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Application of operations research in agriculture

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ABSTRACT

Right from 1954 researchers started analyzing the applications of Operations Research in agriculture. Agriculture makes provision for food and is vital for the GDP of India with the ever growing population. This paper uses Assignment Problems to allot crops to states based on secondary data (to deduce a trend) that shows the crop production of all the states of India. It represents a methodology which can be used to identify which crops should be predominantly grown in which state. It can help to maximize the production of crops in the country, maximize the profits and reduce land usage in the process.

Keywords— *Agriculture, India, Export, Constraints, Maximize, Minimize, Uncertainty*

1. INTRODUCTION

Agriculture acts as the backbone of many countries, including many European countries, Japan and limited parts of the USA. Agriculture plays a very important and fundamental role in India's growing economy. More than 58 percent of the households in the rural sector is dependent on agriculture as their primary means of livelihood.

India is the second largest producer of fruits in the world with their fruit production being more and faster than their vegetable production. India is ranked third in agriculture and farm output products and its horticulture output comprising vegetables, spices and fruits reached its highest at 284 million tonnes this year. Exports in agriculture make around 9 to 10 percent of the total exports in the country and are ranked the fourth largest principal commodity that is exported [1].

Recently, when compared to how the sector was in the past, multiple, new factors have blended together to expedite growth in the agricultural sector in India. These factors include an increase in the household income and also in the consumption, an increase in agricultural exports and also an expansion in the food processing sector.

Agriculture has for a long time been a low profitability and high-risk occupation. The sector is in such a bad state that thousands of farmers are committing suicide every year. This year, the agricultural sector is projected to increase by 2.1 percent [2]. This research paper throws light on the fact that since it is such an important but low-profit sector in India, farmers can use operations research to find out which crop is best suited for which climate and which state. Using operations research would not only help them minimize cost but it would also allow them to use their land adequately to the highest potential [3].

There are different types of agriculture that are pursued in India. Some of them are listed below [4]:

- Farming (cultivation of food crops or cash crops)
- Aquaculture (the practice of raising aquatic life for the purpose of sale)
- Apiculture (the practice of raising bees in order to harvest their products such as honey and beeswax- or for the services provided by them such as pollination)
- Forestry (the practice of tending and harvesting timber for a variety of commercial purposes)
- Sericulture (cultivation of silkworms to produce silk)

The profits that any enterprise enjoys is a holistic function of multiple different variables, like the quantity of output produced, which is arguably the most important one, from the remaining resources, the price at which the output is sold to the customers and the cost of production per unit of output. Then comes risk in farming due to bad weather, pests, credit constraints, and unexpected policy changes.

2. OVERVIEW

Operations research is an analytical method used in problem-solving and decision making in organizations and can be described as a process of using advanced techniques that help in making better decisions. The problems are broken down into basic components and then solved by mathematical analysis.

It has been around in the agricultural and forestry management sectors since the fifties, approaching decision problems that range from more strategic sector level planning to farm operation issues and integrated supply chain management.

Various operations research techniques are very important in the optimization of resource allocation and achieving efficiency in production planning particularly in the agricultural production of food crops (Rice, Maize, wheat, Pulses, and other crops). In this paper, we use the assignment problem method to determine which crop should be grown in which state depending on the yield per hector produced in that state. This helps us decide which crop is most profitable in which state and hence helps us maximize the profits [5].

We have taken the following four crops into consideration:

(i) Rice
(ii) Maize
(iii) Cotton
(iv) Sugarcane

The states that these crops should be grown in are:

(i) Andhra Pradesh
(ii) Gujarat
(iii) Haryana
(iv) Madhya Pradesh

Our first assignment problem helps us decide which of these crops shall be grown in which state so as to maximize production and profitability. Whereas the second assignment helps us decide which crop shall be grown in which state so as to minimize land under cultivation. This can help the farmers to decide their preferred crop in a particular state/area to maximize their profits and production and it can also help the government informing its policies related to farming and agriculture.

The presence of Operations Research in Agriculture and Forest Management applications is already extensive but the potential for development is huge in times where resources are becoming increasingly scarce and more has to be done with less, in a sustainable way.

Given below are the steps to solving an Assignment Problem using the Hungarian Method [3].

- Check if the rows and columns are balanced and if they are not, then add a dummy row or dummy column with all entries as 0.
- Deduct the least number in every row from all the numbers of its row.
- Deduct the least number in every column from all the numbers of its column.
- Construct lines through opposite rows and columns so that all the zeros of the cost matrix are covered by them and the number of such lines used is kept at a minimum.
- Testing the optimality: (i) If the least number of lines covering the zeros is *n*, then an optimal assignment of zeros is possible. (ii) If the least number of lines covering the zeros is less than *n*, an optimal assignment of zeros is not possible as of now, in which case proceed to Step 5.
- Determine the lowest number that is not covered by any line. Minus this number from each uncovered row, and then add it to each covered column. Return to Step 3.

3. LITERATURE REVIEW

This research was carried out to study the application of operations research on agriculture. Agriculture involves a lot of decisions that are to be taken right from what to produce and where to produce, to selling the produce.

The basic components of a decision-making problem can be grouped into (1) objectives, (2) a set of alternative courses of actions available, and (3) uncertainty. The problem of decision-making arises due to the fact that one's uncertain of the future. He has to take a decision in the present for the future in the realm of uncertainty (Agrawal, 1967). The time interval of crop plantation also matters. For example, suppose a dryland wheat farmer makes a decision each year on whether to leave a tract of land fallow or to plant it to wheat on the basis of soil moisture at the wheat-planting time (Burt, 1965).

OR/MS practice requires interactions with the agents that specify, design, build, and operate all the systems involved (M.A. Carravilla, 2013).

In the initial applications to farm management, LPP could be characterized as a mechanized form of budgeting devoted to problems concerned with the optimum organization of farm business. That is, the early attempts were to cover parts of the farmer's decision by budgeting (Hutton, Operations Research Techniques in Farm Management: Survey & Analysis, 1965). The first paper with an application of operations research in agriculture was published in the Journal of Farm Economics in 1954 (Heady, 1954), where Earl Heady finds optimal land allocation on crop planning problems by making use of linear programming problem.

The changing economic conditions over the past century, along with the changes in technology and developments in economic theory and quantitative methods, helped to shape the profession we currently refer to as the agricultural and applied economics (Alex McCalla, 2010)

This paper is for checking the efficiency of coverage. The paper assigns 4 different crops to 4 different states of India where the main occupation is farming, and through assignment problems, we came to a decision so as to grow which crop for minimizing land under cultivation as well as maximize the profits.

4. METHODOLOGY

Step1- Balancing

Rows = Columns, Balanced (*0*-assignment*)

Table 1: Production Matrix– (Production per hectare [6])

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	3466	1670	4145	3579
Maize	1414	572	17	2580
Sugarcane	9312	12960	6510	5031
Cotton	2400	9700	1350	2098

Table 2: Opportunity cost matrix

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	9494	11290	8815	9381
Maize	11546	12388	12943	10380
Sugarcane	3648	0	6450	7929
Cotton	10560	3260	11610	10862

Step 2-Row Minimisation

Table 3: Row Minimisation

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	679	2475	0	566
Maize	1166	2008	2563	0
Sugarcane	3648	0	6450	7929
Cotton	7300	0	8350	7602

Step 3- Column Minimisation

Table 4: Column Minimisation

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh	
Rice	~~0*~~	~~2475~~	~~0~~	~~566~~	
Maize	~~487~~	~~2008~~	~~2563~~	~~0*~~	
Sugarcane	2969	~~0*~~	6450	7929	✓
Cotton	6621	~~0~~	8350	7602	✓
		✓			

Number of Allocations < Order of AP

Therefore, θ = 2969

Step 4- Improved solution

Table 5: Improved Solution

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	~~0~~	5394	0*	566
Maize	487	4977	2563	0*
Sugarcane	0*	~~0~~	3481	4960
Cotton	3652	0*	5381	4633

Step 5- Schedule

Table 6: Schedule

	Andhra Pradesh	Gujarat	Haryana	Madhya Pradesh
Rice	3466	1670	4145*	3579
Maize	1414	572	17	2580*
Sugarcane	9312*	12960	6510	5031
Cotton	2400	9700*	1350	2098

This shows that Rice should be grown in Haryana, Maize should be grown in Madhya Pradesh, Sugarcane in Andhra Pradesh and Cotton in Gujarat.

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$7	ANDHRA PRADESH	0	0	3466	113	1053
$C$7	GUJARAT	0	-5444	1670	5444	1E+30
$D$7	HARYANA	1	0	4145	1E+30	679
$E$7	MADHYA PRADESH	0	0	3579	1053	113
$B$8	ANDHRA PRADESH	0	-1053	1414	1053	1E+30
$C$8	GUJARAT	0	-5543	572	5543	1E+30
$D$8	HARYANA	0	-3129	17	3129	1E+30
$E$8	MADHYA PRADESH	1	0	2580	1E+30	1053
$B$9	ANDHRA PRADESH	1	0	9312	3648	3481
$C$9	GUJARAT	0	0	12960	3652	3648
$D$9	HARYANA	0	-3481	6510	3481	1E+30
$E$9	MADHYA PRADESH	0	-4394	5031	4394	1E+30
$B$10	ANDHRA PRADESH	0	-3652	2400	3652	1E+30
$C$10	GUJARAT	1	0	9700	1E+30	3652
$D$10	HARYANA	0	-5381	1350	5381	1E+30
$E$10	MADHYA PRADESH	0	-4067	2098	4067	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$11	ANDHRA PRADESH	1	0	1	1E+30	0
$C$11	GUJARAT	1	3648	1	1	0
$D$11	HARYANA	1	679	1	0	0
$E$11	MADHYA PRADESH	1	113	1	0	0
$F$10		1	6052	1	0	1
$F$7		1	3466	1	0	0
$F$8		1	2467	1	0	0
$F$9		1	9312	1	0	1

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$7	ANDHRA PRADESH	0	0	3466	113	1053
$C$7	GUJARAT	0	-5444	1670	5444	1E+30
$D$7	HARYANA	1	0	4145	1E+30	679
$E$7	MADHYA PRADESH	0	0	3579	1053	113
$B$8	ANDHRA PRADESH	0	-1053	1414	1053	1E+30
$C$8	GUJARAT	0	-5543	572	5543	1E+30
$D$8	HARYANA	0	-3129	17	3129	1E+30
$E$8	MADHYA PRADESH	1	0	2580	1E+30	1053
$B$9	ANDHRA PRADESH	1	0	9312	3648	3481
$C$9	GUJARAT	0	0	12960	3652	3648
$D$9	HARYANA	0	-3481	6510	3481	1E+30
$E$9	MADHYA PRADESH	0	-4394	5031	4394	1E+30
$B$10	ANDHRA PRADESH	0	-3652	2400	3652	1E+30
$C$10	GUJARAT	1	0	9700	1E+30	3652
$D$10	HARYANA	0	-5381	1350	5381	1E+30
$E$10	MADHYA PRADESH	0	-4067	2098	4067	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$11	ANDHRA PRADESH	1	0	1	1E+30	0
$C$11	GUJARAT	1	3648	1	1	0
$D$11	HARYANA	1	679	1	0	0
$E$11	MADHYA PRADESH	1	113	1	0	0
$F$10		1	6052	1	0	1
$F$7		1	3466	1	0	0
$F$8		1	2467	1	0	0
$F$9		1	9312	1	0	1

Step 1-Balancing

Rows = Columns, Balanced (cost per quintal [6])

Table 7: Balancing

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	3671	2172	2776	1942
Maize	841	582	1286	1383
Moong	2228	5777	2262	2542
Cotton	2510	1988	2539	3433

	MSP
Arhar	5675
Maize	1700
Moong	6795
Cotton	5150

Table 6: Profit Matrix

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	2004	3503	2899	3733
Maize	859	1118	414	317
Moong	4567	1018	4533	4253
Cotton	2640	3162	2611	1717

Table 7: Opportunity Cost Matrix

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	2563	1064	1668	834
Maize	3708	3449	4153	4250
Moong	0	3549	34	314
Cotton	1927	1405	1956	2850

Step 2-Row Minimisation

Table 8: Row Minimisation

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	1729	230	834	0
Maize	259	0	704	801
Moong	0	3549	34	314
Cotton	522	0	551	1445

Step 3- Column Minimisation

Table 9: Column Minimisation

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh	
Arhar	~~1729~~	~~230~~	~~800~~	~~0*~~	
Maize	259	~~0*~~	670	801	✓
Moong	~~0*~~	~~3549~~	~~0~~	~~314~~	
Cotton	522	~~0~~	517	1445	✓
		✓			

Step 4-Improved Solution

Table 10: Improved Solution

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	1729	489	800	0*
Maize	0*	~~0~~	411	542
Moong	~~0~~	3298	0*	314
Cotton	263	0*	258	1186

Step 5- Schedule

Table 11: Schedule

	Andhra Pradesh	Karnataka	Maharashtra	Madhya Pradesh
Arhar	3671	2172	2776	1942*
Maize	841*	582	1286	1383
Moong	2228	5777	2262*	2542
Cotton	2510	1988*	2539	3433

Variable Cells

Cell	Name	Final Value	Reduced Cost	Objective Coefficient	Allowable Increase	Allowable Decrease
$B$7	ANDHRA PRADESH	0	-982	2004	982	1E+30
$C$7	KARNATAKA	0	0	3503	781	53
$D$7	MAHARASHTRA	0	-53	2899	53	1E+30
$E$7	MADHYA PRADESH	1	0	3733	1E+30	781
$B$8	ANDHRA PRADESH	1	0	859	1E+30	258
$C$8	KARNATAKA	0	-258	1118	258	1E+30
$D$8	MAHARASHTRA	0	-411	414	411	1E+30
$E$8	MADHYA PRADESH	0	-1289	317	1289	1E+30
$B$9	ANDHRA PRADESH	0	0	4567	258	5
$C$9	KARNATAKA	0	-4066	1018	4066	1E+30
$D$9	MAHARASHTRA	1	0	4533	5	258
$E$9	MADHYA PRADESH	0	-1061	4253	1061	1E+30
$B$10	ANDHRA PRADESH	0	-5	2640	5	1E+30
$C$10	KARNATAKA	1	0	3162	53	258
$D$10	MAHARASHTRA	0	0	2611	258	5
$E$10	MADHYA PRADESH	0	-1675	1717	1675	1E+30

Constraints

Cell	Name	Final Value	Shadow Price	Constraint R.H. Side	Allowable Increase	Allowable Decrease
$B$11	ANDHRA PRADESH	1	34	1	1	0
$C$11	KARNATAKA	1	551	1	0	0
$D$11	MAHARASHTRA	1	0	1	1E+30	0
$E$11	MADHYA PRADESH	1	781	1	0	0
$F$10		1	2611	1	0	0
$F$7		1	2952	1	0	0
$F$8		1	825	1	0	1
$F$9		1	4533	1	0	1

Objective Cell (Max)

Cell	Name	Original Value	Final Value
$B$14	ANDHRA PRADESH	12287	12287

Variable Cells

Cell	Name	Original Value	Final Value	Integer
$B$7	ANDHRA PRADESH	0	0	Contin
$C$7	KARNATAKA	0	0	Contin
$D$7	MAHARASHTRA	0	0	Contin
$E$7	MADHYA PRADESH	1	1	Contin
$B$8	ANDHRA PRADESH	1	1	Contin
$C$8	KARNATAKA	0	0	Contin
$D$8	MAHARASHTRA	0	0	Contin
$E$8	MADHYA PRADESH	0	0	Contin
$B$9	ANDHRA PRADESH	0	0	Contin
$C$9	KARNATAKA	0	0	Contin
$D$9	MAHARASHTRA	1	1	Contin
$E$9	MADHYA PRADESH	0	0	Contin
$B$10	ANDHRA PRADESH	0	0	Contin
$C$10	KARNATAKA	1	1	Contin
$D$10	MAHARASHTRA	0	0	Contin
$E$10	MADHYA PRADESH	0	0	Contin

Constraints

Cell	Name	Cell Value	Formula	Status	Slack
$B$11	ANDHRA PRADESH	1	$B$11<=$B$12	Binding	0
$C$11	KARNATAKA	1	$C$11<=$C$12	Binding	0
$D$11	MAHARASHTRA	1	$D$11<=$D$12	Binding	0
$E$11	MADHYA PRADESH	1	$E$11<=$E$12	Binding	0
$F$10		1	$F$10=$G$10	Binding	0
$F$7		1	$F$7=$G$7	Binding	0
$F$8		1	$F$8=$G$8	Binding	0
$F$9		1	$F$9=$G$9	Binding	0

5. ANALYSIS

Agriculture is a complicated interplay of nature and economics, it is affected by various social and economic factors. In the past, farmers haven't been able to maximize their potential because of the lack of subsequent technology and research.
However now due to the presence of techniques of Operations Research, a farmer can ensure maximum production and utilization of inputs. Operations Research can also ensure optimum utilization of land by deciding crop rotation patterns. Furthermore, it can help in deciding how land should be under cultivation for a specific crop.

In the first problem, for our data, we have used past Indian agricultural statistics of 2015-16. One part of our data was a yield of various crops in different states in India in unit kg/hectare. The crops being Rice, Maize, Sugar Cane, and Cotton and the states being Andhra Pradesh Madhya Pradesh, Gujrat, and Haryana respectively.

5.1 Objective

This data was used to form a balanced Assignment problem. The objective, in this case, was to maximize the total production of all the crops by assigning a state to a crop.

5.2 Significance

Although this following Assignment problem contains information about just four crops and their production in four states, it represents a methodology which can be used to identify which crops should be predominately grown in which state. Since the type of land in each state is different hence the production of different crops in different states is also varied. The type of land in each state depends on factors like:

1) Soil type
2) Fertility
3) Pest Pressure in the area

The crop that farmers chose to grow in an area depends on a variety of factors such as:

1) Government Incentives in that area – Subsidies
2) Demand for certain crops in the area
3) Season
4) Rainfall

Hence the crops that farmers eventually decide to grow to depend on a multitude of factors, however using the method of the opportunity loss matrix we were able to assign a single state to each specific crop using one simple constraint of production (in kg/hectare). By doing so we use past data to deduce a trend. This data can be used by farmers and other researchers all over India in deciding which crops can be grown in which state. Moreover, Central Government and State Governments can work in cohesion by using this data extensively to decide which crops to focus on in terms yield per hectare, which crops to focus in the market and which crops to provide subsidies on. This will prevent food shortage for the country as a whole

5.3 Results

The Assignment Problem shows that Rice should be grown in Haryana, Maize should be grown in Madhya Pradesh, Sugarcane in Andhra Pradesh and Cotton in Gujarat. These are the states that provide the maximum yield per hectare and are the most efficient.

In the second assignment problem, we have also taken past Indian agricultural statistics from the year 2008-09. We first formed a cost matrix, which contains the cost per quintal of growing four crops (Arhar, Maize, Moong, and Cotton) in four states: Andhra Pradesh, Karnataka, Maharashtra, and Uttar Pradesh respectively. The cost shown is the C2 cost of cultivation which is the sum of paid out costs, imputed value of family labor, interest on the value of owned capital assets, rent paid for leased-in land and the rental value of owned land. The second matrix contains the Minimum Support Price per quintal for the given crops given by the government in the year 2008-09. By subtracting the cost of the specific crop from its MSP we get the profit matrix, which represents profit per quintal for each crop in the given states.

In the second assignment problem, we have also taken past Indian agricultural statistics from the year 2008-09. We first formed a cost matrix, which contains the cost per quintal of growing four crops (Arhar, Maize, Moong, and Cotton) in four states: Andhra Pradesh, Karnataka, Maharashtra, and Uttar Pradesh respectively. The cost shown is the C2 cost of cultivation which is the sum of paid out costs, imputed value of family labor, interest on the value of owned capital assets, rent paid for leased-in land and the rental value of owned land. The second matrix contains the Minimum Support Price per quintal for the given crops given by the government in the year 2008-09. By subtracting the cost of the specific crop from its MSP we get the profit matrix, which represents profit per quintal for each crop in the given states.

5.4 Objective

This data was used to form a balanced Assignment Problem. The objective, in this case, was to maximize the total profit per quintal for the four crops in the given states.

5.5 Significance

Just like the first Assignment problem, this Assignment problem also contains information about just four crops and their costs of cultivation. Minimum Support Prices and their resultant profits in four states, it represents a methodology which can be used be used by farmers to maximize their overall profit by using Assignment problems in agricultural decision making. The cost of producing a certain crop in a given area depends on:

1) Availability of Manual Labor
2) Availability of Irrigational facilities
3) Cost of inputs (Seeds, Fertilizers, Pesticides, etc.)
4) Government Subsidies

The Minimum Support Price set by the government on various crops in a certain year depends on:

1) Cost of production
2) Changes in input prices
3) Input-output price parity
4) Trends in market prices
5) Demand and supply
6) Effect on the cost of living
7) Effect on the general price level
8) Parity between prices paid and prices received by the farmers.
9) Effect on issue prices and implications for subsidy

By using the method of Opportunity Loss matrix we maximize profits per crop, farmers can use these results to decide what crop to grow to attain maximum profits. The agricultural sector gives employment to the maximum number of people in our country, and hence earning higher profits will improve the standard of living. Farmers generating higher revenue leads to an increase in GDP, which leads to the overall advancement of the country.

5.6 Results

The Assignment Problem shows that Arhar should be grown in Madhya Pradesh, Maize should be grown in Madhya Pradesh, Moong should be grown in Maharashtra and Cotton should be grown in Karnataka to maximize profits.

6. LIMITATIONS OF OPERATIONS RESEARCH

- **Dependence on an Electronic Computer:** OR techniques tries to find out an optimal solution taking all the factors into account. In modern society, there are numerous factors and expressing them in quantity and establishing relationships among these require far too many calculations that can only be handled by computers. Small firms and corporations, who wish to get the best techniques in operations research, consider this aspect to be discouraging.
- **Non-Quantifiable Factors:** OR techniques provide a solution only when all the elements related to a problem can be quantified. All relevant factors do not lend themselves to quantification. OR model neglects all the factors that are unquantifiable.
- **Difficulty in conceptualization and utilisation by Managers:** The application of operations research is stated as a job which can be executed only by skilled professionals these experts may be mathematician or a statistician who have adept understanding and knowledge to formulate models, search for an effective solution and the correct suggestion for its execution and explain the working to a manager, but might not be aware of the business problems themselves. Likewise, a manager would be unable to comprehend the complicated working of Operations Research problem.
- **Time Costs:** To find a perfect OR solution and to apply the solution in the particular field is a time-consuming process. Thus at times the solution present at the time is more desirable than a perfect solution to the problem.
- **Costly:** Operations Research (OR) is very costly. This is because, in operations research, mathematical models are used for making decisions and solving different problems. The individual or entity would have to make multiple separate models for solving each type of new problem. All this increments the cost.

- **Not Realistic:** Operations Research professionals make highly complicated models for problem-solving. These models may not be realistic. These models sometimes work under certain assumptions which cannot remain constant in the real world. That is why these models may not be useful in real-life situations.
- **Complex**: OR is a very complex concept. Therefore, taking account of all the complexities of human relations and behaviour implementation of decisions arising from such a complex process is a tough and delicate task. In case of complicated solving of many problems, it is very tough for every real-life factor to be considered in a mathematical problem and henceforth making the formulations of solutions tough too.

7. LIMITING FACTORS FOR APPLICATION OF OR IN AGRICULTURE

- **Natural Calamities:** OR models cannot take into account the damage done to crops by natural calamities like drought, floods etc. Hence application of such techniques can only be done under certain assumptions which limit us to find the perfect solution.
- **Changes in Weather Conditions:** Changes in weather conditions have a direct impact upon the production of crops and it is a factor which cannot be controlled by anyone which makes it a limitation as to any effect of weather on production cannot be taken under consideration while applying OR techniques.
- **Hikes in Fuel Prices:** In OR models where the technique is used to find the perfect transportation or to minimize the cost of transportation the changes in fuel prices which in turn leads to increase in the cost of transportation becomes a limiting factor.
- **Demand for Products:** Agriculture is a highly volatile market which is led by the demand of crops and manipulation of such market is an easy task which results in hiked prices or very low prices which then discourages the production of crops.
- Hence, is a limiting factor while optimizing the production and allocation of resources.
- **Changes in Government Subsidies and Policies:** Subsidies offered to farmer and policies of certain states may change affecting the profit of the farmers and production of crops, another factor limiting the application of OR as it is dependent on the human behaviour and decision-making process.
- **Strikes and Riots:** As discussed the human behaviour is almost unpredictable and highly volatile. Strikes and riots are the outcome of human behaviour and affect the transportation of crops and production as well being an important factor that limits the application of OR

8. CONCLUSION

This research paper discusses how a very important but a very low profitable sector in India, which is agriculture, can use operations research to not only decide which crop can be grown most efficiently in which state but also can conclude which crop is the most profitable in the respective state. Two assignment problems were used to calculate the above-mentioned things. In the first problem it was concluded that Rice should be grown in Haryana, Maize should be grown in Madhya Pradesh, Sugarcane in Andhra Pradesh and Cotton in Gujarat, and in the second problem it was concluded that Arhar, if grown in Madhya Pradesh was most profitable, Maize in Andhra Pradesh, Moong in Maharashtra and Cotton in Karnataka. From these results, we conclude that if farmers in India make use of OR techniques, they can figure out what the maximum revenue they can earn is and also how efficiently they can grow the correct crop in the correct climate and state. If they do this, the agriculture sector will become very efficient and profitable, and it will grow at a much faster rate than what it is right now.

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