

Computer Simulation Using the IFPS Model for the Prediction of Implements Field Performance Variables

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Abstract

A farmer's choice of farm equipment typically depends on the size of the farm and the types of crops cultivated. Therefore, the selection of agricultural machinery should be based on its anticipated performance, operational requirements, and associated costs. In selecting field machinery, one of the most important variables to consider is the size or capacity of the machine. This study developed and implemented an Implement Field Performance Simulator (IFPS) model using Python to evaluate the field performance of agricultural implements. The model considered four key performance parameters: total field time, theoretical field capacity, effective field capacity, and field efficiency. The simulation was conducted using implement widths of 1.0 m and 2.0 m at operational speeds of 4, 5, and 6 km/h. The model was developed, compiled, and tested to identify and correct errors. The results indicated that increasing operational speed and implement width reduced total field time and increased both theoretical and effective field capacities. However, field efficiency generally decreased as operational speed increased. The highest field efficiency of 85.5% was recorded for the 2.0 m implement operating at 4 km/h, while the lowest efficiency of 80.70% was recorded for the 1.0 m implement. The study concluded that implement width had a greater influence on effective field capacity than operational speed within the conditions investigated. Therefore, selecting an appropriate implement width is essential for improving field capacity and overall operational performance in agricultural mechanisation.

Keywords: *Computer Simulation, IFPS Model, field time, Theoretical field capacity, Effective field capacity, Field Efficiency.*

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I. INTRODUCTION

In selecting a piece of farm machinery in order to ensure optional selection, several factors, such as implement performance (trade mark, model, repairs and maintenance, ease of adjustment and adaptability to soil and environmental condition), power requirement and its

availability, labour, timeliness, costs, and social factors, have to be taken into account.

Once a selection is made, the actual performance of the machine depends on various factors, including ecological factors (such as soil, vegetation, topography,

and rainfall), cultural practices (such as mono cropping or mixed cropping and crop type), the management system, the training of personnel and supervisors, and the availability of adequate maintenance facilities (Onwualu *et al.*, 2006).

It is necessary to know how a machine performs a given task and the rate at which it does the work. Machine performance and the rate at which it operates are vital for effective farm machinery management, as well as for the economic efficiency and timeliness of farm operations. Timeliness refers to the ability to perform an activity in a manner that optimises both the quantity and quality of the product. Machine performance includes the rate of work or capacity, completeness of operation and quality of work done (McColly and Martin, 1955; Onwualu *et al.*, 2006; Yohanna *et al.*, 2014).

Size selection of agricultural machinery must necessarily be based on expected or anticipated performance and expected cost. In field machinery selection, the most pertinent variable or factor is the size or capacity of the machine. Forward speed and power are found to affect the field capacity and effectiveness of operation (Donnell, 2001; Yohanna *et al.*, 2014).

Whitney (1988) indicated that implements should be selected based on their width to ensure sufficient capacity for completing the required work within the allotted time and maximising net profit; therefore, the width can be estimated as follows.

$$w = \frac{C_e \times C_f}{S_f \times F_e}$$

Where w – optimum implement width, m,
 C_e – effective field capacity, ha/hr
 C_f – correction factor
 S_f – forward speed, km/hr
 F_e – field efficiency in decimal

Measures of agricultural machine performance include the rate and quality of operations that are accomplished. The rate is a vital measure because few industries require such timely operation as agriculture, with its sensitivity to quality describing a machine's ability to operate without wasting product. Field capacity of an agricultural machine is the rate at which farm operations are accomplished (Donnell, 2001; Onwualu *et al.*, 2006; Yohanna *et al.*, 2014). The capacity of a farm machine, which is the rate at which it can cover a field while performing its intended function or useful work, is usually figured as the hectares per hour the machine will cover. The factors involved are the width of useful work and the speed of travel with an allowance for lost time in turning and servicing the machine.

The theoretical field capacity of an implement is the rate it will perform its intended function if it is operated continuously at its rated width. It is the actual area covered per hour. There is no allowance for loss of time and services (Smith, 1965). Kepner *et al.* (1980) also stated that the theoretical field capacity of an implement is the rate of field coverage that would be obtained when the machine is performing its function using a hundred per

cent of the rated forward speed and always covering a hundred per cent of the rated width. Culpin 1976 and 1981 and McColly and Martin 1955 stated the equation of theoretical field capacity as follows:

$$C_t = \frac{S_f W}{C}$$

Where C_t – Theoretical field capacity, ha/hr
 S_f – speed, km/hr
 W – Implement width, m
 C – Factor or constant = 10

C_f – Constant or correction factor is found by dividing the number of squared meter in hectare by the number of meter in a kilometer. (i.e. $\frac{10,000}{1000} = 10$)

The effective field capacity of an implement is the average or actual rate at which it covers a field expressed in ha/hr. This includes an allowance for loss of time in turning and servicing. The effective field capacity of a machine in ha/hr is determined by dividing the product of the speed in km/hr and the rated width in m, then multiplying the result by the field efficiency in decimal.

Mathematically, effective field capacity, $C_e = \frac{S_f \times W \times F_e}{C_f}$

$$\text{but } \frac{S_f \times W}{C_f} = C_t,$$

$$\text{hence } C_e = C_t \times F_e$$

Where S_f – forward speed, km/hr
 W – rated implement width, m
 F_e – field efficiency in decimal
 C_f – correction factor or constant

The effective field capacity is the actual rate of performance of land or crop processed in a given time, and it can be expressed in area per unit time or material per unit of time. Researchers discovered that implement size influenced effective field capacity. Ahmed and Haffer (1993) reported that a heavy disc harrow showed higher effective field capacity than a light disc harrow. Farmers can increase field efficiency by increasing the operating speed or implement width; it would appear that doubling the size or speed would double the capacity (Kepner *et al.*, 1980). Smith (1965) stated that doubling the size of a machine does not double the theoretical or effective field capacity, but it may decrease the field efficiency.

Smith (1965) defined the field efficiency of a machine as the effective field capacity divided by the theoretical field capacity, multiplied by 100 per cent; this efficiency is always less than 100 and is influenced by various factors related to the effective field capacity. As reported in ASAE (2003), field efficiency is the ratio between the productivity of a machine under field conditions and the theoretical maximum productivity. Field efficiency accounts the failure to utilise the theoretical operating width of the machine, time lost because of operator capacity and habits, to utilise the theoretical operating width of the machine, time lost because of operator capacity and habits and operating policy, and field characteristics. Travel to and from a field, major repairs, preventive maintenance and daily service (or routine maintenance)

activities are not included in field time or field efficiency. Field efficiency refers to the time and width of machine utilisation, specifically comparing the actual time a machine spends in the field performing its intended tasks to the total time it is present in the field (Smith, 1965).

Field efficiency is not constant for a particular machine, but it varies with the size and shape of the field, pattern of field operation, crop yield, moisture content and crop conditions. The following accounts for the majority of time lost in the field.

- (i) Turning and idle travel time at row ends and crossing from one field to the adjacent field.
- (ii) Time for material handling such as adding seeds, fertilisers, etc.
- (iii) Cleaning of clogged equipment
- (iv) Minor repairs and machine adjustment in the field
- (v) Maintenance in the field, such as lubrication and adding or refuelling, besides daily service.
- (vi) Time for unloading harvested products
- (vii) Breakdowns
- (viii) Waiting for other machines
- (ix) Resting animal power

Of all these factors, the percentage of time lost is the most difficult to evaluate (McColly and Martin 1955). The effective field capacity can be determined on an area basis or a material basis as follows:

- (i) On the area base, $C_a = \frac{SWF_e}{10}$

Where, C_a – Area effective field capacity, ha/hr
 S – Field forward speed, km/hr
 W – Implement working width, m
 F_e – Field efficiency, in decimal

- (ii) On material base, $C_m = \frac{SWYF_e}{10}$

Where, C_m – Material capacity, ton/hr
 S – Field forward speed, km/hr
 W – Implement working width, m
 Y – Unit yield of the field, ton/ha
 F_e – Field efficiency, in decimal

The optimum capacity of a machine can be estimated from the equation (ASAE, 2003)

$$M_{oc} = \sqrt{\frac{100A}{C_o K_p} \left[L_c + T_{fc} + \frac{K_3 AW}{ZP(P_{wd})} \right]}$$

Where, M_{oc} – Optimum Capacity of a machine, ha/hr
 A – Area, ha

C_o – Ownership cost percentage, % (percent)

K_p – Unit price function, ₦/ha.hr

L_c – Labour cost, ₦/ha

T_{fc} – Tractor Ownership Cost, ₦/ha

K_3 – Timeliness Coefficient obtained from ASAE D497, clause 8

W – Width of Implement, m.

Z – 4 if the operation can be balanced evenly about the optimum time and a value of 2 if the operation either commences or terminates at the optimum time.

G – The expected time available for field work each day, hr.

P_{wd} – Probability of a working day, in decimal.

Peterson *et al.* (1981) found that field efficiency decreased with increasing implement width when field operations were conducted between terraces. Randel *et al.* (2001) reported that field efficiency decreased with increasing planter width. Field size had little impact on field efficiency. Steichen and Powell (1985) presented a farmability index for terraced fields and concluded that field efficiency was a function of the implement and terrace design. Field efficiency includes the effect of time lost in the field and the failure to utilise the full width of the machine (Bower, 1985). It is not constant for a particular machine but varies with the size and shape of the field, pattern of the field operation, crop yield, moisture and crop condition. Bower (1985) further reported that the lost time is the most vital factor that affects the field capacity and efficiency of a machine. Lost time may occur due to various factors, including adjusting or lubricating the machine, machine breakdowns, equipment clogging, turning at the ends, adding seeds and fertilisers, or personal time taken by the operator (Kepner *et al.*, 1980). Donnell (2001) reported that the factors affecting field efficiency include the theoretical field capacity of the machine, machine manoeuvrability, field shape, field pattern, field size yield (for harvesting operations), soil and crop conditions, and system limitations. The type of implement and the physical condition of the soil are important factors that affect the field capacity and efficiency of tillage implements; when soil conditions are poor for machine operation, the forward speed is usually reduced (Donnell, 2001; Yohanna *et al.*, 2014). Belah and Dahab (1992) found that chisel ploughs recorded higher values of power requirements and theoretical and effective field capacities in loose clay soil compared to disc and mouldboard ploughs.

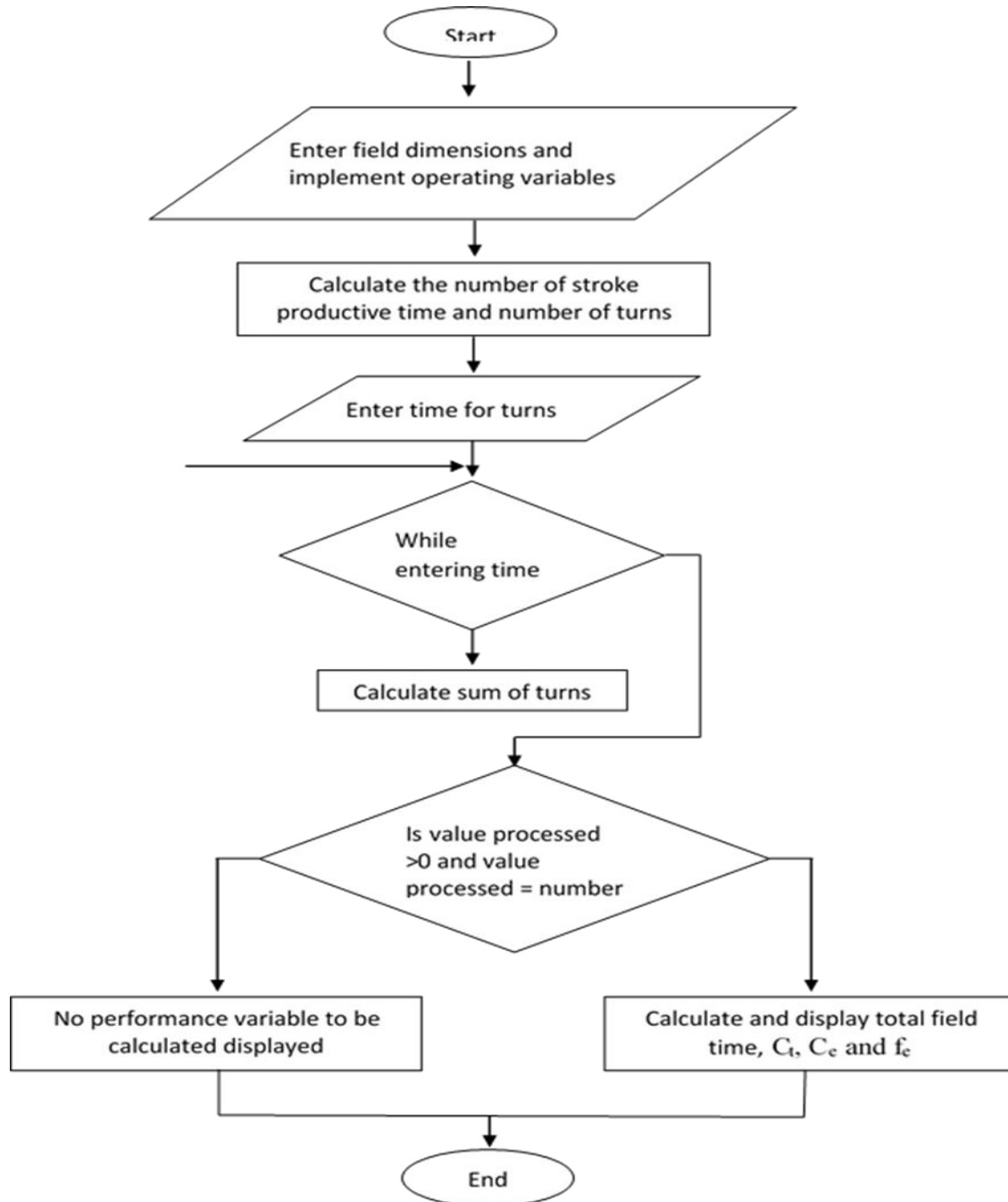
The objective of the research work is to develop an Implement Field Performance Simulator (IFPS) model for predicting the theoretical field capacity, effective field capacity and field efficiency of a field operation for implementation with different effective widths and different operating forward speeds.

2. METHODOLOGY

The variables shown in Table 1 were used as inputs for the programmes developed using the computer. The programme was built and compiled and was then checked for error correction (debugging); the flowchart of the programme developed is as shown in Figure 1. The predicted performance parameters for the implementation are total time, theoretical field capacity, effective field capacity, and field efficiency.

Table 1: The programme parameters/variable or inputs used

Variables	units
Field length, L	m
Field width, W	m
Operating forward speed, S	km/hr
Implement effective width, W	m
Productive time, t_p	sec
Average time for turning, t_a	sec
Time losses, t_L	sec

**Figure 1:** Flow Chart of the IFPS Computer Programme

3. RESULTS AND DISCUSSION

3.1 Results Presentation

Table 2: Plough Performance at 1.0m effective width

Speed km/hr	Performance Parameters or Variables			
	T _t hr	C _t ha/hr	C _e ha/hr	f _e %
4.0	0.589	0.400	0.340	85
5.0	0.485	0.500	0.415	82.9
6.0	0.415	0.600	0.485	80.8

Key

T_t – Total field time
C_t – Theoretical field capacity
C_e – Effective field capacity
f_e – Field efficiency

Table 3: Plough Performance at 2.0m effective width

Speed km/hr	Performance Parameters or Variables			
	T _t hr	C _t ha/hr	C _e ha/hr	f _e %
4.0	0.295	0.800	0.685	85.6
5.0	0.240	1.000	0.835	83.5
6.0	0.205	1.200	0.976	81.4

Legend

T_t – Total field time
C_t – Theoretical field capacity
C_e – Effective field capacity
f_e – Field efficiency

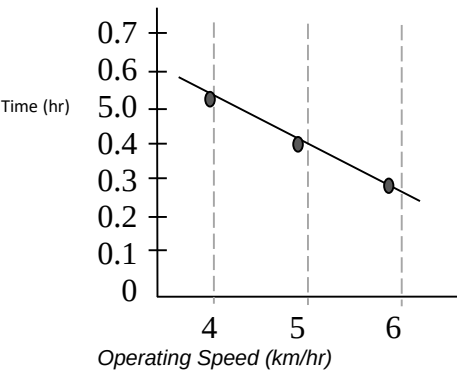


Fig. 2: Total Field Time for 1m wide Implement

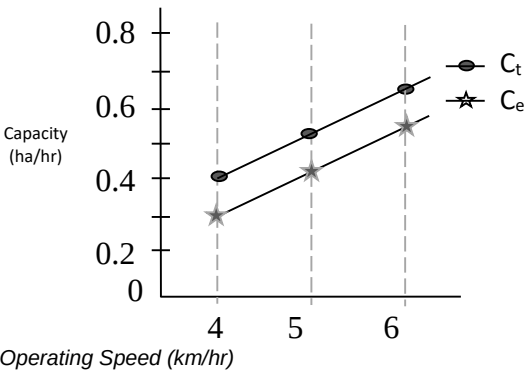


Fig. 3: Field Capacity for 1m wide Implement

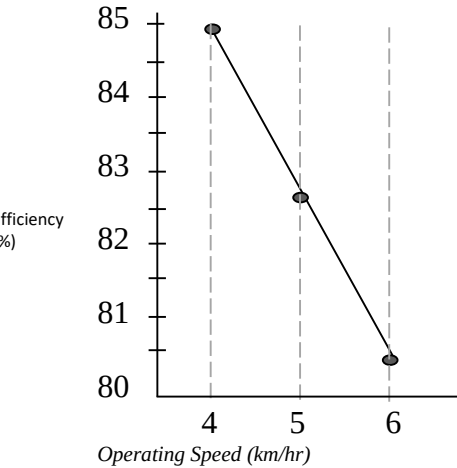


Fig. 4: Field Efficiency for 1m wide Implement

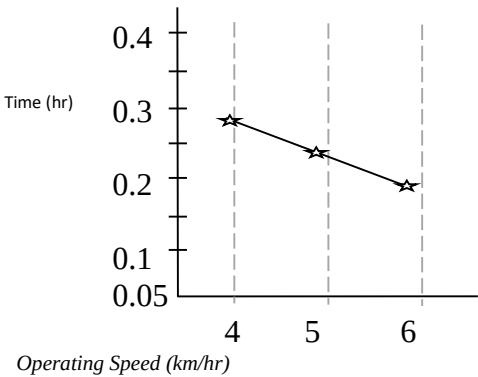


Fig. 5: Total Field Time for 2m wide implement

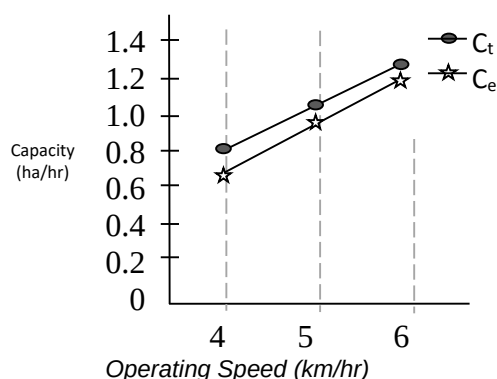


Fig. 6: Field Capacity for 2m wide Implement

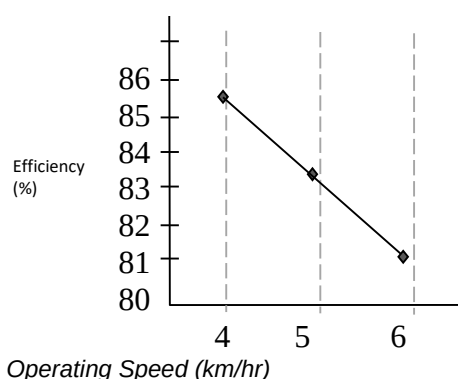


Fig 7: Field Efficiency for 2m wide Implement

4. DISCUSSION OF RESULTS.

Table 2 and figures 2, 3, and 4 showed the performance variables of 1 m effective plough width, which operated at speeds of 4 km/hr, 5 km/hr, and 6 km/hr; the value of total field time was 0.589 hr; the theoretical field capacity was 0.400 ha/hr; the effective field capacity was 0.340 ha/hr; and the field efficiency was 85.0% at 5 km/hr. The values for total field time, theoretical field capacity, effective field capacity, and field efficiency were 0.485 ha/hr, 0.500 ha/hr, 0.415 ha/hr, and 82.9%, respectively. At 6 km/hr the values were 0.415 hr, 0.600 ha/hr, 0.485 ha/hr and 80.8%, which were for total field time, theoretical field capacity, effective field capacity and field efficiency, respectively.

In terms of table 3, figures 5, 6 and 7 for 2m implement width, it was shown that at 4 km/hr, the value of total field time was 0.295 hr, theoretical field capacity was 0.800 ha/hr, effective field capacity was 0.685 ha/hr and field efficiency was 85.6%. At 5 km/hr, the values for total field time, theoretical field capacity, effective field capacity and field efficiency were 0.240 hr, 1.000 ha/hr, 0.835 ha/hr and 83.5%, respectively. At 6 km/hr the values of total field time, theoretical field capacity, effective field capacity and field efficiency were 0.205 hr, 1.200 ha/hr, 0.975 ha/hr and 81.4%, respectively.

These results showed that as speed increased, the total field time decreased and the theoretical and effective field capacities increased, while the field efficiency decreased. It can be deduced here that it is not necessary to have higher efficiency at higher speeds. This conclusion is in agreement with the work of Peterson *et al.* (1981) that field efficiency decreased with increasing implement width when field operations were conducted between terraces. The results also indicated that the width of the implement has a noticeable effect in improving the field efficiency, as shown in Table 3. When the width of the implement was increased from 1 m to 2 m, the field efficiency increased from 85% to 85.6%, 82.9% to 83.5% and 80.8% to 81.4% for speeds of 4 km/hr, 5 km/hr and 6 km/hr, respectively.

5. CONCLUSION

A computer simulation was developed via the IFPS

model to predict the field performance parameters or variables of implements with different widths operated at various forward speeds. The width of the plough was found to have a higher effect than the plough operating speed on increasing the effective field capacity; hence, the field efficiency. The results obtained show that as speed increased, the total field time decreased and the theoretical and effective field capacities increased, while the field efficiency decreased. It can be concluded that higher speeds do not require higher field efficiency, while the width of the implement has a noticeable effect on improving field efficiency.

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