MONTE CARLO SIMULATION MODEL OF ENERGY CONSUMPTION IN WHEATPRODUCTION SYSTEMS UNDER EGYPTIAN CONDITIONS

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ABSTRACT

The Monte Carlo simulation method was used in this study to examine uncertainty propagation in a modeled irrigated wheat production system in Egypt. After running the Monte Carlo Simulation for 10000 runs for each operation, the alternative with higher frequency in each operation was selected and the energy consumption was calculated. The result of the current study was new system in addition to the nineteen systems involved. The total energy consumption was10205.09MJ ⁄fed. This system consisted of Chisel plow 1st pass+ Disc harrow+ Steel leveler + Wooden Ridger + Mounted seed drill + Surface irrigation + Manual fertilizer Broadcasting + Manual operated knapsack sprayer + Combine. Among the nineteen systems involved in the study, the highest energy consumption system was system thirteen which consumed14650.8 MJ ⁄Fed. The system of minimum energy consumption within the 19 systems used in this study was S4 with 10109.174 MJ ⁄fed. This system consisted of Mould board Plow+ Disc harrow+ Wooden leveller+ Wooden ridger+ Mounted seed drill + Surface irrigation+ Manual fertilizer broadcasting + Manual operated knapsack Sprayer +Self-propelled mower+ Trailer + Stationary threshing machine. It can be concluded from the results of this study that Monte Carlo simulation model is capable of selecting the minimum energy consumption wheat production system.

Keywords: Monte Carlo simulation, agriculture, energy consumption, wheat

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INTRODUCTION

Energy plays a major role in providing vital services, which are necessary for human survival and growth of civilization. Energy is a kind of strategic resource and is an important essential basis for economic increase and social development. In fact, per capita energy consumption is an index of growth of any nation in all forms (Asakereh*et al.*, 2010)Energy use in agriculture has been increased in response to increasing population, limited supply of arable land, desire for higher standards of living (Kizilaslan, 2009) and modern farming has become very energy intensive. Nowadays, farmers use more energy to increase output, but due to inadequate knowledge and some mismanagement on using energy inputs, they lead to waste of energy resources and side negative effects. There is an urgent need to assess how energy resources are used, especially in developing countries. Energy consumption in agriculture is directly related to the development of technology in farming and the level of mechanization (Davoodi and Houshyar 2009). However, more intensive energy use has brought some important human health and environment problems so efficient use of inputs has become important in terms of sustainable agricultural production (Yilmaz*et al.*, 2005).

Agriculture is both a user and producer of energy and all agricultural operations require energy in one form or another: human power, animal power, fertilizer, fuels and electricity. Effective energy use in agriculture is one condition for sustainable agricultural production, since it provides financial savings, fossil resources preservation and air pollution reduction (Karimi *et al.,* 2008). Finding a solution to reduce energy consumption per production unit seems to be essential to reach the sustainable development and to save the environment of future generation (Mohammadi *et al*., 2008).

Energy use in agriculture has paid very little attention (Pellizzi,1992). Energy modelling is an interesting subject among engineers and scientists who are concerned about energy production and consumption and environmental impacts (Tester, 2005and Al-Ghandoor *et al*., 2009).

Wheat is the most widely grown cereal crop in the world .Moreover; it has been considered the first strategic food crop. It is the main diet for the

Egyptian population. Wheat is the main winter cereal crop and is widely distributed all over the country (Abd EI-Ghany*et al.*, 2012). According to FAO (2012) wheat is cultivated in Egypt on 1, 350, 000hectare with a production of 8,796,000 tons with an average yield of 6.51 tons per hectare.

The term 'Monte Carlo' was first coined by Ulam and Von Neuman (Rubinstein, 1981) during their work on development of the atomic bomb during World War II (Bonate, 2001).

The name Monte Carlo comes from the gambling scene at the Monte Carlo Casino, Monaco for the simulation's random number generation feature. Monte Carlo simulation is a stochastic sampling method, where parameter values (e.g. inputs) are randomly generated from probability density function (PDFs) for multiple iterations. (PDFs) are often modeled on observed data, but can be developed from expert opinion (Winston 1991, Ayyub and Klir 2006).

Monte Carlo simulation is the term applied to stochastic simulations, either discrete, real-time, or some combination thereof, that incorporate random variability into the model.

Simulation affects our life every day through our interactions with the automobile, airline and entertainment industries, just to name a few. Monte Carlo simulation differs from traditional simulation in that the model parameters are treated as stochastic or random variables, rather than as fixed values (Bonate, 2001).

The performance and behavior of crop models is commonly made through comparison of simulated and observed variables. (Singh, et *al.*2013).In general terms, the Monte Carlo method of simulation can be used to describe any technique that approximates solutions to quantitative problems through statistical sampling "Probabilistic Simulation". Monte Carlo simulation can be considered as a methodical way of doing the so-called what-if analysis. (Raychaudhuri, 2008).

Two types of simulation are seen in research, deterministic and stochastic. Stochastic simulation looks at the long term effect of random variability in the model parameters on the outcome of a model. Deterministic simulation is a special case of stochastic simulation where variability is set equal to zero. As such, there is only one possible outcome for a set of inputs. Monte Carlo simulation differs from deterministic simulation in that the variability of the model parameters is included in the model and the long term impact of that variability is examined (Bonat, 2001).

A Monte Carlo simulation is a statistical simulation technique that provides approximate solutions to problems expressed mathematically. It utilizes a sequence of random numbers to perform this simulation. This technique can be used in different domains:

- Complex integral computations
- Economics specially in risk management
- Making decisions in specific complex problems (Gupta, 2011).

There are two types of problem to which we can apply Monte Carlo methods. The first type is that of purely stochastic problems where it seems natural that a solution may be found by making random number selection mimic the inherent randomness of the physical behavior. The second type is where we replace a deterministic problem, or one with no obvious random behavior, with a stochastic model whose average over many trials gives the same solution. Another important application of the Monte Carlo process, which is often related to the solution of a physical problem, is the evaluation of multi-dimensional integrals. In this application what is obtained is not only an estimate of the integral but also a standard deviation which is a measure of the uncertainty of the estimate. This is a characteristic of all Monte Carlo calculations; one always obtains an estimate and a deviation, and the reduction of the standard deviation, or variance, is an important aspect of the application of the method (Woolfson and Pert, 1999).

Monte Carlo simulation is a method for valuing derivatives that has achieved much interest during the last decades. It is a flexible method that has proved suitable to value complex financial instruments.

Monte Carlo Techniques (or Monte Carlo Methods, or in short Monte Carlo (MC)) are a class of techniques or algorithms that rely on the use of random sampling to finally acquire a solution to a given problem.

In principle, the Monte Carlo (MC) method can be considered as a very general mathematical tool for the solution of a great variety of problems.

The applications of Monte Carlo methods can be divided into two major groups. One consists of direct simulations of systems that are already statistical in their nature; in such cases it is not even necessary to have well defined mathematical equations that describe the behavior of the system. The second group consists of Monte Carlo methods devised for the solution of well-defined mathematical equations. In such cases the methods are used to solve the equations that describe the problem of interes(Jacoboni and Lugli 1989).

In a Monte Carlo simulation we attempt to follow the ‘time dependence’ of a model for which change, or growth, does not proceed in some rigorously predefined fashion (e.g. according to Newton’s equations of motion) but rather in a stochastic manner which depends on a sequence of random numbers which is generated during the simulation. With a second, different sequence of random numbers the simulation will not give identical results but will yield values which agree with those obtained from the first sequence to within some ‘statistical error’ (Landau and Binder, 2000).

Any Monte Carlo method relies on the generation of a sequence of random numbers with given distribution probabilities. Such a technique takes advantage of the fact that nowadays any computer generates sequences of random numbers evenly distributed between 0 and 1 at a sufficiently fast rate.

Simulation optimization has gained wide acceptance among researchers and many approaches have been developed. Simulation modeling has the capability of representing complex real world systems and the constraints in detail. Huseby *et al*. (2013) presented a simulation approach for establishing environmental contour lines for use in structural analysis of marine structures. Villada and Olaya (2013) used simulation approach to evaluate alternative policies for increasing the security of natural gas supply in Colombia. Korytkowski *et al*. (2013) developed evolutionary simulation-based heuristics to construct near-optimal solutions for dispatching rule allocation.

The Monte Carlo simulation method was used in this study to examine uncertainty propagation in a modeled irrigated wheat production system in Egypt.

MATERIALS AND METHODS

Some of the data used in this study was obtained from literature cited. The other data obtained from a field measurements conducted in Egypt in Minya algamh during the season of 2011– 2012. Some of these measurements were fuel consumption, as well as the ground speed and width of equipment. A questionnaire was done to collect data concerning agricultural operations, power, and kind, age of tractors, self-propelled mower, size and age of equipment. Also the questionnaire included Irrigation system, irrigation frequency, irrigation duration (h) and fuel consumption (l/h), number of labors, number of animals, variety of seeds and seeding rate, type and amounts of fertilizers, and pesticide. Finally questionnaire included yield of wheat (tones /fed) for each system in this study.

The data covers the inputs, such as human energy consumption, animal energy consumption, and fuel consumption in different operations from seed –bed preparation up to harvesting and threshing operations which are used in the production of irrigated wheat under Egyptian conditions. In this study, energy consumption in wheat production was analysed based on direct energy sources and indirect energy sources. Direct energy including human energy consumption, animal energy consumption, and fuel energy consumption. While indirect energy included fertilizers, pesticides and seed. The total energy input (E) is determined from the sum of the amount of input factors (Ai) multiplied by appropriate energy conversion coefficients for that factor (Ci).

$$E = \Sigma(Ai\ Ci) \qquad \text{---------------------}(1)$$

Human energy was calculated from the following equations:

$$E_h = \frac{0.1 \times n}{1.36 \times \text{A.F.C}} \times 3.6 \text{ ----------------------}(2)$$

$$E_h = \frac{0.264 \times n}{\text{A.F.C}} \text{----------------------}(3)$$

Where

E_h: Human energy (MJ/ fed).

n: Number of workers required for operation.

A. F. C**:** Actual field capacity of the gang of workers (fed/h).
1.36: Coefficient for transformation from HP to kW.
0.1: Human power (HP)
3.6: Coefficient for transformation from kW.h to MJ

Animal energy was calculated from the following equations

$$\mathbf{Ea} = \frac{\mathbf{0.5 \times n}}{\mathbf{1.36 \times A.F.C}} \times 3.6 \text{ ------------------------}\mathbf{(4)}$$

$$\mathbf{Ea} = \frac{\mathbf{1.323 \times n}}{\mathbf{A.F.C}} \text{ ------------------------}\mathbf{(5)}$$

Where

Ea **:** Animal energy (MJ/ fed).
n: Number of farm animals used
A. F. C **:** Actual field capacity of the team of animals (fed/h).
1.36: Coefficient for transformation from HP to kW.
0.5: Animal (Oxen) power (HP).
3.6: Coefficient for transformation from kW. h to MJ

Energy consumed in operating the machinery calculated from the following equations:

$$E_m = \mathbf{F.C} \times \frac{1}{60 \times 60} \times \rho_f \times C.V. \times 427 \times \frac{1}{75} \times \frac{1}{1.36} \times \frac{1}{A.F.C} \text{ ---- } \mathbf{(6)}$$

$$E_m = \frac{F.C \times 9.884}{A.F.C} \times 3.6 \text{ --------}\mathbf{(7)}$$

$$E_m = \frac{35.58 \times F.C}{A.F.C} \text{ --------}\mathbf{(8)}$$

Where

E_m: Energy consumed in operating the machinery (MJ/fed).
ρ_f: Density of fuel, 0.85 (kg/lit)
C.V. : Calorific value of fuel, 10000 (kCal./kg)
427: Constant (thermo –mechanical equivalent) (kg.m /kcal)
1.36: Coefficient for transformation from HP to kW.
F.C: Fuel consumption (l/h).
A.F.C: Actual field capacity (fed/h).
3.6: Coefficient for transformation from kW.h to MJ

The data for energy equivalences were collected from various sources as indicated in table 1.

Table 1. Energy equivalents of inputs in wheat production.

Input	Energy equivalent(MJ/kg)	Reference
Chemicals		
Granular	120.0	Chaudhary *et al.* (2006)
Topic	271.38	Mohammadi *et al.*(2008)
Pesticide	280.44	Mohammadi *et al.*(2008)
Organic fertilizer		
Manure	0.3	Verma(1987)
Chemical fertilizers		
Nitrogen	66.14	Shrestha (1998)
P_2O_5	12.44	Shrestha (1998)
Wheat seed	14.70	Richard (1992)

The operations for which energy inputs are estimated for on – farm production systems include, seedbed preparation, leveling, dividing, seeding, irrigation, fertilizing, weed control, harvesting, transporting and threshing as shown in Table 2 by using nineteen alternative systems for wheat production.

Table 2. The different nineteen systems of wheat production

System	Components
S1	Chisel plow (1stpass&2ndpass) +wooden leveller wooden ridger+ broadcasting seed manually +surface irrigation+ broadcasting fertilizer manually+ manually operated knapsack sprayer+ sickle+ trailer+ stationary threshing machine (traditional).
S2	Chisel plow (1stpass&2ndpass) +wooden leveller wooden ridger+ mounted seed drill+ surface irrigation +broadcasting fertilizer manually+ manually operated knapsack sprayer+ self-propelled mower +trailer+ stationary threshing machine.
S3	Chisel plow (1stpass&2ndpass) +steel leveller wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically + hydraulic sprayer+ self-propelled mower +trailer+ stationary threshing machine.
S4	Mouldboard plow+ disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer+ self-propelled mower +trailer+ stationary threshing machine.

S5 Mouldboard plow+ disc harrow +steel leveler+ wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically +hydraulic sprayer+ self-propelled mower +trailer+ stationary threshing machine.

S6 Disc plow + disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually + manually operated knapsack sprayer+ self-propelled mower +trailer+ stationary threshing machine.

S7 Disc plow+ disc harrow +steel leveler+ wooden ridger+ mounted seed drill + irrigation by sprinkler system +broadcasting fertilizer mechanically + hydraulic sprayer+ self-propelled mower +trailer+ stationary threshing machine.

S8 Chisel plow (1^{st}pass&2^{nd}pass) +steel leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer +tractor mounted mower +trailer+ stationary threshing machine.

S9 Chisel plow (1^{st}pass&2^{nd}pass) +steel leveller wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically + hydraulic sprayer+ tractor mounted mower +trailer+ stationary threshing machine.

S10 Mould board plow+ disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer+ tractor mounted mower +trailer+ stationary threshing machine.

S11 Mould board plow+ disc harrow +steel leveler+ wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically +hydraulic sprayer+ tractor mounted mower +trailer+ stationary threshing machine.

S12 Disc plow+ disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer+ tractor mounted mower +trailer+ stationary threshing machine.

S13 Disc plow + disc harrow +steel leveler +wooden ridger+ mounted

	seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically + hydraulic sprayer+ tractor mounted mower +trailer+ stationary threshing machine.
S14	Mouldboard plow +disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer+ combine.
S15	Mould board plow+ disc harrow +steel leveler+ wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically +hydraulic sprayer+ combine.
S16	Disc plow+ disc harrow +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer manually+ manually operated knapsack sprayer+ combine.
S17	Chisel plow (1^{st}pass&2^{nd}pass) +steel leveller wooden ridger+ mounted seed drill+ irrigation by sprinkler system +broadcasting fertilizer mechanically +hydraulic sprayer+ combine.
S18	Disc plow+ disc harrow +steel leveler +wooden ridger+ mounted seed drill + irrigation by sprinkler system +broadcasting fertilizer manually+ hydraulic sprayer+ combine.
S19	Chisel plow (1^{st}pass&2^{nd}pass) +wooden leveler+ wooden ridger+ mounted seed drill+ surface irrigation + broadcasting fertilizer mechanically + manually operated knapsack sprayer +combine

Based on energy consumption as optimum criterion in this research work, Monte Carlo simulation was used to find the most reliable system among different systems that are already used for the agricultural operations planting wheat in Egypt.

Monte Carlo simulation

Law and Kelton (2000) provided a 10 steps simulation model. Fig (1) demonstrates the flow chart that describes these steps.

Step 1 problem formulation is setting the objectives of the study and the specific issues to be considered. Resources available for such a

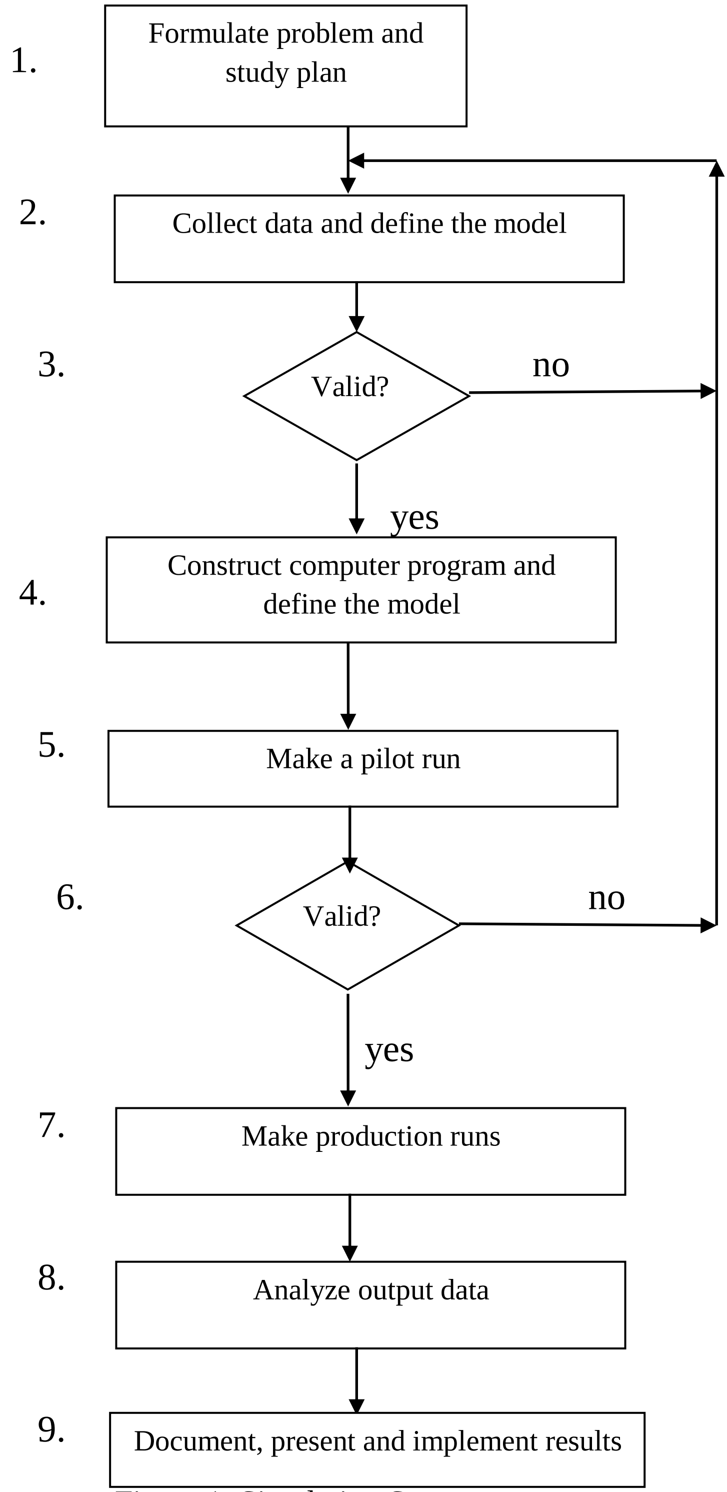

Figure 1: Simulation Steps

Study should also be considered, and expands on the importance of clarifying the issues to be considered; these include hardware design issues and operational issues. In addition, measures of performance have to be defined before starting the study. Step 2 in Fig. 1 is data collection. Data is collected if it exists based on the objectives of the study with the importance of data collection and stress the validation of such data which is step 3. After data is validated then step 4 is constructing a computer model, which is based on the conceptual model. After that a pilot run is done in step 5 the conceptual model is translated into a computerized model before starting step 6 and which is conducts the verification and the validation steps. It must be noted that most agree on the fact that the validation and verification process should be throughout the study. Steps 7 through 10 are design of experiments for defining the different alternatives for experimentation, production runs for providing performance data on systems designs of interest, output analysis which consists of statistical techniques for analyzing output from production runs, and implementation of models findings. We apply the simulation steps for our study in the following section.

The application of Monte Carlo methodology

This methodology is used to select the suitable method (way/alternative) in each operation of the possible agricultural systems.

The methodology consists of the following steps:

<u>Collecting data:</u>

1. Collect the data for the possible systems (S1 to S19)
2. In each system, the field operations machinery (seed bed preparation, Land leveling, Seeding, Irrigation, Fertilizing, Weed Control, and Harvesting) were determined with the possible operable alternatives.
3. For each alternative used in each operation, the consumed energy was determined. From the published relevant data, questionnaire or field measurement. As a typical examples of input data collection table 3shows the operations of system1 (S1) and energy sources and consumption.

Table 3.The operations of system1 (S1).

S1		Energy Consumption (MJ / FED)				
Operation	**Machine**	**Human**	**Animal**	**Mechanical**	**Others**	**Total Energy**
Seed bed preparation	Chisel Plow 1st pass	0.30	0	155.01	0	155.31
	Chisel Plow 2st pass	0.24	0	130.57	0	130.81
Levelling	Wooden Leveller	1.29	6.44	0	0	7.73
Dividing	Wooden Ridger	0.25	2.66	0	0	2.91
Seeding	Manual broad casting	0.8	0	0	882	882.8
Irrigation	Surface irrigation	1.26	0	523.852	0	525.112
Fertilizing	Manual broadcasting	0.396	0.324	0	7997.1	7997.82
Weed Control	Operated knapsack sprayer	1.764	0	0	45	46.764
Harvesting	Sickle	9.62	0	0	0	9.62
Transporting	Trailer	0.64	0	153.64	0	154.28
Threshing	Stationary threshing machine	0.792	0	248.4	0	249.192

After reviewing the 19 systems, they were classified according to how operations are performed as shown in table 4.

Creating Empirical Distributions:

1- For each alternative in each operation of the nineteen systems the frequency of using the implement and the related items were calculated to generate random number.

2- We compute the probability of each alternative and the cumulative probability. Table 5 shows the empirical distribution for seed bed preparation 1st passas an example.

Table 5. The empirical distribution for seed bed preparation 1st pass

Operation		**Seed bed preparation 1st pass**		
Implement	**Chisel Plow 1st pas**	**Mould Board plow**	**Disc plow**	**Total**
Frequency	7	6	6	19
Probability	0.368421053	0.315789474	0.31578947	1
Cummulative	0.368421053	0.684210526	1	
Range of R.N.	From zero to 0.367	From 0.368 to 0.683	From 0.684 to 0.999	

Table 4. Classification of the 19 systems according to how the operations are performed.

	Equipment	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	Total
Seed bed preparation1st	Chisel Plow 1st pas	**	**	**					**	**								**		**	**7**
	Mould board plow				**	**					**	**			**	**					**6**
	Disc plow						**	**					**	**			**		**		**6**
seed bed preparation2nd	Chisel Plow 2nd pas	**	**	**					**	**								**		**	**7**
	Disc Harrow				**	**	**	**			**	**	**	**	**	**	**		**		**12**
Levelling	Wooden Leveller	**	**		**		**				**		**		**		**			**	**9**
	Steel Leveller			**		**		**	**	**		**		**		**		**	**		**10**
Dividing	Wooden Ridger	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**19**
Seeding	Manual broad casting	**																			**1**
	Mounted seed drill		**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**18**
Irrigation	Surface irrigation	**	**		**		**		**		**		**		**		**			**	**10**
	Sprinkler System			**		**		**		**		**		**		**		**	**		**9**
Fertilizing	Manual broadcasting	**	**		**		**		**		**		**		**		**		**		**10**
	Mechanical Broad Casting			**		**		**		**		**		**		**		**		**	**9**
Weed Control	Manually knapsack Sprayer	**	**		**		**		**		**		**		**		**			**	**10**
	Hydraulic Sprayer			**		**		**		**		**		**		**		**	**		**9**
Harvesting	Sickle	**																			**1**
	Self - Propelled Mower		**	**	**	**	**	**													**6**
	Tractor Mounted Mower								**	**	**	**	**	**							**6**
	combine														**	**	**	**	**	**	**6**
Transporting	Trailer	**	**	**	**	**	**	**	**	**	**	**	**	**							**13**
Threshing	Stationary threshing machine	**	**	**	**	**	**	**	**	**	**	**	**	**							**13**

Run the Monte Carlo Simulation:

Table 6 shows the random number generated uniformly using function rand() and the alternative selected according to programming if statement=IF(G4<0.368;"chiesl1st";IF(G4<0.684;"mouldboardplow";IF(G4<=1;"disc plow"))) where G4 the cell which contains the generated random number.

=IF(G4<0.368;"chiesl1st";IF(G4<0.684;"mould plow";IF(G4<=1;"disc plow")))

Where G4 has a random number (=RAND()) uniformly distributed.

Table 6.The random number and the alternative

Random Number	Correspond implement
0.215410284	chisel 1st
0.001367954	chisel 1st
0.054564916	chisel 1st
0.791211133	disc plow
0.548898989	mould plow
0.248796945	chisel 1st
0.235178217	chisel 1st
0.919362189	disc plow
0.078832082	chisel 1st
0.780873981	disc plow
0.051430733	chisel 1st
0.596983268	mould plow
0.765539412	disc plow
0.413287239	mould plow
0.561557583	mould plow

The previous procedure was repeated 10000 runs for each alternative implement and compute the new frequency and ratio. For example the result of land leveling after 10000 runs is shown in table 7.

Table 7.The result of land leveling after 10000 run

Equipment	**Frequency**	**ratio**	**Total Energy**
Wooden leveler	4652	0,465	7.73
Steel leveler	5348	0,535	114.186
Total	10000	1	

RESULT AND DISCUSSION

Table 8 and Table 9 show the empirical distribution for Seed bed preparation (Primary tillage).It is clear that the chisel plow1st pass recorded higher frequency 4200, while disc plow recorded the lowest frequency2000.The same Monte Carlo technique used above for Seed bed preparation (primary tillage) was used for the following operations. seed bed preparation (secondary tillage), leveling, dividing , seeding, irrigation, fertilizing , weed control , harvesting , transporting and threshing.

Table 8. The empirical distribution for Seed bed preparation (Primary tillage)

The alternative	Frequency	Probability of occurance	Cumulative probability	Rang of random numbers
Chisel plow 1st pass	7	0.368	0.368	From 000-367
Mouldboard Plow	6	0.316	0.684	From 368-683
Disc Plow	6	0.316	1.000	From 684-999
Total	19	1.000		

Table 9. The result of Seed bed preparation (Primary tillage) after 10000 simulation runs

Equipment	Frequency	Ratio	Total Energy (MJ/Fed)
Chisel 1_{st} pass	4200	0.420	155.31
Mouldboardplow	3800	0.380	204.238
Disc plow	2000	0.200	232.127
Total	10000	1	

The output of Monte Carlo Simulation:

After running the Monte Carlo Simulation for 10000 runs for each operation, the alternative with higher frequency in each operation was selected and the consumed energy was computed. The result of the current study suggested a new system in addition to the nineteen systems involved. The total energy consumption of this system was 10205.09 MJ/Fed. This system consisted of Chisel plow 1^{st} pass+ Disc harrow+ Steel leveler + Wooden Ridger + Mounted seed drill + Surface irrigation + Manual fertilizer broadcasting + Knapsack sprayer + Combine as shown in table 10.

Table10. The output of Monte Carlo Simulation after 10000 simulation runs

Operation	Alternative	Frequency	Ratio	Energy (MJ/Fed)
Seedbed preparation 1st	Chisel 1st pass (Three alternative)	3685	0.369	155.31
Seedbed preparation 2nd	Disc Harrow (Two alternative)	6319	0.632	72.934
Land Leveling	Steel leveler (Two alternative)	5348	0.535	114.186
Dividing	Wooden ridger (No alternative)	-	-	2.91
Seeding	Mounted Seed drill (Two alternative)	8945	0.895	810.56
Irrigation	Surface irrigation (Two alternative)	5249	0.525	525.112
Fertilizing	Manualfertilizer Broadcasting (Two alternative)	5303	0.530	7997.82
Weed Control	Manual knapsack sprayer (Two alternative)	5276	0.528	46.764
Harvesting	Combine (Four alternative)	3220	0.322	479.5
Total energy				**10205.09**

The system of highest energy consumption within the 19 systems used in this study was $S_{13}$with 14650.8MJ /fed as shown in Table 11. This system consisted of disc plow, disc harrow, steel leveller, wooden ridger, seeding by mounted seed drill, irrigation by sprinkler system, mechanical fertilizer broadcasting, hydraulic sprayer for weed and pests control, tractor mounted mower, trailer and stationary threshing machine.
The maximum value of the highest energy consumption system within the 19 systems used in this study due to the application of disc plow, steel leveller, and irrigation by sprinkler system, mechanical fertilizer broadcasting, hydraulic sprayer and tractor mounted mower, and all of them (equipment or method) consumed high energy.

Table11. The highest energy consumption system within the 19 systems

Operation	Equipment	Maximum energy consumption (MJ/Fed)
Seedbed preparation (primary tillage)	Disc plow	232.127
Seedbed preparation (secondary tillage)	Disc harrow	72.934
Leveling	Steel leveller	114.186
Dividing	Wooden Ridger	2.91
Seeding	Mounted seed drill	810.56
Irrigation	Irrigation by sprinkler system	4249.68
Fertilizing	Broadcastingfertilizer mechanically	8072.66
Weed Control	Hydraulic sprayer	563.176
Harvesting	Tractor mounted mower	129.162
Transporting	Trailer	154.28
Threshing	Stationary threshing machine	249.192
Total energy		**14650.8**

The system of minimum energy consumption within the 19 systems used in this study was S_4 with 10109.174 MJ /fed as shown in Table 12. This system consisted of Mould board plow, disc harrow, wooden leveller, wooden ridger, irrigation by surface irrigation, seeding by mounted seed drill, Manual fertilizer broadcasting, and manual operated knapsack sprayer for weed and pests control, self-propelled mower, trailer and stationary threshing machine.

The minimum value of the minimum energy consumption system within the 19 systems used in this study due to the application of mould board Plow, disc harrow, wooden leveller, surface irrigation, mounted seed drill, manual fertilizer broadcasting, manual operated knapsack sprayer, self-propelled mower, trailer and stationary threshing machine, and all of them (equipment or method) consumed low energy.

Table12. The minimum energy consumption system within the 19 systems

Operation	Equipment	Maximum energy consumption MJ/fed
Seed bed preparation (primary tillage)	Mould board plow	204.238
Seed bed preparation (secondary tillage)	Disc harrow	72.934
Levelling	Wooden leveller	7.73
Dividing	Wooden ridger	2.91
Seeding	Mounted seed drill	810.56
Irrigation	Surface irrigation	525.112
Fertilizing	Manual broadcasting	7997.82
Weed control	Manual operated knapsack sprayer	46.764
Harvesting	Self – propelled mower	37.63
Transporting	Trailer	154.28
Threshing	Stationary threshing machine	249.192
Total		**10109.174**

In this study a complete analysis of energy use in irrigated wheat production systems under Egyptian conditions is shown in Table 12, 13 and 14.

Table12. Number of workers, animals, fuel consumption and consumed energy need for the execution of different operations.

Equipment or method	operation	No. of workers	No. of animals	Fuel cons. (l/h)	Actual field capacity fed/h	Energy consumption (MJ/Fed)		
						H.	A.	M.
Chisel plow	1st pass	1	0	3.79	0.87	0.30	0.00	155.01
Chisel plow	2nd pass	1	0	4.00	1.09	0.24	0.00	130.57
Mouldboard plow	1st pass	1	0	4.47	0.78	0.33	0.00	203.90
Disc plow	1st pass	1	0	4.69	0.72	0.36	0.00	231.76
Disc harrow	Secondary tillage	1	0	3.60	1.76	0.15	0.00	72.790
Wooden leveller	Levelling	2	2	0	0.41	1.29	6.44	0.000
Steel leveller	levelling	1	0	3.78	1.18	0.22	0.00	113.97
Wooden ridger	Dividing	1	2	0	1	0.26	2.66	0.000
Manual broadcasting	Seeding	2	0	0	0.67	0.8	0.00	0.000
Mounted seed- drill	Seeding	1	0	3.73	1.76	0.15	0.00	75.420
Surface irrigation	Irrigation	2	0	22.26	0.42	1.26	0	523.852
sprinkler system	Irrigation	2	0	0	0.05	10.58	0	4239.10 *
Manual broadcasting	Fertilizing	2	1	0	1.33	0.39	0.324	0.000
Mechanical broadcasting	Fertilizing	1	0	3.73	1.76	0.15	0.00	75.420
Manual knapsack sprayer	Weed and pest control	1	0	0	0.150	1.76	0.00	0.000
Hydraulic sprayer	Weed and pest control	2	0	6.320	0.435	1.216	0.00	516.96
Sickle	Harvesting	4	0	0	0.11	9.62	0.00	0.000
Self – propelled mower	Harvesting	2	0	0.62	0.60	0.882	0.00	36.75
Tractor – mounted mower	Harvesting	2	0	3.84	1.060	0.49	0.00	128.91
Combine	Harvesting	2	0	14.27	1.060	0.49	0.00	479.016
Trailer	Transporting	2	0	2.85	0.82	0.64	0.00	153.64
Stationary threshing machine	Threshing	2	0	3.70	0.66	0.792	0.00	248.4

Where: H:Human,A: Animal, M: Mechanical,: Electricity*

Table 13. Amounts of inputs and energy inputs for wheat production

Inputs	Quantity (kg/fed)	Total energy equivalent (MJ/ fed)
Input		
Chemical (kg)		
Granular	0.0080	0.96
Topic	0.1400	38
Pesticide	0.0212	5.94
Organic fertilizer		
Manure	9500	2850
Chemical fertilizer		
Nitrogen (N)	75	4960.5
Superphosphate (P_2O_5)	15	186.6
Wheat seed		
Manual broadcasting	60	882
Mounted seed-drill	50	735

Table 14. Analysis of energy use in irrigated wheat production systems under Egyptian conditions.

Item	Human	Animal	Mechanical	Fertilizer	Seed	Chemical	Total energy input
S1	17.34	9.424	1211.476	7997.1	882	45	10162.34
S2	7.947	9.424	1323.646	7997.1	735	45	10118.117
S3	15.392	2.66	5745.245	7997.1	735	45	14540.406
S4	7.9	9.424	1314.75	7997.1	735	45	10109.174
S5	15.346	2.66	5736.358	7997.1	735	45	14531.464
S6	7.929	9.424	1342.61	7997.1	735	45	10137.063
S7	15.375	2.66	5764.218	7997.1	735	45	14559.353
S8	7.316	9.424	1415.806	7997.1	735	45	10209.646
S9	14.762	2.66	5837.408	7997.1	735	45	14631.93
S10	7.27	9.424	1406.91	7997.1	735	45	10200.704
S11	14.716	2.66	5828.518	7997.1	735	45	14622.994
S12	7.299	9.424	1434.77	7997.1	735	45	10228.593
S13	14.745	2.66	5856.378	7997.1	735	45	14650.883
S14	6.076	9.424	1354.97	7997.1	735	45	10147.57
S15	13.522	2.66	5776.578	7997.1	735	45	14569.86
S16	6.105	9.424	1382.83	7997.1	735	45	10175.459
S17	13.568	2.66	5785.474	7997.1	735	45	14578.802
S18	13.803	2.984	5729.018	7997.1	735	45	14522.905
S19	5.87	9.1	1439.286	7997.1	735	45	10231.356

CONCLUSION

After running the Monte Carlo Simulation for 10000 runs for each operation, we select the alternative with higher frequency in each operation and compute the energy consumed. The results of the current study introduced a new system in addition to the nineteen systems involved. The total energy consumption of this new system was 10205.09 MJ/Fed. This system consisted of Chisel plow 1st pass+ Disc harrow+ Steel leveler + Wooden Ridger + Mounted seed drill + Surface irrigation + Manual fertilizer Broadcasting + Knapsack sprayer + Combine.

The highest energy consumption system within the nineteen systems used in this study was S_{13} with 14650.8MJ / Fed. This system consisted of disc plow, disc harrow, steel leveller, wooden ridger, irrigation by sprinkler system, mechanical fertilizer broadcasting, hydraulic sprayer for weed and pests control and tractor mounted mower, trailer and stationary threshing machine. The system of minimum energy consumption within the 19 systems used in this study was S_4 with 10109.174 MJ /fed. This system consisted of Mould board Plow + Disc harrow+ Wooden leveller + Wooden ridger+ Surface irrigation+ Mounted seed drill + Manual fertilizer broadcasting+ Manual operated knapsack sprayer +Self-propelled mower+ Trailer + Stationary threshing machine.

The results of this study proved the ability of Monte Carlo simulation model to predict energy consumption in wheat production systems.

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الملخص العربي

نموذج محاكاة مونت كارلو لاستهلاك الطاقة في انظمة إنتاج القمح تحت الظروف المصرية

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يهدف هذا البحث الى استخدام أسلوب محاكاة مونت كارلو لدراسة انتشارعدم التيقين في نظم إنتاج القمح تحت الظروف المصرية .ولتحقيق هذا الهدف تم استخدام تسعة عشر نظام لانتاج القمح بدءا من عمليات اعداد وتجهيز مرقد البذرة حتى عمليات الحصاد والدراس والتذرية. وتم تشغيل خطوات محاكاة مونت كارلو لعدد ١٠٠٠٠ محاولة لكل عملية ،وتم اختيار البديل ذو التردد العالي في كل عملية وكذلك تم حساب الطاقة المستهلكة في كل نظام . وتم التوصل من خلال النتائج المتحصل عليها الى ظهور نظام جديد بالإضافة إلى التسعة عشر نظام محل الدراسة وكان إجمالي الطاقة المستهلكة في هذا النظام 10205.09ميجا جول/ فدان. يتكون هذا النظام من المحراث الحفار (وجه واحد) + المشط القرصي + القصابية الحديدية + البتانة + آلة التسطير المعلقة +الري السطحي + نثر السماد يدويا + الرشاشة الظهرية المحمولة لمكافحة الحشائش والحشرات+ الكومباين. وكان النظام الثالث عشر أكثر الأنظمة استهلاكا للطاقة من ضمن النظم التسعة عشر محل الدراسة وكان مقدار الاستهلاك 14650.8ميجا جول/ فدان في حين سجل النظام الرابع اقل استهلاكا للطاقة وكان مقدار الاستهلاك ١٠١٠٩,١٧ ميجا جول/ فدان. يتكون هذا النظام من المحراث المطرحي + المشط القرصي + الزحافة الخشبية + البتانة + آلة التسطير المعلقة + الري السطحي + نثر السماد يدويا + الرشاشة الظهرية المحمولة لمكافحة الحشائش والحشرات+ محشة ذاتية الحركة+ المقطورة+ الة الدراس الثابتة.

يمكن الاستنتاج من نتائج هذه الدراسة أن نموذج محاكاة مونت كارلو قادر على تحديد النظام الاقل استهلاكا للطاقة في انتاج القمح .

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