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Agriculture Production Planning Using a Hybrid Simulation and Genetic Algorithm Approach

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ABSTRACT

One of the oldest and most powerful optimizing methods is mathematical programming which used as a powerful tool in decision making. In spite of widespread use of these models, these models are not flawless. Simplifying hypothesizes in approaches like Minimization of Total Absolute Deviation (MOTAD) and Expected Value Variance (EV) reduce the reliability of proposed programs. The hybrid of Genetic Algorithm (GA) and Monte Carlo Simulation (MCS) improve decisions by recognizing the best accidental processes of production planning. The goal of this research is to determine the optimal cropping pattern of agricultural production in Mashhad plain. Data were gathered from Agricultural Jihad Organization of Khorasan Razavi province of Iran including time series of main seven crops in Mashhad plain from 1982 to 2007. Simulating the program was done by using The Decision Tools Suite ver 4.5.2 and improving accidental processes were attained by MATLAB. The linear and quadratic risky programming model were also attained and solved by using WINQSB software. Finally, the results of hybrid model were compared with the result of quadratic risky and linear programming model. Given the stochastic processes without any presumption, the results are more reliable and more realistic. Therefore, having the required information such as the time series of variables, this hybrid model can efficiently suggest the best planning production.

Keywords: Genetic algorithm, mathematical programming, MATLAB, Monte Carlo simulation, MOTAD, optimal cropping pattern, WINQSB.

Abbreviations:

APP: Aggregate Production Planning; **EV:** Expected Value Variance; **GA:** Genetic Algorithm; **MCS:** Monte Carlo Simulation; **MOTAD:** Minimization of Total Absolute Deviation.

INTRODUCTION

Crops are obviously under risky and uncertainty conditions in any agricultural activities. Farmers always deal with a wide variety of risks especially in prices of products which make decisions undulate and unstable (Hardaker, 2000). Furthermore, the risks due to weather conditions such as hurricane, flooding, drought and etc. also make problems bigger and make agriculture too risky (Torkamani, 1996 a and b). A large number of developing countries depend on agriculture sector in a situation that farmers face risk. Therefore, understanding the attitude towards and responses to production in risky conditions needs attention (Hurley, 2010). Optimum pattern of cultivating is a program with the goal of optimum management of positional herbal composition. This program is contoured according to season and eco physiology threatens producing elements, economic issues, culture and social factors and modern technology. Contouring and presenting optimum patterns of charting have been using in most countries of the world from many years ago and with the help of them many problems of producing agricultural, garden and pasture products have been solved. The portion of giving land to different kinds of products such as cereals, grains, industrial products, vegetables, forage vegetables and other agricultural products will be determined in one agricultural season and based on consistent cultivating pattern. On the other hand the portion of cultivating agricultural products in one region must be determined according to existing sources, price and production costs, functions of products, countries needs and good policies. Decision about choosing different agricultural or garden products must be made base on existing infrastructures social and economic factor and degree of technology with saving sources for providing main necessities of the country. Presenting a good cultivating pattern will guarantee food safety and consistency of production. Presenting a good cultivating pattern is a necessary factor for reserving basic sources and increasing exploitation of production factors.

In a real world especially in agricultural section (according to the changes of weather), making only risk about condition decision is not enough. In decisions models, the decisions are important which carry the best possible information. In mathematical programming models, some sampling hypothesizes used to estimate the total gross margin which needs estimating variance that as a function it depends on distribution of all accidental complicated variables. But accidental information can have more complicated forms like nonsymmetrical distributions, trends, seasonal swings, plural and accidental variables and correct prediction of analyzing time series needs correct determining of variables processes (Musshoff and Hirschauer, 2009). Inertia formulation in mathematical programming models even in stationary time process which there are not any relation between accidental variables or in situations of multi correlation of accidental variables with different distributions or even when the distribution is not estimated by expecting value and variance, is so hard and sometimes impossible to do.

There are several studies which use similar approaches. Chakrabortty and Hasin (2013) used a multi-objective genetic algorithm model for Aggregate Production Planning (APP) problem. They examined an industrial case to evaluated the proposed approach and found out the feasibility of applying this method to real APP decision issues. Moreover, Montazar and Snyder (2012) using a multi-attribute preference model for optimal irrigated crop planning. They concluded that the model can create different groups of criteria in the preference elicitation of the crop type and cultivated area. Musshoff and Hirschauer (2009) suggested a hybrid simulation–genetic algorithm approach to optimize production decision. They concluded that this method has a high performance in farm-program decisions by assuming static distributions.

Sharmaa and Janab (2009) also presented a fuzzy goal programming based genetic algorithm model for rice crop planning in India in order to nutrient management decision-making. Pal et al. (2009) introduced a genetic algorithm based hybrid goal programming approach in order to land allocation issues for optimal cropping plan in agriculture and the level of successfulness of proposed approach was proved by a case of the Nadia District in India. Further, Raju and Kumar (2004) used Genetic Algorithm (GA) for an irrigation system concluded that this method is an acceptable tool for irrigation planning so that it can be used for efficient planning of any irrigation program.

The aim of this study is to determine the optimal pattern of agricultural products cropping in the plain of Mashhad, Khorasan Razavi, Iran using a hybrid of genetic algorithm and simulation approach for seven main crops during 1982 to 2007.

MATERIALS AND PROCEDURES

Monte Carlo Simulation:

Simulation takes the role of modeling the function and finding the relation between parts of a system, with contemplating the effect of time. The accidental Monte Carlo Simulation (MCS) model was created by Ulam (1947) during World War II (Roger, 1987) (Fig. 1). This model is based on sampling and possible symbols, in a way which accuracy of estimation is like accuracy of a statistical estimation. MCS model mostly uses in disjointed accidental processes which don't change over time. It means that, those models which are not depend on time and are constant in all moments are in our consideration (Metropolis, 1987).

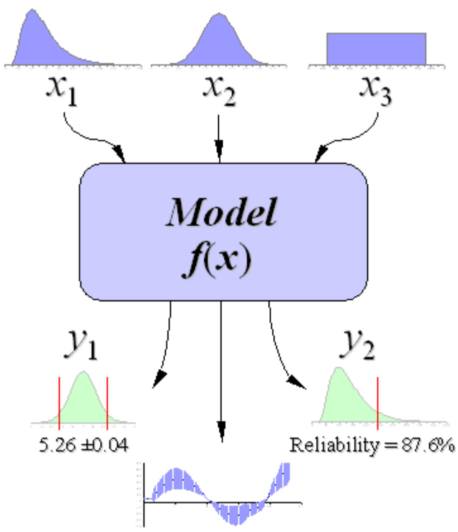

Fig. 1. Monte Carlo Simulation Model.

Monte Carlo Simulation is based on this fact that in following phrase if T have tendency extreme value, means will have tendency to expected value of $E_f[h(X_i)]$ (Musshoff and Hirschauer, 2009).

1. Stages of Monte Carlo Simulation

a. Creation of one parametric model: $Y=f(X_1, X_2, X_3, \ldots, X_n)$

b. Creation of one accidental outcome collection: $X_{i1}, X_{i2}, \ldots, X_{in}$

c. Estimation of the model and saving result as a title of Y_i

d. Repetition of second and third step for i=1, 2, 3, ..., n.

e. Analyzing the results by using histogram and statistical abstracts

Monte Carlo Simulation (MCS) is used for estimating expected value of an accidental variable. An important assumption is an existence of correlation, between variables. Therefore, it should be considered the correlation between variables during simulation. At first stage we estimate the accidental value for programmatic output, which can differ from minimum to maximum. At next stage we add accidental values of production to find total gross output, at the end expecting value of total gross output is the average of all values (as mentioned before MCS model is an estimation of expecting value of an accidental variable).

Genetic Algorithm:

Genetic Algorithm (GA) was created by John Holland (1975) as an accidental method of improving. This method found its position with hard works of Goldberg (2002) and because of its own abilities now days it has an acceptable place among other methods. The process of improving in GA is based on an accidental conducted procedure. This method is based on gradual evolution method and fundamental view of Darwin. GA have some advantage over other methods including: improving correlation variables or disjointed ones with complicated target functions and using possible transmission rules over absolute rules and having chance to work with allot of variables. Although GAs are naturally parallel, most of them can only indicate the foresaid problem space and if the finding result is a local optimum answer or a subsection of main answer, all parts of process must begins from the first stage. As GA has several start points, it can search in problem space from different sides. If it does not reach our point from one side it can continue from other sides and have more sources. GA does not know anything about problem which it solve (Blind Watchmakers). they accidentally change result solutions of their candidates and then use embedding function to estimate if there is any progress based on changes or not as all the decisions to be made are basically accidental, based on theory all solutions are possible. But problem which have limitations based on information. One of benefits of GA is that it can change several parameters at the same time (Musshoff and Hirschauer, 2009).

Data Collection:

Elements which were needed for model limitation coefficient were given from second hand elements. The statistical figures of agricultural products prices at the time of research study and variable costs of one hectare of productions are obtained from statistical sector of Department of agriculture, Mashhad, Iran. In this research we are modeling the accidental information derived from of time series, and using of accidental modeling of simulation method. Modeling based on MCS method is so flexible and can make adjustment between possible information such as accidental processes, and accidental multi variables. The achieved model must improve by an improving method such as genetic algorithm.

RESULT AND DISSCUSSION

Mixing Accidental Simulation and Genetic Algorithm:

1. Initializing

According to the time series of existing cultivating pattern and it is limitation optional levels will produce by using of producing average of accidental numbers. This collection is called first production in genetic algorithm (GA) literature (Fig. 2).

2. Estimating Fitness Value

For estimating fitness value 4 steps were used.

a. Simulation of accidental total gross for each activity: with us in total gross of first year products (GM_0^j), total gross of next year products for each activity and correlation of them will be simulated for thousand times (S=1, 2, 3, … S).

b. Analyzing total gross of each cultivation pattern in every performed simulation: in any repetition total gross will be simulated by using total gross of simulated production activities of previous stage.

c. Analyzing total gross of each cultivation pattern: at this stage we estimate the expected total gross by using repeated simulation programs and their average.

d. Analyzing accidental interest of each producing program: at the end fitness value were estimated as mentioned bellow (Fig. 2).

3. Usage of Genetic Algorithm Functions

Cultivation patterns were changed by using genetic element:

a. Giving priority based on estimated value of fitness value.

b. Selection and replication processor: according to these processors programs which are not at priority will be deleted and replaced by better programs.

c. Recombination: Survived programs are not necessarily optimum and we need new programs with possible solution. So fitness value were increased by one percent possibility, all activity levels of one program were coupled with other activity levels. By application of mathematical operations (horizontal recombination), in a vertical combination this activity happens between activity levels of each program. After improving programs, a possible generation derived from the mentioned recombined process will be replaced by parent's generation. Therefore all the programs of all generations will be consistence.

d. Mutation: This function effects only on individual activities. Activity levels are changing with one percent low possibility in one predicted extension. Mutation has a critical role in finding optimum result, since this algorithm does not limit to a primitive and simple solution sub collection (Fig. 2).

4. New Generation

After using functions a new generation of cultivation pattern will be reached. With repetition of stage 2 and 4, we can achieve an optimum pattern. This stage repetition will stop when the results are consistent and powerful and when we have below conditions (Musshoff and Hirschauer, 2009) (Fig. 2).

Total gross profit of products is modeled by analyzing existed time series as accidental variables. In tables 1 and 2 the function of agricultural products, their total gross profit and technical indexes are provided.

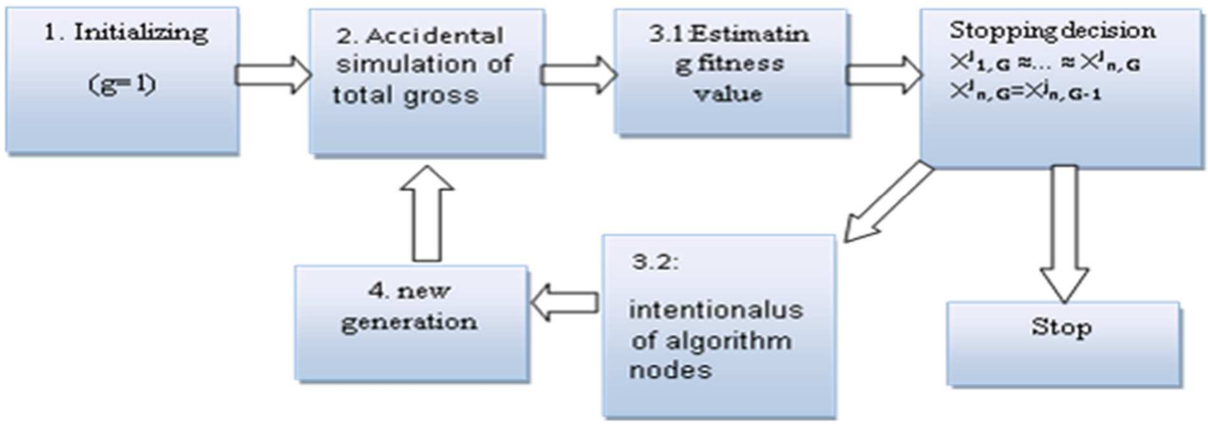

Fig. 2. Stages of recombination method of Genetic Algorithm and Accidental Simulation.

Table 1. Technical coefficients of required facilities for production of seven main crops in Mashhad's plain during 1984-2007.

Product	MH (ha hr^{-1})	MD	WC (ha m^{-3})	FE (ha kg^{-1})	
				Chemical	Organic
Wheat	22	37	3800	159	212
Grain	22	26	3400	140	199
Alfalfa	21	43	7200	135	255
Corn	25/5	37	2100	114	235
Potato	22/5	92	7300	220	245
Beat	23	73	8000	269	262
Chickpea	13/5	31	1900	50	97

MH: mean of hours which machines work for cultivating in each hectare.
MD: man power needed for cultivating in each hectare (hectare/many-day of work).
WC: water needed for cultivating in each hectare.
FE: fertilizer needed for cultivating in each hectare (kg ha^{-1}).

Table 2 shows the agricultural products function in cultivating pattern. As it is shown, before 1991 which was at the time of Iran-Iraq War, and before starting of economic development programs, the functions of all productions per hectare were lower than normal. Therefore for preventing wrong results the mean of products functions and the medium cost of function productions were considered after this time. Total gross profit of the mentioned agricultural products were calculated by the bellow formula:

$$GM_j = TR_j - TVC_j \; ; \; TR_j = P_j * Y_j$$

Where, GM_j is total gross profit, TR_j is total income, TVC_j is total variable cost, P_j is product price, Y_i is space of cultivated forms in hectare.

Specifying Accidental Process of Total Gross Profit With Analyzing Time Series:

For specifying the best accidental process in a time series, first ADF examination were used to analyze the accumulation. In this research ABM accidental process for not static processes and OUP accidental process for static processes were used.

ABM: $GM_t^j = GM_{t-\Delta t}^j + \mu^j.\Delta t + \sigma^j.\sqrt{\Delta t}\,.\,\varepsilon_t^j$

OUP: $GM_t^j = \overline{GM}^j . (1 - e^{-\eta^j.\Delta t}) + e^{-\eta^j.\Delta t} . GM_{t-\Delta t}^j + \sigma^j . \sqrt{\frac{1 - e^{-\eta^j.\Delta t}}{2.\eta^j}}$

σ^j : Standard deviation of total changes of total grosses profit.

ε_t^j : Accidental variable process.

η^j : The time distance of total gross profit return from normal level $\overline{GM}^j$

μ^j : Fix profit.

GM_t^j : Total gross profit.

Δt : Time distance between two observations.

Table 3. Mean of yield and total gross profit.

Description	Wheat	Grain	Alfalfa	Corn	Potato	Beat	Chickpea
Yield (ha kg^{-1})	2650.201	2485.253	8636.3	36688.85	21853.85	29379.32	1276.26
Gross Profit	4253019	2887581	7917605	25491000	13750727	9613505	4155553

Table 2. The function of agricultural products cultivating pattern (kg ha^{-1}).

Year	x1 Wheat	x2 Grain	x3 Alfalfa	x4 Corn	x5 Potato	x6 Beat	x7 Chickpea
1984	1400	1600	10000	30000	15000	29400	1300
1985	1500	1600	10000	30000	20000	27000	1400
1986	1700	1800	10000	30000	20000	27000	1400
1987	1600	1700	10000	40000	15000	31500	1500
1988	1600	1700	10000	30000	15000	28571.43	1300
1989	1500	1599.99	10000	30000	15000	20714.29	1250
1990	1858.35	1984.87	10000	28000	16000	20458.2	1300
1991	2307.69	1739.13	4687.5	30000	20000	16296.3	1000
1992	2500	2000	5303.03	33333.33	25294.12	35000	1250
1993	3173.91	2500	5693.37	35000	24937.66	35001.1	1300
1994	3173.91	2500	5693.37	39285.71	23333.33	42901.03	1300
1995	2901.3	2500	9048.09	40000	24263.55	28102.26	1500
1996	2400	2437	8000	26809.86	18000	28000	1230.77
1997	2600	3200	9000	45000	22000	27800	1300
1998	3560.99	2754.02	6499.85	52000	25000	30500	1100
1999	3050	3099.99	7052.63	45762.71	26000	30000	1233.33
2000	2245.67	2350.04	7700	42000	25542.86	27500	1200
2001	2700	2710.39	8506.33	44156.86	29848.99	27527.52	1200
2002	3700	3400	8802.17	42584	25673.76	30031.53	1200
2003	3747.14	3321.88	9000	42000	22500	34000	1320
2004	3800	3347.53	9000	43000	23000	32000	1400
2005	3800	3600	8600	49000	24000	34000	1400
2006	3090.87	2801.24	7575.85	42000	23696.08	31000	1246.15
2007	3367.80	3094.30	17109	10600	25402	28764.50	776.40

Source: Department of Agriculture, Mashhad, Iran.

By having access accidental process of gross profit and their correlation, the optimum question would be solved by using accidental simulation and genetic algorithm. During simulation consider the following accidental route of correlation between gross profits of production activities should be considered. The correlation matrix of all production activates have been shown in table 5.

Actually α parameter shows the portion of escaping from doing risks by farmers, and (α =0) shows maximum risk taken by the decision maker which is maximum total gross profit and can be solved by simplex algorithm. Increase of not taking risk will cause decrease in cultivating portion and increase in ash tends. Recombination of Activities which their gross profits are minus, may causes decrease in standard deviation of total gross profit.

Final cost will be increased by reduction of instability. It means that decrease in standard deviation with one extra unit will decrease the total gross profit.

Table 4. Processes and parameters of accidental total gross profit for different activities.

Activity level		Wheat	Grain	Beat	Chickpea	Potato	Alfalfa	Corn
Statistic Situation		Yes	Yes	Yes	Yes	No	No	No
GM_0^j		-	-	-	-	16577472	7917605	25491000
ABM	μ^j	-	-	-	-	5122108	350316	12332150
	σ^j	-	-	-	-	4291.05	1705.774	7407.338
	$E(GM_1^j)$	-	-	-	-	21699580	8267921	37823150
OUP	$\overline{GM}^j$	3666750	2125867	12266000	2414900	-	-	-
η^j		-1061975	319615	17051550	-1126628	-	-	-
σ^j		826.0786	664.5475	5458.537	115.6747	-	-	-
$E(GM_1^j)$		2604775	2445482	29317550	1288272	-	-	-

Table 5. Correlation matrix of activates gross profits.

Correlation	Corn	Alfalfa	Potato	Chickpea	Beat	Grain	Wheat
Wheat	0.738664	-0.42504	0.718491	-0.11757	0.514665	0.908237	1
Grain	0.78323	-0.16039	0.659894	-0.01417	0.424869	1	0.908237
Beat	0.428476	-0.26035	0.387653	0.33262	1	0.424869	0.514665
Chickpea	-0.01946	0.593346	-0.23083	1	0.33262	-0.01417	-0.11757
Potato	0.680373	-0.52374	1	-0.23083	0.387653	0.659894	0.718491
Alfalfa	-0.18574	1	-0.52374	0.593346	-0.26035	-0.16039	-0.42504
Corn	1	-0.18574	0.680373	-0.01946	0.428476	0.78323	0.738664

CONCLUSION

The usual styles of mathematical programming such as MOTAD or expected value variance are not as efficient as accidental variables with unmoral distribution and multi correlations and other accidental complexities. These problems can be solved by the mentioned hybrid method. This hybrid method has a potential for improving programming decisions of farms even with the existence of unsymmetrical distributions trends, seasonal instability, accidental multi variables. It can also proficiently predict the correct processes of variables. Even in static models when there is not any mathematical relation between increasing accidental variables, or even in the situation which there is multi recombination between accidental variables with different distributions or even when distributions are not totally estimated by expected values and variance, which is impossible with ordinary mathematical programming methods. Result show that recombination has the potential of improving farm decisions even based on statistical explained simplifying variable methods have unsatisfying results comparing with this recombination method is such a way that this method have an ability to processing the accidental information which are based on systematic and statistical analyzing without taking any side or advocating one of information. Simplifying ways such as considering previous values based on weight and not growing accidental variables in MOTAD models which categorizing the previous distributions, or models which emphasis on second had programming have happened continuously. If accidental attributes of accidental variables fundamentally deviate from these hypothesizes, designing and using these models are not enough. According complexities, in using other methods with simplest structures it should be done more cautiously. Finally, there is no need to mention that there are considerable differences between production in agriculture and production in other sectors. Its frequently indicates that risk management is the best manner to manage mentioned uncertainties. In this particular way, the insurance of these strategic crops is suggested to reduce the volatility of farm income, in the face of sudden changes and risky conditions.

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