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Simulation of economic damage at mechanized wheat harvesting in Khuzestan province of Iran

E. Bougari[1*], H. ZakiDizaji[2], M. E. Khorasani[2]

[1]Department of Agricultural Mechanization Engineering, Ramin Agriculture & Natural Resources University, Khuzestan, I. R. Iran
[2]Department of Agricultural Faculty, Shahid Chamran University of Ahvaz, Ahvaz,I. R. Iran

* Corresponding Author: bougarieisa@yahoo.com

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ABSTRACT-The aim of this research is to present a simulation model for reducing economic damages of mechanized wheat harvesting in Khuzestan province, Iran. The simulated model is composed of three sub-models; for determining the appropriate working hours, grain losses, and economic sub-model. In order to determine the appropriate working hours, a mathematical model was developed. For determining the grain losses, 52 fields in Hamidieh, a small town in southwest of Iran were selected. Several mathematical models were developed for predicting the natural cutting platform and combine end losses plus the percentage of broken seeds. The average appropriate working hours was obtained by a computer simulation model based on meteorological information of an 8-year period. The maximum acceptable speed for the two combines; 955 John Deere and TC56, was 2.5 and 4 km per hour, respectively. A minimum grain loss happened in 4 days after physiological maturity and the best time range for wheat harvesting in Khuzestan was 2 to 15 days after physiological maturity. At the beginning of the harvest season, the combine loss in the early hours of day, due to high moisture of crop, was more than the mid-day time or afternoon. However, after 10 days of physiological maturity, the reverse happened. Results showed that despite the growing costs of delay in harvesting, no matter how vast the fields are, it will not justify combine ownership; thus, employing rental combines is more cost-effective in fields of any size in Khuzestan.

INTRODUCTION

Agricultural industry is one of the most important economic sectors in Iran. It comprises a considerably high percentage of production and employment (Asadi et al., 2010). It accounts for over 8.8% of the Gross National Product (GNP), over 104 Million tons of agricultural products, 20% of non-oil exports (Anonymous, 2014) and 17.9% of employment (Anonymous, 2015).

Recently, with the advancement of technology, many models have been developed to earn more profits from agricultural products prediction of the weather condition. Developing models for ground preparation, seeding, harvesting, drying, storage and transportation, which are dependent on weather conditions, are very important (Royce, 2001). Despite the difference between the out farm studies and farm studies, the analysis and prediction of agricultural machinery performance is an important part of the management of machinery (Witney, 1995).

In their study of the rate of threshing in the 1165 John Deere combines, Navid et al. (2010) investigated the knocker performance with two threshing criteria, i.e. percentage of beaten seeds per total seeds to knocker and percentage of separation in knocker per total beaten seeds. They used Poisson models as probability density function. In their study, Masdari et al. (2009) tried to predict wheat losses using Imaginary Variables Model data in Khorasan Razavi province. In this study, the effect of area, wheat variety, cultivation type, combine model, combines life, harvest date, and harvest time were taken into consideration and investigated based on the model.

Among the models which have been developed for cereal harvest Audsley – Boyce and Philips - O'Callaghan can be mentioned. This model was developed to determine the optimal combine level size and favorable speed for products and field conditions. New models are also used to assess the economic benefit of combine adapted with automatic speed control system (Mcgechan, 1985).

Johnson offered curves that revealed natural and cutting platform losses for wheat in one site and one year. De Jong and Zelhorst (1971) reported losses for winter wheat and spring barley for a five-year period and based on these data, Van Kampen presented mean curves for dry matter, shedding and cutter bar loss. Kliier and Biggar (1972) measured shedding and cutter-bar loss in one year on one site; they related cutter-bar losses to the direction of a leaning crop, the position along the cutter-bar, and the use of crop lifters; they observed accelerated shedding losses due to high winds late in the season. Later, they presented mean curves and tabulated data for wheat and barley based on these experiments (Mcgechan, 1985).

Audsley and Boyce (1974) developed a model for minimizing cost of combine to grain losses and cost of drying seeds for a period of 10 years. They also obtained desirable sizes and speed of combine and size of grain storage according to the field conditions with the model.

Nazmi et al. (2010) developed a wheat harvest system simulation model in different weather conditions for three main wheat growing regions in Australia. In this study, 15-year (1991-2005) history of weather data for Goondiwindi, Scaddan and Tamworth was used. Results showed that the weather conditions during the harvest period had a significant influence on the predicted returns. For the given farm, setups the optimum harvest moisture contents for different climatic regions were quite different. The optimum harvest moisture contents for Goondiwindi, Scaddan and Tamworth were 14, 15 and 17%, respectively. It was also found that farmers in dry areas can have a more returned capital and in most humid and cool areas delays in harvesting increase the grain losses due to natural losses and unharvesting grains also reduced grain quality.

De Toro et al. (2012) simulated wheat harvest operations based on meteorological data and surveyed total cost of the harvesting operation in Stockholm of Sweden. They found that the available combining time highly depended on grain moisture contents which showed large annual variation, e.g. a moisture ceiling of 21% (w.b.). In order to complete harvesting operations in most years, it was necessary to operate at a moisture content of 22-24% (w.b.), overall harvesting costs were estimated approximately 140 Euros per hectare. The main sources of annual cost variation were firstly the timeliness costs and secondly the drying costs.

High percentage of the costs of wheat production is related to harvest stage. Optimal management of harvest stage is essential to reduce costs and losses. Achieving this needs long studies, spending time and high costs on the farm. Harvest System Simulation model can reduce research cost and yield useful information by analyzing farms in a long-time period. With this model, farmers and farm managers can estimate the best methods of harvesting, the most desirable harvesting capacity, and finally the most desirable return capital to farm to the possible extent. Thus, the aim of this research is to present a simulation model for reducing economic damages of mechanized wheat harvesting according to weather conditions in Khuzestan provinceand areas with similar weather conditions

MATERIALS AND METHODS

In this section, in order to provide a computer simulation model for reducing economic damages of mechanized wheat harvesting system, different stages of research project will be discussed including data collection, farm tests, obtaining relevant relations, preparing a model and validating it.

The most important part of a model is to collecte required information. Information needed to develop the model includs two main parts, meteorological and farm data. Meteorological data required for this research included day length in hour, daily rainfall in millimeters, daily minimum and maximum temperatures, and relative air humidity in hours 7, 13 and 19. This information was received from Meteorological Organization of Khuzestan and Agricultural meteorological station of Ahvaz for an 8-year period from 2005 to 2012.

Due to the lack of accurate data for developing the model, extensive field experiments were conducted.

Determining the Appropriate Working Hours

These experiments were implemented at Shahid Chamran University of Ahvaz Agricutural experiment station. Fied. Samplings were carried out at two wheat farms.

When cereal seeds reach physiological maturity, their dry weight will increase and begin to lose their moisture and become dry. Information on cereal physiological maturity time is important for farmers and farm managers. Abawi (1993) and Nazmi et al. (2010) considered the wheat physiological maturity at 30% moisture content.

To determine physiological maturity and the appropriate harvesting times, samplings began from 11, April up to 5 May 2012 in two farms.

Sampling Methods

While observing the proper distance from farm edges for each sample, 20-25 wheat clusters (approximately 30 g grain) were harvested randomly in different parts of the field. Seeds were separated from the clusters and weighed with a digital-scale with an accuracy of ±0.01 gr. The sampling operation was repeated three times at each sampling time. It should be noted that sampling was conducted three times a day at 7 am, 13 and 19. However, in some days, the sampling was increased up to five times a day.

The weighed samples were (Wet-weight basis) transferred to the laboratory in marked pockets. The samples dry weights were obtained after drying them in an oven at 105° C for 24 hours. (Damavandi et al., 2008; ISTA, 2009)

Evaluating Wheat Harvesting Losses

For determining the grain losses, 52 fields in Hamidieh, in southwest of Iran were selected. Of these farms, 28 were harvested by John Deere 955 Combine and the rest by a new Holland TC56 (It should be noted that more than 52 farms were visited but some of them due to combine high life or inappropriate crop conditions were not included in this study). In order to determine qualitative and quantitative wheat losses in the field and determine affecting factors on losses, necessary information was collected using plots on the farm (for calculating natural, cutting platform and back combine losses) and questionnaires completed by farmers and combines drivers. Many factors affect combine losses but the aim of this study was to evaluate the effect of combine forward speed, product yield, grain moisture content (%, w.b.), combine (John Deere955 and new Holland TC56) and cultivation type on combine losses. To minimize the influence of other factors such as combine settings, cutting height, carousel and rotor speed, necessary recommendations were given to drivers.

In all these farms, parameters such as combine type, combine life, combine forward speed, carousel and rotor speed, grain moisture during harvest, product yield, cultivation type, harvesting date, cutting height, and product density were measured and recorded. Finally, natural, cutting platform, the combine end losses, and percentage of broken seed were evaluated with conventional methods.

Formulation and Simulation Model

In this section, the equations and the applied sub-models are discussed. This consists of three sub-models for determining the appropriate working hours, grain losses and economic sub model.

Sub-Model for Determining Appropriate Working Hours

The most important factor in determining the appropriate working hour's r is grain moisture content. After physiological maturity, the humidity, temperature, and harvest date are the most influential factors on grain moisture content. In rains, dramatic changes will happen in grain moisture content according to the amount of rainfall. In order to determine the appropriate working hours, the formulas used in Australia by Cramp in and Dalton in (1971) and Nazmi et al. (2010) were used. These formulas were modified for Khuzestan weather conditions according to the data of grain moisture content which were collected in Shahid Chamran University of Ahvaz farms.

$$M = W_e + Ae^{-0.04t} \quad (1)$$

$$w_{e=}K[\frac{-log\ (1-rh)}{1.8T+492}]^{\frac{1}{n}}$$

where, rh: air relative humidity measured as a decimal

t: temperature of the air in 0C

For wheat, K is 113 and1n is 3.03.

M: grain moisture content

We: equilibrium moisture content a constant for any given dry period

$$A = M_f - W_e \quad (2)$$

where, A: a constant for any given dry period

Mf: grain moisture content at the beginning period

$$\Delta M: 0.345AR + 6.11HR + 0.548 \quad (3)$$

where AR: amount of rain in mm,

HR: duration of rain in h

Grain Loss Sub-Model

Grain loss sub-models included natural, cutting platform, the combine end losses, and percentage of broken grains of the model. Considered dependent variables surveyed in this research are shown in Table 1.

Regression equations and correlations were used to obtain these models. The best equations with the least error and the highest correlation coefficient were selected among linear, exponential, logarithmic and etc. Regression equations were defined in SPSS software. Ten to 20% of the collected data were reserved to validate the models.

Economic Submodel

In this section, the net income and harvesting system costs including annual fixed and variable machinery costs, labor and transportation costs were calculated (Table 2).

Model Assumptions

The required assumptions which can be different for each model are the start of the harvest season, size of farm, grain yield per hectare, and straw per grain ratio.

The start of the harvest season**:** harvesting starts when wheat grains reach their physiological maturity. In this study, wheat physiological maturity time assumed for 30% grain moisture content (wb %.) was 9 - 19 of April.

The size of farm: This model is prepared for the management of large-scale farms; however, it can also provide useful information for small farm owners as any farm size can be defined for the model.

Grain yield per hectare and straw per grain ratio: According to data obtained from the survey of 52 farms in this research, average grain yield and straw per grain Ratio were considered 3500 kg per hectare and 0.9, respectively.

Crop Price**:** For evaluating the model in an 8-year period, wheat grain price was calculated based on the price in 2012.

Delays due to rain: In this research, considering views of combine operators, farmers, weather experts, farm visits and soil type of wheat fields in Khuzestan, which are of low permeability, rain causes long delay in agricultural operations (Table 3).

Table 1. Models of grains losses

Model name	Independent variables
Natural losses model	Days passed from the beginning of wheat harvest season
cutting platform losses model	Forward speed (km hr^{-1}), Yield (t ha^{-1}), grain moisture content
back combine losses	Feed rate (t ha^{-1}), grain moisture content
Broken seed model	Feed rate (t ha^{-1}), grain moisture content

Table 2. Parameters of economic sub model

Fixed costs	Annual ownership cost. Depreciation, Shelter, Insurance,
variable costs	Repairs and maintenance, Fuel, Oil, Labor
Justified level of ownership	Justified level of ownership = Annual Fixed costs / Custom rate ($/unit of use)- Operating costs ($/unit of use).
return	It got from reducing the costs of harvesting machines or custom rate in rental systems, labor costs, transporting costs and the grain loss costs from the income of total performance.

Table 3. Relationship between rainfall and delay in harvest (defined by researchers)

Rainfall(mm)	R< 2	2<R<5	5<R<10	10<R<20	20<R<40	40<R
Delay in harvest(day)	0	1	3	2	5	7

Model Operation

All equations along with other required information were written in MATLAB programming environment so that each variable could be changed as an input according to the farm conditions and farm manager recommendations. This program can be easily used. As the input changes, output (amount of losses, costs and the net income, etc.) changes can be practically observed. According to the flowchart of Fig. 1, at first, the model receives all the meteorological data including day length in hours, maximum and minimum daily temperature, relative air humidity and amount of rainfall. Other information, such as farm size, grain yield, combines type, combine speed, and also constant parameters related to the machinery and farm will be read subsequently by the model. After reading the inputs, the model calculats the grain moisture content for each hour of the day in the total harvest period and thus, the number of hours in each range of moisture during harvest season will be determined. If the grain moisture is not suitable for harvesting (>20%) or ground conditions do not allow the operation (heary rainfall), the model delay the harvesting for one day until appropriate harvesting time arrives. When the harvest begins, based on the date of harvest and input parameters related to product and combines, the model calculates and shows the natural losses, combine losses and patches and side farm losses. Economic costs of wheat harvesting including costs of combines (leased or owned), grain transfer to retailers centers and siloes, collection and packaging of straw, straw transfer and labor costs are calculated and finally deducted from the product sales, and thus, the farm net income (excluding the costs of the land preparation and planting) is obtained.

RESULTS AND DISCUSSION

In this section, the researcher discusses the sub models for determining the appropriate working hours, the grain and economic losses for making the computer simulation model that has been developed using farm experimentations and other information. Furthermore, in addition to presenting the output of the final model, the results are also discussed and interpreted.

A Model for Determining Appropriate Working Hours

Results obtained from data of grain moisture content in the harvesting season showed that the change of grain moisture content depends more on days past maturity than weather conditions and these changes were significant at the level of 1%. (Table 4).

Eqation.1 is for calculating grain moisture content in Ahvaz weather conditions is showed as follows, for which, grain moisture content and meteorological data were collected at Shahid Chamran University of Ahvaz

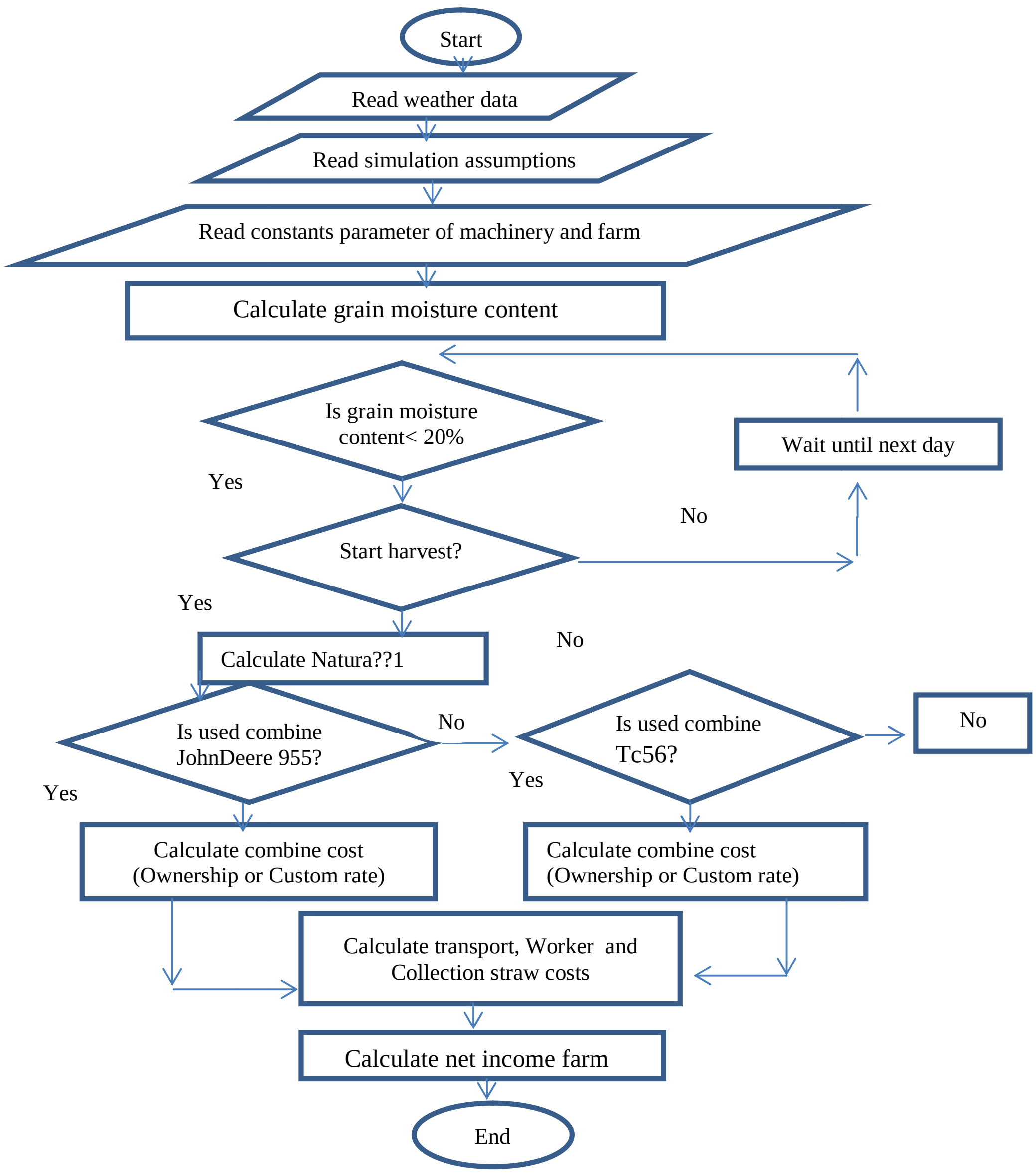

Fig. 1. Flowchart of the Wheat Harvest Simulation Model

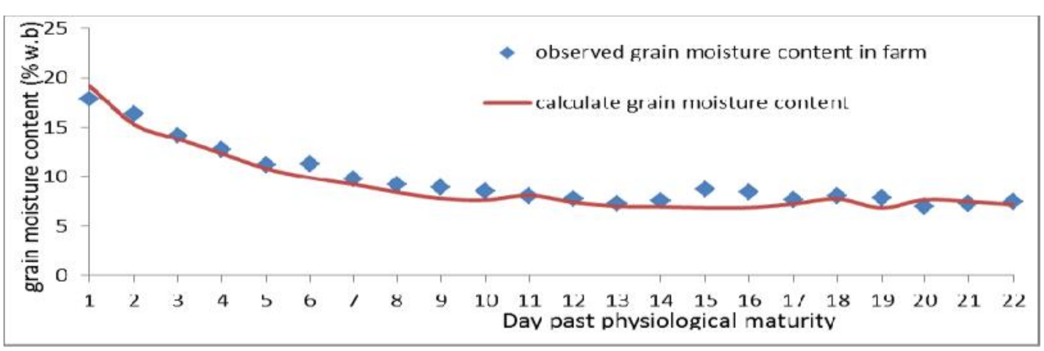

Fig. 2. Comparison between predicted grain moisture content by the model and the one measured in the field

Eqation. 1, A was obtained 14% (Difference between grain moisture content at the beginning of the dry season with grain equilibrium moisture content), B is -0.01 and determination coefficient (R^2) is 0.86. The average calculation errors of this model for collected data in the two farms was 9.5 and 12.7%, respectively. Figure. 2 shows the comparison of model results with real data of the first farm.

Model results show that the relative humidity is the most important factor for determining the appropriate working hours. According to an eight-year period data obtained from the Department of Agricultural Meteorology of Ahvaz during the harvest season, the average relative humidity was highest in 2004. Figure. 3 shows the number of working hours in 2004 and 2012 and the average of grain moisture content of a period of 8 years.

Table 4. Summary of Regression models grain moisture content

Dependent variables	model	B	Std. Error	t
grain moisture content	the time in hours measured from the beginning of the dry period.	0.01	0.01	18.62**
Adjusted R^2 =0.86			R=0.92	

Nazmi et al. (2010) reported optimum grain moisture contents in wheat harvest for Goondiwindi, Scaddan and Tamworth of Australia to be 14, 15 and 17%, respectively. Rahama and Ali (1990) reported the optimum moisture for wheat harvest in Sudan between 9 and 14%. In the present research, according to the researcher's findings and the agricultural experts' recommendations, the optimal range for the harvesting of wheat in Khuzestan was considered between 10 and 16%. In Fig. 4, the total number of the existing working hours and the optimal working hours for wheat harvesting (between Moisture content 10 and 16%) is shown in different years. Computer model results for a period of 8 years show that in the harvest season, there is an average of 576 working hours during 45 days for wheat harvest. But the number of hours suitable for harvesting is very low during the season due to sharp drop in grain moisture. Results of farm observations and simulation model show that the lowest combine losses happen in a range of 10 to 16% of the grain moisture content. Average of available working hours in this range for 8 years of simulation was 153 hours. These results can be considered as the average for the coming years. Moreover, with the tremendous advancement in meteorology through which we can predict weather for more than one month by satellites, the data regated for this model can be received in time for new harvesting season.

A **Model for Determining Grain Natural Losses**

After separating the irrelevant data, the data of only 49 farms were left for obtaining an equation for predicting natural losses. The natural losses data of 41 farms were used to build a model; the data of 8 farms which were selected randomly were used to build an evaluation model. Overall, the obtained average natural losses were 23.13 kg per hectare. Field experiments showed that delay in harvesting increased natural grain losses. For analyzing and predicting the effect of the variable of harvesting time (past days from starting of wheat harvesting season) on natural grain losses, regression analysis was used. The effect of this variable was statistically significant. In Table 5, the regression model of the effect of variable of harvesting time on the natural losses is shown briefly.

Therefore, the following regression model can be used for predicting natural losses commensurately with the delay in harvesting.

$$nl_w = 0.175e^{(.062t)} \quad (4)$$

where, nl_w = Natural losses wheat (%)

Days past maturity= t

To determine the amount of regression errors of this equation for predicting the natural losses of wheat, the data of 8 farms were separated and compared with the results of this model. Fig. 5 shows the natural losses calculated by the model and natural losses observed in the farms. The average error observed in predicting the natural losses by this model was 31.36%.

Table 5. Summary of Regression models natural losses

Dependent variables	Model	B	Std. Error	t
Natural loss	Constant	-1.75	0.006	-10.95**
	Days past maturity	0.062	0.022	8.11**
Adjusted R^2 = 0.86			R=0.92	

Cutting Platform Losses Model

To survey the dependent variable of cutting platform in combines, three independent variables were examined including forward speed, product performance and grain moisture content. To analyze and predict dependent variable changes (cutting platform losses) with changing independent variables, regression analysis was performed. The effect of these variables was statistically significant. Table 6 shows a summary of regression models for variables surveyed on cutting platform losses of John Deere 955 and new Holland TC56.

According to the results presented in Table 6 and the appropriate modified determining coefficients (R^2 ad, for John Deere 955 and new Holland TC 84% and 81%, respectively), the following regression models are used to determine cutting platform losses if other affecting factors are controlled.

$$CPL_{J955=} 2.93\, e^{-0.106\, P + 0.42\, S - 0.11\, GM} \quad (5)$$

$$CPL_{TC56} = 3.5\, e^{-0.14\, P + 0.254\, S - 0.098\, GM} \quad (6)$$

where, CPL_{J955} = cutting platform losses John Deere 955

CPI_{TC56} = cutting platform losses TC56

PF Yield, t ha-1

S = Forward speed, km hr-1

GM= moisture content grain

To determine the amount of error of regression equations for predicting wheat losses, 3 John Deere 955 and 2 new TC 56 were compared with the results of the models. The average of observed errors of cutting platform combines losses was 24% and 27% for John Deere 955 and new TC 56, respectively.

Back Combine Losses Model

To determine the dependent variable of back combine losses in combines, two independent variables feed rate (ton/h) and grain moisture content (%wb) were considered. The effect of these variables was statistically significant. In Table 7, a summary of regression model is shown. Variables examined on back combine losses were John Deere 955 and new Holland TC 56.

According to the results in Table 7 and the appropriate modified determining coefficients (R^2 ad, for John Deere 955 and new Holland TC 84% and 81%, respectively), the following regression models are used to determine back combine losses if other affecting factors are controlled:

$$BCL_{J955} = 0.04e^{(0.334\,F + 0.126\,GM)} \quad (7)$$

$$BCL_{TC56} = 0.03e^{(0.17\,F + 0.119\,GM)} \quad (8)$$

where, BCL_{J955} = back combine losses John Deere 955

BCL_{TC56} = back combine losses TC56

F= Feed rate, t ha-1

GM= moisture content grain

The average of observed errors in back combine losses in John Deere 955 and New Holland TC was 35% and 28%, respectively.

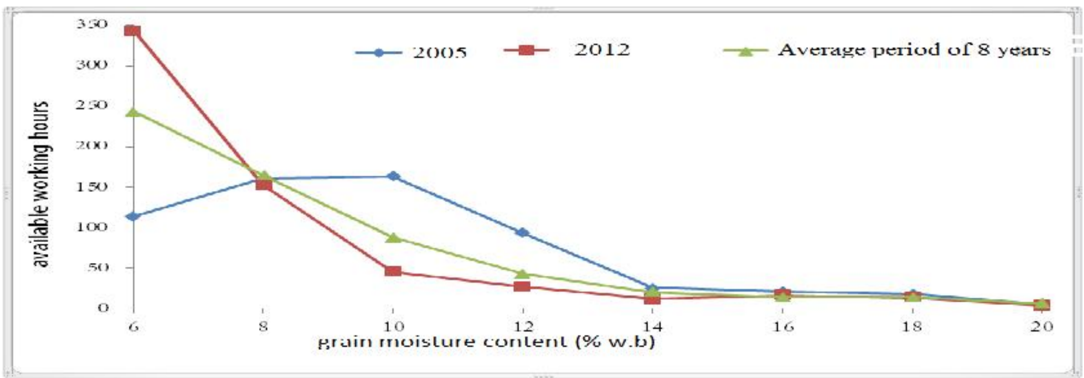

Fig. 3. Comparison between predicted number of work hours in 2005, 2012, and average 8-year in different Moisture content grain by model

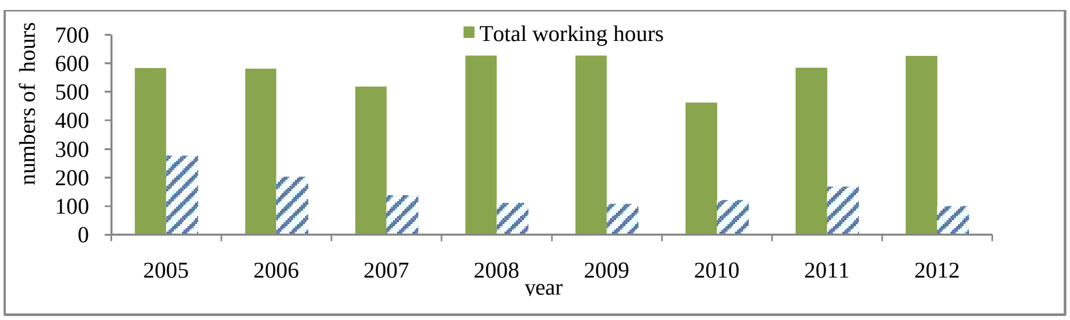

Fig. 4. The total number of work hours and the optimal work hours of 2005-2012

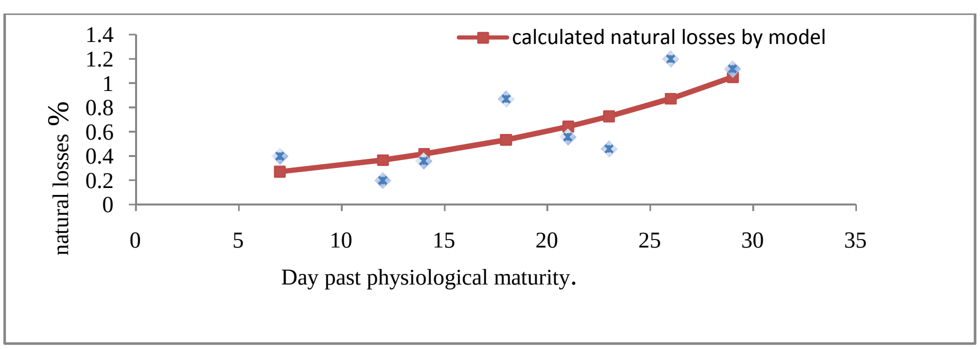

Fig. 5. Comparison between predicted natural losses by model and those observed in the field

Table 6. Summary of Regression models for cutting platform losses

Dependent variables	Model	Unstandardized coefficients		t	VIF
		B	Std.Error		
Cutting platform losses in John Deere 955	Constant	1.121	0.552	2.149*	
	Yield (kg/ha)	-0.106	0.054	-2.457*	2.20
	Forward speed(km/h)	0.420	0.174	2.173*	1.07
	Moisture content(%wb)	-0.110	0.022	-4.883**	2.18
	Durbin-Watson=2.42	R=0.93		Adjusted R^2 =0.84	
Cutting platform losses in TC56	Constant	1.18	0.301	3.951**	
	Yield (kg/ha)	-0.140	0.082	-1.756*	2.7
	Forward speed(km/h)	0.254	0.71	3.589**	1.07
	Moisture content(%wb)	-0.098	0.023	-4.515**	2.63
	Durbin-Watson=1.86	R=0.92		Adjusted R^2 =0.81	

Broken Grains Rate

In this study, for investigating the dependent variable of broken grains rate in combines, two independent variables of feed rate (total materials grain and non-grain inputs to combine, tons per hour) and moisture content grain (%wb) were considered. The effect of these variables was statistically significant. In Table 8, a summary of regression models is shown. Variables examined on broken seed losses were John Deere 955 and new Holland TC 56. According to the results in Table 8 and the appropriate modified determining coefficients (Adjusted R^2 for John Deere 955 and new Holland TC 67% and 73%, respectively), the following regression models are used to determine back combine losses if other affecting factors are controlled:

$$bs_{j955} = e^{(4.31-0.305F-0.321GM)} \quad (9)$$

$$bs_{TC56} = e^{(2.977-0.105F-0.221GM)} \quad (10)$$

where, bs_{j955} = broken seed in John Deere 955
bs_{TC56} = broken seed in TC56
F= Feed rate, t ha-1
GM= moisture content grain.

Computer Model

Results of the computer model for a period of 8 years have shown that in the harvesting season, there is an average of 576 working hours during 45 days of wheat harvest. But, the number of hours suitable for harvesting due to sharp drop in grain moisture is very limited during the season. Results of farm observations and simulated model show the lowest combine losses in the range of 10 to 16% of grain moisture content. The average available working hours in this range for simulated 8 years was 153 hours. These results can be considered as the average for the coming years.

Table 7. Summary of Regression models of back combine losses

Dependent variables	Model	Unstandardized coefficients		t	VIF
		B	Std. Error		
Back combin losses John Deere 955	Constant	-3.127	0.336	-8.799**	
	Feed rate(ton/h)	0.334	0.066	5.045**	1.035
	Moisture content(%wb)	-0.126	0.024	5.242**	1.035
	Durbin-Watson=2.25	R=0.86		Adjusted R^2 square =0.72	
Back combin losses TC 56	Constant	-3.5	0.325	-10.46**	
	Feed rate(ton/h)	0.17	0.033	4.03**	1.39
	Moisture content(%wb)	-0.119	0.03	4.73**	1.39
	Durbin-Watson=2.425	R=0.89		Adjusted R^2 square =0.77	

Table 8. Summary Regression models for broken seed losses

Dependent variables	Parameter model	Unstandardized coefficients		t	VIF
		B	Std. Error		
Broken seed losses John Deere 955	Constant	4.133	0.761	5.43**	
	Moisture content(%wb)	-	0.046	-7.04**	10.025
	Feed rate(ton/h)	-	0.135	-2.25**	10.025
	Durbin-Watson=1.51	R=0.83		Adjusted R^2 =0.67	
Broken seed losses TC 56	Constant	2.977	0.412	7.22**	
	Moisture content(%wb)	-0.221	0.040	-588**	1.394
	Feed rate(ton/h)	-0.105	0.045	-2.035**	1.394
	Durbin-Watson=1.51	R=0.86		Adjusted R^2 =0.73	

Results of field experiments and this computer simulation model have shown that the important factors leading to increased grain losses are date and time of harvest (the time during day). The minimum grain losses in simulated 8 years happened in 4 days after physiological maturity and the best time ranges for wheat harvesting in Khuzestan were 2 to 15 days after physiological maturity. The best time of harvesting during the harvest season varied with the day. At the beginning of the harvest season, in the early hours of the day (6 to 10 am), due to high moisture crop, combine losses were remarkable while after almost 20 days of physiological maturity, this became vice versa; that is, in the early morning hours during the harvesting, combine losses were fewer than those of the mid-hours day and afternoon due to sharp drop of grain humidity which is result of the decrease in air humidity and sharp increase in the air temperature in May in Khuzestan (Fig. 6).

The type of selected combines had a significant impact on economic damage caused by losses of product. In all of the harvest dates, wheat losses in John Deere 955 combine was more than Combine TC56. Since the new Holland Combine has a higher farm capacity than John Deere combines, using this type of combine or similar combines in large farms, reduces not only unusual losses, but also losses due to delay in the harvest.

Another important factor influencing grain losses is the forward speed of combine. In this study, the maximum acceptable speed for john Deere 955 and new Holland TC were 2.5 and 4 km per hour, respectively. Harvesting with higher speeds will cause significant economic damages (Fig.7).

Average Total Costs of Wheat Harvest

Average total costs of wheat harvest including costs of harvesting operation (rental price of combine, collection of straw, grain transportation to retailers and labor costs) and costs of grain losses (grain losses in harvesting and weight loss due to delay in harvesting to reduce grain moisture) in a period of 45 days of harvest season are shown in Fig. 8. These costs were obtained from a computer model output. The average of farm performance is 3500 kg per hectare. Moreover, John Deere 955 combine was used with forward speed of 2km/h. Costs of harvesting operations and price of wheat per kg were considered based on the prices of 2012, and costs of grain losses and other costs of harvesting were obtained in 8 years (Fig.8).

Regardless of the costs of delay in harvesting, the minimum hectares for justifying the ownership of John Deere combines was 320 and of New Holland TC56 combines was 683 hectares. Computer model output results showed that the use of private combines for owners of large farms due to high costs of delay in harvesting in Khuzestan province would not be economical. However, in the harvest season, in addition to private combines, they can rent combines and for covering the cost of ownership, they can lend their combines in areas where the harvest season is different.

CONCLUSIONS

More than 933 fields with 100 hectares in size, in Khuzestan province, which make up 21% of the total farms of the province, were included in our study; these farms are often under annual cultivation of crops such as wheat. Planning and schedule\ng for a timely harvest, especially in large farms, is the task of farmers and farm managers. The average of available working hours in the range of 10 to 16% of grain moisture content for simulated 8 years was 153 hours. The best time ranges for wheat harvesting in Khuzestan were 2 to 15 days and the minimum grain losses happened in 4 days after physiological maturity. The type and number of selected combines showed a significant impact on economic damage caused by losses Hiring new combines working at optimum forward specd can reduce unusual grain losses and is more economical

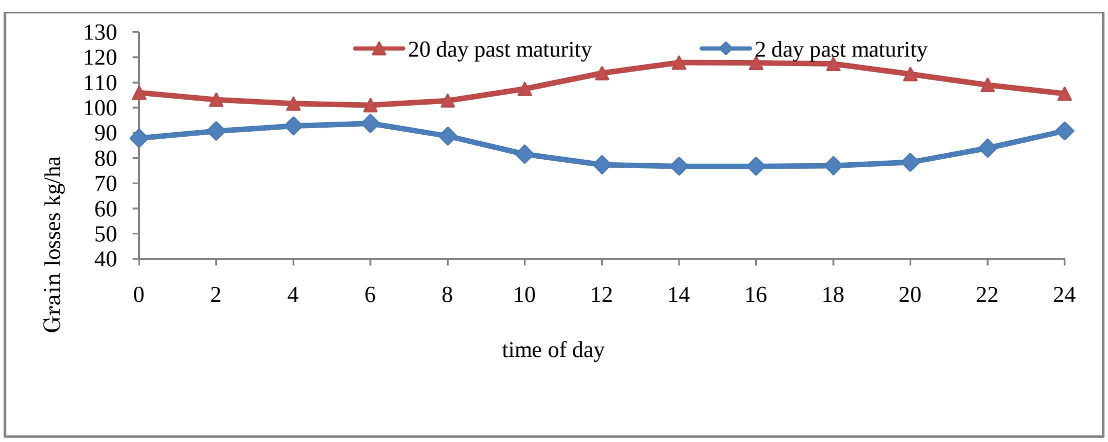

Fig. 6. The effect of working hours in a day on grain losses for different dates of wheat harvesting

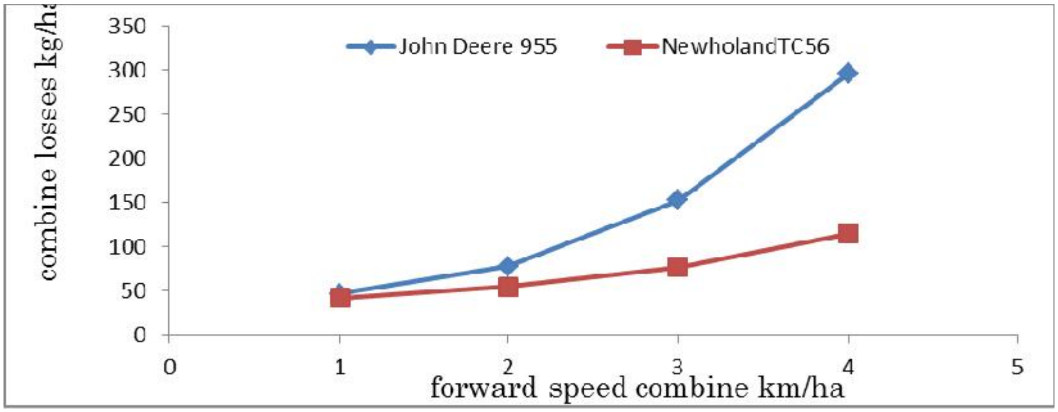

Fig. 7. The effect of forward speed of combines, John Deere 955 and new Holland TC on rate of grin losses

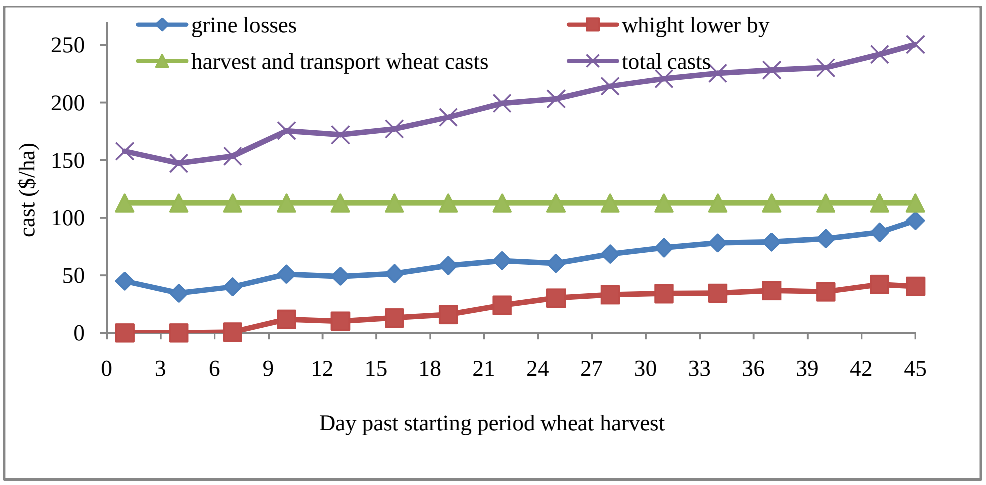

Fig. 8. Average costs of wheat harvesting during the harvest season

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شبیه سازی خسارت‌های اقتصادی برداشت مکانیزه گندم در استان خوزستان

عیسی بوگری[1*]، حسن ذکی دیزجی[2]، محمداسماعیل خراسانی فردوانی[2]

[1]گروه مکانیزاسیون کشاورزی، دانشگاه علوم کشاورزی و منابع طبیعی رامین خوزستان، خوزستان، ج. ا. ایران.
[2]گروه مکانیک ماشینهای کشاورزی و مکانیزاسیون، دانشکده کشاورزی، دانشگاه شهید چمران، اهواز، ج. ا. ایران

*نویسنده مسئول

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واژه‌های کلیدی:
گندم
مدل‌سازی رایانه‌ای
محتوای رطوبتی‌دانه
کمباین
تلفات برداشت

چکیده-هدف از این تحقیق ارائه یک مدل شبیه‌سازی برای کاهش خسارت‌های اقتصادی برداشت گندم در شرایط آب و هوای استان خوزستان و مناطق مشابه می‌باشد. این مدل از سه زیرمدل تعیین زمان‌های‌کاری مناسب، زیرمدل تلفات دانه و زیر مدل اقتصادی تشکیل شده است. به منظور تعیین ساعت‌های کاری مناسب برداشت، یک مدل ریاضی برای تعیین محتوای رطوبتی دانه درو نشده تدوین گردید. برای تعیین تلفات دانه، ۵۲ مزرعه دربخش مرکزی وحمیدیه شهرستان اهواز انتخاب شد. تلفات طبیعی، سکوی برش و انتهای کمباین و همچنین درصدشکستگی دانه بررسی گردید و مدل‌های ریاضی این پارامترها بدست آمد. توسط مدل رایانه توسعه یافته میانگین تعداد ساعت‌های مناسب کار، بر اساس اطلاعات هواشناسی یک دوره ۸ ساله برای فصل برداشت بدست آورده شد. بیشینه سرعت پیشروی قابل قبول برای دو کمباین جاندیر۹۵۵و نیوهلندTC56 به ترتیب ۲/۵و ۴ کیلومتر بر ساعت بدست آمد. کمترین تلفات گندم، ۴ روز پس از رسیدگی فیزیولوژیکی و بهترین بازده زمانی برای برداشت گندم درخوزستان ۲ تا ۱۵ روز پس از رسیدگی محصول بدست آمد. در ابتدای فصل برداشت تلفات کمباین در ساعت‌های ابتدای روز به علت رطوبت بالای محصول بیشتر از ساعت‌ها میانی روز و بعد از ظهر بود ولی با گذشت تقریباً ۱۰ روز از زمان رسیدگی عکس این حالت اتفاق افتاد. نتایج نشان داد به علت هزینه‌های بالای تأخیر در برداشت هیچ سطحی از مزرعه توجیه‌کننده مالکیت کمباین نیست و استفاده از کمباین‌های اجاره‌ای در هر اندازه‌ای از مزرعه در استان خوزستان مقرون به صرفه‌تر است.