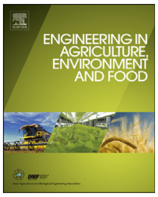
Engineering in Agriculture, Environment and Food xxx (2016) 1–7

Contents lists available at ScienceDirect

Engineering in Agriculture, Environment and Food

journal homepage: http://www.sciencedirect.com/eaef



Research paper

Work patterns, capacity and cost of rice combine

Yu-Kai Weng, Chiachung Chen*

Department of Bio-industrial Mechatronics Engineering, National Chung Hsing University, 250 Kuokuang Road, Taichung, 40227, Taiwan

A R T I C L E I N F O

Article history:
Received 23 August 2015
Received in revised form
15 May 2016
Accepted 20 May 2016
Available online xxx

Keywords:
Work pattern
Capacity
Cost
Rice combine

A B S T R A C T

The mechanization of rice production is important, especially for harvesting. To improve the work capacity and reduce the operating cost of rice combines, we studied the work patterns and the operating efficiency of the machinery. The factors affecting operating costs were evaluated.

To study the effect of two harvesting patterns – circuitous and continuous on the efficiency of rice combine; we estimated a series of work locus equations. Work efficiency and capacity were defined by the area of the paddy field, type of machinery, and work patterns. With field area <0.4 ha, a circuitous pattern was efficient. With fields 0.4–0.5 ha, either pattern could be used. A continuous pattern was efficient for larger areas.

Operating capacity and purchase price were the major factors determining operating cost. In terms of long-term development, a larger combine is more economical.

1. Introduction

Harvesting is the most important farm work in rice production. In 2014, about 99% of rice paddies in Taiwan were harvested by machinery. To increase the operation areas, machinery-owners work for themselves and neighbors. The fee for paddy field harvesting paid to the machinery-owner is called the custom service rate. Because of the prevalence of the custom work system, the typical work hours per year for rice combines is high so the depreciation period is reduced (Kamboj et al., 2012). Improving work capacity and reducing the operating cost of rice farming requires studying the work patterns and the efficiency of rice combines. The factors affecting operating costs need to be evaluated.

Hunt (1973) described different work patterns for large farm equipment in the Unites States. In addition, farm machinery costs have been estimated (Hassan et al., 1978; Kepper et al., 1994; Renoll, 1981; Robb et al., 1988). Also, Salassi and Deliberto (2010) proposed one set of software to calculate the operating costs of rice combines.

The study of work patterns of the harvesting machinery in Japan included only two-row riding-type combines (Shimizu and Fukayama, 1971). Busato et al. (2007) modelled the efficiency of combines for the interaction of work patterns and field bin positions to improve the efficiency of transportation.

In this study of work capacity, we modeled work patterns for rice combines as a series of equations, investigated related parameters and substituted into equations to find the work efficiency of three types of combines. The cost of rice combines was divided into fixed and variable costs. Five types of machinery were compared.

2. Model development

2.1. Work patterns and capacity

To utilize a rice paddy field effectively, no unprocessed land of paddy field should be left for headland. Before harvesting, the fields need to be reaped by hand at the four corners and around the four sides to provide enough turn strips for operating of machinery (Fig. 1). All reaped grains are threshed by the combine thresher.

2.1.1. Work methods

The first stage involves harvesting around the field sides to obtain enough headland and for the next stage (Fig. 2). Turning a 90° corner required time. The second stage involved two different patterns: circuitous and continuous.

a. Circuitous pattern (Fig. 3)

With a residual field width (W_1) was <20 m, the combine circle around the work area as shown in Fig. 2. The field length for

---

* Corresponding author.
E-mail address: ccchen@dragon.nchu.edu.tw (C. Chen).

http://dx.doi.org/10.1016/j.eaef.2016.05.005
1881-8366/

Notation

A_h	headland area, m^2
a	length of headland, m
b	width of headland, m
C_m	manual capacity of reaping by hand, sec/m^2
C_r	total repair coefficient
D_c	annual depreciation charge, NT $/yr
F_c	estimated cost of fuel, NT$/yr
E_f	operating efficiency
F_o	field operating capacity, ha/hr
H	annual operating hours, hr/yr
hp	horsepower of the rice combine
i	annual interest rate
I_c	interest cost per year, NT$/yr
K	number of sub-regions with the same width
K_f	fuel consumption coefficient
L	length of paddy field, m
L_c	annual labor cost, NT $/yr
L_w	hourly wage, NT$/hr
L_1	residual field length, m
N_y	estimated economic years of life, yr
N_1	required circuit number for the first stage
N_2	required time for rotation times of circuitous pattern with $W_1 < 20$ m
N_3	required time for rotation times of circuitous pattern with $W_1 > 20$ m
N_4	total required rotation times for continuous pattern
O_c	lubricant oil costs
P_c	purchase price, NT$
P_m	required labor
P_s	salvage value, NT$
P_t	total travelled paths, m
r	average ratio value for oil cost
R_c	repair cost per year, NT$/yr
s	operating velocity for the combine, m/sec
S_m	operating capacity for the thresher to thresh the grains reaped by hand, sec/m^2
T_a	total annual work area, ha
T_e	theoretical total work time, sec
Ti	total work time for the whole field operation, sec
T_f	time to turn a 90° corner, sec
T_h	manual reap-time for the headland, sec
T_s	required time to thresh the grains, sec
T_{ui}	required turning time for the “U” -type rotation of circuitous pattern, sec
T_r	time for turning of 180, sec
T_w	total economic work hours for this machinery, hr
T_1	required operating time for this first stage, sec
T_2	required operating time for circuitous pattern with $W_1 < 20$ m, sec
T_3	required operating time for circuitous pattern with $W_1 > 20$ m, sec
T_4	total operating time for continuous pattern, sec
w	effective operating width of combine, m
W	width of paddy field, m
W_h	width of the manual reaped around four sides, m
W_{s1}	some sub-regions have equal width with $W_1 > 20$ m for circuitous pattern, m
W_{s2}	smallest sub-region width with $W_1 > 20$ m for circuitous pattern, m
W_1	residual field width, m

harvesting was fixed at L_l.

With $W_1 > 20$ m, the residual work field is divided into several sub-regions with width 10–12 m. The sub-regions are harvested by inner- or outer-circular patterns (Fig. 3). As the combine finishes one long side, it turns along a “U” -type path to the next starting point.

b. Continuous pattern (Fig. 4)

After the first stage, rice is harvested by a continuous pattern. Each time requires a 180° turn at a limited distance.

2.1.2. *Analysis of required time*

a. Headland area and operation time

The headland area, A_h (m^2), can be calculated as follows:

$$A_h = 4a^*b + 2W_h^*(L + W - 2a - 2b) \quad (1)$$

where a = length of headland (m).

b = width of headland (m),
W_h = width of the manual reaped around four sides (m),
W = width of paddy field (m) and
L = length of paddy field (m).

The manual reap-time for the headland was T_h (sec),

$$T_h = A_h{}^*C_m \quad (2)$$

where C_m = manual capacity of reaping by hand (sec/m^2).

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

$$T_s = A_h{}^*S_m \quad (3)$$

where S_m = operating capacity for the thresher to thresh the grains reaped by hand (sec/m^2).

b. Operating time for the first stage

The travel paths of the combine during the first stage are in Table 1.

The total travelled paths was P_t (m),

$$P_t = 2^*N_l{}^*(L + W) - 4 * w * N_1^2 \quad (4)$$

where N_1 = required circuit number for the first stage and

w = effective operating width of combine (m).

The required operating time for this first stage was T_1 (sec),

$$T_1 = (2 * N_1 * (L + W) - 4 * N_1^2 * W)/s + 4 * N_1 * T_f \quad (5)$$

where s = the operating velocity for the combine (m/sec) and

T_f = the time to turn a 90° corner (sec).

Please cite this article in press as: Weng, Y.-K., Chen, C., Work patterns, capacity and cost of rice combine, Engineering in Agriculture, Environment and Food (2016), http://dx.doi.org/10.1016/j.eaef.2016.05.005