc=70 NT$ /hr. By Eq. 29, Ca became,

$$Ca=9.333E-4\times\frac{Pc}{Fc}+4.675E-2\times\frac{Pc}{Ta}+3.51\times\frac{Hp}{Fc}+\frac{140}{Fc} \qquad (33)$$

Hp was found to have a highly linear relation with Pc, so the purchase price and operating capacity were the major effective factors for operating cost per hectare per year.

The operating costs for five rice combines with different annual working areas are shown in Fig. 7. All costs decreased as total working areas increased. The smallest combine, YS-1300, had the lowest cost which reflected their simple design and lower

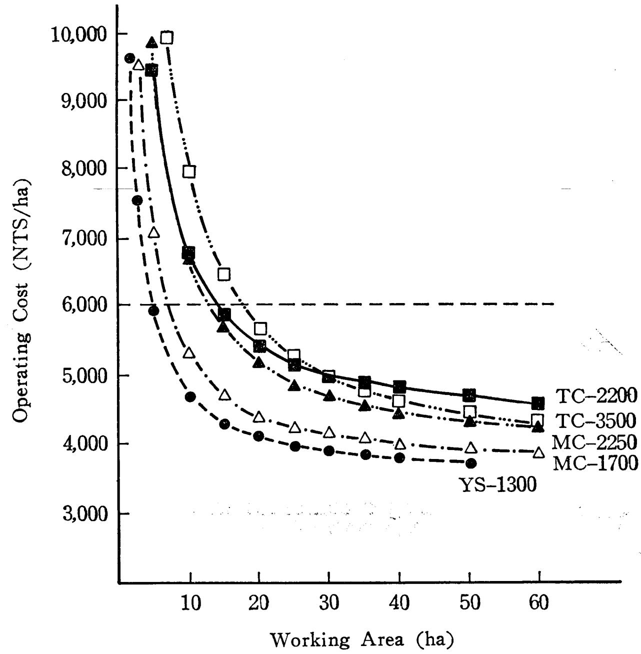

Fig. 7. The operating costs for five Rice Combines

purchase price. A special case was TS-3500. As total working areas increased, its operating cost significant decreased. It indicated its potential to work for more areas.

The average custom rate was 6000 NT $ /ha. As the operating area was above 20ha, the benefit became positive for all types of combines.

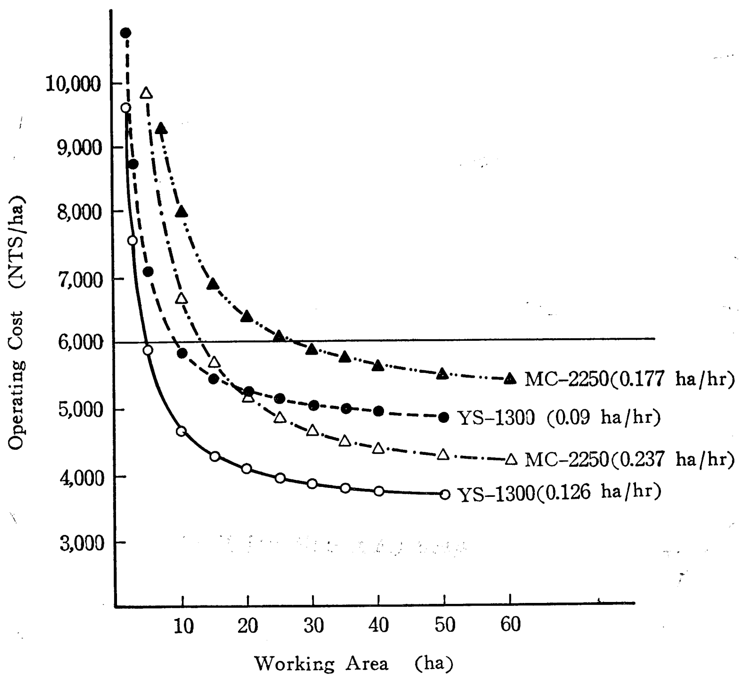

Fig. 8. The effect of field capacity on operating cost

The effect of the operating capacity on cost could be estimated by Eq. 33. The comparison of the costs for combines with different capacity are shown in Fig. 6. As the capacity reduced 30%, the increase cost was 1168NT$/ha for YS-1300, and 1218 NT$/ha for MC-2250. No benefit could be obtained as the annual working area below 30ha for MC-2250. This result indicated the significant effect of capacity on operating cost.

Smallest combine had the lowest cost. However, the weather and crop condition seriously restricted the available working days of combines for each harvesting seasons. The required working day of three combines for two annual working areas are listed in Table 4. In some years, small combine did not finish enough annual working area to reduce the operating cost because of its low capacity. For long-term development, the operator's wage will increase hastilly because of the rapidly development of industry. The annual interest rate graduately reduce at governmental bank to promote the overall mechanization of rice production. Larger combines will be more economical.

Table 4. The required working days of rice combine

Types	Capacity (ha/hr)	Working Areas 30	(ha/years) 50
YS —1300	0.094	43	71
MC—2250	0.177	23	38
TC —3500	0.256	16	26

CONCLUSION

In order to study the effect of two working patterns on efficiency of rice combines, a series of working locus equations were established. The working efficiency and cap acity were defined under the conditions of the area of paddy field, the type of machine ry, and the working patterns. As the field area was less than 0.4ha, circuitous method was better. At the range of 0.4—0.5ha, either pattern could be adopted. Continuous pattern was good for larger area.

Operating capacity and purchase price were the major deterimining factors for operating cost. From the view point of long-term development, larger combined will be more economical.

ACKNOWLEDGMENTS

My thanks goes to Mr. Lung-Hu Lu and Jong-Jui Cheng, for their help in collect ing the data of parameters.

I also wish to thank Dr. Chaplin (Agricultural Engineering Dept., University of Minnesota) for his very useful comments and review for this manuscript.

REFFERENCE

Bowers, W. and D. R. Hunt. 1970. Application of mathematical formulas to repair cost data. Trans.

of ASAE 13 : 806-809.

Chen, C. C. 1983. The study on the utilization costs of the paddy machinery. Journal of Chinese Agricultural Engineering Vol. 29, No. 4 : 116-132.

Chen, C. C. and J. J. Cheng. 1984. The study on the relation between the working methods and the working capacity of rice combine. Journal of Chinese Agricultural Engineering Vol. 30, NO. 1 : 84-91.

Hassan, C. I. and D. L. Larson. 1978. Combine capacity and costs. Trans. of ASEA 21 : 1068-1070.

Hunt, D. 1973. Farm and Machinery Management. The six edition. Iowa State University.

Renoll, E. 1981. Predicting machine field capacity for specific field and operating conditions. Trans. of ASAE 24 : 45-47.

Shimizu, H. and S. Fukayama. 1971. Studied on the efficient utilization of agricultural machinery (I). Journal of Society of Agricultural Machinery. Japan. Vol. 33, No. 1 : 39-44.

水稻聯合收穫機作業方式、能力、與成本之研究[1]

陳 加 忠[2]

摘 要

在此研究中，以聯合收穫機的行走軌跡建立各項方程式以解析作業效率和能力與作業方式之關係，和決定各項影響因子。利用田間調查資料以研究最佳作業方式。調查結果顯示小田區以迴繞法較好，大田區作業以往復法爲主。作業面積0.4—0.5公頃時，兩者方法都可適用。由作業成本研究顯示，作業能力和農機售價是使用成本的主要決定因素。以長期經濟發展觀點，大型農機更爲合算。

1.臺灣省農業試驗所研究報告 1440 號。本文依作者於1988年美國農業工程學會夏季年會發表之論文（ASAE Paper No. 88-5009）補充資料，改寫而成。

2.本所農機系副研究員。臺灣省　臺中縣　霧峰鄉。