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MODELING THE EFFECT OF MECHANIZATION LEVEL INDEX ON CROP YIELD APPROACHING SYSTEM DYNAMICS METHODOLOGY

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ABSTRACT

A system dynamics methodology used for estimating effects of mechanization level index on the mean yield of farm crop products, considering the main input and output of farming crops' production system of Iran. A collection of constant parameters, logical relations and statistically estimated functions which were effective in mechanized farm crops' production of Iran, defined as an autonomous system and time span for modeling is defined a period 70-year viz. 1981 up to 2051. Running the established model by simulation software, resulted in key parameters, needed for creating "The production function" as mean yield of farm crop products depended to mechanization level index. After testing validity of the created model, analyzing estimated production function resulted in recognizing three economic production regions. The first economic production region continued from 1.342 Kw/ha to 2.013 Kw/ha; The second production region started at 2.013 Kw/ha and ended at 2.386 Kw/ha, and finally the third production region started from 2.386 Kw/ha for mechanization level Index, while the maximum profitable point for farm crops production appeared at 2.218 Kw/ha in simulation procedure. All the analysis based on the available statistics for agricultural sector of Iran, since 1981 up to the recent time.

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1 Introduction

A major advantage of using dynamic simulation approaches is their ability to represent actual processes rather than observed behavior (Neuwirth & Peck, 2013). The necessity of system dynamics approach for investment analysis and system dynamics application, such as to evaluate different types of investment decisions for developing have been showed previously (Luban, 2009). Due to the nature of machinery inputs, estimation of machinery input based farm crop production dependent on common agricultural economics methods is restricted. The operational field of such experiments for applying mechanization as test inputs should be covered by large-scale regions like a province, state or country.

Furthermore, due to the diversity of planted farm crops' species within a region, using the mechanization level indicators, measured by Kw/ha, to large scaled areas for observing the effect of input on farm production as output would be so complicated. Thus a system dynamic based method designed for simulating the real situation of the mechanized farming production system of Iran. In a research under the title of "A System Dynamics Model for Evaluating Investment Strategies for Agriculture Development", some strategies planned and tested to optimize the profits from the investment in agriculture system of India (Gupta & Kortzfleisch, 1987). In a case study, Singh (2006) proposed a linear model about the relationship between the yield and mechanization level index estimated in India for estimation of a mechanization index and its impact on production factors. Additionally, another study for estimating a yield model for irrigated and non- irrigated wheat and barley based on mechanization level indicator in Iran was conducted by Abbasi et al. (2013), result of study revealed an additive relationship for the effect of farm mechanization level, on mean yield of wheat and barley in Iran. Strategic importance of food security issues for each community, forces the relevant sector managers to have a sustaining, Improvement, optimizing

and development program for food production. Farm crops have the main role in supplement of inputs for livestock and poultry feeding, dairy industries, edible oil productions and all other the food-processing industries. Use of machinery in farming crop's production, considered as the most expensive input in farming crop's production after land costs (Edwards, 2015).

So this research conducted to focus on defining mechanized farm production collective agents of Iran as a system and a system dynamic modeling used for anticipating real situation by virtual simulating; due to the complexity of changing conditions and environment of farm crop production during time (Fisher et al., 2000). Estimating production function for farm crops of Iran based on machinery inputs, and determining the optimum production point were the main purposes of this research. So that the maximum profitable production point, the maximum capacity of system for physical production and the optimum proposed range for economic production, based on the rate of machinery inputs could be forecasted and determinable.

2 Materials and Methods

The main objective of this study was the collection of information involved in mechanized farm crop production in Iran and to establish relationships between them which could form a dynamic autonomous system. Such a conceptually defined system should imitate the real situation regarding the role of machinery in farming procedure, for predicting future conditions acceptably. Cash's liquidity current set as the basic element for designing a dynamic simulating model and a conceptual diagram of cash flow in a system designed so that could illustrate how inputted capital to system converts to mechanization input and then how it converts to farm products and finally to money in an enclosed loop (Figure 1).

Figure 1 Conceptualization of Cash flow diagram and conversion of money to assets in a mechanized farming production system designed for present research.

Main structure of this modeling built for predicting future trajectory of involving parameters based on their past trajectory for this all the analysis based on the available statistics for agricultural sector of Iran, since 1981 up to the recent time used in this study. At first step for building simulation model, basic concepts for system creation defined as the diversity of all types of farm crops and farm machinery, a conceptual homologous average value defined and calculated for all various parameters for the machinery function in farm crop production system of Iran.

A collection of 48 commercial mechanized farm crop products of Iran (FAOSTAT, 2015), involving cereals, pulses, oilseeds, vegetables, kitchen garden crops, forage and industrial farm crops defined as material output from the system. Mean yield of farm crop's products through the system, estimated by calculating the ratio of total farm crop's production to the entire cultivated area of farm crops (Eq. 1).

Mean yield of farm crop products through the system (kg/ha) = (Total farm crops production (kg)/ (Total cultivated area of farm crops (ha)(1)

The portion of total available draft power in system involving draft power of any type of all working 2WD and 4WD farm tractors, combine harvesters and pedestrian controlled (single axle) tractors, to total mechanically cultivated area of farm crops resulted in "The mechanization level index" of the system (Almassi et al., 2008). A time period since 1981 to 2051 defined as a 70-years simulation time span; so that future trajectory of system outputs could be predictable virtually based on the previous trajectory of variable inputs of the system since 1981 to 2014. Then a collection of involved components in mechanized farm crop production of Iran and the relationship between them, gathered as endogenous parameters of the system, and classified in four categories of system inputs:

Category 1: Initial values for system inputs, are values of time independent parameters at the start time of simulation in 1981 (Table 1).

Category 2: Constant system inputs are fixed numerical agents, which assumed to be fixed during simulating time. Considering the generally unchanging nature of the inputs or lack of sufficient statistics about them, was the reason to assuming this category of inputs as the fixed parameters and to be set independent of the time (Table 2).

Category 3: Cause and effect relationship (Sterman, 2000) between each pair of involved parameters, defined as arithmetical functions; so that the cause factor set as independent variable and the effect factor set as the dependent variable of function (Table 3). Intending to create a mathematical relationship between an effect factor and its corresponding cause factor, at first step annually statistics for each variable from related references since 1981 to current time for years 2012, 2013, 2014 or 2015 gathered depending on availability of statistics.

For predicting forthcoming behavior of a time-dependent parameter up to year 2051 based on the previous behavior of that parameter, the Time-Series Analysis (Shumway & Stoffer, 2011) have been used.

Nine predefined time series models (Embedded in SPSS®), tested for finding the best fitting model for predicting the future behavior of each time dependent parameter. Captions of the nine tested models were Auto-Regressive Integrated Moving Average (ARIMA) models, Exponential Smoothing Models, Simple, Holt's Linear Trend, Brown's Linear Trend, Damped Trend, Simple Seasonal, Winters' Additive and Winters' Multiplicative. All statistical calculations performed by using SPSS® 22 software.

To find out the best-fitting function for relationship between each pair of a cause parameter and its related effect parameter, the Regression Analysis method has been used. Eleven Predefined regression analysis models in analyzing software were Linear, Logarithmic, Inverse, Quadratic, Cubic, Power, Compound, S-Curve, Logistic, Growth model and Exponential models.

Table 1 Initial values as the system fixed inputs at the starting time of simulation.

"Type of Input as the Initial Value"	"Value"	(Unit)	"Reference of Data"
"Initial Total Compiled Available Motor Power in System"	5,412,410	(Kw)	Mechanization Development Center of Ministry of Agriculture of Iran (2015)
"Initial Mean Farm Crop Production Unit Cost"	1.573	(\$/ha)	The World Bank, 2015
"Initial Unit Value of Available Mechanization Capital"	0.675	(\$/Kw)	The World Bank, 2015
"Initial Sales Price Unit Value of Farm Crop Products"	0.001	(\$/kg)	FAOSTAT, 2015
"Initial Life Unit Cost of a Rural and Urban Family"	13.682	(\$/Family)	The World Bank, 2015

Table 2 Inputs of farm crop production system of Iran with fixed values.

“Constant Value Input Type”	“Value”	(Unit)	“Reference of Data”
“Draft Power Coefficient (Ratio of available draft power to Indicated motor power of a tractor)”	75	(%)	Almassi et al., 2008
“Mean Annual General Inflation Rate of Iran”	20.56	(%)	The World Bank, 2015
“Total Farm Land to Total Arable Land Ratio”	81.58	(%)	FAOSTAT, 2015
“Mean Power of a Motor Driven Ambulant Vehicle (4 wheeled Farm Tractors, Combine harvesters and 2 wheeled Pedestrian tractors)”	61.512	(Kw)	The World Bank, 2015
“Machine Mean Work Time per Area Unit”	51.897	(Kw/ha)	Rajabi et al., 2012
“Mean Total Technical Worktime of a Motor Equipped Machine”	11,253	(Hours)	American Society of Agricultural Engineers, 2000 & FAOSTAT, 2015
“Mean Number of Family Members”	3.55	(Person)	FAOSTAT, 2015
“Number of Farmer Families to Number of all Families Ratio”	18.88	(%)	FAOSTAT, 2015
“Mechanization Rate of Farm Crops”	71.73	(%)	Mechanization Development Center of Ministry of Agriculture of Iran (2015)
“Total Machinery Costs as Percent of Total farm crops Production Costs”	21.1	(%)	Abbasi et al., 2011
“Number of Loan Repayments”	5	(1/Year)	Agriculture Bank of Iran, 2015
“Total Loan Repayment Time”	5	(Dimensionless)	Agriculture Bank of Iran, 2015
“Banks Loan Yearly Mean Interest Rate”	15	(%)	Agriculture Bank of Iran, 2015
“Fixed Costs of a Machine as Percent of Total Machine Costs”	64.89	(%)	Ashtiani et al., 2006
“Mean Yearly Paid Loans by Banks for Farm Machinery Supplement as a Percent of GDP”	0.0311	(%)	Mechanization Development Center of Ministry of Agriculture of Iran (2015)
“Portion of Farmers Revenue Spend for Mechanization Development”	0	(%)	Information and Communication Technology Center for Ministry of Agriculture of Iran (2012)

Table 3 The cause and effect relation formulation between the system internal parameters.

“Cause Factor (t)- Independent”	“Effect Factor (Y)- Dependent”	“Effect as a Function of Cause”
“Total Available Capital (\$)”	“GDP (Current US\$)”	$Y = (2.366E+7) + (1.458E-7) t - (8.538E-23) t^2$
“GDP (Current US\$)”	“Total Population (Person)”	$Y = (1.97E+7) + (0.002E) t - (1.021E-14) t^2$
“Total Population (Person)”	“Total Arable Area (ha)”	$Y = (1.59E+7) - (2.052E - 9) t^2 + (3.262E - 17) t^3$
“Mechanization Level Index (kw/ha)”	“Mean Yield of Farm Crop Production (kg/ha)”	$Y = (3538.588) + (1683.504) t + (45.481) t^2$

Category 4: A collection of 33 logical relationships between input and outputs of the designed system defined as below:

1. Mechanization level (Kw/ha) = Total Available Draft Power (Kw) / Total Farm Area (ha)
2. Total Available Draft Power (Kw) = Total Available Mechanical Power (Kw) / Draft Power Coefficient (%) $\times 100$
3. Total Mass of Farm Products (kg) = Mean Yield of Farm Products (Kg/ha) $\times$ Total Farm Area (ha)
4. Farm Production Total Costs (\$) = Total Farm Area (ha) $\times$ Mean Farm Production Unit Cost (\$/ha)
5. Fully Mechanized Production Costs (\$) = Farm Production Total Costs (\$) $\times$ Mechanization Rate (%) / 100
6. Farm Production Total Mechanization Costs (\$) = Fully Mechanized Production Costs (\$) $\times$ Total Mechanization Cost Percent of Total Production Cost (%) / 100
7. Total System Fixed Costs (\$) = Farm Production Total Mechanization Costs (\$) $\times$ Fixed Costs as Percent of Total Costs (%) / 100
8. Total Farming System Costs (\$) = Farm Production Total Costs (\$) + Total Loan Repayment (\$) + Total Life Costs (\$)
9. Initial Net Revenue of Farm Production (\$) = Initial Gross Revenue (\$) - Initial Total Costs (\$)
10. Number of Total Families (Family) = Total Population (Person) / Mean Number of Family Members (Person/Family)
11. Net Revenue of Farm Production (\$) = Total Revenue Rate (\$) - Total Costs Rate (\$) + Initial Net Revenue of Farm Production (\$)
12. Total Gross Revenue of Farming (\$) = Unit Sales Price of Farm Products (\$/kg) $\times$ Total Production of Farm Products (kg)
13. Inputted power to Mechanization System (Kw) = Inputted Capital into Mechanization System (\$) / Unit Value of Mechanization Capital (\$/Kw)
14. Value of Total Available Capital in Mechanization System (\$) = Total Available Mechanical Power (Kw) $\times$ Unit Value of Mechanization Capital (\$/Kw)
15. Number of Farmer Families = Farmer Families Ratio (%) $\times$ Number of Total Families / 100
16. Total Available Mechanical Power (Kw) = Total Power Input Rate (Kw) - Total Power Exit Rate (Kw) + Initial Compiled Power (Kw)
17. Initial Power Exit (Kw) = Initial Compiled Power (Kw) / Expected Lifetime of a Machine (Year) $\times$ Time Step (Year)
18. Current Power Exit (Kw) = Delaying Input Power to Mechanization System (Kw) equal to Expected Lifetime of a Machine
19. Total Power Exit (Kw) = Initial Power Exit (Kw), up to Expected Lifetime of a Machine + Current Power Exit (Kw), after Expected Lifetime of a Machine.
20. Number of all Tractors, Combine harvesters and Pedestrian Controlled Tractors = Total Available Mechanical Power (Kw) / Mean Power of a Machine (Kw).
21. Yearly Work time of a Machine (hour/Year) = Total Required Work Time of System (hour/Year) / Number of Tractors, Combine harvesters and Pedestrian Controlled Tractors

22. Mechanization Development Capital (\$) = Mechanization Development Costs as Percent of Total Net Revenue of Farm Production (%) $\times$ Net Revenue of Farm Production (\$) / 100 + Banks Finances Input (\$)
23. The inputted capital into Mechanization System (\$) = Mechanization Development Capital (\$) + Total System Fixed Costs (\$)
24. Total System Fixed Costs (\$) = Farm Production Total Mechanization Costs (\$) $\times$ Fixed Costs as Percent of Total Costs (%) / 100
25. Total Banks Finances Input (\$) = GDP (Current US\$) $\times$ Total Bank Finances as Percent of GDP (Current US\$) (%) / 100
26. Total Required Work Time of System (hour/Year) = Total Farm Area (ha) $\times$ Power Work Time per Area Unit (hour/ha/Year)
27. Expected Lifetime of a Machine (Year) = Total Technical Work time of a Machine (hour) / Yearly Work time of a Machine (hour/Year)
28. Total Farm Area (ha) = Farm Land to Arable Land Ratio (%) $\times$ Total Arable Area (ha) / 100
29. Total Farming System Costs (\$) = Total Loan Repayment (\$) + Farm Production Total Costs (\$) + Total Life Costs (\$)
30. Each Loan Installment Value (\$) = "Banks Finances Input (\$)" $\times$ ("Total Repayment Time"+1) $\times$ "Loan Interest Rate (%) / 200" + "Banks Finances Input" / "Number of total Repayments"
31. Repayment Step = Total Repayment Time / Number of Repayments
32. Total Population (Person) = Effect of GDP on Population (Person/\$) $\times$ GDP (Current US\$)
33. Mean Yield of Farm Products (kg/ha) = Effect of Mechanization Index on Yield (kg/Kw) $\times$ Mechanization level (Kw/ha)

All defined fixed and variable parameters and relations in categories 1, 2, 3 and 4 assembled as a dynamic system for simulation and predicting future values of both dependent and independent parameters of production function of Iran's farming production system.

The conceptually designed model by using the simulation software "Vensim ® PLE 6.3" were converted to an applicable software (Figure 2).

3 Results and Discussion

Overall structure of the system consisted of 95 input and output parameters among these 5 are initial value type inputs, 14 constant value type inputs, 6 Level type parameters and 70 are Auxiliary type parameters (Ventana Systems, Inc. 2007). Furthermore, four causes and effect type functions, and 33 logically defined relations, finally assembled as basic structure of agricultural machinery utilization for the mechanized production of farm crops in Iran.

Figure 2 Operational Schematic of the main simulation model built by Vensim 6.3 PLE simulation software.

Table 4 Comparative results for outputs of the modeled system vs real situation for point wise validation test of system outputs.

“Test Parameter”	According to the Measured Records at 2011	Vensim Output for Simulation Model at 2011	Model Output and Measured Records Difference	“Percent of Difference (%)”
Value of Total Available Machines (\$)	4,962,974,123	5,599,450,215	636,476,091	12.82
Total Available Motor Power (Kw)	35,126,904	30,348,299	-4,778,605	-13.6
“Total Available Draft Power (Kw)	26,345,178	22,761,225	-3,583,953	-13.6
Total Arable Land Area (ha)	17,541,000	18,564,676	1,023,676	5.84
Mechanization Level of System (Kw/ha)	1.502	1.503	0.001	0.064
Unit Value of Mechanization Capital (\$/Kw)	186.175	184.506	-1.669	-0.9
GDP (Current US\$)	18,838,322,969	17,926,061,905	-912,261,064	-4.84
Total Farm Crop Yearly Production (Kg)	72,007,472,000	76,165,242,880	4,157,770,880	5.77
Mean Yield of Farm Crop Production (kg/ha)	5,152	5,029	-123	-2.39
System Population (Person)	74,799,000	76,624,552	1,825,552	2.44
Mean Life Costs of Rural & Urban Families (\$)	3,705.99	3,734.69	28.696	0.77
Total Number of all Tractors, Combine Harvesters and other Power driven vehicles (Set)	553,098	493,375	-59,723	-10.8
Mean Farm Crop Production Costs (\$/ha)	429.365	429.489	0.123	0.03
Power Inputting to System (Kw)	916,416	779,851	-136,565	-14.9
Mean difference of 14 forecasted parameters and related really records in 2011 (%)				6.34

For checking the reality of system behavior and validating functionality of the built model response, four static and three dynamic tests have been done. As a static test, the built system at first step should be capable of predicting the values of system output parameters in a specified previous time section which statistical data for the same outputs had been recorded at that time previously. Collating system output for a number of 14 parameters in the year 2011 through the running software with the registered statistics for the same items resulted that the built system could predict the value of 14 outputs of the system by mean error of $\pm 6.34\%$ different from the mean of really recorded values in 2011 (Table 4).

Examining of the ten predefined regression models for relationships between crop yield and mechanization level index (Embedded in SPSS® 22) based on simulation model outputs for these parameters, resulted in the effect of “The mechanization level Index” on “The mean yield of 48 farm crop products.”

The arithmetic relation determined as a third-degree polynomial formula in this study (Eq. 2)

$$Y = 3406.087 - 1316.370t + 1827.328t^2 - 337.958t^3 \quad \dots (2)$$

(The equation “2” assumed as production function formulae and some testes implemented to show the reality of this assumption in continue).

In comparison the results of this research with the results of other correspondent studies, the effect of mechanization level on mean yield of irrigated and non-irrigated wheat and barley in this study, compared with results of same previous studies. So the mean yield of both irrigated and non- irrigated wheat and barley were as the ratio of 41% of The mean farm crops yield, so the effect of mechanization level index on the mean yield of food grain crops estimated as a triple degree nonlinear function by multiplying equation “2” by 0.41 (Eq. 3)

$$Y = 1872.755 - 970.555t + 1806.699t^2 - 448.092t^3 \quad \dots (3)$$

In a case study in India for estimation of the mechanization level index and its impact on farm production factors, a linear model has been proposed for establishing the relationship (Eq. 4) between the yield of food grains and the mechanization level index (Singh, 2006).

$$Y = 708.97 + 911.65t \quad \dots (4)$$

Where; $0.40 \text{ Kw/ha} \leq t \leq 2.80 \text{ Kw/ha}$

Furthermore, another study for estimating the yield model of both, irrigated and non-irrigated wheat and barley based on mechanization level indicator in Iran, resulted a linear relationship (Eq. 5) for the effect of farm mechanization level, on mean yield of wheat and barley in Iran (Abbasi et al., 2013).

$$Y = 625.7 + 798.65t \quad \dots (5)$$

Where; $0.477 \text{ Kw/ha} \leq t \leq 2.073 \text{ Kw/ha}$

Consistency with the basic reference patterns of agricultural production (Sterman, 2000) is another proof for validation of the established model. To test this capability of the model, by continuous increasing of the system leading input, the amount of main system output should be initially increased and after reaching the maximum point, it should be starting to decrease.

Comparison results showed that against the current research, both previously proposed linear models (Singh, 2006) and (Abbasi et al., 2013) didn't fulfill the principle of diminishing returns in agricultural production economics (Figure 3).

For establishing relationship between the mechanization level for farm crop production and the mean yield of farm crops (Eq.

2) as a production function of the system, some criteria which should be fulfilled. (Debertin, 1985) are 1st should have a third-degree polynomial formula for the production function; 2nd it should be consistent with the principle of diminishing returns' law in agricultural production economics for both physical production and net profit; 3rd it should be involved in three standard production regions and 4th, The maximum profitable production point should fall in the second region of production function.

The maximum value for mean yield of 48 types of farm crops was 9,161 kg/ha, while the mechanization level index reached to 2.386 Kw/ha. These results fulfilled the principle of diminishing returns in agricultural production economics (Colman & Young, 1989). Ratio of net revenue of total farm crop production to total available capital in system as mechanization inputs (A dimensionless parameter for omitting yearly inflation effects of prices) defined as "Economic Effectiveness of the Mechanized Farming Production System of Iran".

Figure 3: Graphical comparative results of this study and previous studies on the response of mean yield of food grain crops vs changes in the mechanization level index.

Figure 4 The maximum economic efficiency of system while overloaded by increase in banks loans to find the optimum value of mechanization level Index (2.218 Kw/ha).

Running the established model based on current values for all inputs, didn't result in maximum point of economic efficiency. Then to find the maximum value for economic efficiency, system overloaded by banks' loans increase up to 150% of current value, as input from start time to end time of simulation. Results of this experiment showed that the maximum reachable value for defined economic efficiency of the system will appear on year 2040 as 7.0 (dimensionless), while at this time mechanization level index will reach to 2.218 Kw/ha as the maximum point for the net profit of production (Figure 4).

For diagnosis the three economic production regions (Colman & Young, 1989), the mean yield of farm crop products (Eq. 2) set as equal to the total physical product (T.P.P) of the system (Eq. 6).

$$T.P.P = 3406.087 - 1316.370t + 1827.328t^2 - 337.958t^3 \quad \dots (6)$$

The Marginal physical product (M.P.P), calculated by first derivation of total physical product (Eq. 7).

$$M.P.P = -1316.370 + 3654.656t - 1013.874t^2 \quad \dots (7)$$

Also the average physical product (A.P.P) calculated as ratio of "The total physical product" to "t" (The Mechanization level index), (Eq. 8).

$$A.P.P = -1316.370 + 1827.328t - 337.958t^2 \quad \dots (8)$$

According to the equations (6), (7) and (8) the first economic production region begins from 0 up to 2.013 Kw/ha for mechanization level Index, which consisted of two regions, from 0 up to 1.342 Kw/ha (Maximum value of M.P.P) and from 1.342 up to 2.013 Kw/ha (Maximum value of A.P.P). The second economic production region begins from 2.013 up to 2.386 Kw/ha (Maximum value of T.P.P). Finally, the third production region begins from 2.386 Kw/ha (Table 5).

Table 5 The boundary values of Production Function and distinguishing three economic production regions.

Maximum Value	T.P.P.	M.P.P.	A.P.P.	Profit of Production
The Boundary Values of Production Function	Start of 3rd Economic Production Region	Start of 2nd Part of 1st Economic Production Region	Start of 2nd Economic Production Region	Maximum Economic Efficiency of Production
Mechanization Level Index (Kw/ha)	2.386	1.342	2.013	2.218

Figure 5 Triple production regions for the production function of farm crops as depended to machinery Input

Because of estimating the maximum profitable production point of system equal to 2.218 Kw/ha by dynamically overloading the system cash input in simulation procedure (Figure 4), and calculating the maximum value of T.P.P and A.P.P as 2.386 and 2.013 Kw/ha respectively, thus the maximum profitable production point of system fell at second production function for farm crops of Iran. This run of model fulfilled the 4th condition as mentioned in “Developing Realistic Agricultural Production Functions” (Debertin, 1985). And due to estimating accuracy rate of model outputs for the system mean total outputs as 93.66% in comparison to the recorded actual values in 2011 (Table 4), the total estimation error of production function of Iran's farm production system estimated as 6.34% in comparison to the recorded values in real situation (Eq. 9).

$$“2.013(Kw/ha) \pm (6.34\%)” \leq “2.218(Kw/ha) \pm (6.34\%)” \leq “2.386(Kw/ha) \pm (6.34\%)” \quad \dots (Eq. 9)$$

Conclusion

Results showed that due to the restrictions of field experiments, estimating a valid production function of farm crop products as the yield index depended to mechanization level index, could be accomplished by using a virtual modeling based on system dynamics approach. The estimated function for Iran's farm crops production (Eq.2 same as Eq. 6) was consistent with results of previous studies and fulfilled the basic principles of agricultural production economics.

Finally analyzing the created production function resulted that, the maximum profitable point for farming production system of Iran based on machinery input, will occur by 2.218 ($\pm 6.34\%$) as Kw/ha for the value of mechanization level index. And the physical production of the yield index will exceed to its maximum value, while the mechanization level index as the

main input could increase up to 2.386 ($\pm 6.34\%$) as Kw/ha with the probability level of 100%.

Recommended region for farm crops production in Iran, defined as “Second Economic Production Region” from 2.013(Kw/ha) $\pm$ (6.34%) up to 2.386(Kw/ha) $\pm$ (6.34%) considering the machinery input.

Comparing the results of this study with the current value of mechanization level index (0.895 Kw/ha) showed that, at least there is a need to increase mechanization level index of the system by 1.323 ($\pm 6.34\%$) as Kw/ha to reach the maximum profitable point for farming production system of Iran.

Conflict of interest

Authors would hereby like to declare that there is no conflict of interests that could possibly arise.

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