



UDK: 681.3

*Originalni naučni rad  
Original scientific paper*

## INVESTIGATING MACHINERY MANAGEMENT PARAMETERS WITH COMPUTER TOOLS

**Robert D. Grisso<sup>\*</sup>, John S. Cundiff, David H. Vaughan**

*Virginia Tech University, College of Agriculture and Life Sciences,  
Department of Biological Systems Engineering, Blacksburg, VA, USA*

**Abstract:** Engineering tools have been effective in demonstrating the parameter impacts on machinery systems. This paper shows four class exercises and discusses the parameter influences and decision-making for the examples. These engineering tools are useful for complex relationships that are beyond the scope of hand calculations or applications of “rules of thumb.” Engineering tools can improve the application and student understanding of complex systems involved in machinery management considerations. As students use these tools, they are able to envision how engineering tools can be used to solve new problems that they confront both in the classroom and profession.

**Key words:** *Machinery management, engineering tools, management parameters, decision-making, undergraduate education.*

### INTRODUCTION

Many engineering tools have been effective in demonstrating the parameter impacts on machinery systems. The engineering and mechanized systems curriculum uses the problem solving environment and the problem solving techniques as fundamental principles for the development of students. Many times, system problems are complex with interacting parameters that should be considered and evaluated before a viable solution can be provided. In complex simple systems, “rules of thumb” and intuition are difficult to develop without experiencing and working with the system. Engineering tools, used in undergraduate curriculums, are useful in developing solutions to complex systems and to gain understanding of how changing parameters impact the solution. These engineering tools can show complex relationships that are beyond the scope of hand calculations or applications of “rules of thumb.”

---

<sup>\*</sup> Corresponding author. E-mail: rgrisso@vt.edu

## MATERIAL AND METHODS

This paper discusses four undergraduate exercises and discusses the parameter influences and decision-making for engineered systems. The teaching objectives of these exercises are to demonstrate machinery management criteria and the various parameters that impact the system solution.

In the first example, students are asked to use a MatLab [1] interface to calculate the logistical pattern of removing round hay bales from a field. The students develop a MatLab program to determine the timing, distance and pattern of moving, handling and storing round bales. The students develop a loading pattern for a self-loading bale wagon. The goal of the project is to minimize the travel distance of the self-loading wagon.

Well-matched tractor-implement systems are important for maintaining high operating efficiency for farm operations. The spreadsheet used in this second example is based on the Brixius Model and ASABE Standard to predict tractor performance and implement draft, respectively. The program demonstrates matching of tractors with implements and implements with tractors. Optimization of weight distribution and inflation pressures for maximum power delivery efficiency can be determined and computation of field capacity and fuel consumption of the systems selected can be compared.

In the third example, an exercise uses a spreadsheet to demonstrate how field capacity and efficiency change as different planter sizes, crops and operational characteristics (travel speed) are considered. This exercise helps the student visualize the operational details and the impact of various planter options.

In the fourth example, the tractor database developed from the Nebraska Tractor Test reports make a selection problem with tractor parameters. This framework discusses various decision-making options that a producer may consider when selecting a tractor model.

## RESULTS AND DISCUSSION

### Example 1 – Using MatLab for Bale Logistics

In the first example, students are asked to use a MatLab [1] interface to calculate a logistical pattern of removing round hay bales from a field with a self-loading, self-propelled bale wagon. This machine self-loads six round bales from a field, travels to a storage location, and then dumps the bales into storage.

Experienced operators can drive the machine into a field where the bales are randomly distributed (as they were dropped from the baler) and experienced operators can do a good job of collecting six bales with minimum travel time between bales. The purpose of this assignment is to calculate the minimum time required to load and move 34 round bales into storage.

Each student can start with any bale they choose. They must travel to this bale from the field inlet, load the bale, and then choose the next bale. This process continues until six bales are loaded. The machine must then travel back to the field inlet. Time required is calculated as follows:

$$t_{tot} = (t_{1t} + t_{1L}) + (t_{2t} + t_{2L}) + (t_{3t} + t_{3L}) + (t_{4t} + t_{4L}) + (t_{5t} + t_{5L}) + (t_{6t} + t_{6L}) + t_R \quad (1)$$

Where:

$t_{it}$  [s] - time to travel to bale  $i$

$i$  [-] - 1 to 6,

$t_{iL}$  [s] - load time for bale  $i$  ( $t_{iL} = 30$  s for all bales)

$t_R$  [s] - travel time to return to field entrance

Average travel speed for the machine in the field is  $2.23 \text{ m}\cdot\text{s}^{-1}$ .

**Computation of Distance between Bales.** Straight-line distance between bales is calculated as shown in Fig. 1. The grid coordinates for bale 1 are  $x_1, y_1$ . In like manner, the grid coordinates for bales 2 and 3 are  $x_2, y_2$  and  $x_3, y_3$ , respectively.

$$\text{Distance from bale 1 to bale 2: } d_{12} = [(x_1 - x_2)^2 + (y_1 - y_2)^2]^{1/2} \quad (2)$$

$$\text{Distance from bale 2 to bale 3: } d_{23} = [(x_2 - x_3)^2 + (y_2 - y_3)^2]^{1/2} \quad (3)$$

Distance between any two bales can be calculated in like manner.

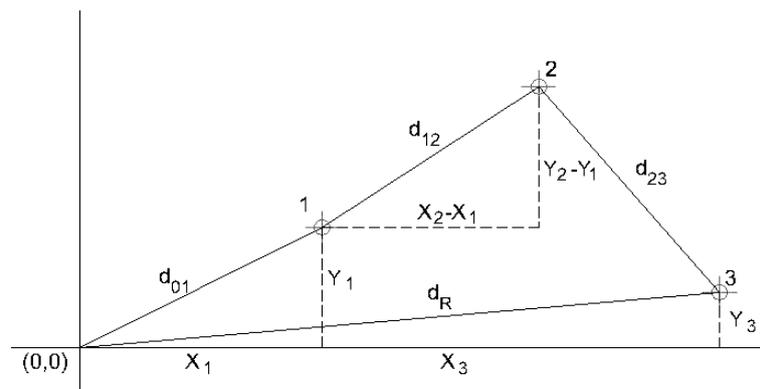


Figure 1. Illustration showing how distances between bales are calculated

The students are given Assignment #1 and asked to develop a MatLab solution to minimize the hauling distance that the loading machine has to haul the round bales from the field to the field inlet.

**Assignment #1.** Student assignment for bale logistics determination for a field.

The grid location for each bale is given in Fig. 2, and the corresponding coordinates are given in Tab. 1. Each grid division is 5 m.

$$d_R = [(x_3 - 0)^2 + (y_3 - 0)^2]^{1/2} \quad (4)$$

Note: For convenience, the entrance to the field is taken as the origin for the grid systems.

Requirements:

- Calculate the total time to haul the first 6-bale load from the field.
- Eliminate the six bales already hauled from the dataset. Calculate the total time to haul the second 6-bale load from the field.
- Continue the analysis for additional loads until all the bales are hauled.
- Describe any technique you developed to select the shortest distance to the next bale.
- Develop a table with your results and discuss what you learned from this exercise.

Table 1. Grid locations for bales

Bale No.	Coordinates		Bale No.	Coordinates	
	X	Y		X	Y
1	-8	21	18	-17	8
2	-12	19	19	-13	8
3	-13	16	20	-17	6
4	-9	16	21	-12	6
5	-6	18	22	-8	8
6	-3	17	23	-6	6
7	-3	15	24	-3	8
8	-7	14	25	-1	6
9	-3	13	26	-3	4
10	-1	11	27	-2	2
11	-5	10	28	-5	1
12	-8	12	29	-7	4
13	-11	14	30	-9	1
14	-12	11	31	-12	3
15	-15	13	32	-16	3
16	-18	13	33	-14	1
17	-17	11	34	-12	-1

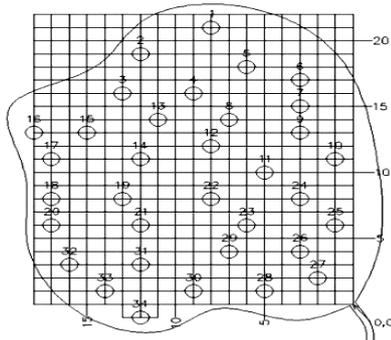


Figure 2. Grid locations of bales in field

This assignment introduces the student to topics they will explore further in their later coursework. It is possible to use a hand-held GPS unit and map the grid locations for hay bales in a field. It may be possible to develop one or more rules for hauling bales from this field using the map. If these rules increase the productivity of the self-propelled bale wagon over what can be achieved by an operator using his/her best judgment, and economic advantage is achieved.

Even if GPS cannot increase the productivity of the bale wagon, this exercise has the following objectives:

1. Introduces GPS technology
2. Application of a practical example using vector analysis.
3. Experience is gained using subscripted variables in MatLab.

### Example 2 – Tractor-Implement Matching

A spreadsheet was developed based on the Brixius Model [2] and ASABE Standard [3] to predict tractor performance and implement draft, respectively. The program demonstrates the matching of tractors with implements and implements with tractors. Optimization of weight distribution and inflation pressures for maximum power delivery efficiency can be determined and computation of field capacity and fuel consumption of the selected system is possible.

The operating efficiency of a tractor-implement system depends on how well the tractor and implement are matched. When they are ideally matched, the student (and clients) should expect reduced power loss, improved operating efficiency, reduced operating costs, and optimum utilization of capital on fixed costs [4].

The students are presented with the tables and mathematical expressions in the ASABE standard for Agricultural Machinery Management data as part of ASABE D497.5 [3]. This information is used to predict the tractive ability of tractor and the draft on tillage implements in different soil types.

*Traction and Tillage Mechanics.* Students learn how to predict tractive performance of the tractor unit and the draft requirement of the implement. The models available to predict the tractive performance of tractors and draft requirements of implements are available in Zoz and Grisso [5] and ASABE [3] respectively. In this section, the models used to develop the spreadsheet are included.

The spreadsheet for predicting the tractor performance is based on Brixius model [2]. He developed the relationships for net traction ratio (NTR), gross traction ratio (GTR), and motion resistance (MRR) as a function of mobility number and wheel slip. They are:

$$B_n = \left( \frac{CI \cdot b \cdot d}{W} \right) \cdot \left\{ \frac{1 + K_1 \cdot \left( \frac{\delta}{h} \right)}{1 + K_2 \cdot \left( \frac{b}{d} \right)} \right\} \quad (5)$$

$$GTR = \frac{T}{r \cdot W} = C_1 \cdot \left( 1 - e^{-C_2 \cdot B_n} \right) \cdot \left( 1 - e^{-C_3 \cdot s} \right) + C_4 \quad (6)$$

$$MRR = \frac{M}{W} = \frac{C_5}{B_n} + C_4 + \frac{C_6 \cdot s}{\sqrt{B_n}} \quad (7)$$

$$NTR = \frac{NT}{W} = GTR - MRR \quad (8)$$

Where:

- $B_n$  - the mobility numbers,
- $b$  - the unloaded tire section width,
- $r$  - the tire rolling radius,
- $h$  - the tire section height,
- $s$  - the wheel slip,
- $NT$  - is the net traction or pull,
- $T$  - the axle torque,
- $CI$  - is the cone index,
- $d$  - the unloaded tire diameter,
- $\delta$  - the tire deflection,
- $W$  - the dynamic load on the tractive devices,
- $M$  - is the motion resistance,
- NTR - is the net traction ratio.

Equations (5), (6) and (7) include six coefficients ( $C_1 \dots C_6$  and two constants ( $K_1$  and  $K_2$ )). Values of these coefficients and constants depend on the type of tires (which can be for bias, radial tires, or tracks). For example for radial tires, values of  $C_1, C_2, C_3, C_4, C_5, C_6, K_1, K_2$ , are 0.88, 0.08, 9.5, 0.032, 0.90, 0.5, 5 and 3, respectively.

The spreadsheet for the implement draft prediction is based on the equation published in ASABE Standard [3] and shown below:

$$D = F_i [A + B (S) + C (S) ] W T \quad (9)$$

Where:

- $D$  - the implement draft,
- $F_i$  - dimensionless soil texture adjustment  
( $i = 1$  for fine,  $i = 2$  for medium,  $i = 3$  for fine textured soils),
- $A, B, C$  - machine specific parameters,
- $S$  - is operating speed,
- $W$  - implement width,
- $T$  - operating depth for major tools  
(for minor tillage tools and seeding implements  $T=1$ ).

ASABE [3] table provides the values for the machine and soil parameters for commonly used implements.

The spreadsheet is provided and can be downloaded at:

[http://filebox.vt.edu/users/rgrisso/Dist\\_Lecture/Predicting\\_Tractor\\_Implement\\_Sizing.xls](http://filebox.vt.edu/users/rgrisso/Dist_Lecture/Predicting_Tractor_Implement_Sizing.xls)

The student predicts the tractive performance including the pull a specific tractor (usually specified for each individual student) can develop under a given terrain condition. The second component predicts the draft force on a soil engaging tool taking into consideration factors such as soil texture, tool width and operating speed and depth of the tool. Both components are briefly described in this section. The spreadsheet, the database and the instructions to use are available at:

<http://filebox.vt.edu/users/rgrisso/Tractor.htm>

A user's manual helps the student set-up and use the features of the spreadsheet application and can be downloaded at:

[http://filebox.vt.edu/users/rgrisso/Papers/Ext/Spreadsheet\\_Instructions.pdf](http://filebox.vt.edu/users/rgrisso/Papers/Ext/Spreadsheet_Instructions.pdf)

The spreadsheet component developed for predicting the tractor performance is designed to predict the performance of wheeled tractors of different configurations (2WD or 4WD/MFD) in different soils. This part of the spreadsheet includes data on 700 tractors (101 AGCO, 146 John Deere, 127 Case, 123 New Holland, 122 MF, and 87 others) extracted from the published Nebraska Tractor Test Reports (NTTR). The database also includes data on 39-R1 bias tires, 51-R1 radial tires, and 17-front F2 tires (bias). Thus when the tractor model and the tire sizes are specified, the database will provide the needed information (weight distribution, power input, tire width and diameter etc.) for predicting the performance of tractors. The tractor performance component of the spreadsheet has the ability to predict the tractor performance for a specified weight distribution on the front and rear axle (performance mode) or to calculate the weight distribution and performance for a specified wheel slip (weight mode). The weight mode can be used to calculate the required weight for desired performance. This mode together with an optimizing ballast scheme can predict the optimum wheel slip and maximum tractive efficiency. A Visual Basic macro uses a

golden section search [6] as the optimization algorithm when weight mode is in use. The algorithm reviews the results of changing the weight distribution and travel reduction and searches for the optimal power delivery efficiency.

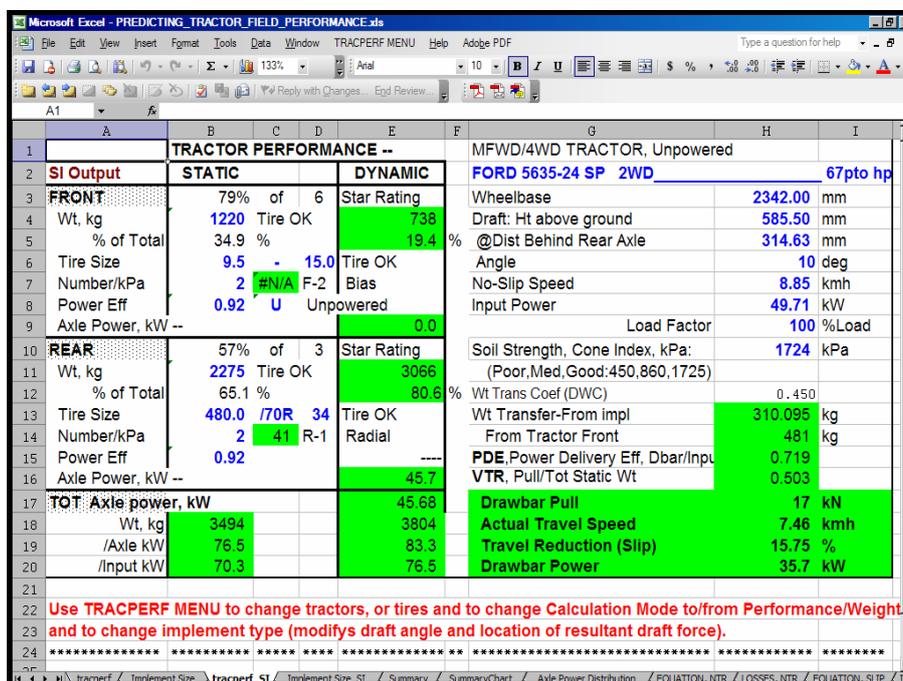
The implement sizing component of the spreadsheet predicts the draft requirement of twelve major and seven minor tillage implements and twelve seeding implements. Outputs from the tractor performance component serve as input for estimating draft and implement width. For example, for a tractor-implement combination, the speed and the predicted tractor pull are inputs for computing the force per soil engaging tool and the allowable implement width.

*Spreadsheet Applications.* Several cases, that demonstrate the use of the spreadsheet for matching tractors and implements and the results, can be reviewed in [7]. Matching the tractor with implement and vice versa are demonstrated.

In the cases considered, three tractors of different power levels and configurations were selected. Three different implements (Moldboard plow with no coulter, Disc Harrow-Tandem, and Field Cultivator) are to be matched with each tractor. These implements were operated in three different soils:

- A) fine textured, loose soil,
- B) medium textured, and
- C) coarse textured, firm soil.

Figs 3 and 4 are typical outputs from the analysis of tractor performance and implement selection respectively. In a second set of cases, the objective is to select tractors to match a set of implements to operate in fine, medium and coarse textured soils.



TRACTOR PERFORMANCE --				MFWD/4WD TRACTOR, Unpowered	
SI Output	STATIC		DYNAMIC		FORD 5635-24 SP 2WD
<b>FRONT</b>	79% of 6	Star Rating	Wheelbase 2342.00 mm		
Wt, kg	1220	Tire OK	Draft: Ht above ground 585.50 mm		
% of Total	34.9 %	19.4 %	@Dist Behind Rear Axle 314.63 mm		
Tire Size	9.5 - 15.0	Tire OK	Angle 10 deg		
Number/kPa	2 #N/A	F-2	No-Slip Speed 8.85 kmh		
Power Eff	0.92	U	Input Power 49.71 kW		
Axle Power, kW --			Load Factor 100 %Load		
<b>REAR</b>	57% of 3	Star Rating	Soil Strength, Cone Index, kPa: 1724 kPa		
Wt, kg	2275	Tire OK	(Poor,Med,Good:450,860,1725)		
% of Total	65.1 %	80.6 %	Wt Trans Coef (DWC) 0.450		
Tire Size	480.0 /70R 34	Tire OK	Wt Transfer-From impl 310.095 kg		
Number/kPa	2 41	R-1	From Tractor Front 481 kg		
Power Eff	0.92	---	PDE, Power Delivery Eff, Dbar/Input 0.719		
Axle Power, kW --			VTR, Pull/Tot Static Wt 0.503		
<b>TOT Axle power, kW</b>			Drawbar Pull 17 kN		
Wt, kg	3494		Actual Travel Speed 7.46 kmh		
/Axle kW	76.5		Travel Reduction (Slip) 15.75 %		
/Input kW	70.3		Drawbar Power 35.7 kW		

Use TRACPERF MENU to change tractors, or tires and to change Calculation Mode to/from Performance/Weight and to change implement type (modifys draft angle and location of resultant draft force).

Figure 3. Tractor performance output from spreadsheet analysis for Tractor 1 (Ford 5635)

A5 MAJOR TILLAGE TOOLS																
A	B	C	D	F	G	H	I	J	K	L	M	N	O	P	Q	
1	Draft (kN) =	17	Power (kW)	35.7	Fuel Consumption (gal/h) =	15.74										
2	Speed (km/h) =	7.5	X-Ratio	1.00	Nred	0										
3	Soil Type =	1														
4	Implement		Est Depth (mm)		Depth (mm)		Width (m)	FE	Capacity	Fuel Use	Width (Est)	m	Draft	Db-hp	PTO-hp	
5	MAJOR TILLAGE TOOLS				spacing (mm) between tools			ha/hr	l/ha		spacing (mm) between t	kN	kW		W	
6	Subsoiler/Manure Injector															
7	narrow point	# tools	254	609.6	2	263.4	1.2	0.85	0.77	20.38	588	6	3.7	49.9	103	138
8	12-in winged point	# tools	203	609.6	2	203.4	1.2	0.85	0.77	20.38	588	6	3.7	51.7	107	143
9	12-in winged point + coulter	# tools	203	609.6	2	160.9	1.2	0.85	0.77	20.38	588	6	3.7	56.2	117	155
10	Moldboard Plow (no coulters)															
11	no coulters	m	203	NA	3	202.2	0.9	0.85	0.58	27.17	NA	12	3.7	69.3	144	182
12	w/ smooth or ripple coulters	m	203	NA	3	160.2	0.9	0.85	0.58	27.17	NA	6	1.8	39.2	81	108
13	w/ bubble or flute coulters	m	203	NA	3	153.9	0.9	0.85	0.58	27.17	NA	6	1.8	40.1	83	111
14	Chisel Plow															
15	2-in straight point	# tools	203	203.2	6	219.8	1.2	0.85	0.77	20.38	196	18	3.7	47.9	99	132
16	3-in shovel/14-in sweep	# tools	203	254	6	186.8	1.5	0.85	0.97	16.30	245	19	4.8	59.4	123	164
17	4-in twisted shovel	# tools	203	304.8	5	195.0	1.5	0.85	0.97	16.30	294	14	4.3	50.3	104	139
18	Sweep Plow															
19	primary tillage	m	203	NA	5	213.9	1.5	0.8	0.91	17.32	NA	16	4.9	52.4	109	145
20	secondary tillage	m	152	NA	10	151.2	3.0	0.8	1.82	8.66	NA	14	4.3	24.3	50	67
21	Disk Harrow, Tandem															
22	primary tillage	m	152	NA	9	147.3	2.7	0.8	1.64	9.62	NA	30	9.1	59.5	123	164
23	secondary tillage	m	102	NA	19	100.0	5.8	0.8	3.45	4.56	NA	24	7.3	22.1	46	61
24	Disk Harrow, Offset															
25	primary tillage	m	152	NA	7	161.7	2.1	0.75	1.19	13.20	NA	18	5.5	41.8	87	115
26	secondary tillage	m	102	NA	16	99.9	4.9	0.75	2.73	5.77	NA	38	11.6	41.7	86	115
27	Disk Gang, Single															
28	primary tillage	m	152	NA	22	152.6	6.7	0.7	3.50	4.50	NA	52	15.8	40.7	84	112
29	secondary tillage	m	102	NA	46	101.9	14.0	0.7	7.32	2.15	NA	110	33.5	41.1	85	114
30	Coulters															
31	smooth or ripple	# tools	76	NA							Not a standalone unit					
32	bubble or flute	# tools	76	NA							Not a standalone unit					
33	Field Cultivator															
34	primary tillage	# tools	127	190.5	21	124.8	4.0	0.85	2.54	6.21	196	71	14.3	58.9	122	163
35	secondary tillage	# tools	127	190.5	28	128.7	5.3	0.85	3.38	4.66	183.75	40	7.6	24.3	50	67
36	Row Crop Cultivator															
37	S-line	# rows	127	254	7	128.3	1.8	0.8	1.06	14.85	245	10	2.5	24.4	51	67

Figure 4. Output from spreadsheet analysis of implement selection for Tractor 1 (Ford 5635)

Results that can be discussed with students are:

- The tractor develops higher draft in coarse, firm soil than in fine, loose soils.
- Optimizing weight distribution has very little influence on predicted draft developed by the tractor and thus on the width of the implements selected.
- The optimized weight distribution provided an increase in power delivery efficiency.
- The implements selected, in general, are wider in fine, loose soils. This results from lower draft requirement per width.
- Field capacities of the implements were higher in fine, loose soil.
- Field capacity increased greatly from high-draft moldboard plow to low-draft field cultivator.
- The fuel consumption (l/ha) for each implement-soil combination are almost the same irrespective of ballasting used.
- Fuel consumption decreased greatly from high-draft to low-draft implement.

**Example 3 – Field Capacity and Efficiency during Planting**

In the third example, the students develop a spreadsheet to calculate how field capacity change and operational efficiency change for a given field (constant row length), turning times and operational characteristics. This exercise helps the student visualize the operational details and the impact of various planter options on the machinery performance. The class assignment is shown in Assignment #2.

The students use the criteria in Assignment #2 to develop a spreadsheet to assure calculation accuracy and speed of making adjustments. With these criteria, each student

is given a specific planter size and speed. When the solutions have been collected, the collective answers are tabulated. The students draw conclusions from their exercise as well as the collective (impact of changing parameters-speed and planter size). Students discuss impact of these changing parameters. For example, class results shown in Tab. 3 indicate the impact of speed (increase of field capacity but a slight drop in field efficiency), crop system impacts (corn vs soybean), the impact of handling seed, fertilizer and chemicals, and impact of planter width (increase of field capacity but a drop in field efficiency). This exercise also demonstrates the losses that occur in normal planting operations and helps the student envision techniques that will help minimize them.

As a follow-up to this exercise, the students are asked to size the planter based on an 85% completion probability at a specific location, start and finish dates. A common start dates of: Corn: April 18th, and Soybeans: April 26<sup>th</sup> was selected. The results of this exercise are shown in Tab. 3. During the class discussions, the incorrect solutions provided by the students are not corrected and the students are asked to review the table and draw conclusion and relationships and what error may have potentially occurred. The impact of region and finish dates has an influence on planter size.

**Assignment #2.** Student assignment for field efficiency determination for a planter.

**Objective:** Determine the field efficiency of a planter from the given information.

**Procedure:** Follow the example outlined in class for determining the field efficiency of a planter. Find the field efficiency for the planter system traveling at **6.6, 8.0, and 10.3 km·h<sup>-1</sup>**.

A **4-, 6-, 8-, 12- or 16-row** planter is selected to plant 255 ha of furrow irrigated corn and 200 ha of dry land soybeans annually. Row width is 76.2 cm. The fertilizer hopper capacity is 41 kg·row<sup>-1</sup>, seed capacity is 41 kg·row<sup>-1</sup> and chemical capacity is 32 kg·row<sup>-1</sup>. Most row lengths are 0.4 km long. Soil is a sandy loam with slopes of 4%. Planting operation is to follow a continuous pattern.

**Corn:** Seed (18.5 kg·ha<sup>-1</sup>), fertilizer (134 kg·ha<sup>-1</sup>) and chemical (4.5 kg·ha<sup>-1</sup>).

**Soybeans:** Seed (56 kg·ha<sup>-1</sup>) and chemical (4.5 kg·ha<sup>-1</sup>).

Positional time: Fertilizer - 0.28 min·unit<sup>-1</sup>, Seed - 0.50 min·unit<sup>-1</sup>, and Chemical - 0.20 min·unit<sup>-1</sup>.

Transfer of material times: Fertilizer – 210 kg·min<sup>-1</sup>, Seed – 195 kg·min<sup>-1</sup>, Chemical – 48.5 kg·min<sup>-1</sup>.

Planter/Tractor Turn Time: **0.20 min·turn<sup>-1</sup> or 0.30 min·turn<sup>-1</sup>**.

Time between delays - 50 min of pass time, Time of delays - 4 min·delay<sup>-1</sup>.

Personal Delays - 15 min per 180 min of pass time.

**Determine** the time for moving the refill vehicle. Drive the planter to the refill vehicle (in the corner of the field) at the same rate as tractor speed.

*Note: Each student was given a specific crop (corn or soybeans), travel speed and planter size (number of rows – see Tab. 2).*

Table 2. Example of student results for determining field efficiencies as given in Assignment #2

Student	Number of rows	Crop	Speed (km·h <sup>-1</sup> )	Field Efficiency	Capacity (ha·h <sup>-1</sup> )
1	6	Corn	6.6	76.9	2.3
2	8	Corn	6.6	75.4	3.0
3	12	Corn	6.6	72.5	4.4
4	16	Corn	6.6	69.8	5.6
5	4	Corn	8.0	77	1.9
6	6	Corn	8.0	75.1	2.8
7	10	Corn	8.0	71.7	4.4
8	12	Corn	8.0	70.1	5.2
9	16	Corn	8.0	67.1	6.6
10	4	Corn	10.3	74.8	2.3
11	6	Corn	10.3	72.6	3.4
12	10	Corn	10.3	68.5	5.4
13	12	Corn	10.3	66.7	6.3
14	16	Corn	10.3	63.2	7.9
15	4	Soybeans	8.0	77.6	1.9
16	8	Soybeans	8.0	74.6	3.7
17	10	Soybeans	8.0	73.1	4.5
18	12	Soybeans	8.0	71.6	5.3
19	16	Soybeans	8.0	69.3	6.8
20	4	Soybeans	10.3	75.6	2.4
21	6	Soybeans	10.3	73.7	3.5
22	8	Soybeans	10.3	72	4.5
23	12	Soybeans	10.3	68.4	6.4

Table 3. Student results of determining planter size and completion probabilities for specific finishing dates for the items shown in Table 2

Student	Region	Finish Date	# of Rows	Completion Probability	
				Days	pwd
1	Lincoln	5-May	8	17	0.646 50-80%
2	Southeast	10-May	8	22	0.382 >95%
3	Grand Island	15-May	6	27	0.215 >>95%
4	North Platte	20-May	6	32	0.141 >>95%
5	Southeast	5-May	8	17	0.794 <50%
6	Lincoln	10-May	6	22	0.419 >95%
7	Grand Island	15-May	6	27	0.215 >>95%
8	North Platte	17-May	4	29	0.17 >>95%
9	Scottsbluff	20-May	4	32	0.121 >>95%
10	Southeast	9-May	6	21	0.517 80%
11	Lincoln	12-May	4	24	0.311 >95%
12	Grand Island	15-May	4	27	0.175 >>95%
13	North Platte	17-May	4	29	0.14 >>95%
14	Scottsbluff	20-May	4	32	0.1 >>95%
15	Southeast	9-May	10	13	1.03 << 50%**
16	Lincoln	12-May	8	16	0.435 95%
17	Grand Island	15-May	6	19	0.299 >95%
18	North Platte	17-May	6	21	0.23 >>95%
19	Scottsbluff	20-May	6	24	0.156 >>95%
20	Lincoln	9-May	8	13	0.826 <50%
21	Grand Island	12-May	6	16	0.459 90-95%
22	North Platte	15-May	6	19	0.297 >95%
23	Scottsbluff	20-May	4	24	0.164 >>95%

#### Example 4 – Nebraska Tractor Test Database for Tractor Selection

In the final example, the student use a tractor database developed from the Nebraska Tractor Test reports to selection a specific tractor model for certain operating conditions. This framework provides various decision-making options that a producer might consider when selecting a tractor model. A database is downloaded at:

[http://filebox.vt.edu/users/rgrisso/Pres/Nebdata\\_05.xls](http://filebox.vt.edu/users/rgrisso/Pres/Nebdata_05.xls)

Example Nebraska Tractor Test reports are made available so the linkage between the report and database can be established. Then the students are given a power range and asked to select a specific tractor based on fuel consumption, lugging ability and ballast configuration as shown in Assignment # 3.

*Assignment #3. The exercise using the Nebraska Tractor Test results to categorize and select tractor.*

Use the Nebraska Tractor database and find all tractors (all models) that match the between 50-75 kW

1. Get the results for: Chassis, PTO-Performance & Drawbar Performance
2. Compare the specific fuel consumption (kW-hr/l) during the maximum PTO power run. Make sure you drop out same or similar models (they have the same PTO power results). Plot your findings. Which is the best? What is the average and standard deviations?
3. Did tractor manufacturer have any impact on the specific fuel consumption within this range?
4. Review the Drawbar Performance data, drop the ones that do not have the full runs (75 & 50% runs). What is the fuel savings for “Gear-up & Throttle-Back” situations? Compare the % savings in fuel consumption ( $l \cdot hr^{-1}$ ) within a reduced load test. Compare the % increase in specific fuel consumption ( $kW \cdot hr \cdot l^{-1}$ ) for a reduced load test. Then compare (graph) the specific fuel consumption at maximum drawbar power with the ballast ratio ( $kg/\max\text{-PTO-power}$ ). Does the ballast influence the tests within this range?

Since fuel use is an important factor in machinery management, the students review and contrast the fuel consumed during different power tests. They describe the impact of manufacturer or other factors on fuel consumption such as engine (natural aspirated, turbocharged, air-cool, etc.) and transmission (manual, power-shift, CVT) configurations. The students investigate these factors with statistical inference and graphic methods.

#### CONCLUSIONS

- Engineering tools can improve the application and student understanding of complex systems involved in machinery management considerations.
- As the student use these tools, they are able to envision how engineering tools can be used to solve new problems that they confront both in the classroom and profession.

**BIBLIOGRAPHY**

- [1] MatLab, 2007, Copyright by the MathWorks, Inc. <http://www.mathworks.com/> [Accessed on 6/19/12]
- [2] Brixius, W.W. 1987. Traction prediction equations for bias ply tires. *ASABE Paper and Presentation No. 87-1622*. St. Joseph, Mich.: ASAE.
- [3] ASABE Standards, 2006. D497.4 Agricultural machinery management data. *St. Joseph, Mich.: ASABE*.
- [4] Taylor, R., Shrock, M., Wertz K. 1991. Getting the most from your tractor. <http://www.ksre.ksu.edu/library/ageng2/mf588.pdf> [Accessed on 6/19/12]
- [5] Zoz, F.M., Grisso, R.D. 2003. Traction and tractor performance. *ASAE Distinguished Lecture Series #27*, ASAE Publication Number 913C0403, St. Joseph, MI:ASAE
- [6] Jones, D., Grisso, R.D. 1992. Golden section search an optimization tool for spreadsheets. *Computers and Electronics in Agriculture* 7(4):323-335
- [7] Grisso, R.D., Perumpral, J.V., Zoz, F.M. 2007. Spreadsheet for Matching Tractors and Implements. *Applied Engineering in Agriculture*. 23(3):259-265

**ISPITIVANJE PARAMETARA UPRAVLJANJA MAŠINAMA  
KOMPJUTERSKIM ALATIMA**

**Robert D. Grisso, John S. Cundiff, David H. Vaughan**

*Tehnički Univerzitet Virđžinije, Fakultet za poljoprivredu i prirodne nauke,  
Institut za inženjering bioloških sistema, Blacksburg, VA, SAD*

**Sažetak:** Inženjerski alati su bili efikasni u demonstraciji uticaja parametara na mehanizovane sisteme. Ovaj rad pokazuje četiri klase vežbi i razmatra uticaj parametara i donošenje odluka na primerima. Ovi inženjerski alati su korisni za kompleksne odnose koji su daleko izvan mogućnosti ručnih proračuna ili aplikacija tipa “pravilo palca”. Inženjerska sredstva mogu da unaprede aplikaciju i pomognu studentu da razume kompleksne sisteme koji su uključeni u upravljanje mehanizacijom. Kako student koriste ove alate, tako stiču predstavu o načinima na koje inženjerski alati mogu biti upotrebljeni za rešavanje problema sa kojima se susreću, kako u učionici, tako i u profesionalnom radu.

**Ključne reči:** *upravljanje mašinama, inženjerski alati, parametri upravljanja, donošenje odluka, do-diplomsko obrazovanje*

Datum prijema rukopisa:	20.06.2012.
<i>Paper submitted:</i>	
Datum prijema rukopisa sa ispravkama:	25.06.2012.
<i>Paper revised:</i>	
Datum prihvatanja rada:	01.07.2012.
<i>Paper accepted:</i>	