Development of a Computer Model to Predict the Performance and Cost of Use of an *Acha* Harvesting Machine in Nigeria

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ABSTRACT

Large scale production of *acha* (Digitaria specie) has been hampered for non-availability of machines for various aspects of its production. Lack of design data is responsible for lack of development of appropriate harvesters for *acha* crop. Previous research identified pertinent parameters that affect *acha* harvesting and the functional relationships between these parameters were developed. These functions required labourious computations to determine an *acha* harvester Material Capacity, Energy requirements and Cost of the harvest operation. The aim of this paper was to develop a computer model that will simplify the computation of these factors of operation performance. A dynamic programming algorithm was used and a flowchart describing the process was developed, from which a programming code in the Java programing language was adopted. The output from the programme showed that the programme was able to adequately compute the harvester Material Capacity, Energy Required to achieve the observed material capacity as well as the cost of the operation. The paper therefore concluded that the model was able to predict the outcome of *acha* harvesting operation, and recommends its use by *acha* farmers and adaptation to similar crops.

Keywords: Material capacity, Energy requirement, Operating cost, Computer model

INTRODUCTION

Acha (Digitaria Specie) is a cereal crop with Plateau state of Nigeria being worlds largest producer (Tanam, 2021), producing about half of world total production. In the year 2002, about 347,380 ha of land was devoted to *acha* production, with Nigeria alone cultivating almost half of this size (FAOSTAT, 2003). Tanam (2021) observed the production of *acha* has been on the decline inspite of its increase in demand due its medicinal and nutritious values. This is attributed to the fact that its production is still by traditional manual methods employing hand tools. Philip and Itodo (2006), cited by Tanam and Olaoye (2022) reported that no aspect of its production is known to be mechanized. Mechanisation problems are futher compounded by the fact that crops have widely varying characteristics (Ajiboye, 2007) and no single machine can be applied to all crops.

Harvesting *acha*, a critical aspect of its production is done manually because appropriate harvesters are not availbel as a result of nonavalability design data (Tanam, 2021), hence level of losses are high. Tanam and Olaoye (2022) reported that parameters pertinent to the design of a mechanical harvester for *acha* include Operating speed, Knife cutting speed, and Reel index. Tanam *et al.* (2022) developed statiscal model (Equations 1 and 2) to predict the performance of a rig developed by Tanam (2021). Performance was measured by the Material Capacity of the machine, which is a measure of the quantity of material per hectare the machine is capable of gathering, and energy, measured by quantity of fuel, required to achieve the material capacity.

The models had p-values of 0.0000209 and 0.0008454 for material capacity anf energy respectively.

$$C_m = 56.63 - 35.04I^2 - 10.442\,VI^2 - 4.29I - 135.23V - 0.04S + 23.00V^2 - 22.20V^2I + 143.57VI - 0.06V^2S + 0.06V^2SI - 0.32VSI - 0.00025S^2 + 0.35VS + 0.24SI \qquad 1$$

$$E = 24.23 - 0.000007VS^2 + 0.003V^2S - 0.0035V^2 + 0.50V^2I - 5.95I - 0.02S - 6.47V + 0.01VSI \qquad 2$$

Where C_m = material capacity (kg/h), I = reel index (decimal), V = operating (km/h), S = knife speed (rpm) and E = energy (l/h)

Tanam (2021) grouped cost of use of the harvester rig into fisxed cost and operating cost. Fixed costs are incurred whether or not the machine is used and include depreciation, interest on investment, taxes and insurance, while operating costs are those incurred as a result of normal use (operation of machine) and include cost of fuel, maintenance and labour. Total cost of operation of the machine was given by Tanam (2021) as Equation 3.

$$C_T = D_{Aha} + I_{ha} + T_{ha} + E_{cha} + M_{cha} + L_{cha} \qquad 3$$

Where

D_{Aha} = Annual depreciation per hectare
I_{ha} = Interest cost per hectare
T_{ha} = Tax, Insurance and shelter cost per hectare
E_{cha} = Energy cost per hectare
M_{cha} = Cost of maintenance/repairs per hectare
L_{cha} = Labour cost per hectare

The objective of this paper was to develop a computer model to predict the material capacity, energy requirement and cost of operation of a harvesting machine for *acha*. This would enable the farmer determine in advance what quantity of material to expect in a given time and at what cost.

MATERIALS AND METHOD

The flow chart representation of the model is presented as Figure 1. The farmer would have to decide what machine operating parameter settings to use, the program then supplies the required output.

To determine the cost of use of the machine, the following assumptions were made:

i. Machine working hour/day = 8 h
ii. harvesting is completed in 25 days therefore working hours / year = 200 hours
iii. lifespan of harvester = 10 years
iv. interest rate = 12% of cost of harvester. Interest rate was obtained from the Nigeria Bank of Agriculture.
v. estimate for maintenance = 0.025% of cost of harvester (Kepner *et al*, 1987)
vi. estimate for insurance and tax = 2% of cost of harvester (Kepner *et al*, 1987)

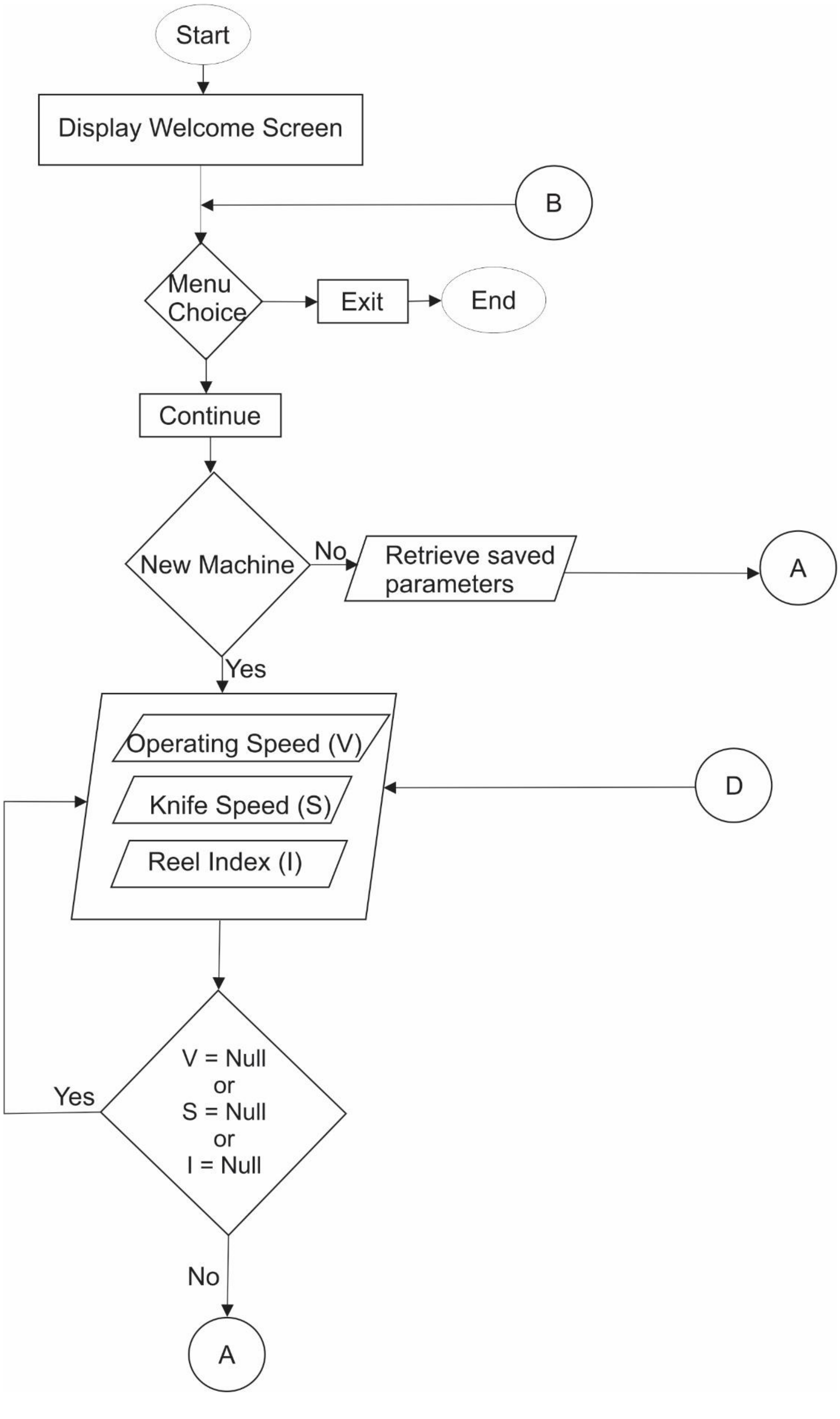

Figure 1: Model Flowchart (Section 1)

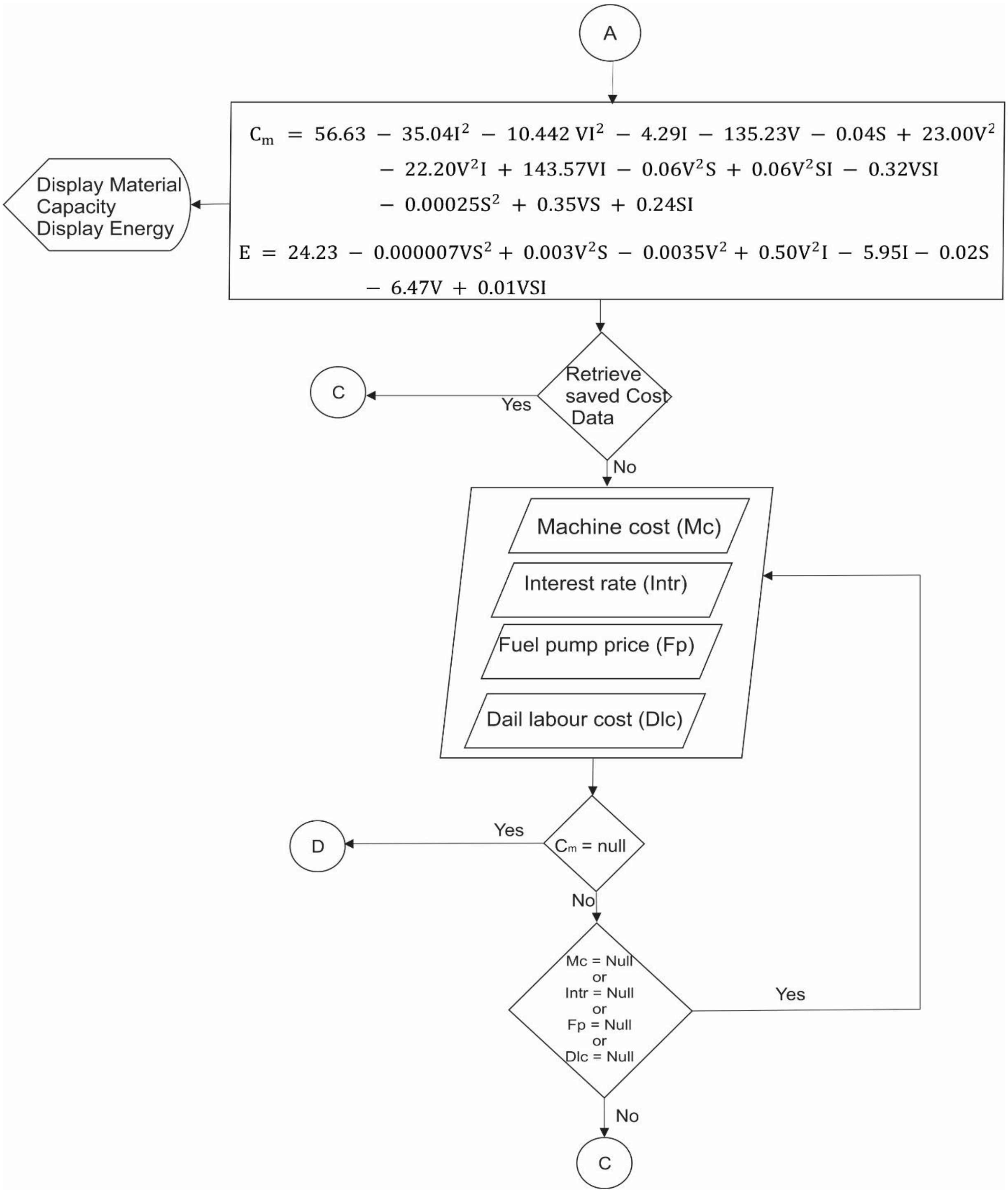

Figure 1: Model Flowchart (Section 2)

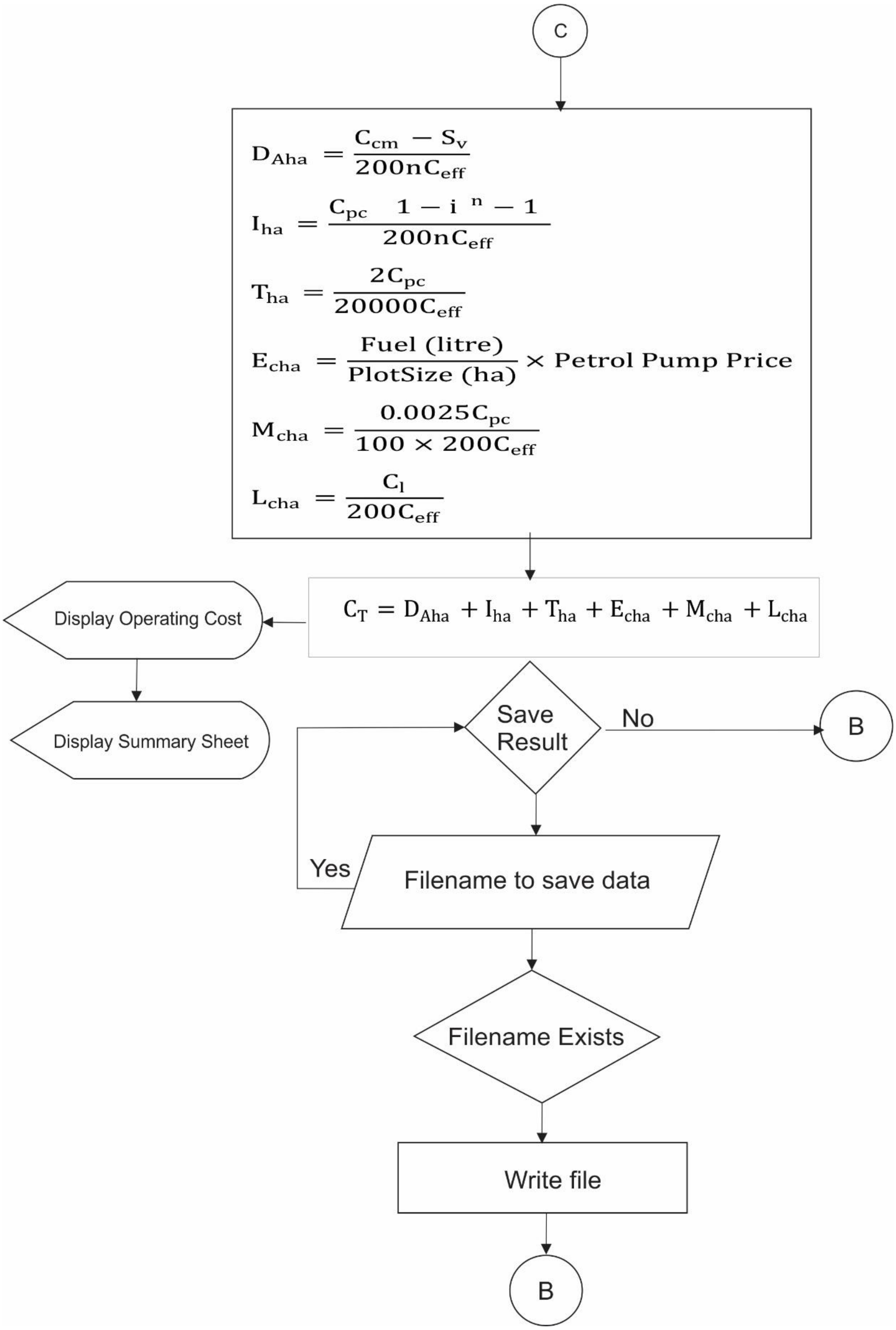

Figure 1: Model Flowchart (Section 3)

Annual depreciation was determined by the straight-line method for its simplicity, practicality and acceptability and recommendation (Kepner *et al.*, 1987). Annual depreciation is given as

$$D_{Aha} = \frac{C_{cm} - S_v}{200nC_{eff}} \quad 4$$

where
D_{Aha} = Annual depreciation
C_{pc} = Purchase Cost of machine
S_v = Salvage value (= 10% of machine cost)
n = estimated useful life of machine (yrs)
C_{eff} = Effective field capacity of machine

Since the straight-line method based on the average investment during the machine's useful life was used to determine machine depreciation, a constant interest was used to determine Interest on investment. Interest on investment for each year is therefore given as

$$I_{inv} = \frac{C_{fc} - C_{pc}}{n} \quad 5$$

where

I_{inv} = interest on investment
C_{pc} and n are as earlier defined.
C_{fc} = future cost of machine

$$C_{fc} = C_{pc}(1 + i)^n \quad 6$$

Where i = prevailing interest rate

Putting Equation 6 into Equation 5, Equation 5 becomes

$$I_{inv} = \frac{C_{pc}(1 - i)^n - C_{pc}}{n} = \frac{C_{pc}[(1 + i)^n - 1]}{n} \quad 7$$

I_{inv} can be expressed per hectare as

$$I_{ha} = \frac{I_{inv}}{200C_{eff}} = \frac{C_{pc}[(1 - i)^n - 1]}{200nC_{eff}} \quad 8$$

Kepner *et al.* (1987) recommended the inclusion of 2% of machine purchase cost as total annual cost for taxes, insurance and shelter, if straight-line method was used to determine depreciation.

$$\therefore T_{IS} = \frac{2C_{pc}}{100} \quad 9$$

Where T_{IS} = Cost of Taxes, Insurance and shelter charge. Expressing in hectare, Equation 9 becomes

$$T_{ha} = \frac{2C_{pc}}{100 \times 200C_{eff}} = \frac{2C_{pc}}{20000C_{eff}} \qquad 10$$

Fuelling cost was determined by average fuel quantity consumed in harvesting and multiplying by the prevailing pump price of petrol. This value forms the cost of fuel per hectare, E_{cha}, giving as

$$E_{cha} = \frac{\text{Fuel (litre)}}{\text{PlotSize (ha)}} \times \text{Petrol Pump Price}$$

Maintenance cost includes cost repairs or replacement of parts, daily service, lubrication, adjustments of worn parts, re-tightening of bolt and screws and the like. Although maintenance cost per hour of use increases with age of machine, for straight-line depreciation, uniform annual charge was applied throughout the useful life of the machine. Kepner *et al* (1987) recommended a value of 0.025% of cost of machine as the average hourly repair/maintenance cost, giving as Equation 11, expressed per hectare.

$$M_{cha} = \frac{0.0025C_{pc}}{100 \times 200C_{eff}} \qquad 11$$

To determine cost of labour it was assumed that hired hands would work 8hrs per day for 25 days.

$$\therefore \quad L_{cha} = \frac{C_l}{200C_{eff}} \qquad 12$$

Where

C_l = daily labour cost

L_{cha} = labour cost per hectare.

Progrmme Inputs were desired speed of operation, knife cutting speed reel index and all cost factors (machine cost, interest rate, fuel pump price and daily labour cost). Programme Output were material capacity, energy required and estimated cost of the operation

RESULTS AND DISCUSSION

Figures 2 and 3 show the welcome screen and data input/output screen respectively of the developed programme based on the flowchart. Figure 4 shaows error dialog that appears if an attempt is made to determine cost of operation with providing the machine parameter. Figure 5 shows Output Summary screen, showing details of all results. These show that the programme was able to determine the machine Material Capacity as well as the cost of producing the observed material capacity. The application of this model can be very helpful to farmer growing *acha* in Nigeria as they would be able to forcast their production expenditure and predict possible revenue.

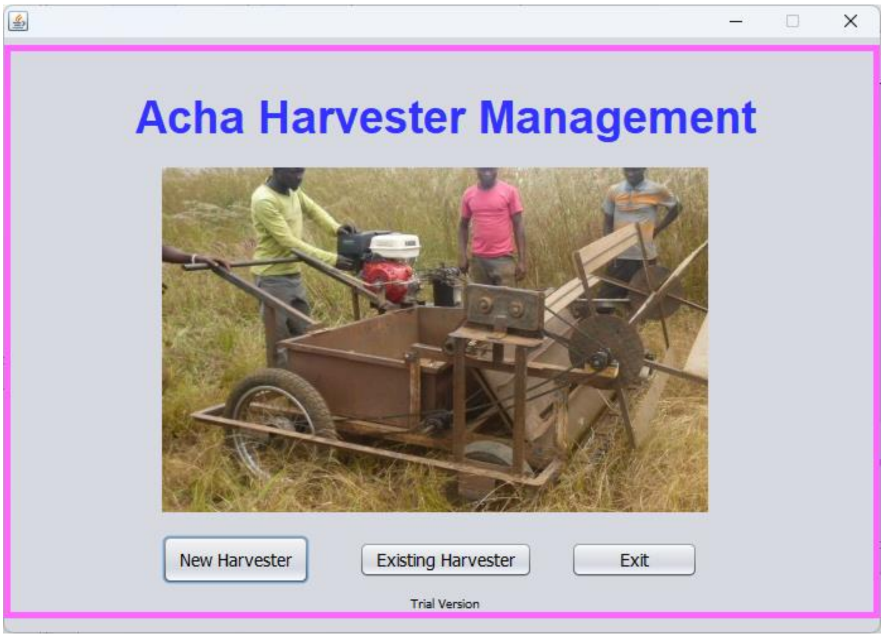

Figure 2: Programme Welcome Screen showing initial menu

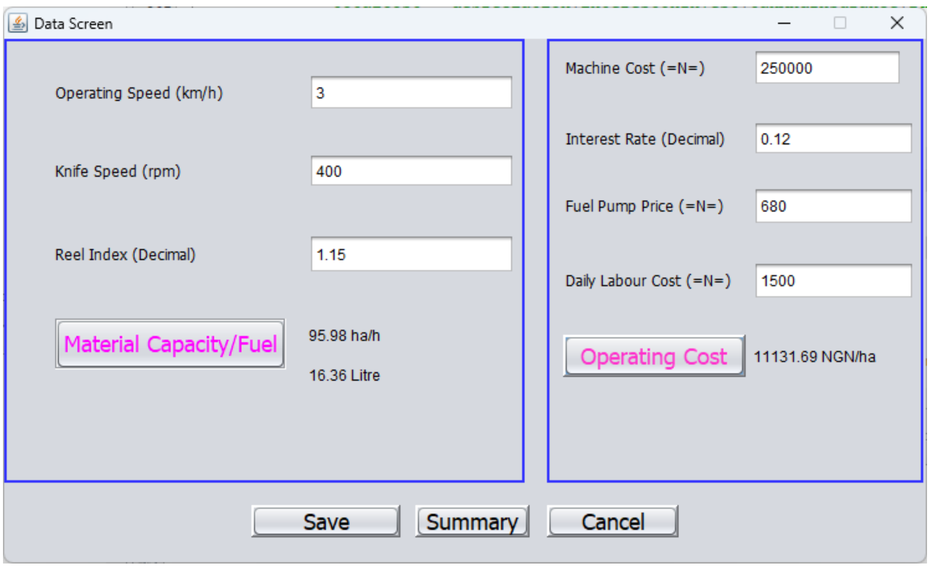

Figure 3: Data Input/Output Screen, showing machine Parameters and Cost Factors

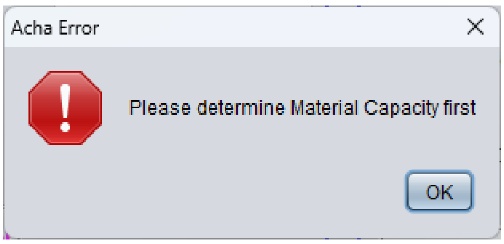

Figure 4: Error Dialog, indicating the need to fisrt determine Macterial Capacity before cost

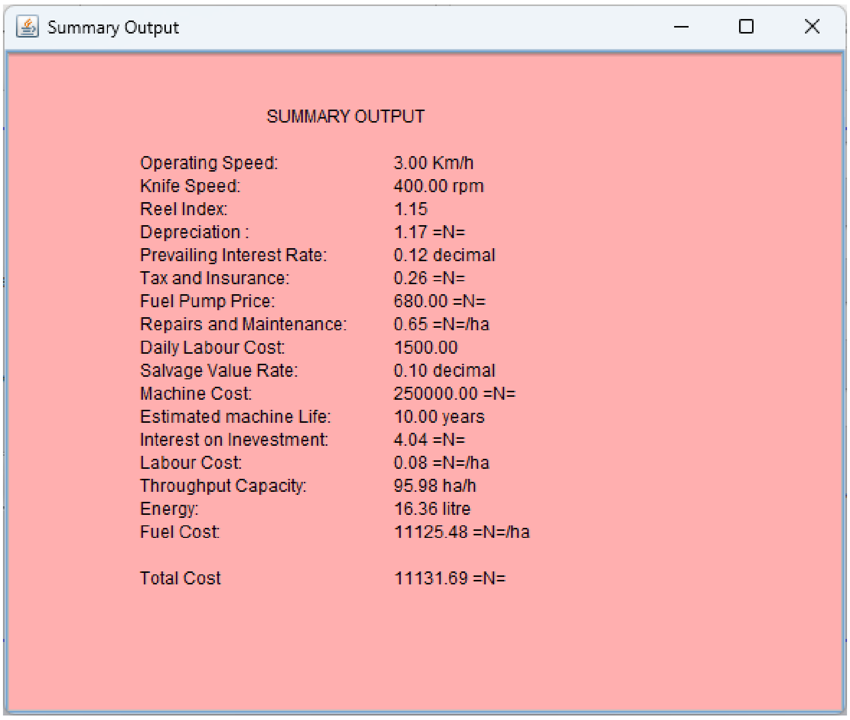

Figure 5: Summary Output Screen

A DialogBox to input the name of a file to save machine parameters is shown in Figure 6. Saving the data simplifies future data entry for the same machine parameters.

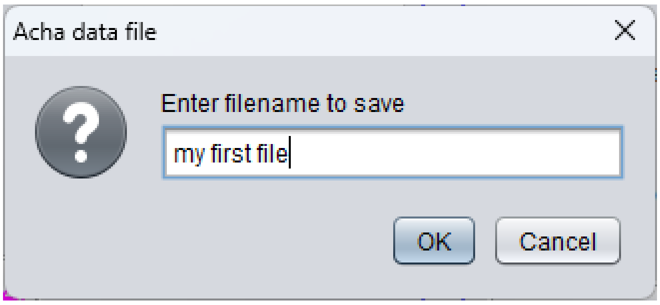

Figure 6: File Request Dialog

CONCLUSION

A computer model to simplify the computation of an *acha* haverter Material Capacity, Energy requirement and Cost operation of the machine was developed. A Flowchart describing the process was developed, from which a simple Java Application was developed. The model was able to compute the haverter Material Capacity, Energy requirement and Cost operation.

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