

A web-based decision support system to select proper machinery size and tractor power

Çağdaş CİVELEK*, Sait Muharrem SAY

Department of Agricultural Machinery and Technologies Engineering, Faculty of Agriculture, Çukurova University, Adana, Turkey

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Abstract: One of the most important key factors for efficient and profitable agricultural production is agricultural mechanization. Since agricultural mechanization system expenses are nearly 30% of an agricultural enterprise investment, the mechanization system should be planned very carefully. Since internet technologies have spread into all areas, including agriculture, a web-based decision support system (DSS) was developed to plan an agricultural machinery system to be used in Turkey's farm enterprises. The developed DSS was written in PHP and the databases were created using the MySQL database administration system. Several tables to select proper machine size and tractor power, including tractor test report data, technical data of the machines produced in Turkey, field work days for Turkey's climatic conditions, and typical working speed and efficiencies of the machines, were included in the databases. For the areas over 10 ha surveys were done for collecting data according to main production and machinery commonly used. Average daily working time data were also estimated. By conducting simulations using the developed DSS based on the survey data, for the machines that are used for producing the most common products in the Adana region, machinery fleets were created and tractor power sizes were selected. According to the results, for farms smaller than 40 ha, one tractor of less than 157 kW would be sufficient, and for the areas that are over 40 ha, two or three tractors would be sufficient to complete the agricultural activities in an effective amount of time.

Key words: Agricultural mechanization, tractor selection, web-based decision support system

1. Introduction

Today farmers are faced with economic difficulties such as fuel and fertilizer prices, machinery and farm investments, and labor costs, along with difficulties that occur in a usual agricultural production circle. Agriculture as an open-air industry is affected hard by economic and climatic conditions. For that reason, farmers are trying to increase their products' quality and quantity while decreasing machinery investment, operating, and labor costs. To achieve this goal, during machinery and tractor selection certain care should be taken. Before deciding what power of tractor to be used, proper machine size should be calculated. Crop, area, labor supply, tillage practices, crop mixture, weather conditions, and risk management are the factors required to make the right calculation for machine size (Iowa State University, 2009). Due to the fact that there are several factors that have to be taken into account in calculation of machine and tractor power size, decision support systems (DSSs) have been developed as useful tools. DSSs are interactive and computer-based systems that help users in judgment and choice activities (Grisso et al., 2007; Druzel and Flynn, 2010). Application areas of DSSs are management and planning in business, health care, the military, and other areas where complex

situations may occur (Druzel and Flynn, 2010). DSSs are becoming very common in agriculture and several studies have been conducted for selection of proper machine and tractor size.

For machinery and tractor selection many DSSs have been developed by researchers. The works of Mehta et al. (2011) and Loghmanpour Zarini et al. (2013) are some of these studies. Several DSSs were developed using the Visual Basic programming language and Microsoft Access databases. These DSSs only worked on the computer that they were installed on and could not be accessed using the Internet.

For tractor selection, tractive efficiency was the most used coefficient for estimating the drawbar power of the tractor. However, when it comes to engine power for tractors, and especially power take-off (PTO) power used, since a tractor has a complex drivetrain and hydraulic system, losses should be considered for calculating the PTO power needed. For that reason, the power delivery efficiency coefficient developed by Zoz et al. (2007) is more useful than tractive efficiency for tractor power calculations.

As the world's population grows, the need for food is becoming more urgent. The only way to overcome

* Correspondence: cagdasrivelek@gmail.com

this problem is to produce crops with higher yields by using less production inputs. To achieve this goal, new technology for agricultural tractors and machinery should be used. Unplanned tractor and machinery selection leads agricultural production away from this target. For bigger farms, agricultural machinery and tractor selection is becoming more complex than ever before. Therefore, the need for a web-based DSS is getting more urgent. With this study a DSS that uses machines' and tractors' technical data and calculates tractor power based on a power delivery efficiency (PDE) coefficient is developed using PHP and MySQL databases. These are very useful open-source web programming and database tools.

2. Materials and methods

2.1. Databases

There are two databases in the developed software. One of them is the main database for the software to run menus, make calculations to select machines and tractors, and store user data and the machine system, and the other database contains tables with technical data of different machines that are produced or imported to Turkey. These technical data were taken from test reports for tractors and companies' leaflets for agricultural machinery, which can be found on websites or were published. The main database contains different tables. Information about the farmer like name, surname, address, and field crops owned are inserted into the database by the user. The working speed and efficiency of the equipment, tractive efficiency of the tractors for different soil conditions, and power transmission types were taken from the Agricultural Machinery Management Data, which is an ASABE standard (ASABE, 2011). Data on probability of a workable day for a year by 15-day periods was inserted into the database using the data taken from a survey done by

Sindir et al. (1997). The working periods of different types of machines based on crop production were inserted into the database by surveys done with different producers in the Adana region. In the other database, technical data for several machines like a plough, subsoiler, mower, chisel plough, disc harrow, seeding machine, rototiller, baler, land mower, and spraying machine were stored as tables by using leaflets taken from the producers' websites.

Tractor test report data have a crucial role in selection of the tractor power (Grisso et al., 2009). Thus, tractors test report data tables were included in the main database, which contained over 300 tractors' test report data such as power at rated engine speed and standard PTO speed, drawbar performance data for different percentages of pulling load, static front and rear weight, wheel size, and power delivery efficiency coefficient that are used in calculating the right tractor power size.

Since tractor models are produced in different power sizes and with different drive train designs, the PDE value is not the same for all tractors. For calculation of PDE, PTO power versus drawbar power should be known. Unfortunately, maximum PTO power for maximum drawbar power is unavailable in the tractor test reports published by the Nebraska Tractor Test Laboratory or the OECD, but there is a way to calculate it. If one tractor's PTO power is measured for variable engine speeds, a graphical curve can be obtained. By fitting a curve on this graphic, a regression equation can be achieved (Figure 1). Since Nebraska Tractor test reports have these PTO power tests for variable engine speeds, it is possible to develop a regression equation to be used in the calculation of PDE. Since PDE is the ratio of drawbar power over PTO power, by inserting the engine speed of the maximum drawbar power in the equation produced, PTO power for that drawbar power can be estimated and then PDE can be calculated.

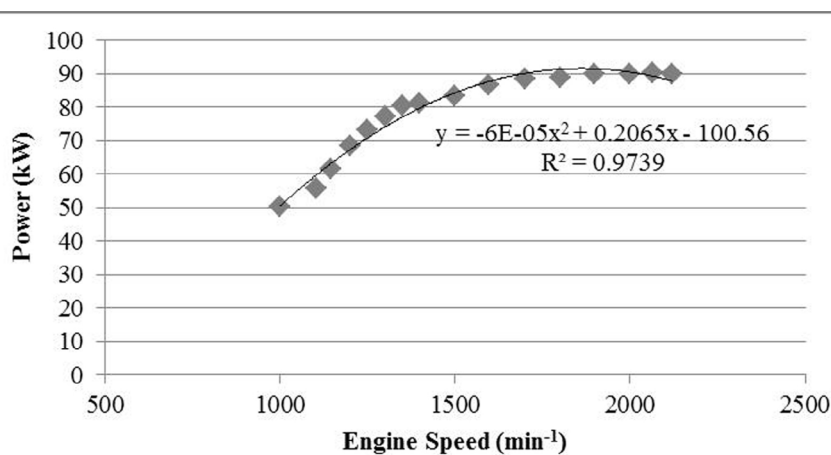


Figure 1. Tractor power variation according to engine speed and regression model.

The other important table is the data on probability of a workable day for Turkey, which contains working day percentages for 15 days of a month at 80% probability level (Sındır et al., 1997). The machines' working speed and efficiency coefficient table has been created for calculation of machines' draft power requirement using an ASAE standard (ASAE, 2003). Another important table is the production table, which contains data for the implements used for a specific agricultural product with the period of usage information. For a specific agricultural product the user can make a decision with these data to choose the proper implement size to be used at the right time based on the production area location or region.

2.2. Development of the DSS

The developed DSS was created using PHP scripting language to work on the web or to be used as a service to be embedded in a web page interface. The databases related to the software were created using MySQL, which is a commonly used free database management system.

The working structure of the DSS is as follows: the user signs up with the software and chooses a username and password. After logging in, field crops are listed along with soil type according to the user's inputs. The equipment and machines are selected by the user for the chosen field crops. If more than one tractor is needed for the chosen field crop, the DSS chooses the main tractor for the machine group with the most power needed. For the other machine group the DSS chooses another tractor with less power.

2.3. Machine working width calculation and selection

For a specific production area, the user has to select the machines to be used. For every type of machine selection the cycle is repeated. The machine working width (W) is calculated according to Eq. (1):

$$W = 10 \times A / 0.1 \times S \times e \times D \times H \times u \times g, \quad (1)$$

where A is the area size to be covered (ha), S is machine working speed (km/h), e is machine efficiency (a decimal), D is the probable day number decided by the farmer for the task to be completed by the machine (days), H is daily working hours, u is probability of a workable day for the task (a decimal), and g is the reliability of the machine. The machine width calculation algorithm is based on the equation shown in Figure 2. For this calculation the DSS takes area size data based on the field crop from the user database, while machine working speed and efficiency are taken from the machine database and the probability of a workable day is taken from another database based on the field crop. The software has the ability to change all parameters to be entered manually by the user. The data that have to be entered manually by the user are daily working hours and probable day number for the task to be finished based on his/her previous experiences, since task

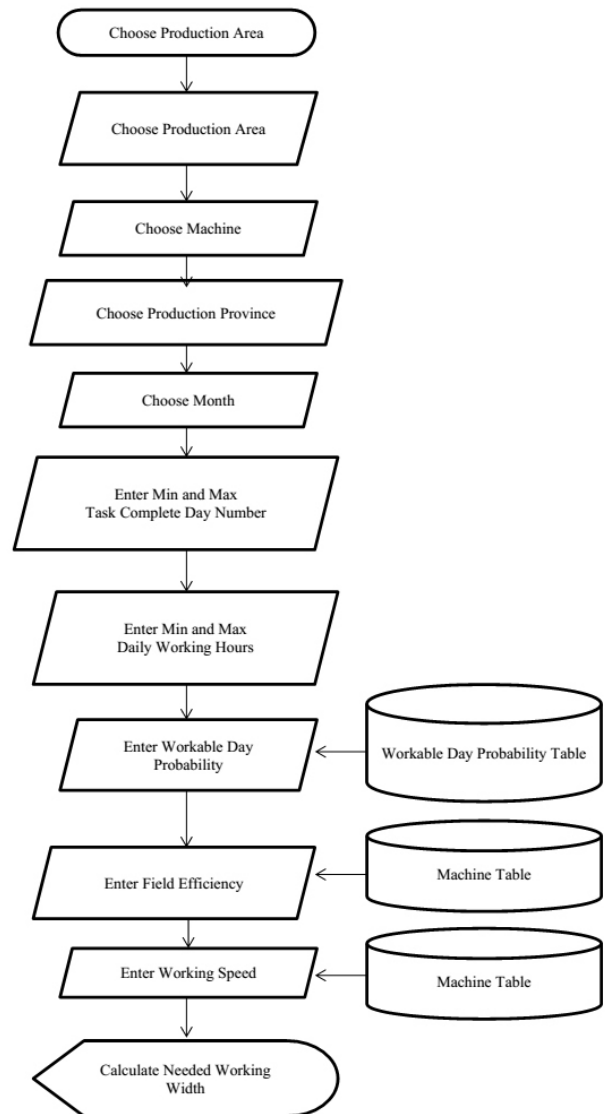


Figure 2. Machine working width calculation algorithm.

completion days depend on the farmer's available time and prevailing weather in the area (Figure 3). As shown in Figure 3, there is a table that shows the usage periods of the machines that helps the user in selecting a machine for which the usage period is the same as for another crop. With this information the user may enter proper daily working hours and task completion period in days to select proper machine width.

As shown in Figure 3, after the production area is selected, the software asks for the machine for which working width is to be calculated. By using this information the software finds out the machine's working speed and field efficiency from the database. After that, the production area and the working period of the machine are estimated according to the crop parameters requested

Change Area	Machine Selection	Show Machines	Tractor Selection	Tractors	Machine Database
-------------	-------------------	---------------	-------------------	----------	------------------

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Choose Product and Area

Product	Area	Soil Type
Cotton	200	Heavy

Working Schedule

Province	Product	Plough	Subsoiler	Chisel	Cultivator	Rotovator	Disc Harrow	Bedder	Straw Chopper	Seeding Machine	Silage
Adana	Cotton	October 15-31	October 15-31	October 15-31		November 1-14	November 1-14	November 1-14		April 15-30	
Adana	Corn		November 1-14	November 1-14			November 1-14	November 15-30	September 15-30	February 15-29	
Adana	Soya			May 15-31	May 15-31					October 15-31	
Adana	Wheat	October 15-31		October 15-31			October 15-31			November 1-14	
Adana	Sunflower	June 15-30		June 15-30	September 15-31					October 15-31	

Note:In the table above you can see the conflicted working periods of the machine for another product you have chosen.

If you use the same machine for another product, conclusion day of the task should be shorned.

For that reason it is suggested to choose another machine with higher width or multiply machine number.

Chosen Machine: Plough

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Province: ADANA

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Working Period: September15-September30

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Area 200 da

Min Day for Task Completion Max (day) ?

Min Daily Working Hour Max (h/day) ?

Workable Day Probability 100 (%) ?

Field Efficiency 85 % ?

Speed 7.0 (km/h) ?

Reliability % ?

Calculate

Figure 3. Machine working width calculation page.

respectively. With this information, the software finds out the probability of a workable day from the database.

After those parameters are entered the “calculate” button is clicked for the calculation of the working width

of the machine. The DSS then checks the proper database table based on the machine type to be chosen. If one or more machines are found in the database for which the width is above the calculated working width, it is shown

on the following screen (Figure 4). If no such machine is found, the DSS system divides the calculated width one by one from 2 to 5 respectively until a machine can be found in the database. Machines over the divided width are selected and shown on the screen and after selection

of the first machine, the width of the selected machine is exported from the overall width and the last machine is selected according to this width and recorded in the user's machinery fleet database (Figures 5–7). For example, if the calculated working width of a chisel plough is 5

Change Area Machine Selection Show Machines Tractor Selection Tractors Machine Database

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There are conflicts for this machine between products below.

Plough----->Wheat

	Opt. Task Completion Day Number	Daily Working Hour	Working Width cm	Selection
a3	5	10	134	☐
a2	4	10	168	☐
a1	3	10	224	☐

Find Machine

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Figure 4. Working width selection screen.

Change Area Machine Selection Show Machines Tractor Selection Tractors Machine Database

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Select Machine

Selection	Make	Model	Type	Furrow Number	Min Working Width	Min Power	Max Power	Power Type
☐	ALPLER	DP16	Half-Turn Plough	5	175.0	100	120	HP
☐	ALPLER	PSP16	Profile	5	175.0	100	110	HP
☐	ALPLER	PSP14	Profile	6	180.0	125	135	HP
☐	ÜNLÜ	360001000	Garden	7	194.0	40	75	HP
☐	ALPLER	DP18	Half-Turn Plough	5	200.0	120	130	HP
☐	ALPLER	URPH41	Half-Turn Plough	5	200.0	180	200	HP
☐	ALPLER	URPM41	Half-Turn Plough	5	200.0	170	190	HP
☐	ALPLER	PSP18	Profile	5	200.0	110	120	HP
☐	ALPLER	YADP06	Half-Turn Plough	6	210.0	170	190	HP
☐	ALPLER	PSP16	Profile	6	210.0	135	145	HP
☐	ALPLER	PSP18	Profile	6	240.0	145	160	HP
☐	ALPLER	YADP07	Half-Turn Plough	7	245.0	180	220	HP
☐	ALPLER	YADP08	Half-Turn Plough	8	280.0	210	250	HP

Save Machine

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Figure 5. Machine options display and selection page.

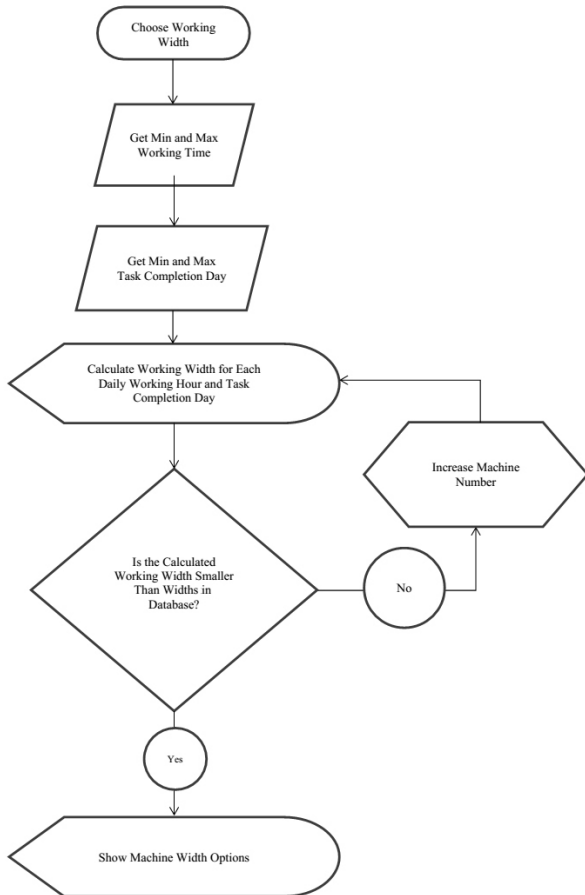


Figure 6. Machine width selection algorithm according to database.

m and if there is no machine found in the database for which working width is over 5 m, DSS divides 5 m of working width by 2 and starts searching for a machine with a working width over 2.5 m. If there is one with 3 m of working width, the software chooses that machine and subtracts 3 m from 5 and starts to search for a machine with a working width over 2 m. Any time the user wants to see the machinery fleet according to a production area, it is possible by clicking the “Show Machines” button (Figure 8.) On this page it is also possible to delete one or multiple machines from the fleet.

2.4. Tractor selection

After all machines are selected and creation of the machinery fleet is finished, it is possible to move to the tractor selection phase. For tractor selection, the user should choose the

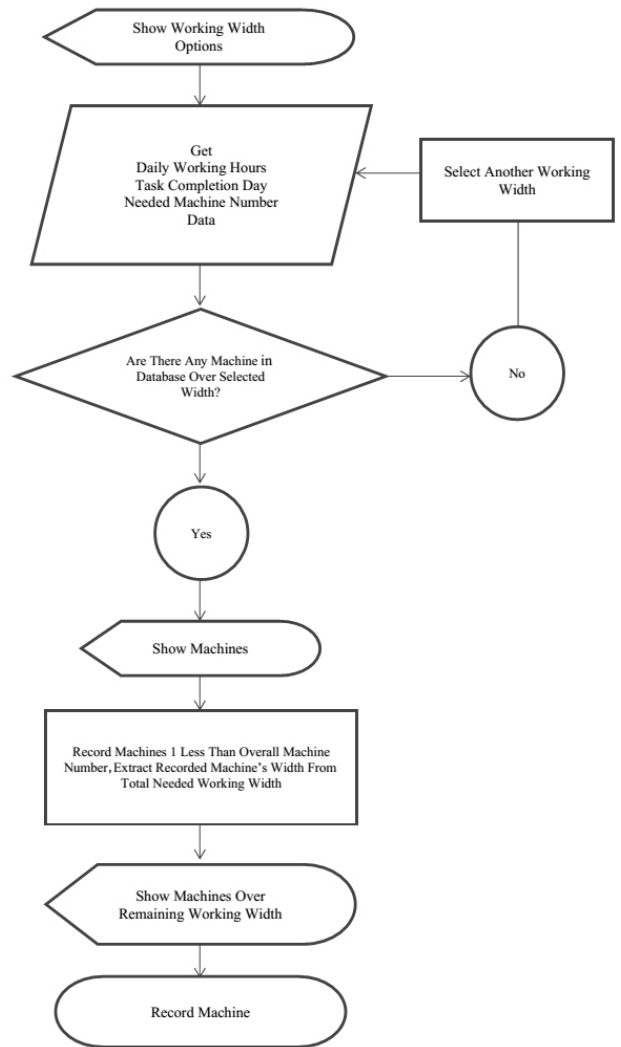


Figure 7. Machine recording algorithm.

field crop from the dropdown menu for tractor selection. After that, with the field crop information, the DSS finds the selected machinery from the database that was chosen by the user as defined in Section 2.3. With the machinery data the DSS chooses each type of machine with the highest power requirement one by one and groups them. If there is more than one machine for that machine type, the system chooses the machine with the highest power requirements. An example code of this phase for plough selection and power calculation is shown in Figure 9.

The machine draft power requirement is calculated according to ASAE D497.5 standard (ASAE, 2003) using Eq. (2):

$$D = F_i \times [A + B(S) + C(S)^2] \times W \times T \times S \times 3.6 \quad (2)$$

Change Area
Machine Selection
Show Machines
Tractor Selection
Tractors
Machine Database

Select Production Area

▼

Selected Product

Product	Production Area hectare
Wheat	125

MACHINERY

	ID	Machine	Make Model	Specs	Weight	Min Working Width	Min Power	Max Power	Power Type	ASAE Power HP	Product
☐	1271	Discharrow	ALPLER DHV28-610	Drawn Offset Disc Number: 28	1470	322	110	120	HP	84.32	Wheat-12.5 hectares
☐	1266	Discharrow	ALPLER CDHLX20	Drawn Tandem Disc Number: 20	900	190	40	60	HP	21.13	Wheat-12.5 hectares
☐	1265	Cultivator	ALPLER SKL07	Spring Type Leg Number: 7	150	150	30	40	HP	22.32	Wheat-12.5 hectares
☐	1264	Moldboard Plough	ALPLER YADP08	Reversible Mold Number: 8	3760	280.0	210	250	HP	210.91	Wheat-12.5 hectares
☐	1263	Chisel Plough	ALPLER CP07	Leg Number: 7 Chasis Height: 62 Leg Spacing: 30	421	210	60	80	HP	31.17	Wheat-12.5 hectares
☐	1262	Moldboard Plough	ALPLER PSP18	Profile Mold Number: 6	996	240.0	145	160	HP	144.63	Wheat-12.5 hectares

Delete Selected

Figure 8. Selected machinery fleet.

```

$query2='SELECT * FROM plough WHERE id="'.$row['alet_id'].'"';
$result2=mysql_query($query2,db2()) or die(mysql_error(db2()));
$row2=mysql_fetch_assoc($result2);
$query3='SELECT * FROM implements WHERE implement_name="plough"';
$result3=mysql_query($query3,db1()) or die(mysql_error(db1()));
$row3=mysql_fetch_assoc($result3);
if($soil=="heavy")
{
$select_soil=$row3['sp1'];
}
if($soil=="midium")
{
$select_soil=$row3['sp2'];
}
if($select_soil=="light")
{
$select_soil=$row3['sp3'];
}
$power=$select_soil*($row3['mp1']+(($row3['mp2']*$row3['velocity'])+(($row3['mp3']*$row3['velocity']*$row3['velocity'])*$row2['min_working_width']
/100*$row2['max_working_depth']*$row3['velocity']/3600;
${'power'}.${a}=$power;
${'id'}.${a}=$row['id'];
}
for($x=1;$x<=$a;$x++)
{
$plough[${'id'}.${x}]=${'power'}.${x};
}
if($plough!=NULL)
{
$value=max($plough);
$key=array_search($value,$pulluk);
$maxalet[]=$value;
$impid[]=$key;
echo '<input type="hidden" name="impid[]" value="'.$key.'" />';
$query='SELECT * FROM user_aletler WHERE id="'.$key.'"';
$result=mysql_query($query,db1()) or die(mysql_error(db1()));
$row=mysql_fetch_assoc($result);
$query2='SELECT * FROM '.$row['imp_name'].' WHERE id="'.$row['impid'].'"';
mysql_query("SET NAMES 'utf8'");
$result2=mysql_query($query2,db2()) or die(mysql_error(db2()));
while($row2=mysql_fetch_assoc($result2))
{
echo '<tr><td align="center">Plough</td><td align="center">'.number_format($value,2).'/></td><td align="center">'.$row['day'].'</td><td align="center">'.$row['hour'].'</td></tr>';
}
}
}

```

Figure 9. Machine grouping and power calculation code example for tractor selection.

where D is the draft power of the machine (kW); F is the soil factor; i is soil factor type F_1 for light soil, F_2 for medium, and F_3 for heavy soil; A, B, and C are draft parameters for machines that were given in ASAE D497.5; S is working speed (km/h); W is machine working width (m); and T is the working depth of the machine (for main soil tillage machines working depth should be used in cm, and for secondary soil tillage machines and seeding machines 1 should be used).

After the draft power requirement is calculated for each type of machine, machines with the highest power requirement are shown on the screen as a group for tractor selection. After the user clicks on the "Select Tractor" button, the software selects the highest draft power requirement for that group. With this, the software is connected to the tractors' table from the database and for each tractor's data it calculates the equivalent PTO power using Eq. (3):

$$\text{Equivalent PTO power} = \text{drawbar power} / \text{power delivery efficiency.} \quad (3)$$

As shown in Eq. (4), drawbar power is calculated using axle power multiplied by tractive efficiency. In the tractors' table obtained from the database, the PDE coefficients are calculated according to tractor test reports, which are done on a concrete surface. Those power delivery coefficients should be updated for the soil condition of the farm on which the tractor is going to be used. For that reason, tractive efficiency coefficients from the ASAE D497.5 standard as shown in Table 1 are used.

$$\text{Drawbar power} = \text{axle power} \times \text{tractive efficiency} \quad (4)$$

To transform the drawbar power requirement according to the soil type, the system checks for the tractor traction type and calls the related tractive coefficient from the tractive efficiency table in the database. It then multiplies drawbar power by the tractive coefficient for concrete and divides by the soil-related tractive coefficient

so that the drawbar power calculated at the end is the proper value for the soil type of the farm under study. After the real drawbar power requirement is found, PTO power is calculated using Eq. (3). If the calculated PTO power requirement is higher than the PTO power of the tractors of the database (according to tractor test reports), the tractor is shown on the screen as a selectable tractor. If not, the tractor is removed from the list. This procedure is repeated until the tractor's PTO power is over 1.2 times the calculated equivalent PTO power. After selectable tractors are determined, results are shown on the screen and the user can select one of them as a power source for that machinery group. If there is more than one machine chosen for that field crop, i.e. two moldboard ploughs, the same loop is repeated for selection of a second tractor. That is because one type of machine can be used with one tractor. For example, with one tractor one plough can be used. If there is a second one it can be used with another tractor at the same time as the first one. The algorithm for tractor selection is shown in Figure 10.

3. Results

For the five main crops produced in the Adana Region, simulations are done for selecting machines for the machinery fleet and selections of tractors for powering machines. Simulation results of the developed DSS are given in this section.

As shown in Table 2, for all products 1 tractor is needed below 30 ha, for 30 ha of area size for cotton and corn 2 tractors are needed, and over 40 ha for all crops usually 2 tractors are needed. It should be noted that tractor power as defined in Table 1 is the real tractor equivalent power, which is included in the database according to tractor test reports. It is clear that increasing tractor test report numbers in the database can result in changes in tractor power results.

According to Figure 11, the total tractor power requirement increases as production area increases. This increment is clear over 40 ha of production area. Over 40 ha the increment is more prominent for sunflower.

Table 1. Tractive coefficients of different surfaces (ASAE, 2003).

Tractor type	Tractive condition			
	Concrete	Firm	Tilled	Soft
2WD	0.87	0.72	0.67	0.55
MFWD	0.87	0.77	0.73	0.65
4WD	0.88	0.78	0.75	0.70
Track	0.88	0.82	0.80	0.78

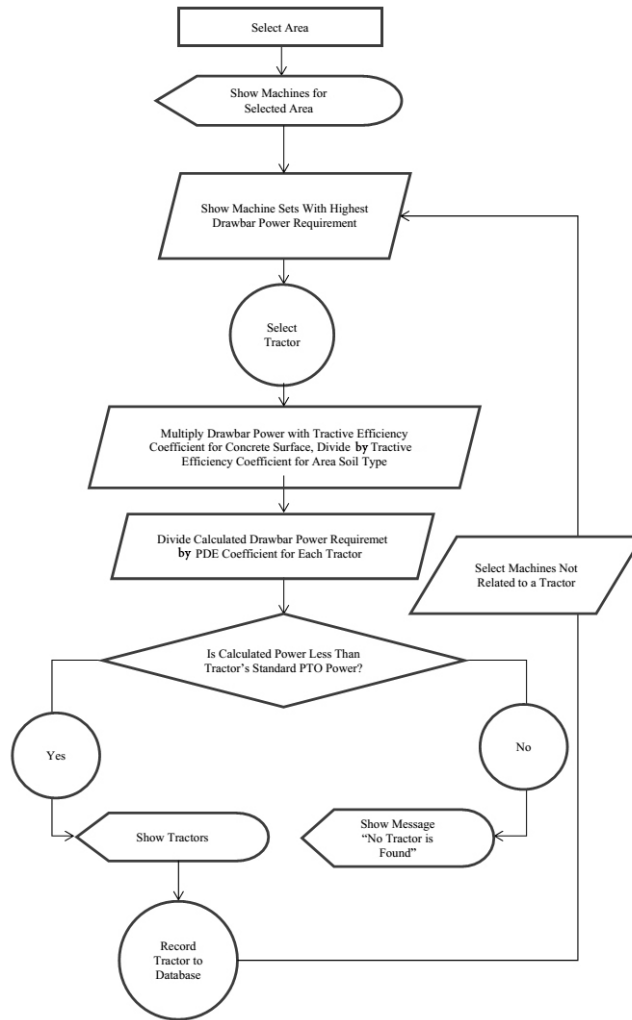


Figure 10. Tractor selection algorithm.

Table 2. Tractor power requirements for different crops and areas.

Area (ha)	Cotton		Corn		Soybean		Wheat		Sunflower	
	Selected tractor power (kW)									
5	89		89		89		85		65	
10	75		75		70		89		65	
20	112		125		110		112		110	
30	157	157 112	157	157 112	147		157		102	
40	139	125 112	125 125		147	110 75	112 94		157	157 183
50	125 110	139 139 94	125 125		125 125		139 139		204 139	
100	147 147	147 147 125	139 139	147 147 125	125 125		139 139	147 147 125	157 147 112	

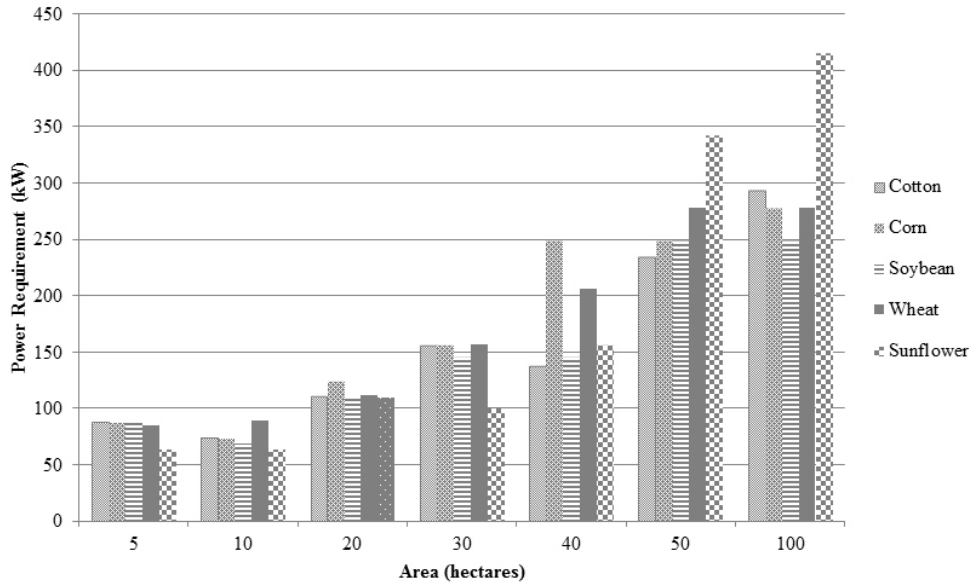


Figure 11. Total power requirements for different crop area sizes.

For the main machines used in production of these five crops, the machines' working width requirements vs. three sizes of farm are shown in Figure 12. In general it can be said that the total working width requirement for all types of machines increases with the increase of the cropping area. However, it is clear from the figures that the increment of working width is not the same for all machines. This is because the working periods of the machines are not the same and nor are workable days for different crops. Especially for chisel ploughs for corn and soybean production, working width increment is greater than those in cotton, wheat, and sunflower. Seeding machine working width for wheat production does not change as much as it does for cotton, corn, soybean, and sunflower. It should be noted that these results depend on the machinery working width data in the database. Sometimes the DSS is unable to find a machine with a working width close to the calculated one. This is because of machines produced by manufacturers that have commonly used working widths. For that reason, these results may be affected by adding new machinery with variable working widths to the list.

By conducting surveys it was found that in the Adana region the average daily working period is 10 h according to farmers. By using these data, minimum and maximum working hours were determined as 5 and 15 h, respectively; working speed of different machines was determined according to the ASAE D497.5 standard (ASAE, 2003). By multiplying variable daily working hours and working speed of the machine, the working width requirement is highly affected, as shown in Table 3.

As the software calculates the required draft power by using related coefficients given in the ASAE D497.5 standard, those values were compared to the draft power requirement suggested by the producers of those machines by calculating the mean power requirement for each working unit of the machine (leg, mold, knife, etc.). These comparisons were done for a moldboard plough, chisel plough, offset disc harrow, and field cultivator, and results are given in Figure 13. For the moldboard plough and offset disc harrow the producers' power suggestions and the power calculated by using the ASAE standard were very close. The mean difference between the two values was 6.28% for the moldboard plough and 10.33% for the offset disc harrow. However, for the chisel plough and field cultivator, as the number of working parts increased, the difference between power requirement suggestions by the manufacturers and the calculated power increased. Mean difference between those values was 18.6% for the chisel plough and 23.6% for the field cultivator. These analyses showed that power requirement values should be updated and added to the databases in the software by making further field trials for better calculation of draft power requirements.

4. Discussion

With this study it was found that a web-based DSS using PHP and the MySQL database system can be created for farmers to help properly choose machinery and tractors for their farms. With the developed web-based DSS, it is possible to create different agricultural machinery fleets and choose proper tractor power sizes. Most important

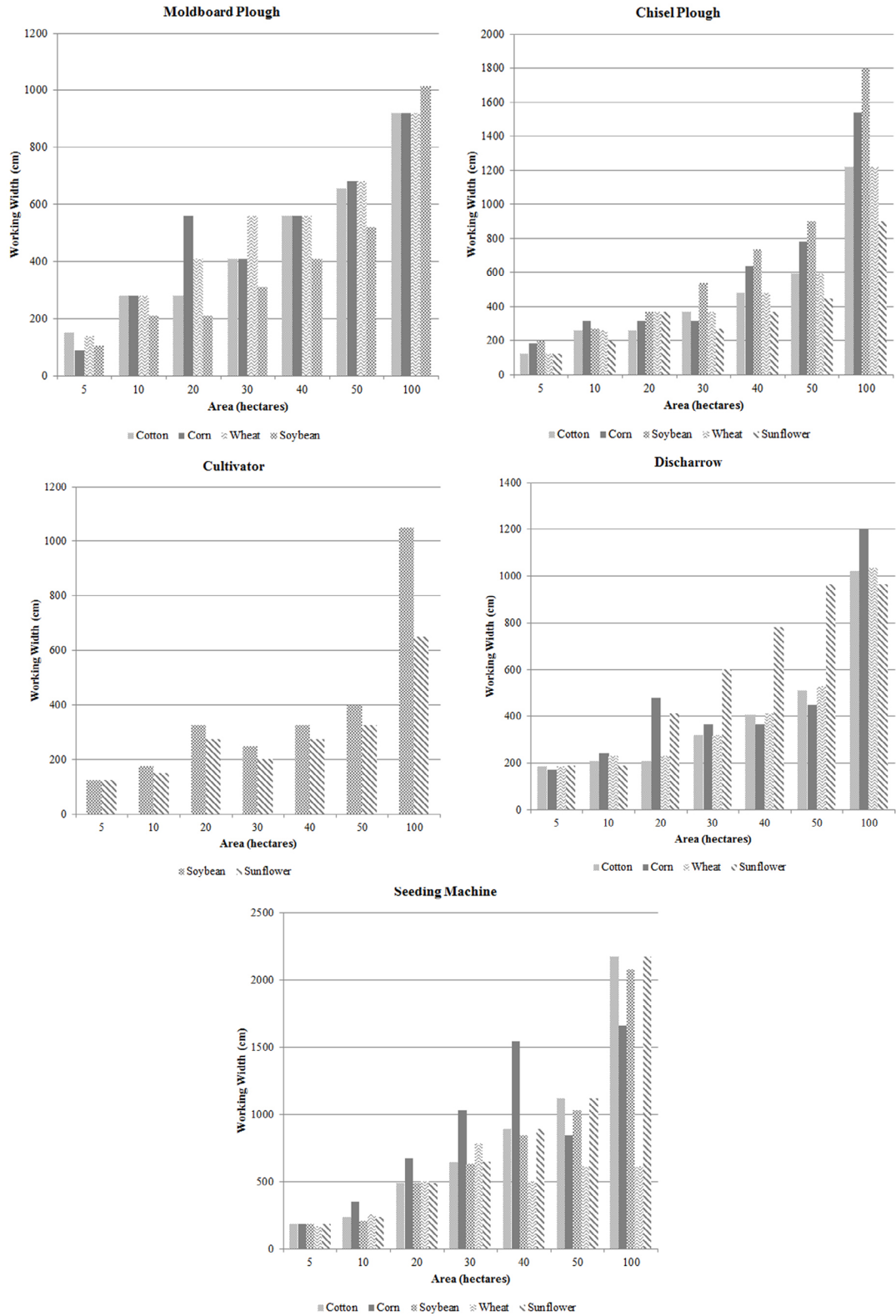


Figure 12. Working width requirements for different machines based on different area sizes and products.

Table 3. Variable workable area and machine number requirements for different products based on different working conditions.

Machinery	Variables	Wheat	Sunflower	Cotton	Corn	Soybean
		Area (ha) [Required machine number]				
Chisel plough	AS-AWH	77.66 [1.97]	103.88 [1.97]	77.66 [1.97]	60 [1.97]	51.31 [1.97]
	MinS-MinWH	31.55 [4.85]	42.20 [4.86]	31.55 [4.85]	24.41 [4.85]	20.85 [4.85]
	MaxS-MinWH	50.96[3]	68.17 [3.01]	50.96 [3]	39.44 [3]	33.67 [3]
	MinS-MaxWH	95 [1.61]	126.60 [1.62]	95 [1.61]	73.24 [1.62]	62.69 [1.61]
	MaxS-MaxWH	152.89 [1]	205 [1]	152.89 [1]	118.31 [1]	101.02 [1]
	Average	81.6 ± 46.69	109.17 ± 62.61	81.61 ± 46.69	63.08 ± 36.12	53.91 ± 30.85
Disc harrow	AS-AWH	135.48 [2.36]	163.66 [2.06]	135.48 [2.36]	114.95 [2.37]	116.27 [2.36]
	MinS-MinWH	53.22 [6.01]	56.26 [6]	53.22 [6.01]	45.16 [6]	45.68 [6]
	MaxS-MinWH	106.45 [3.01]	112.51 [3]	106.45 [3.01]	90.32 [3]	91.35 [3]
	MinS-MaxWH	160 [2]	168.77 [2]	160 [2]	135.48 [2]	137.03 [2]
	MaxS-MaxWH	320 [1]	337.54 [1]	320 [1]	270.96 [1]	274.06 [1]
	Average	155.03 ± 100.43	167.75 ± 105.27	155.03 ± 100.43	131.23 ± 85.02	132.88 ± 85.96
Seeding machine	AS-AWH	103.19 [1.83]	127.51 [2.06]	129.52 [2.06]	73.57 [2.06]	127.51 [2.06]
	MinS-MinWH	37.26 [5.08]	51.80 [5.08]	52.62 [5.08]	29.89 [5.08]	51.80 [5.08]
	MaxS-MinWH	63.06 [3]	87.66 [3]	89.05 [3]	50.58 [3]	87.66 [3]
	MinS-MaxWH	111.79 [1.69]	155 [1.7]	157.85 [1.69]	89.66 [1.69]	155 [1.7]
	MaxS-MaxWH	189.189 [1]	262.99 [1]	267.14 [1]	151.74 [1]	262.99 [1]
	Average	100.90 ± 57.88	136.99 ± 80.59	139.24 ± 81.89	79.09 ± 46.51	136.97 ± 80.55
Moldboard plough	AS-AWH	30 [2.13]	40 [2.13]	30 [2.13]	23.09 [2]	19.71 [2.14]
	MinS-MinWH	10.65 [6]	14.25 [5.96]	10.65 [6]	8.24 [6]	7.08 [5.97]
	MaxS-MinWH	21.31 [3]	28.50 [2.98]	21.31 [3]	16.49 [3]	14.08 [3]
	MinS-MaxWH	31.96 [2]	42.76 [1.99]	31.96 [2]	24.73 [2]	21.12 [2]
	MaxS-MaxWH	63.93 [1]	85 [1]	63.93 [1]	49.47 [1]	42.24 [1]
	Average	31.57 ± 19.95	42.10 ± 26.49	31.57 ± 19.95	24.73 ± 15.43	20.85 ± 13.18

AS: Average working speed; MinS: minimum working speed; MaxS: maximum working speed;
 AWH: average working hours; MinWH: minimum working hours; MaxWH: maximum working hours.

points of the developed DSS are that machine working width is determined based on the working day probability coefficient included in database, and tractor power is determined not only using tractive efficiency but also using PDE coefficients calculated for each tractor using tractor test reports.

The results showed that for areas smaller than 40 ha one tractor of less than 157 kW in power size can be used, and for areas larger than 40 ha 2 or 3 tractors are needed to complete the agricultural activities in an effective amount of time.

Since a module for machine reliability was included in the software, and by updating databases with further studies to determine each machine's reliability coefficients, it is possible to take into account time losses according to machine malfunctions to determine more reliable machine working width. For any type of machine the measured draft and PTO power requirement data can be included in the database, so in the tractor selection section of the software the machine's real power requirement is available for tractor power calculation.

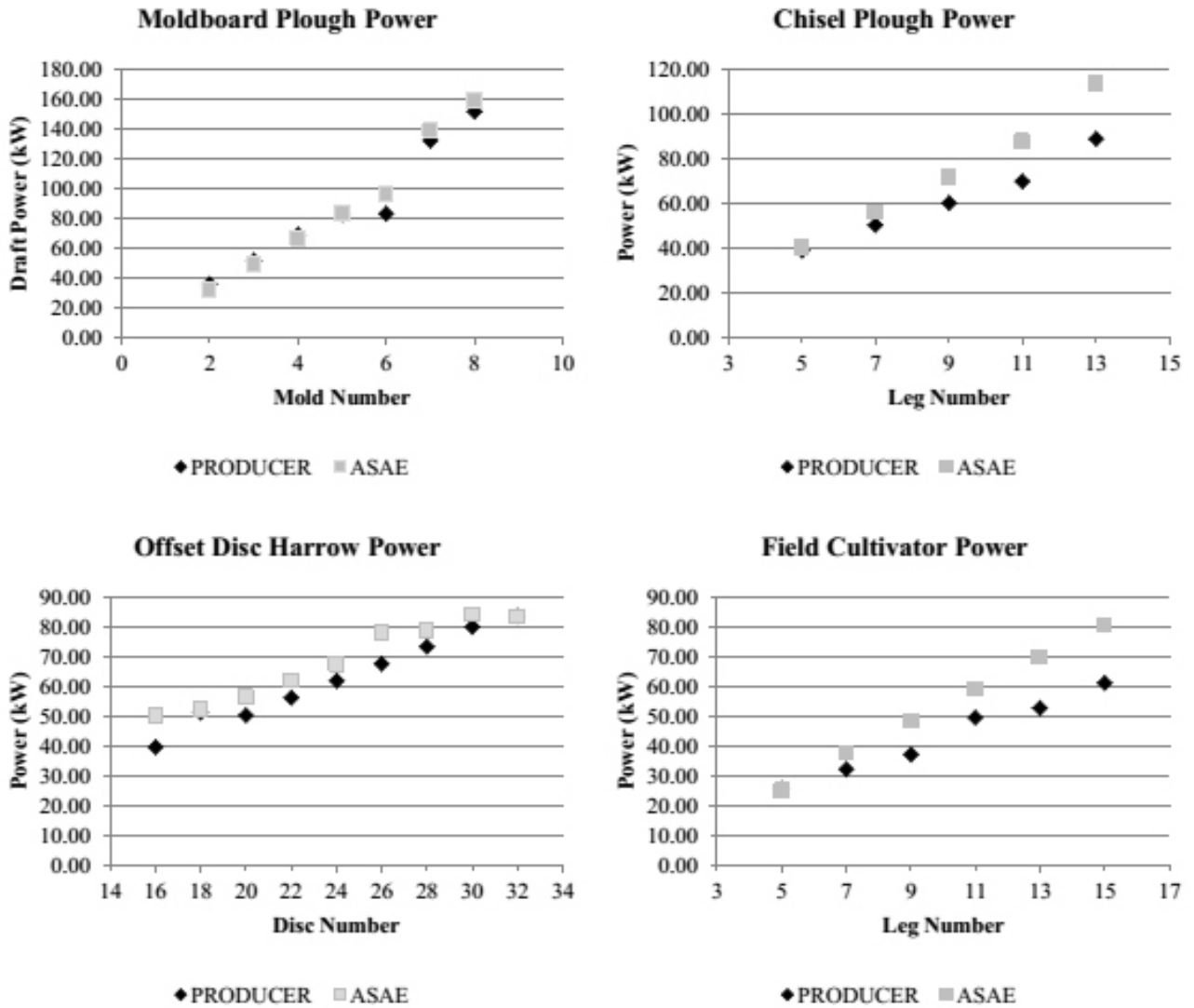


Figure 13. Tractor power requirement comparison between producer suggestion and ASAE calculation.

In conclusion, with this study it was found that a practical web-based software tool for choosing the right machinery and tractor power could be developed using PHP. The developed DSS is very flexible since it was written in PHP and those codes can easily be inserted into any web page. Not only can the software's working method be updated by further studies, but also DSS databases can be easily updated by using any web browser or using a software tool developed for control of MySQL databases. While precision farming and its tools are becoming very common, the developed DSS can serve as a useful tool

since it has the capability to be published on a web page, to be embedded in a mobile phone application, or to serve as an embedded service for cloud applications. Therefore, it will make agricultural practices more efficient and profitable for middle-sized and large-scale farms.

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