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Evaluation of Tractor Field Performance Using Visual Basics Programming for Agricultural Farm Lands

Yared Seifu[1*], Someshakher S Hiremath[2], Simie Tola[1], Amana Wako[1]

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ABSTRACT

The purpose of this research was to developed a program in visual basic software for predicting tractor implement performance of tractor implement combination. A conventional tillage system with a mounted mouldboard plough and three bottoms was used to collect data from a Chery tractor (Model RM750) with a four-wheel drive. The soil texture class were determined in laboratory. Soil cone index value was measured using a SpotOn digital compaction meter. The output of the visual basics simulation in this study was obtained by varying the depth of operation and soil cone index for an experimental farm field. From the simulation output the results this study covers of drawbar power, implement draft, pull, tractive force, fuel consumption, slip, power delivery efficiency, dynamic weight and wheel dynamic reactions were drawn by varying depth and soil cone index value.

INTRODUCTION

In a mechanization system, farm machinery is employed for land preparation to harvesting processes by driving in agricultural land. Computer simulations and modelling for predicting tractor performance assist researchers in determining the relative importance of many factors affecting tractor field performance without conducting costly and time-consuming field tests. Mathematical modelling for soil and traction device interaction makes researchers and designers to analyse problems associated to traction performance of agricultural tractors, to improve the design of tractors, to optimize operational parameters and to improve the performance of the tractor-implement systems.

The tractor performance program in Visual C++ developed to predict the performance of 2WD and 4WD tractors for both bias-ply and radial tires (Al-Hamed *et al.*, 2001). Specifically, the program has to predict the performance parameters for a given tractor by accessing databases concerning tractor specification, tire information, and traction equation coefficients. The performance of an agricultural tractor's three-point linkage hitch system in the vertical longitudinal plane is assessed using a visual basic program (Dhruw *et al.*, 2018).

The Visual Basic programming language was developed for predicting tractors performance on agricultural soils for predicting tractors field performance (Almaliki *et al.*, 2016). A computer simulation were developed on how ballast, Tyre inflation pressure, transmission gear, engine speed, and work load affect fuel consumption per work hour, fuel consumption per tilled area, and specific volumetric fuel consumption (Lee *et al.*, 2016).

In order to evaluate a tractor's performance in terms of drawbar power, fuel consumption, rolling resistance, and tractive efficiency, numerous configurations of artificial neural networks (ANNs) were constructed (Almaliki *et al.*, 2016). Tractor, wheel slip in tillage operations concerning forward speed and ploughing depth on a two-wheel drive and four-wheel drive simulated using data mining methodologies of artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) (Shafaei *et al.*, 2019) .

A graphical method for forecasting tractor field performance was provided by (Wismer & Luth, 1974; Zoz, 1972). The method predicted drawbar pull, drawbar power, travel speed, and travel reduction of 2WD tractors under various soil conditions. Many researchers used these equations to develop tractive performance models for tractors after they described the tractive characteristics of both towed and driven tires. The robust predictive controller model for path tracking of a tracked vehicle towing a steerable trailer is developed (Wang *et al.*, 2016). For a broader range of actual field conditions, (Clark, 1985) proposed generalized forms of the Wismer and Luth model. (Brixius, 1987) presented equations to predict the tractive performance of bias-ply tires operating on agricultural soils as revisions to equations (Wismer & Luth, 1973).

Using the equation-solving program TK Solver, (Evans *et al.*, 1989) created a traction prediction and ballast selection model based on the traction equations suggested by (Brixius, 1987). By changing the coefficients of the traction equations, the traction model that was created for a specific small front-wheel assist tractor operating on a grass surface was presented. A three dimensional (3D) discrete element model (DEM) for the simulation of the soil–cone penetrometer interaction in a slightly cohesive loamy sand soil is developed (Kotrocz *et al.*, 2016). Polcar

[1] Department of Mechanical Engineering, Adama science and technology university, Adama, Ethiopia
[2] Department of Mechanical Engineering. Indian Institute of Technology Madras University Chennai, India
[*] Corresponding author's email: yaredseifu80@gmail.com

et al experimentally determine how the tractor's weight distribution changes during loading by drawbar pull, and how the tractor's weight affects its drawbar pull properties (Polcar *et al*., 2017). The objective of this study was to developed the Visual Basic programming language for predicting tractors performance on different agricultural soils for predicting tractors field performance.

MATERIALS AND METHODS

Field experiments

In this study, a conventional tillage system with a mounted mouldboard plough and three bottoms was used to collect data from a Chery tractor (Model RM750) with a four-wheel drive. The soil texture class were determined in laboratory by Putting sample soil into a flask and filling water. After Stirring the water and soil well and waiting for an hour, the water will have cleared and the larger particles have settled with different layers based on size and density. Using a soil texture triangle, the texture of the soil was identified. Soil cone index value was measured using a SpotOn digital compaction meter with a 12.8 mm steel cone diameter with 30° included angle. For depth reference, the stainless-steel shaft is marked every 10 cm with a probe length of 76 cm. The specifications of tractor showed in Table 1.

Table 1: Technical information Chery RM750 tractor

Chery RM750 Technical information	
Fuel	Diesel
AG front tires	6.5-20
AG rear tires	14.9-30
Weight	2669 kg
Length	398 cm
Width	165 cm
Wheelbase	218 cm
Ground clearance	42 cm
Rear tread size	152.91cm
Front tread size	139.95cm
Engine size	4.9 L
Number of cylinders	4 cylinders
Horsepower	75 hp or 55.9 kW
Power RPM	2200 rpm
Engine torque	320.0 Nm
Engine torque RPM	1600 rpm
Bore stroke	108 x 135 mm
PTO claimed power	66.4 hp or 49.5 kW
Rear PTO RPM	540 rpm

Drawbar and tractive performance Prediction equations

Axle power

Consider the engine running at a rotational speed 'Ne' and torque 'Te' driving the drive wheels as the speed reduced the torque will increase. The engine power 'Pe' can be calculated by the following equation(Macmillan, 2003).

$$P_e = \frac{2\pi N_e T_e}{60} \qquad (1)$$

Considering the overall transmission ratio 'q' which is the ratio of engine speed to wheel speed (Ne/Nw) or wheel torque to engine torque (Tw/Te) (Macmillan, 2003)

$$q = \frac{N_e}{N_w} = \frac{T_w}{T_e} \qquad (2)$$

The axle power 'Pax' can be calculated by the (equation 3) (Macmillan, 2003)

$$P_{ax} = \frac{2\pi N_w T_w}{60} \qquad (3)$$

Drawbar power

Drawbar power is obtained using the relation between pull (net traction capacity) and actual travel speed as (Equation 4) (Kim *et al*., 2020):

$$P_{db} = P \times V_a \qquad (4)$$

where Pdb is drawbar power (kW), P is pull or net traction (kN) and Va is actual velocity (m/s).

By dividing Eqn. (3.4) by the weight on the wheel (W), the following equation results, (Kim *et al*., 2020)

$$\frac{T}{rW} = \frac{MR}{W} = \frac{P}{W} \qquad (5)$$

were,

$\frac{T}{rW}$ = Torque ratio or gross traction ratio,

$\frac{MR}{W}$ = Motion resistance ratio and

$\frac{P}{W}$ = Pull ratio or coefficient of traction.

Draft

The implement draft is estimated based on break horse power, implement type, depth of tillage, furrow slice width and angle of share. The implement draft is calculated using (equation 6) below (Sharma & Mukesh, 2019)

$$D_i = 3.6 \times P_{db} / V_a \qquad (6)$$

Where Pdb = Drawbar power,in KW, Va = Working speed of tractor in m/s and Di = Implement draft in Niwton

Also, the Implement draft can be calculated in terms of tillage parameters using (equation 7) below (Sharma & Mukesh, 2019)

$$D_i = k.n.a.b \qquad (7)$$

Where K = specific draft in N/mm2, n = number of bottoms, a = depth of plough, mm and

b = width of furrow slice, mm

Based on the mould board implement geometry the forces on the implement with respect to the pull can be derived (Sharma & Mukesh, 2019)

$$D = P\cos\theta_s \cos\alpha, \quad D_s = P\cos\theta_s \sin\alpha, \quad D_v = P\sin\theta_s \cos\alpha \qquad (8)$$

Where D = Horizontal draft, Dv = Vertical draft, Ds = Side draft, α = Load angle, Ψ =Cutting angle and θs =Shear angle

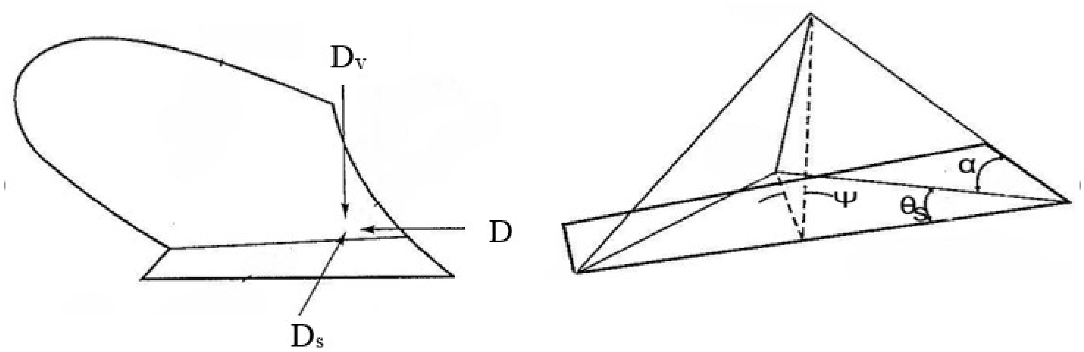

Figure 1: Mould board geometry with force components

Wheel Slip

Slip in a traction device occurs between the surfaces of the device and the medium on which it operates. This is defined as using (Equation 9) (Kim *et al.*, 2020)

$$S = 1 - \frac{V_a}{V_t} = 1 - \frac{V_a}{r\omega} \qquad (9)$$

where, r= rolling radius of wheel on hard surface, m,
S= wheel slip or travel reduction, %,
Vt= theoretical travel speed, m/s,
Va = actual travel speed, m/s and
ω= angular velocity of wheel in rad per second.

Tractive efficiency

The tractive efficiency (TE) is the ratio of output power to input power or drawbar power to wheel power. Tractive Efficiency considers only the losses between axle and drawbar (Kim *et al.*, 2020)

$$TE = \frac{\text{Output power}}{\text{Input power}} = \frac{P/W}{T/rW} \times (1 - S) \qquad (10)$$

$$TE = \left(1 - \frac{NTR}{GTR}\right) \times (1 - S) \qquad (11)$$

Where,
NTR=net traction ratio, GTR=gross traction ratio

Power Delivery Efficiency

Power Delivery Efficiency considers the entire vehicle from engine to drawbar including all hydraulic and drivetrain power losses. When using PDE as a performance comparison tool, either engine or PTO power can be used for the comparative calculations depending on what is available and convenient (Kim *et al.*, 2020).

$$PDE = \frac{P_{db}}{P_e} \qquad (12)$$

Fuel economy

The fuel consumption estimates used in cropping and machinery budgets are based on the average annual fuel consumption from Agricultural Machinery Management engineering practice. In determining the cost for a particular operation such as plowing, the fuel requirement should be based on the actual power required. The most widely used relationship for estimating fuel consumption of diesel engine in letter per hour (L/h) is given by (equation 13) (Grisso *et al.*, 2004):

$$FC = 0.223 \times P_{pto} \qquad (13)$$

Where, FC= Volumetric fuel consumption in l/h and Ppto = maximum PTO power, kW

The equation used to estimate of specific volumetric fuel consumption, SVFC is given in (equation 14) (Grisso *et al.*, 2004)

$$SFC = (2.64X + 3.91 - 0.203\sqrt{738X + 173}) \times X \times P_{pto} \qquad (14)$$

Where, X = the ratio of equivalent PTO power to rated PTO power, decimal

Dynamic front wheel reaction (Rf`)

The dynamic weight on tractor axles is required for predicting the field performance of tractor implement. A free body diagram of tractor implement combination is shown in Fig. 2.

Considering force and moments in figure 2 (Kumar and

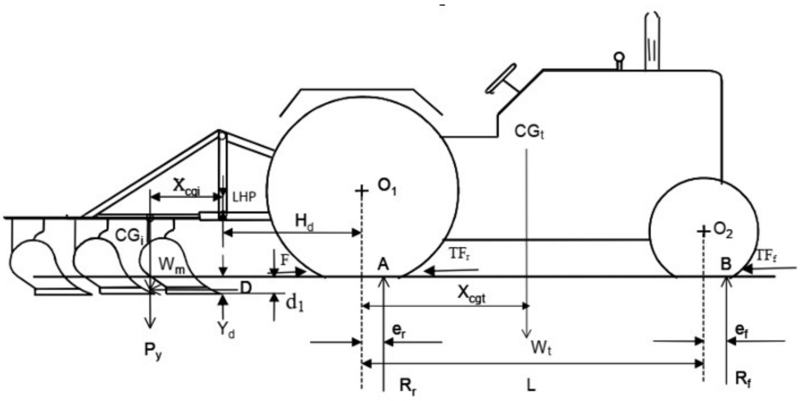

Figure 2: Forces acting on tractor- mould board plough combination

Pandey, 2012), the dynamic reaction on tractor rear wheel, Rr, and front wheels, Rf can be expressed as follows

$$R_r = \frac{W_t\left(L+e_f-X_{cgt}\right)+\left(W_m+P_y\right)\left(X_{cgi}+H_d+L+e_f\right)-DY_d}{L-e_r+e_f} \quad (15)$$

$$R_f = W_t + W_m + P_y - R_r \quad (16)$$

(Brixius, 1987), (Tiwari, 2006) and (Tiwari *et al.*, 2010) developed the following expressions for GTR and MRR as a function of mobility number (Bn) and wheel slip(S).

$$GTR = A_1\left(1-e^{-A_2B_n}\right)\times\left(1-e^{-A_3S}\right)+A_4 \quad (17)$$

$$B_n = \left(\frac{CI.b.d}{W}\right)\times\left(\frac{1+A_5\,{}^{\delta}\!/_{h}}{1+A_6\,{}^{b}\!/_{d}}\right) \quad (18)$$

Where, b = Unloaded tire section width
d = Unloaded tire diameter
δ = Tire deflection
h = Tire section height

$$MRR = \frac{A_7}{B_n}+A_4+\frac{0.5\times S}{\sqrt{B_n}} \quad (19)$$

$$NTR = GTR - MRR \quad (20)$$

Substituting equation 17 and equation 19 in to equation 20

$$NTR = \left(A_1\left(1-e^{-A_2B_n}\right)\times\left(1-e^{-A_3S}\right)+A_4\right)-\left(\frac{A_7}{B_n}+A_4+\frac{0.5\times S}{\sqrt{B_n}}\right) \quad (21)$$

Table 2: Traction equation coefficients for bias- and radial-ply tyres.

Traction coefficient	Bias-ply tyre		Radial-ply tyre	
	(Brixius, 1987)	(Tiwari, 2006)	Recommended range by (Brixius, 1987)	Mean value
A1	0.88	0.66	0.88	0.88
A2	0.1	0.09	0.1	0.1
A3	7.5	5.25	8.50–10.50	9.5
A4	0.04	0.035	0.03–0.035	0.032
A5	5	5	5	5
A6	3	3	3	3
A7	1	1.2	0.9	0.9

Development of the program software

The program was developed in Visual Basics 6.0 to calculate the tractive performance parameters based on the tractor parameters, soil type, depth of operation, implement geometry and implement type. Flow chart of the developed software for the prediction of drawbar performance of tractor implement is shown in (Figure 3). The input parameters for predicting the performance of tractors and implements in farm field is shown in (Figure .4). The performance of tractors and implements are shown in (Figure 5) of performance resuslt output desplay screen. Motion resistance ratio, growth traction ratio and net traction ratio were calculated in the program based on (Tiwari, 2006) equation. Visual Basic is an object-oriented programming language that focuses on the user's interaction with the program. The user who controls the flow of an application through actions performed via the graphical user interface, typically via the mouse or keyboard. Classes are a feature of visual basics, and they have methods and properties that can conduct actions and change an object's attributes. Class modules, modules, and forms are the three main building blocks of visual basics. An object's methods, properties, and other details are described in each class modules. The modules include a list of actions that must be taken. The visible portion of visual basics is represented by the forms. The visual basics programming form window used in this simulation consists of object window and code window. The object window is the place where the overall input and output parameters are added to the software as indicated in (Figure 4 and Figure 5). The code widow is the command window where the codes are written shown in (Figure 6). The object window is the screen consists of label to write the name of parameters with their units, text box to insert the input value for the parameters and to display the result value of the parameters, combo box to choose model of tractor, drive type, fuel type, experimental farm location, soil texture class and tillage implement type, the picture box to insert the picture.

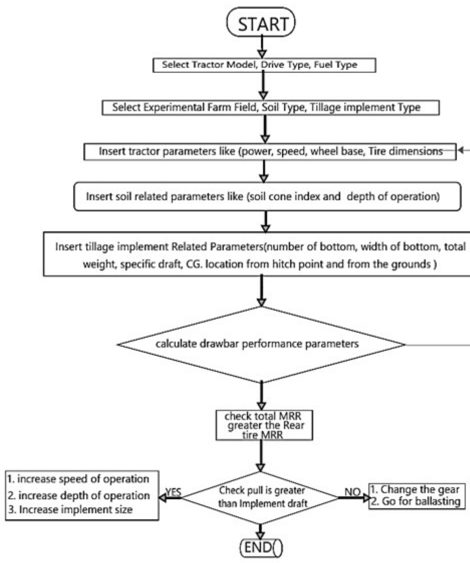

Figure 3: Performance flowchart of tractor implement combination

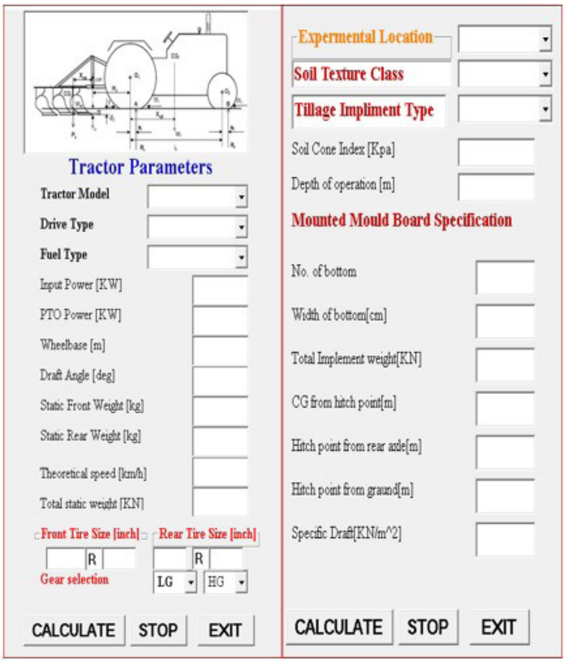

Figure 4: Tractors and implements specification input data base

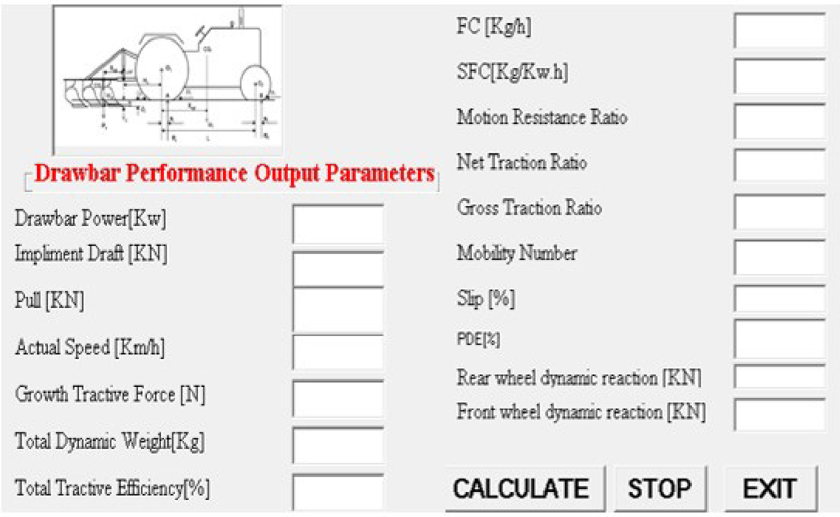

Figure 5 Performance resuslt output desplay screen

```
cmd1                                    Click
Private Sub cmd1_Click()
txtas = Val(4.5)
txtss = Val(0.125)
txtid = Val(txtdoo * txtwob * txtnb * txtsd)
txtdp = Val(txtip * 0.6)
txtpull = Val(txtdp / txtas)
txtmn = Val(txtsci * 0.0110537)
txtfc = Val(0.223 * 49.5 * 0.33)
txtsfc = Val((6.3124 - 5.8995) * 0.91 * 49.5 * 0.033)
txtgtr = Val(0.88 * (1 - (2.718 ^ -(0.1 * txtmn))) * (1 - (2.718 ^ -(9.5 * txtss))) + 0.032)
txtmrr = Val((0.9 / txtmn) + 0.032 + ((0.5 * txtss) / (txtmn ^ 0.5)))
txtntr = (txtgtr - txtmrr)
txttte = Val(((1 - (txtntr / txtgtr)) * (1 - txtss)) * 100)
txtpde = Val((txtdp / txtip) * 100)
txtgtf = Val(txtgtr * txttsw)
txtrwdr = Val(((26.2 * 1.91) + (4.992 * 3.35) - (txtpull * 0.4)) / 2.18)
txtfwdr = Val((26.2 + 2.992 + 2) - txtrwdr)
txttdw = Val(txtrwdr + txtfwdr)
End Sub
```

Figure 6: Program code window

RESULTS AND DISCUSSION

The result of this study covers the visual basics simulation output by varying the depth of operation and soil cone index as indicated in (Table 3) for Bishoftu farm field. The soil texture class is determined in soil laboratory and the implement is mould board plow which is mounted

Table 3: Changeable input parameters

Depth of Operation (cm)	Soil Cone Index before tillage (KPa)	Soil Cone Index after tillage (KPa)
5	864.7	574.4
10	1011.2	630.1
15	1366.1	697.7
20	1918.1	549.3
25	1838.3	548.2

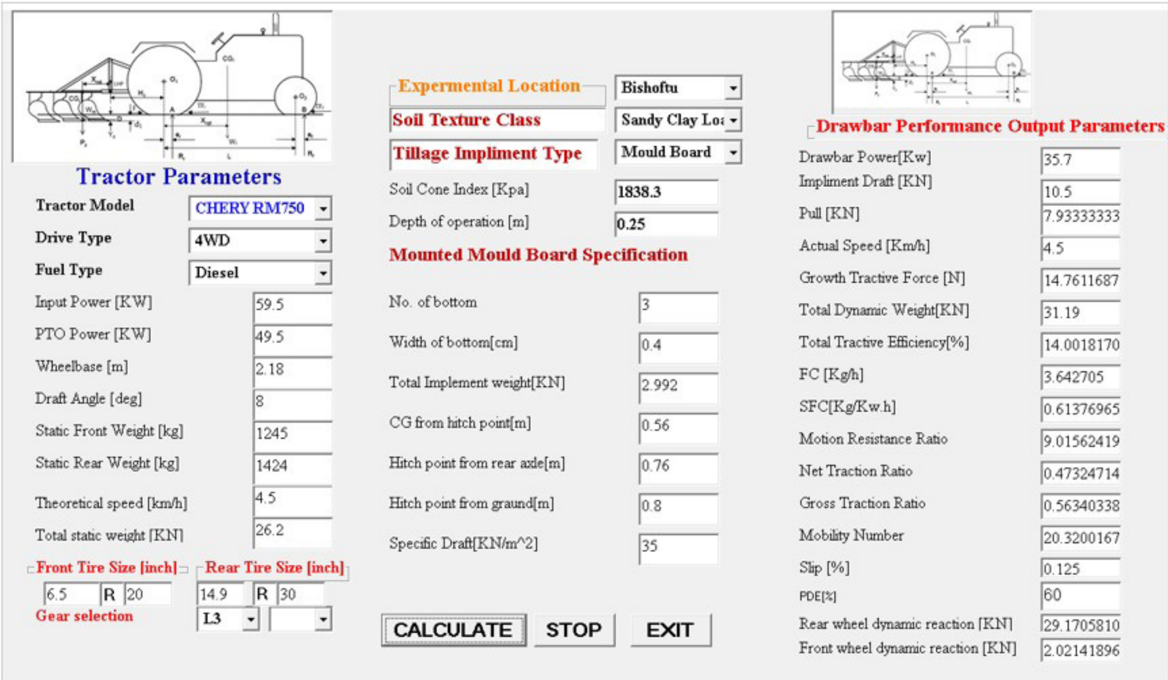

Figure 7: Input and output display window for selected parameters

From the simulation output the results of drawbar power, implement draft, pull, tractive force, fuel consumption, slip, power delivery efficiency, dynamic weight and wheel dynamic reactions were drawn by varying depth and soil cone index value. The maximum output performance parameters were found at 25 cm depth are: - drawbar power of 35.7 Kw, pull 7.9 KN, fuel consumption of 3.64 Kg/h, slip12.5%, power delivery efficiency 60%, and dynamic weight of 31.19KN. From the above parameters the relation of soil cone index, tractive force and implement draft with respect to depth of operation was plotted in (Figure 8).

From the (Figure 8) the soil cone indices of experimental farmland had a general tendency to increase with soil

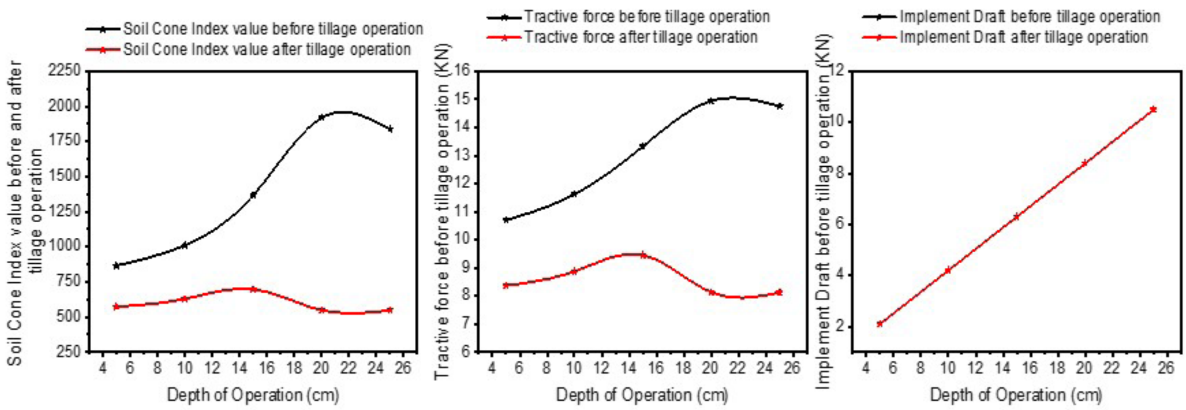

Figure 8: Soil cone index, implement draft and tractive force vs. depth relation

depth up to 20 cm and start to decrease after 20 cm for the before tillage. Soil cone indices after tillage operation had a general tendency to increase with soil depth up to 15 cm and start to decrease after 15 cm. The soil compaction value of two seasons as shown in (Figure 8) the compaction value before tillage operation is higher than compaction value after after tillage operation. The relation of tractive force and depth were the same as the relation between soil cone index and depth. The implement draft continuously increases as the depth increase. A visual basic software was developed for predicting field performance of tractor implement combination. The database prepared is quite useful for researchers and engineers.

CONCLUSION

Visual Basics 6.0 program was developed to calculate the tractive performance parameters based on the tractor parameters, soil type, depth of operation, implement geometry and implement type. Motion resistance ratio, growth traction ratio and net traction ratio were calculated in the program based on (Tiwari, 2006) equation. The visual basics programming form window used in this simulation consists of object window and code window. The object window is the place where the overall input and output parameters are added to the software. The code widow is the command window where the codes are written. The object window is the screen consists of label to write the name of parameters with their units, text box to insert the input value for the parameters and to display the result value of the parameters, combo box to choose model of tractor, drive type, fuel type, experimental farm location, soil texture class and tillage implement type, the picture box to insert the picture. From the simulation output the results of drawbar power, implement draft, pull, tractive force, fuel consumption, slip, power delivery efficiency, dynamic weight and wheel dynamic reactions were drawn by varying depth and soil cone index value. The maximum output performance parameters were found at 25 cm depth are: - drawbar power of 35.7 Kw, pull 7.9 KN, fuel consumption of 3.64 Kg/h, slip12.5%, power delivery efficiency 60%, and dynamic weight of 31.19KN.

Data availability statement

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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