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OPTIMIZING THE MAIZE CROP YIELDING AND CROPPING SYSTEM USING TABU SEARCH APPROACH

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Abstract:
In developing countries, many researchers have been carried out in the cropping systems to yield maximum profit. The profit from the cropping system can be enhanced by predicting the variables which affects yield. In this research, these variables have been predicted and optimized for maize cropping productivity using Tabu search approach. Rainfall, temperature and irrigation are the major variables considered for maize cropping system in this research. The details of these three variables for twelve months and for eight years had collected. Minitab software had used to frame a mathematical relationship among these variables and this relational equation has been used as the objective function for Tabu search approach. Using this equation, Tabu search approach identifies the best optimal yielding period for maize crop cultivation and also it can be used to forecast the best optimal combination of variables that can yield best productivity for cropping system. The developed model have been tested with the data obtained from the farmer and aback that the results are lined up with the real time data. The developed model will help the agriculturist to take decision on efficient resource allocation with the aim of optimizing productivity and profitability of maize cropping system.
Keywords: *Forecasting, Optimization, Maize cropping system, Tabu search, Yield.*

1. Introduction

In developing countries, agriculture plays a major role in the economy of the country. The major issues faced by the farmers are false prediction and failure of the natural parameters like rainfall, temperature, etc. In general, Agriculture is an assemblage of components united by some form of interdependence and which operates within a prescribed boundary to achieve a profitable yield. In order to maximize the profitability and productivity, different strategies have to be applied for different cropping systems, Because different crops require different environments. To achieve better benefits, the parameters which are related to the cropping system should be in the favorable range. Some of the parameters are irrigation, rainfall, temperature, fertility of land, monsoon behavior, rainfall, irrigation, application of fertilizers, climatic conditions, marketing facilities, prices, availability of agricultural labourers, etc. as most of the parameters are unpredictable in nature, the forecasting have been done only through experimentation, field research or on-farm trials. This trial and error methodology depends on experience, territory, type of crop, type of land, type of irrigation, etc. so it might not be suitable for all situations and having several shortcomings.

Thus a need arises for mathematical models to forecast and optimize these parameters. Because many engineering applications proved that the mathematical models can provide better results and it can be the best alternative to experimentation of a real system. In most of the countries, these mathematical models have not been used on cropping systems as a tool to optimize and forecast the profitability in the cropping system. Because the decision effectiveness of the mathematical models depends on the accuracy of the input data such as rainfall, temperature, etc. In this type of situations, the mathematical models failed to produce better results. This issue has been addressed by many researchers and found that the evolutionary and intelligent algorithms can be used to produce better results with the unpredictable input parameters. Evolutionary algorithms are now became a tool for optimizing the unpredictable problems and Tabu search approach has been one among the tool which is used in this research to predict long-term productive and environmental effects of maize cropping systems.

In this research, the data of the rainfall, irrigation availability and temperature had been collected for ninety six months in the town Karur, southern region of Tamilnadu, India. These data have been given as input to the developed Tabu search module. The module gives the best period for the maize crop cultivation and also the best parameter required for better yield for the required period. Thus it helps the agriculturist to cultivate the maize with maximum profit.

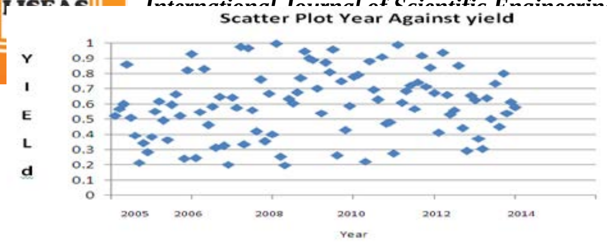
2. Literature Survey

Jehle et al. (1998) denoted that the main objective of the cropping system is to maximize the output, so as to reap more profits. Such behavior can be modeled using a profit function approach, production function approach, cost function approach, mathematical optimization and dynamic programming. Varian (1992) used the Hotteling's lemma, the derivative of the profit function, with respect to input price, demand factor and output prize. Stokle et al (2003) noted that simulation models can underestimate the yield of maize by up to 27 %, without necessarily undermining reasonability of estimates obtained. Jhs et al (2004) considered the climate changes on the river basin and discussed the impacts of the climatic changes on crops. Di Luzio et al (2008) considered the temperature dataset for his analysis. Similarly the temperature dataset had been developed in this work. Zhang (2009) developed an approach to solve the un-certainty using genetic algorithm and Bayesian model. Cantelaube and Terres (2005) developed a model to predict the changes in the seasons and proved that he seasonal forecasting will yield more profit for crops. Ines and Hansen (2006) studied the effect and impact of rainfall and level of rainfall for crop yield using simulation models. Alva et al (2004) developed a model for potato crop yielding system and predicated the optimal parameters that yield maximum potato cultivation. Dillion in 1992 and 1993 developed a management strategy for the small scale farmers to yield maximum profit and analysed the various factors which affects the profits. Giardini et al (2004) developed a mathematical model to simulate two Cropping Systems. The models used for the profit maximization are EPIC and CropSyst Models. Grabisch (2003) introduced a model based on the probability approach for crop cultivation. Fleisher (1999) discussed the various factors and the parameters which influences the agriculture. Jehle and Reny developed the economic theory for agriculture management and resource management. Kelton (2003) simulated a model for agriculture management. Kothari (1999) developed the model for simulating the profit using quantitative approach for agriculture. Lordanova (2007) introduced the concept of Monte Carlo model for agriculture profitability. Staggenborg and Vanderlip developed the simulation model and proved that the simulation models can be best suited for predicting the profits for cropping systems. Stockle (2003) developed the mathematical model for cropping system and proved that the model in line with the real data.
From the literature it is clear that the researchers are taking different parameters for produce better yield in crops. So in this research, rainfall, temperature and the irrigation had been taken for crop yield maximization.

3. Mathematical Modelling

In general, maize is a commercial crop and the maize farmers are driven by the profit motive. Therefore, a necessity arises in developing a mathematical model that leads to profit is more appropriate. Some of the commonly used tools used by the researchers are mathematical optimization, dynamic programming, simulation analysis, intelligent methods, etc. Most of these models do not predict how much of each variable input should be used to achieve optimal output or deficient in their ability to capture various dynamically changing variables or time consuming.
So in this research, Tabu search algorithm has been used to forecast and optimize the maize crop cultivation. As the Tabu search prevent the duplication of the search and avoid the stagnation, it proved to be a best algorithm to search in the large solution space.
The data for ninny months has been collected form thirty farmers in the Karur town located in the southern part of Tamilnadu, India. The collected data had been given as input to the Minitab software to generate a mathematical relation between the inputs. The scatter data obtained from the software is given in the figure 1.

Figure 1: Minitab Scatter data plot



The mathematical equation has been formed and that equation has been used as the objective function for the Tabu search module. They have been widely studied and applied to optimize the non-linear functions bounded with constraints in less computational time. The various stages are explained in the following sections.

3.1 Tabu Search

Tabu search is a kind of heuristic search proposed by Fred Glover and Hansen in 1989 to solve combinatorial optimization and NP hard problems. It is a deterministic iterative improvement local search method with a possibility to accept worse-cost local solution in order to escape from local optimum. The set of legal local solutions are restricted by a Tabu list which is designed to present from going back to the recently visited solutions. The set of solutions in taboo list are not accepted in the next iteration. The first stage of the Tabu search is the solution space formulation.

3.1.1 Solution Space Formulation

Initially the search space has to be formed based on the input parameters and the constraints are used to create the boundary for the possible solution space. The input parameters considered in this research work are the combination of temperature, rainfall and the irrigation facilities. As all these three parameters are having different units and ranges, these parameter values have been normalized between zero to one for simulation purpose. Thus a solution space has been formulated and ready for Tabu search.

$S = (T, R, I)$

$T = \{t_1, t_2, \ldots\ t_n\}$; t_1 = 28°C and t_n = 40°C in the step ration of 0.1°C.

$R = \{r_1, r_2, \ldots r_n\}$; r_1 = 10 cms and r_n = 550 cms in the step ratio of 1 cms.

$I = \{y, n\}$

T, R and I are the temperature, rainfall and irrigation availability in the solution space 'S'. As there is no linear relationship among the parameters, the combinations have to be formulated as feasible and non-feasible solutions such that S_i should not be S_j.

A sample formulated solution space is given in the Table 1.

Table 1: Sample Tabu Solution Space

Rainfall	Temp.	Irrigation	
10	28	A	Node 1
15	29	NA	Node 2
20	30	A	Node 3
25	31	NA	Node 4
30	32	A	Node 5

3.1.2 Neighborhood Search / Move:

Neighborhood solution is a solution which must exist in a set of feasible solution, and which is not in the Tabu list. The major principle of Tabu search is the neighborhood search. In the neighborhood search, the algorithm switches to various possible solutions in the space and identifies whether the solution is the best and the worst using the fitness function given in the equation 1. If it had been found to be worst, then that solution node have to be marked as taboo node and the search proceeds to the next node. The move or the search is the process of constructing the best solution x' form x. i.e. moving from the current solution to the neighborhood solution. The size of the each Tabu parent is set as 12, as the three variables have been considered in this work. The number of Tabu parents has been set to 100 by doing sensitivity analysis. The sample generated Tabu sequence is given in the figure 2.

Tabu Parent 1: 010028010105
Tabu Parent 2: 050031010208
Tabu Parent 3: 425049000306
Tabu Parent 4: 350045000412

Figure 2: A Sample Set of Generated Parent

3.1.3 Tabu Memory / List:

Tabu memory is a special tool used in Tabu search to save the timing and prevent the search from local convergence inside the solution space. In this memory, taboo node had been stored and the search skips these nodes at the search. Thus it pays the way for best nodes in the solution space and thereby increasing the search space. The sample Tabu state space is given in the figure 3.

Figure 3: Tabu State Space Representation

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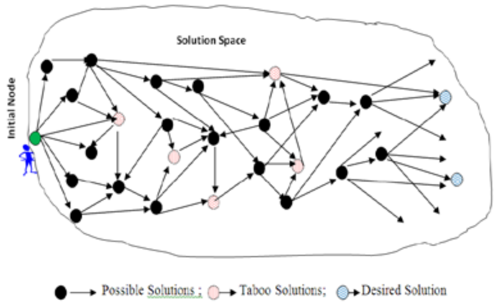

Computing and storing the fitness difference may be easier than that of the fitness function is the concept of Tabu memory. The size of the Tabu list plays a major role. Too large Tabu list deteriorate the search result and diversify the search by penalizing the moves. Too short Tabu list cannot effectively prevent from cycling and intensify the search. In this research, the size of the taboo list has been set as 25 % of the solution space with the assumption that 25 of the solution can be worst. Because of size limitation, the worst solution have retained in the list. The sample taboo list obtained is given in the Table 2.

Table 2: Sample Taboo Memory Items

Rainfall	Temp.	Irrig.	
10	32	NA	T.Node 1
12	32	NA	T.Node 2
15	34	NA	T.Node 3
15	33	NA	T.Node 4
12	34	NA	T.Node 5

3.1.4 Identify the Best Solution

The Tabu search identifies the best solution and stored in the separate memory as the best optimal solution. For each and every iteration, it compares the new best solution with the existing best solution and the better has to be replaced in the memory. This is called as Tabu aspiration criteria and the logic is given below

While
Next = a highest-valued successor of *Current*
If(not Move-Tabu (*H*, *Next*) **or** Aspiration(*Next*)**) then**
Current = *Next*
Update *BestSolutionSeen*
H = Recency (*H* + *Current)*
End if
End-While
Return *BestSolutionSeen*

3.1.5 Modify the Taboo list

The taboo list need to be modified based on the results obtained in current iterations. Normally the concept of first come first out has been used, but in this work, the least worst have retained to reduce the computational time.

3.1.6 Stopping Condition

The computation time and the quality of the solution are inversely proportional and there always a trade off exist between the both. So by conducting sensitivity analysis, the stopping conditions had been set in this research work and are as follows.

1. If 1000 iterations reached.
2. If the $f(x)_{ij}$ =1 for i,j = 1 to n.

If $V_g = V_{(g+5)}$ Where as, g is iteration number.

4 Experimental Implementation

The study area was Karur, Namakkal district, Tamilnadu, southern region of India. Primary data are the maize output, prices, input cost, annual rainfall, irrigation and temperature. Secondary data are the irrigation facilities, yielding season, market demand, water resources, fertilizers, distribution centres, mist, minimum temperature, etc. Lists of questionnaires were prepared from brain storming sessions and from literature survey. These questionnaires were pre-tested and refined. The interviews were held for the selected maize farmers who cultivate maximum maize in the year 2014. Surveys with thirty maize farmers were done and average of the 25 maize farmers data have been taken for the analysis. The collected data were encoded to formulate the solution space. In the solution space, three sub regions were formed with nodes having three decimal digits. the first three digits in the first sub-region represents the average rainfall in millimetres, the three digit in the second sub-region represents temperature, and the nodes in the third sub-region having two digits to represent irrigation facility.

In the developed Tabu search model, inputs (X_1, X_2 ------- X_n) used were the rainfall, irrigation and temperature. The yield function obtained from Minitab software is the maximization function used as the fitness function in this model. The model was then run to produce results (Yi) in the form of maximum yield and in-turn maximum profit. The Tabu search steps were re-run for 1000 times to achieve high degree of accuracy.

Results of simulated yield show that the highest yield of maize averaging at 54 bags/hector and the lowest yield with only 20 bags/hector which are aligned with actual yields reported in the zones considered in the research. The average district simulated yield was estimated at 38 bags/hector, which is also mapping with the actual district average. Comparison between actual and simulated maize yields revealed that simulated values are in line with the actual values and therefore they can be used for planning and decision making.

Thus this model helps the farmers to predict the suitable period for maize cultivation which can yield profitability. The model also forecast the parameters in the future, so the cultivation decisions can be taken by the farmers. The model also suggest the farmers how to control the parameters along with the seeding period. It also identifies the optimal set of parameters which gives maximum yield based on the past history. With this model the farmers can take the decision to maximize their profit. The sample output module is given in the Figure 5.

The best temperature : 32'C
The best rainfall : 60-75 cms
The Best irrigation : Available
Best Month : October 2014

Month-wise Analysis
Jan 2014 : Not Suitable
Feb 2014 : Satisfactory with High irrigation
March 2014 : Satisfactory with High irrigation
April 2014 : Not recommended
May 2014 : Not Recommended
June 2014 : Satisfactory with irrigation facilities
July 2014 : Best Suited
August 2014 : Satisfactory with irrigation facilities
September 2014 : Satisfactory if night temp. is minimum of 25'C
October 2014 : Best Suited
November 2014 : Satisfactory if night temp. is minimum of 25'C
December 2014 : Not recommended

Optimal set of parameters			Best Set of Parameters			Worst Set of Parameters		
Rainfall	Max. Temp.	Irrigation	Rainfall	Max. Temp.	Irrigation	Rainfall	Max. Temp.	Irrigation
200	42	NA	420	44	A	14	29	NA
415	35	A	418	44	A	32	28	NA
210	42	NA	445	48	A	21	31	NA
390	38	A	414	49	A	41	30	NA
198	41	NA	456	50	A	51	32	NA
211	38	A	458	52	A	59	32	NA
220	43	NA	468	53	A	65	32	NA
230	35	A	472	53	A	62	33	NA
380	48	NA	481	54	A	68	33	NA
230	51	A	492	53	A	101	34	NA

Figure 5 : Output

5 Conclusion

It is concluded that the forecasted result obtained from the developed genetic module for maize yield have been in line with the actual data. Thus the developed module has been validated. The developed module is efficient and consistent forecasters of productivity and profitability in cropping systems. It will help the farmers to take wise decision in yielding, to get maximum profitability.

It is also recommended that the various crops have to be considered for that place to improve farmer's access to information on alternative crops and their risks, uncertainties associated with cropping system. Further research is also required to test the models under different locations, soil types, management styles and scales of production.

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