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CONTRIBUTION FOR ESTABLISHMENT OF SOFTWARE FOR DETERMINING THE TENSILE STRENGTH OF AGRICULTURAL TOOLS. SIMPLE AND COMPLEX SHAPED TOOLS

Baha-Eddine BADOUNA[1]*, El-Hadi MECHENTEL[2]

[1]Mohamed-Cherif Messaadia University, Agronomic and Veterinary Sciences Institute, Agronomic Sciences Department, Laboratory of Life Sciences and Techniques, Souk Ahras, Algeria
[2] Mohamed-Cherif Messaadia University, Agronomic and Veterinary Sciences Institute, Agronomic Sciences Department, Laboratory of Modelling and Socio-Economic Analysis in Water Science, Souk Ahras, Algeria, elhadi.mechentel@univ-soukahras.dz

*correspondence: bahaeddine.badouna@univ-soukahras.dz

The importance of evaluating the energy requirements of soil preparation operations is a concern of researchers specializing in agricultural equipment. To answer such a question, they have proposed several mathematical models for the evaluation of tensile strength. However, given the large number of parameters introduced in these models, the selection of one of these models under specific agro-pedological conditions often poses an issue. Knowing the difficulties of selecting a mathematical model from those proposed in literature, the work presented allows a judicious choice of the model to be used, taking into account the precise working conditions. The work employs the MERISE method (it is a method of analysis, design and management of IT projects) to realize this work. For these purposes, a computer program was designed to quickly determine the tractive effort from a system of information on predefined equipment and working conditions. This program is called DERT (Fr: Détermination de l'Effort de Résistance à la Traction; En: Determination of Traction Resistance Effort) and grants the possibility to convert the traction effort into energy using the most appropriate mathematical model. This computer tool enables the establishment of a database on the tractive effort and energy requirements of mechanized agricultural work. Eighteen farms permitted testing the DERT program to evaluate the efforts using the appropriate models. A generalization of its use at the level of different farms will allow the creation of a national map of energy needs and thus the optimization of agricultural equipment and energy consumption.

Keywords: energy; mathematical models; draught; software

In crop plantation, accurate assessment of energy requirements is very important, as it affects the production costs (Badouna and Guidjou, 2018; Tieppo et al., 2019). According to Amara et al. (2016), agricultural energy requirements for soil preparation account for more than 50% of the total energy required to establish a crop. Friction and soil adhesion increase the tractive force of the implement and energy consumption, especially for implements that have a larger soil contact area (Abbaspour-Gilandeh et al., 2018). Therefore, it is necessary to focus on the tractive force developed by the tractor for different soil preparation operations (Amara and Couhert, 2007). According to da Silva Martins et al. (2010), soil quality parameters are directly related to agricultural production. The variability of soils is revealed by models of physical properties (Zeng et al., 2017).

Energy consumption during soil preparation and crop establishment depends on several parameters (Badouna et al., 2018) – the structural soil condition at the time of mechanical interventions (Abbaspour-Gilandeh and Abbaspour-Gilandeh, 2019), the depth and width of work (Varga et al., 2013), the speed of agricultural aggregates (tractor – farm implements), the type of agricultural tool used, as well as the tractor condition and the technical level of operators (Badouna, 2002).

The essential indicator retained for the evaluation of energy requirements for the realization of cultivation methods during crop establishment is traction effort (Badouna and Guidjou, 2018). Several researchers have proposed models for the determination of this parameter. There are two types of tools – simple tools and complex tools. For these purposes, the Binesse model, the Boubrit model, the Gorjatchkin model and the Gee Clough model were utilized (Badouna et al., 2018; Amara and Feddal, 2013). The models listed and described in the following equations (Eqs 1–4) are the ones used in the computer program presented due to their easy application. Ying et al. (2018) considered that the application of intelligent algorithms requires the support of a database, which is an aspect that was taken into account.

Gorjatchkin and Sohene (1960):

$$f_t = fG + kab + \varepsilon abv^2 \tag{1}$$

where: f – coefficient of friction ground-metal; G – plough weight (kg); k – specific resistance of ground; a – depth of ploughing (m); b – width of ploughing (m); v – speed (m·s^{-1}); ε – coefficient of plough form

Binesse (1970):

$$f_t = S\left[\frac{C}{\cos\phi}(0.85 + \sin\phi)\right] \tag{2}$$

where: S – section of the worked strip soil; C – soil cohesion; ϕ – angle of internal friction of the soil

Gee Clough et al. (1978):

$$f_t = ab\left\{13.30\gamma a + 3.06\gamma\frac{v^2}{g}\right\} \quad (3)$$

where: g – gravity acceleration; γ – dry soil density

Boubrit (1999):

$$R = e^{-9.3806}\left(\frac{CI}{dl}\right)^{1.0019}\left(\frac{p}{l}\right)^{1.8595}\alpha^{1.3929}dl^3 \quad (4)$$

where: α – angle of inclination of the ploughshare; d – dry soil density; l – width of work; p – depth of work; R – tractive effort; CI – cone index

Power

$$P(W) = Ft(N) \cdot v \quad (5)$$

where: P – power (W); Ft – force (N)

The working depth and width are utilized in all four models; working speed is used only in the Gorjatchkin and Gee Clough models; while Binesse and Boubrit introduced parameters related to the soil state, namely soil cohesion and cone index, into their models. Amara and Feddal (2013) showed that the geometric characteristics have a great impact on the tensile strength effort determination precision and especially model selection. The authors came to conclusion the Gorjatchkin model is more suitable for cylindrical-helicoid mouldboards, while the Gee Clough model is preferable for cylindrical mouldboards. Choosing one of the aforementioned models is a complex process in terms of an accurate assessment of energy consumption; opting for a tractor with high power is inevitable, which results in its under-use and leads to an over-equipping of agricultural holdings and overpricing of agricultural production.

All in all, in the design of a software for precise tensile strength effort determination, it was necessary to utilize the MERISE method – an information system design and development methodology widely used in France. The framework of MERISE has three cycles: abstraction cycle, approval cycle and life cycle. The software must take into account the following parameters:

- the working depth and width of the working part;
- the forward speed of the tractor–tillage implements assembly;
- the physical and mechanical soil characteristics;
- the geometric characteristics of the active surfaces of working parts.

These different models were used in the DERT (Determination of Traction Resistance Effort) computer program. The selection of one will depend on working conditions and the shape of working parts. Software efficiency was tested in 18 farms. Generated data were utilized for the production of maps.

Material and methods

In order to carry out this work, the MERISE method was employed. It is a method of design and development of information system, which was created during the 70s and 80s in France and is still popular even nowadays. For the purposes of testing the software designed, 18 farms producing durum wheat in the Tipaza area were subjected to experiments, which is presented in the following paragraphs and diagrams.

The primary computer tools selected for the development of database and DERT software were "Java 5 and MySQL 5.6.12" for multiple reasons. For the computer program realization, the results achieved by several works regarding the tensile strength effort determination under various soil conditions and characteristics of variable working parts were utilized. QGIS was used for the purposes of creation of maps. The exported files of the designed program (DERT) were in the .csv format.

Methodology for the DERT program design

The DERT program is based on the models previously presented (Gorjatchkin, Gee Clough, Binesse and Boubrit) for estimating the energy for a technical itinerary of a crop by calculating the traction effort. Furthermore, these models were also utilized for generating a database, which had to enable recording all the information related to the soil work to be done (soil characteristics, tools used, working conditions and tractors). However, it had to firstly locate the soil work in time (farmer owner, crop to be planted, field surface, coordinates, and location of the farm). All this information was stored in tables. The analysis of all these parameters revealed seven (7) entities corresponding to the database tables: 1 – the plot; 2 –the fields of each plot; 3 – the tractors; 4 – agricultural machinery; 5 – the work to be done in each field; 6 – the passages of each work; and 7 – mathematical models.

The computer program completion depends on the identification of the tensile strength effort environment. The tensile strength effort environment presented by groups of parameters is provided in Fig. 1.

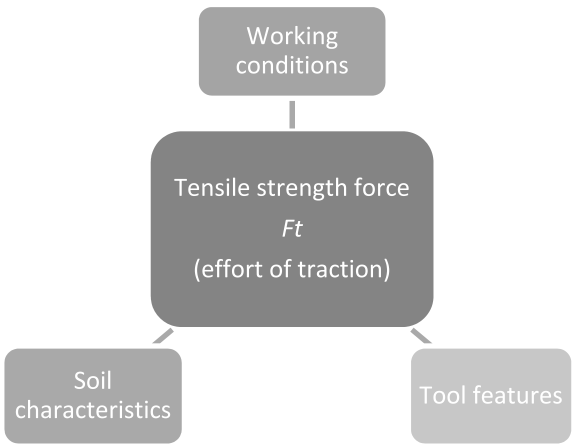

Fig. 1 Synoptic diagram showing the characteristics influencing the tensile strength effort

After analysing and identifying the main groups of parameters influencing the effort of traction value, a logical flowchart of the main computer program parts was proposed (Fig. 2). The DERT program will use a local database comprising tables, as previously explained and illustrated in Fig. 4, to record all the information necessary for the analysis and accurate determination of the effort of traction. This will allow the establishment of a national database. This database can be shared between users on a local or remote networks.

Relationship between the organigram entities

The analysis of models for the effort of traction evaluation of agricultural machines for the establishment of a crop and the needs for localization of these efforts gave rise to the flowchart of the types of relations between entities (farmer, plots, fields, works, operations and passage) and additionally entities such as tractor, machine and soil.

This functional (Fig. 2) and relational (Fig. 3) construction allowed the definition of database tables and building them physically via MySQL (Fig. 4).

All the tables (entities) generated using MySQL are represented in Fig. 4. The entire structure of the DERT program database is grouped in Fig. 4 as well.

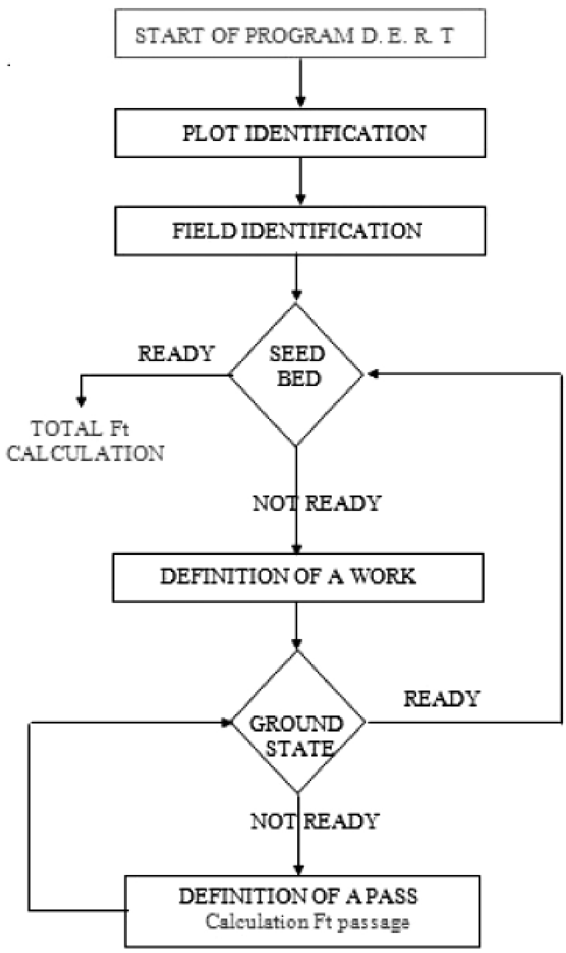

Fig. 2 Organigram showing the overall logic of the DERT program flow

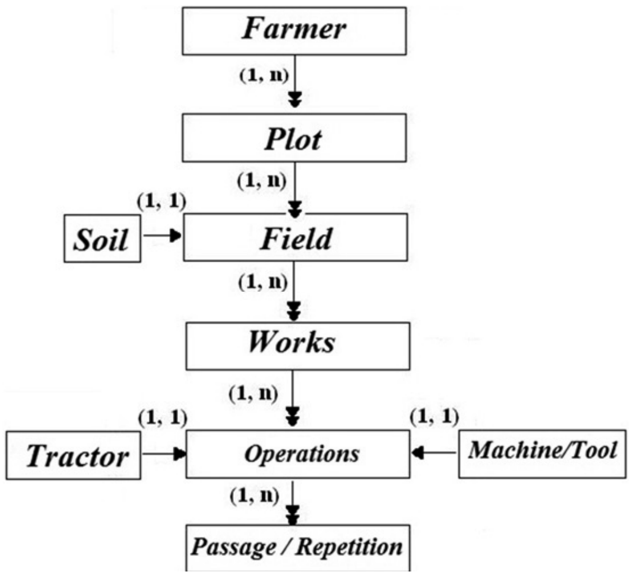

Fig. 3 Diagram of relationship entities

Methodology for DERT program utilization

The DERT program represents a way to calculate the tensile strength effort needed to pull a tillage implement. The program uses the database designed to store the information used for calculation and the results generated. It is an interesting source of information on the conditions for evaluating the tractive effort of tillage tools. The main program menu offers three possibilities of calculation stored in the same database (sample calculation, prediction calculation and direct calculation, Fig. 5). The first two options go through the windows shown in Figs 6–9, while the direct calculation gives direct access to the four models of tensile strength calculation without the need to store information on the environment of this effort. Sample calculation – this option is based on real data taken from the field. Predictive calculation – this option is a simulation of theoretical cases to make predictions. Direct calculation – a use of the models without taking into account spatial and temporal conditions. The DERT program utilization goes through the steps of the algorithm (Fig. 2), which are:

- identification of the region where the crop establishment works will be carried out (Fig. 6);
- pedoclimatic characterization of the region and plots to be worked (Fig. 7);
- characterization of the means of traction, type of tractors, power, and general condition (Fig. 8);
- agricultural machines used: forms of the active surfaces of working parts, width and depth of work (Fig. 9);
- selection of the mathematical model to use; this choice depends on the main parameters that are available at the level of a pre-established database in collaboration with pilot farms and farmers at the national level.

In the background, all program phases explained in Fig. 2 utilize the relational schema of the database tables explained in Fig. 3. Figure 4 represents the interface that appears when the program is launched. After estimating the values of *Ft*, it is necessary to convert the effort into

Fig. 4 Database design diagram

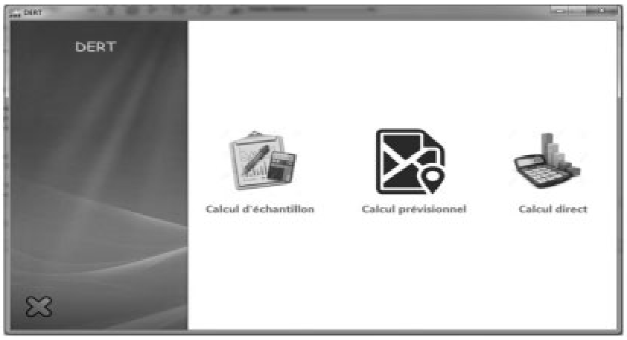

Fig. 5 DERT program menu

Fig. 6 Adding a plot sheet

Fig. 7 Adding a field form

Fig. 8 Works management sheet

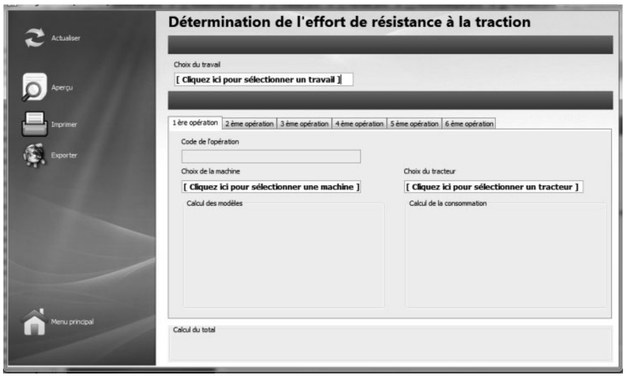

Fig. 9 Determination sheet for tensile strength and equivalent energy

power using Eq. 5 and into energy using the following conversions:

1 Watt (W) = 0.239 cal·s^{-1}; 1 Calorie (cal) = 4.18 Joules

Example of application of the mathematical models used in the computer program

Calculation tests to determine the tensile strength of certain working tools utilize the models proposed above (Eqs 1–4). For these purposes, a number of parameters necessary for the use of the models in question are recorded in Table 1, Table 2, Table 3 and Table 4. Particularly, these are the primary conditions related to the soil, used types of agricultural machinery and working conditions. These calculations also show the importance of selecting a mathematical model in the DERT computer program (Amara and Couhert, 2007; Amara et al., 2016).

Table 1 Soil characteristics

Characteristics	Values
Initial bulk density	1.2 g·cm^{-3}
Humidity	18%
Cohesion (CI)	7 daN·cm^{-2}

Table 2 Working conditions

Working conditions	Tools	
	plough	tooth cultivator
Width	35 cm	4 cm
Depth	25 cm	15 cm
Speed	4 km·h^{-1}	7 km·h^{-1}

Table 3 Values depth and width of factor work of stability of the strip of land for various types of ploughing

Type of ploughing	Depth *a* (cm)	Width *b* (cm)	Coefficient *b/a*	
			practical	theoretical
Very deep	35–100	40–70	0.7–1.1	0.7–1.0
Deep	25–35	30–40	1.1–1.5	1.2–1.3
Means	18–24	25–35	1.3–1.8	1.4–2.5
Stubble cultivation	5–12	24	2.0–5.0	2.0–2.5
Ploughing on meadow	15–25	30–50	1.8–2.5	2.0–2.5

Source: Bernacki et al., 1967

Table 4 Constructive angular characteristics of the various shapes of ploughs

Ploughs' shapes	Angles (°)		
	attack angle	penetration angle	curved angle
Cylindrical	22–20	15–20	40–50
Cylindrical-helicoid	22–28	14–18	35–45
Semi-helicoid	20–25	12–15	30–35
Helicoid	20–25	12–15	30–35

Source: Amara, 2009

Table 5 Geometrical characteristics of the used tine tools

Shape of the tine / Characteristics	Retractable rigid tine	Flexible tine with simple curve
Tine height *H* (mm)	484	468
Tine width *b* (mm)	49	41
Tine thickness *e* (mm)	19	06
Type of ploughshare	ploughshare of scarifying	ploughshare of scarifying
Shape of ploughshare	dish and curved	dish and curved
Width of ploughshare *b* (mm)	40	37
Length of ploughshare *l* (mm)	248	235
Thickness of ploughshare *e* (mm)	12	10

Results and discussion

The results obtained are recorded in Tables 6 and 7.

To verify the values obtained with the Gorjatchkin, Gee Clough, Binesse and Boubrit models, calculations were conducted in the DERT program with different shapes of tools, forms of ploughs (Table 4) and tines for tine cultivators (Table 5). Based on the calculation results (Table 6 and Table 7), it can be seen that tractive effort is different from one model to another for the same tool, the same soil and the same working conditions (Table 1 and Table 2), which was already observed by Amara et al. (2006), Amara (2009) and Amara and Feddal (2013). Selecting a model to use for accurate effort determination is delicate. The best use of available mathematical models for real-world evaluation is essential and necessary. The results should be compiled in a database. The DERT program is designed to calculate the tractive effort using the four models – Gorjatchkin, Gee Clough, Binesse and Boubrit. The DERT program generates an energy database and allows the results to be exported to QGIS for effort or energy maps (Figs 10–13). The results are exportable in the .csv format. It should be noted that, in 2016, a research team at the University of Novi Sad in Serbia used a sensor-based measurement system and geostatistics to generate maps of the physical properties of soil in interaction with tensile strength (Kostić et al., 2016). The DERT program was tested by evaluating the tensile strength in 18 farms producing durum wheat in the Tipaza region. The results obtained were exported to QGIS for the purposes of creating maps of tractive effort *Ft* for the Gorjatchkin (Fig. 10), Gee Clough (Fig. 11) and Boubrit (Fig. 12) models corresponding to the plough, cover crop and tine cultivator, respectively. The DERT's systematic conversion of effort *Ft* into energy allowed establishing of an energy map (Fig. 13). This last map is the total energy needed for the three tools used for three soil preparation operations based on the Gorjatchkin, Gee Clough and Boubrit models.

An evaluation of energy requirements of tillage operations in 18 plots located in northern Algeria was based

Table 6 Tractive effort results for a ploughshare

Shape	Gorjatchkin model	Gee Clough model	Binesse model
Cylindrical plough	15,177.46 N	3,887.91 N	2,071.49 N
Helicoid plough	7,615.74 N	3,887.91 N	2,071.49 N
Farmer plough	11,396.65 N	3,887.91 N	2,071.49 N

Table 7 Tractive effort results for one tine of a tine cultivator

Form	Binesse model	Boubrit model
Ploughshare of the rigid tine	142 N	56.79 N
Ploughshare of the flexible tine	142 N	80.60 N
Ploughshare of the simple tine	142 N	80.60 N

on the tensile strength calculation. The tools selected for these soil preparation operations were the ENPMA plough, the cover crop 16 and the 11-tine cultivator, which are the most popular in Algeria. Tables 4 and 5 present the tool characteristics. Table 8 summarizes the averages by model corresponding to each tool, as well as illustrates the minimum and maximum values corresponding to the plots by model. Moreover, Table 8 also presents the quartiles and standard deviations.

The tool that generated the most effort is the plough, as it showed a value of 950.60 daN produced by a single plough body in Farm 1. Employment of a two-share plough will automatically double the value of *Ft* which will become (2 · 950.60 = 1,901.20 daN), while a three-share plough will triple the effort provided (3 · 950.60 = 2,851.8 daN). It should be also noted that the tine cultivator tool required the lowest effort (101.366 daN) calculated with the Binesse model, while the Boubrit model estimated the effort at a minimum

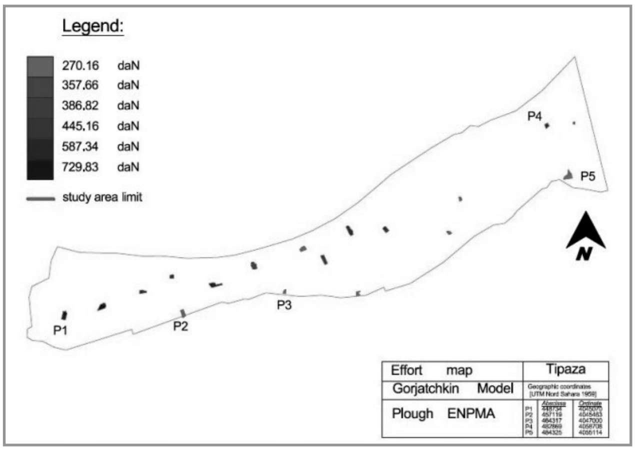

Fig. 10 Distribution of the traction forces of an ENPMA plough evaluated with the Gorjatchkin model

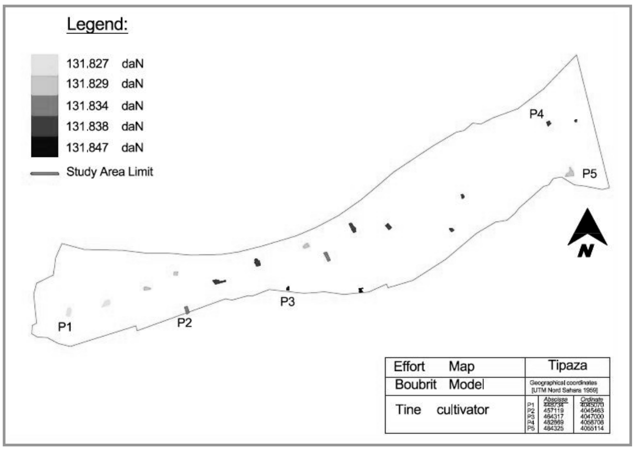

Fig. 12 Distribution of the tensile strength of a cultivator with tines evaluated with the Boubrit model

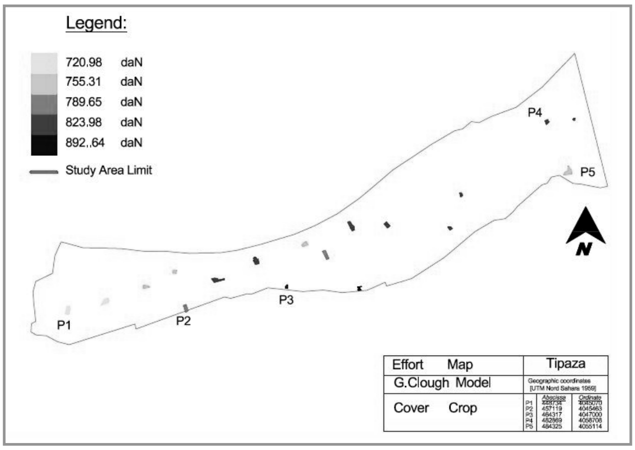

Fig. 11 Distribution of the tensile strength of a cover crop evaluated with the Gee Clough model

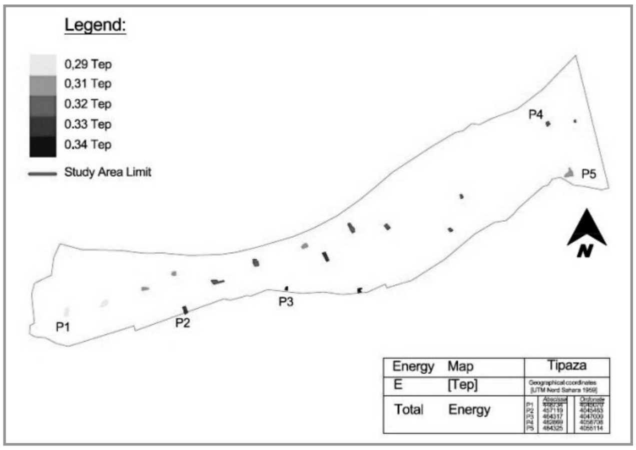

Fig. 13 Energy needs for the sum of three tillage operations (in ton of oil equivalent, Tep)

of 619.90 daN. This phenomenon of sensitivity was explained previously in the example of application of mathematical models used in the computer program (Tables 6 and 7).

Figure 14 shows the computational results of tensile strength for the 18 farms obtained by means of DERT. All these results are stored in the DERT program database after calculations (Table 8). The 18 farms alone generated 770 pieces of data (396 were calculation results and 374 were basic data related to soils, machinery and working conditions), 34% of which were *Ft* values, 11.5% were power values and 6% were energy values. The basic parameters represented globally 49% of the data produced against 51% of the calculation data. The 17% of the basic parameters were related to working conditions (speed, depth and working width), 14% to soil data, 11.5% to machinery data and, finally, 6% were coefficients. The data that the program generated in quantity was apparently tractive effort *Ft* (34%); this was followed by the working conditions (17%) and soil conditions (14%). This proves that the program is based on *Ft*, and the models are based on working conditions and soil.

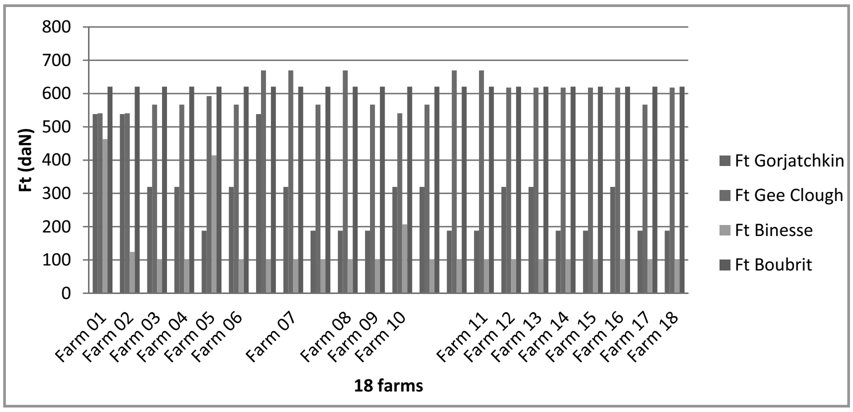

Fig. 14 Traction effort *Ft* per model and per farm

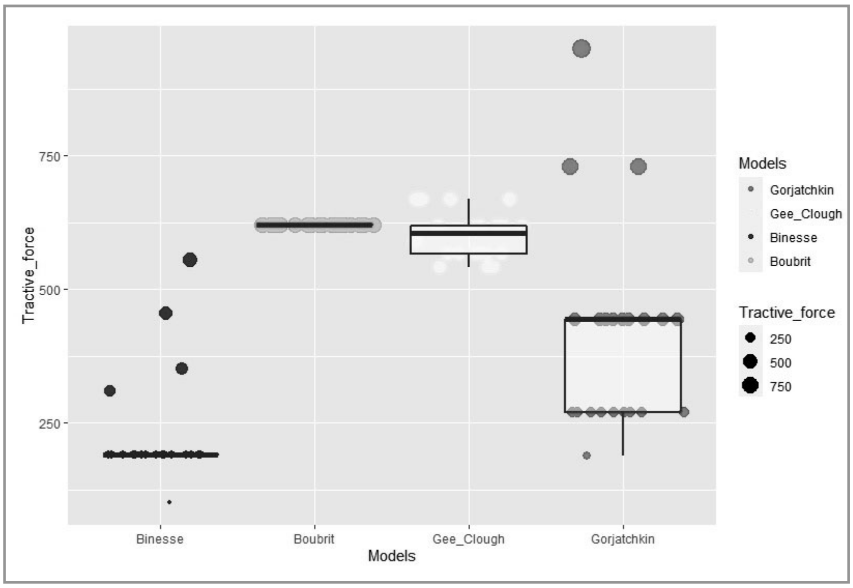

Fig. 15 Efforts of four models

According to the DERT program algorithm, the Gorjatchkin model was used for the ploughshare plough for a ploughing operation, the Gee Clough model was used for the cover-crop for the resumption of ploughing operation as surface work, and the Binesse and Boubrit models were used for the tine cultivator. The tractive effort *Ft* obtained was converted into power (*hp*) and energy (GJ and Tep). Table 8 expresses the analysis results with a distribution of efforts at the farms evaluated using the Gorjatchkin and Binesse models for the ploughshare plough and tine cultivator tools with standard deviation (*Sd* = 186.80 plough and 102.27 cultivator). On the other hand, a concentration of *Ft* values calculated with the Gee Clough and Boubrit models for the cover crop and tine cultivator was represented

Table 8 Minimum, maximum and average traction forces of tillage operations by models

Plough (ENPMA)		Cover-crop (12)		Tine cultivator			
Gorjatchkin		Gee Clough		Binesse		Boubrit	
Min.	188.10	**Min.**	540.70	**Min.**	101.40	**Min.**	619.90
1st quartile	270.20	**1st quartile**	566.50	**1st quartile**	191.30	**1st quartile**	620.30
Median	445.20	**Median**	605.10	**Median**	191.30	**Median**	620.30
Mean	410.70	**Mean**	601.60	**Mean**	228.50	**Mean**	620.30
3rd quartile	445.20	**3rd quartile**	618.00	**3rd quartile**	191.30	**3rd quartile**	620.30
Max.	950.60	**Max.**	669.50	**Max.**	555.00	**Max.**	620.50
Sd	186.80	***Sd***	46.02	***Sd***	102.27	***Sd***	0.09

with standard deviation *Sd* = 46.08 in the cover crop with Gee Clough and *Sd* = 0.09 in the tine cultivator with the Boubrit model. For this test, each machine at every farm and working conditions for each tool (width, depth and speed) were fixed (Fig. 15). Farm 8 showed the highest energy requirements (14.15 GJ), while Farm 1 showed the lowest requirements (12.12 GJ). This is the total energy of the three tools (plough + cover crop + tine cultivator). To obtain these energy values, the machine forward speeds were 1.5 $m \cdot s^{-1}$ (plough with coulter) and 3 $m \cdot s^{-1}$ (cover crop and tine cultivator). Finally, the DERT program database provided a significant amount of data representing mechanized work in agriculture. This data set includes the bulk density, cone index, cohesion, soil moisture, as well as data related to tool shape (angles, weight) and working conditions such as tool speed, working depth and width. The analysis of these data requires a dedicated article. Employment of the DERT program for the management of draft forces and energies required for tillage can help scientists understand the spatial and temporal distribution of draft forces and the corresponding energies. Furthermore, it can be utilized for highlighting the specificities of different study areas. In 2021, a group of researchers proposed a discrete element method (DEM) model of soil-tool interaction that allowed a design of agricultural machines. This method is a simulation of prediction of tractive force as a function of tillage depth using DEM software (Kim et al., 2021). The database generated by the DERT program can give this possibility to specialists to propose agricultural tools that are better adapted to soil working conditions, referring not only to the working depth but also to all the other parameters (working width, working speed, soil parameters and the tool geometry parameters).

Conclusion

In this contribution, a computer program DERT is proposed as a tool for evaluating the effort required during tillage operations. The DERT program answers the objective of selecting a mathematical model for the evaluation of effort which is delicately confirmed by the example. Among the four mathematical models, it grants the possibility to choose the most appropriate model to quantify the effort and energy of tillage operations; it also allows comparison of results obtained via different program models, making thus possible a rational use of agricultural machinery. Finally, the use of the DERT program allows the establishment of a database on the energy needs of 18 farms, which generated 770 pieces of data (396 are calculation results and 374 are basic data related to soils, machinery and working conditions). The program generated an amount of *Ft* tractive effort data corresponding to 34% of all data, proving that the program is *Ft* based. The use of this program also allows the generation of maps and graphs of energy distribution, tractive effort requirements by farm machine, by model, by farm or globally via QGIS. The maximum effort recorded was equal to 950.60 N for the ENPMA plough evaluated with the Gorjatchkin model. The minimum effort recorded was equal to 101.4 N for the tine cultivator with the Binesse model. It remains interesting to monitor the values of the same piece of machinery obtained using the Binesse and Boubrit models. Furthermore, it should be noted that Farm 8 showed the highest total energy demand for the three defined operations (14.15 GJ) and Farm 1 showed the lowest total energy demand for these three defined operations (12.12 GJ).

An exploitation of the parameterized database would allow energy consumption reduction without neglecting the agronomic objectives required by tillage operations. This last point will be the subject of further work.

References

ABBASPOUR-GILANDEH, Y. – ABBASPOUR-GILANDEH, M. 2019. Application of computational intelligence methods for predicting soil strength. In Acta Technologica Agriculturae, vol. 22, no. 3, pp. 80–85.

ABBASPOUR-GILANDEH, Y. – HASANKHANI-GHAVAM, F. – SHAHGOLI, G. – SHARABIANI, V. R. – ABBASPOUR-GILANDEH, M. 2018. Investigation of the effect of soil moisture content, contact surface material and soil texture on soil friction and soil adhesion coefficients. In Acta Technologica Agriculturae, vol. 21, no. 2, pp. 44–50.

AMARA, M. – BOURARACH, E. H. – GUEDIOURA, I. – HARRAD, F. 2006. Modelling the tensile strength of tine tools: influence of shape, angle of inclination and working speed on the tensile strength. In Actes de l'Institut Agronomique et Vétérinaires Rabat – Maroc, vol. 25. no. 1 & 2, pp. 61–75. (In French: Modélisation de l'effort de résistance à la traction des outils à dents: influence de la forme, de l'angle d'inclinaison et de la vitesse de travail sur l'effort de résistance à la traction.)

AMARA, M. – COUHERT, J. P. 2007. Modelling of the effort of active surfaces of the share plough. In Agricultural Journal, vol. 2, no. 3, pp. 434–440.

AMARA, M. – FEDDAL, M. A. – LAICHE, K. – GUEDIOURA, I. – BADOUNA, B. 2016. Optimization of Tillage Techniques in Drylands. Saarbrücken : Éditions Universitaires Européennes, 88 pp. ISBN 3639507851. (In French: Optimisation des techniques de travail du sol en zone arides).

AMARA, M. – FEDDAL, M. A. 2013. A force prediction model for the plough introducing its geometrical characteristics and its comparison with Gorjatchkin and Gee Clough models. In International Journal of Engineering Research & Technology. vol. 2, no. 11, pp. 4054–4062.

AMARA, M. 2009. Contribution to the Modelling of the Soil-Aratory Tool Interface Optimization of the Shape and Tensile Strength of Plough Bodies with Shares and Tine Tools. Paris : Edilivre Edition Universitaire, 292 pp. ISBN 2812116005. (In French: Contribution à la modélisation interface outils aratoires-sol Optimisation de la forme et de l'effort de résistance à la traction des corps de charrue à socs et des outils à dents).

BADOUNA, B. – GUIDJOU, Y. 2018. Energy Needs in Tillage. (Evaluation Method). Chisinau : Noor Publishing, 96 pp. ISBN 9786202348928. (In French: Besoins Énergétiques dans le Travail du Sol (Méthode d'Évaluation)).

BADOUNA, B. – MECHENTEL, E. – DAANI, R. 2018. Mapping the energy requirements of ploughing a cereal system from the evaluation of the tensile strength in north-eastern Algeria. In Séminaire International, Agriculture 4.0: Le Génie Rural au service de l'Environnement 2018. Alger : Ecole Natinale Supérieure Agronomique El Harrach-Alger, pp. 145–152. (In French: Cartographie des besoins energetiques du labour d'un systeme cerealier à partir de l'evaluation de l'effort de resistance a la traction au nord-est de l'algerie).

BADOUNA, B. 2002. Design of a database and establishment of a computer program for the evaluation of the tensile strength of agricultural tools. INA El HARRACH-Alger. 45 pp. (In French: Conception d'une base de données et établissement d'un programme informatique pour l'évaluation de l'effort de résistance à la traction des outils aratoires).

BERNACKI, H. – HAMAN, J. – KANAFOJSKI, Cz. 1967. Theory and Construction of Agricultural Machinery. Warszawa, Poland : Państwowe Wydawn. Rolnicze i Leśne, 826 pp. TT 69-50019. (In Polish: Teoria i konstrukcja maszyn rolniczych).

BINESSE, M. 1970. Shear and specific soil resistance during conventional ploughing. In Etude du CNEEMA, pp. 341–342. (In French: Cisaillement et résistance spécifique du sol lors des labours classiques).

BOUBRIT, B. 1999. Evaluation of the tensile strength of a tooth according to the physical characteristics of the soil. Application of dimensional analysis and modelling. Magister thesis, Institut National Agronomique – El Harach – Alger, 200 pp. (In French: Evaluation de la résistance à la traction d'une dent en fonction des caractéristiques physiques du sol. Application de l'analyse dimensionnelle et modélisation).

DA SILVA MARTINS, A. L. – DE MOURA, E. G. – CAMACHO TAMAYOJ, H. 2010. Spatial variability of infiltration and its relationship to some physical properties. In Ingenieria E Investigacion, vol. 30, no. 2, pp. 116–123. (In Spanish: Variabilidad espacial de la infiltración y su relación con algunas propiedades físicas).

GEE CLOUGH, D. G. – MCALLISTER, M. – PEARSON, G. – EVERNDEN, D. W. 1978. The empirical prediction of tractor implement field performance. In Journal of Terramechanics, vol. 15, no. 2. pp. 81–94.

GORJATCHKIN, V. P. – SOHENE, 1960. Collected Works in Three Volumes. Ed. N. D. Luchinskii. Translated 1972. Jerusalem, Israel : Ketter Press.

KIM, Y. S. – SIDDIQUE, M. A. A. – KIM, W. S. – KIM, Y. J. – LEE, S. D. – LEE, D. K. – HWANG, S. J. – NAM, J. S. – PARK, S. U. – LIM, R. G. 2021. DEM simulation for draft force prediction of moldboard plough according to the tillage depth in cohesive soil. In Computers and Electronics in Agriculture, vol. 189, article no. 106368.

KOSTIĆ, M. M. – RAKIĆ, D. Z. – SAVIN, L. Đ. – DEDOVIĆ, N. M. – SIMIKIĆ, M. Đ. 2016. Application of an original soil tillage resistance sensor in spatial prediction of selected soil properties. In Computers and Electronics in Agriculture, vol. 127, pp. 615–624.

TIEPPO, R. C. – ROMANELLI, T. – MILAN, M. – SØRENSEN, C. – BOCHTIS, D. 2019. Modeling cost and energy demand in agricultural machinery fleets for soybean and maize cultivated using a no-tillage system. In Computers and Electronics in Agriculture, vol. 156, pp. 282–292.

VARGA, F. – MOJŽIŠ, M. – ABRAHÁM, R. 2013. Soil resistance and its impact on tillage depth. In Acta Technologica Agriculturae, vol. 16, no. 1, pp. 26–30.

YING, D. – LIANG, W. – YONGWEI, L. – DAOLIANG, L. 2018. Model predictive control and its application in agriculture: A review. In Computers and Electronics in Agriculture, vol. 151, pp. 104–117.

ZENG, Z. – CHEN, Y. – ZHANG, X. 2017. Modelling the interaction of a deep tillage tool with heterogeneous soil. In Computers and Electronics in Agriculture, vol. 143, pp. 130–138.