Utilizing LINGO, basic linear programming for cropping patterns

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***Abstract*— Water has emerged as a resource that is essential to the development of civilisation. Water scarcity necessitates careful planning, development, and management in order to use it effectively and sustainably. When there is a shortage of water, water resource managers' main goal is to make the best use of the water that is already available from a variety of sources while taking into account socioeconomic, ecological, and environmental factors. It has been observed that the inflows into the reservoirs frequently fall short of meeting the demand. In these situations, it is necessary to investigate the possibilities of combining the usage of abundant groundwater in the area with surface water to alleviate the shortage. Understanding of reservoir process and infield process is necessary for a reservoir system to operate optimally for the efficient usage of both surface and groundwater resources concurrently. By using optimization models, which are characterised by a mathematical definition of the objective function subjected to a set of constraints to produce global optimum solutions, this knowledge makes it easier to decide how to operate reservoirs and how to plant crops. Optimized flow chart of methodology is discussed for optimization of cropping pattern.**

***Index Terms*— Lingo, Linear Programming, Optimization, Irrigation Planning**

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[1] Introduction:

The primary goal of professionals in the field of water resources engineering is the effective, economical, and sustainable use and management of naturally renewable water resources. For life to exist and reproduce on earth, water, which makes up the hydrosphere and is one of the major components of the biosphere, is crucial. Water has a significant socioeconomic importance in addition to serving as the basis for life and as a source of environmental support. There are 30.8 million acres in Maharashtra State (India), of which 73% are arable. 40% of this cultivable region is at risk for drought, and 7% is at risk for flooding. According to Nikam and Regulwar, in order to keep the groundwater table within an acceptable range, irrigation demands for meeting crop water needs should be carefully met by using groundwater and available canal water.

Increased pumping costs, land subsidence, the infiltration of water of poor quality, the drying up of springs and shallow wells, and sea water intrusion in coastal areas are all possible consequences of unchecked overexploitation of groundwater that results in progressive drawdown below the minimum permissible piezometric levels. Therefore, by addressing the aforementioned issues caused by excessive pumping, optimal use of the region's surface water and groundwater would help in simultaneously addressing the water scarcity problems.

For agricultural scientists and practitioners, choosing a workable irrigated cropping system has always been a difficult professional and technical task while taking into accounts all agronomy and extension constraints. However, by utilising optimization approaches, such as the linear programming model, can be solved scientifically using Excel software.

CROPWAT is a useful tool that aids irrigation engineers, agrometeorologists, and agronomists in doing common calculations for evapotranspiration and crop water consumption studies, more particularly the design and management of irrigation schemes. It enables the formulation of suggestions for new irrigation techniques, the scheduling of irrigation systems under various water supply constraints, and the evaluation of crop output under rainfed or deficit irrigation conditions.

Since the 1980s, the foundation of Ethiopia's food security initiatives supported by the government and foreign donors has been the sustainable growth of small-scale irrigation systems. To address the continuous need for food security, a number of ground-breaking ideas have been put forth, including the creation of fresh small-scale irrigation projects. The choice of a workable cropping scheme that farmers can successfully apply is one of the main obstacles during the early stages of development of a new irrigation project. When engineers try to establish a system that maximises the revenue of the farmers while taking into account agronomic circumstances and the knowledge and experience of the farmers, this is often included in the feasibility study. Designers must discreetly take into account a range of agronomy and extension restrictions while deciding on the ideal cropping pattern, including crop water consumption, market demand, fertiliser input, labour requirement, capital input, the necessity for post-harvest processing, crop output level, and market prices.

It is thought that the choice of the best cropping method can be scientifically addressed by applying optimization techniques like a linear programming model, despite the fact that this is a difficult scientific and professional task. For irrigation farmers, the linear programming model quantifies the best approach to integrate restrictions in order to maximise crop yield and revenues. In many technical domains, the linear programming model is well-known as a trustworthy optimization tool.

Table 1 Few Review remarks

Author	Remarks
Stigler (1945)	First application of LP in the field known today as "diet problems"
Aparnathi and Bhatt	Surface and ground water were added as limitations, in order to improve the cropping pattern for a

(2014)	project being researched in their area.
Bertomeu and Gimenez (2006)	used a straightforward linear programming model to allocate farmers' resources and lands in the most advantageous way possible
Frizzone et al. (1997)	This method was used to optimise the utilisation of water resources in the irrigation project for Senator Nilo Coelho in Brazil.
Shreedhar et.al (2015)	carried out study to review the crop yield responses to deficit irrigation for the major crops in Kunigal command area
Srinivasa Raju et al. (2000)	Used LP models to obtain possible optimal cropping patterns and optimal operational policies considering different dependability inflow levels

[2] Water Resources Scenario in India

In 1950–1951, only 22.6 Mha of India's land was irrigated; however, due to subsequent attention, irrigation potential increased to 102.8 MHA till 2006–2007. According to estimates, India has a total irrigation potential of 140 Mha, of which 64 Mha would come from groundwater sources and 76 Mha from surface water sources. 300 km3 of surface water and 128 km3 of groundwater, or a total of 428 km3, were the amounts of water used for irrigation during the previous century. According to the estimations, by 2025, irrigation would require 611 km3 of water for a high-demand scenario and 561 km3 for a low-demand scenario. By 2050, these requirements are probably going to be 628 km3 for low demand and 807 km3 for high demand (Anonymous, 2011). India is blessed with a vast supply of water resources thanks to its 14 major and 44 medium river basins. The country's total water resources are estimated to be 185 M ha, of which 135 M ha are surface water and 50 M ha are ground water. However, the total utilisable water resources of the nation have been estimated at 105 million hectares, of which 35 million hectares are subsurface water resources and 70 million hectares are surface water flows (CWC, 2016).

Presently, the renewable water resources in India are being overexploited with climate change predictions pointing to a drier future. Changing global climate patterns coupled with declining per capita availability of surface and groundwater resources have made sustainable agricultural production a great challenge. In India, per capita availability of water is steadily declined from 5177 m3 in 1951 to 1544 m3 in 2011 which are projected to reduce as 1401 and 1191 m3 by the years 2025 and 2050, respectively resulting from rapid growth of population, industrialization, urbanization and declining groundwater table (Kumar et al., 2005). In addition, water quality both in urban and rural India is an issue requiring urgent attention at policy level. This challenge is even more severe, where groundwater is depleting, soil quality in respect of its water holding capacity is deteriorating and rainwater is getting more variable (Ayyappan, 2016).

Irrigation has long been recognized as an important factor for increasing agricultural production in India; the major reason for this dependency is the monsoon pattern of rainfall, which is generally capricious in its incidence and variable in its amount. Although the average annual rainfall is more than 1100 mm, there is tremendous variability from region to region. An estimated 80 to 85 per cent of the total average annual river flows occurs in the 3 to 4 monsoon months, which demonstrate the importance of water storage and irrigation (Dhawan, 2017).

Although, India has made tremendous progress in development of its irrigation potential, only two-third of the created irrigation potential is actually being utilized with very poor overall irrigation project efficiencies. Similarly the lack of qualitative and quantitative assessment of surface and ground water resources has made the management of irrigation sector more difficult. For managing the problems of water sector, effective analysis of hydrological process is essential which requires huge quantity and quality data. The system that allows storage and dissemination of hydrologic data is hardly available in the developing country like India. In addition institutional policies often limit access to the available data. Hence, there is a need for a dynamic hydrologic information system that is capable of handling hydrological data over space and time (Abbas et al., 2014).

[3] Linear programming (LP)

The restrictions and the function that needs to be optimised are linear relationships between the variables in the class of programming problems known as linear programming (LP). When resources are scarce, they must be distributed among the most important tasks or projects. This approach will increase or reduce a certain target function. The simplex method was used to arrive at the solution to the linear programming (LP) model. According to Maji and Heady (1980), a common LP problem can be expressed as follows in a more practical matrix notation:

Max/ (Min) Z = CT x; Subject to the constraints Ax > B and x> 0

Where C is a (nx1) known constant vector, x is a (n*1) known constant vector of choice variables, A is a (m*n) known constant matrix, and B is a (m*n) known constant vector. Finding x-advantages, or choice variables, that maximize (or minimize) the objective function Z and satisfy the equation, is the problem.

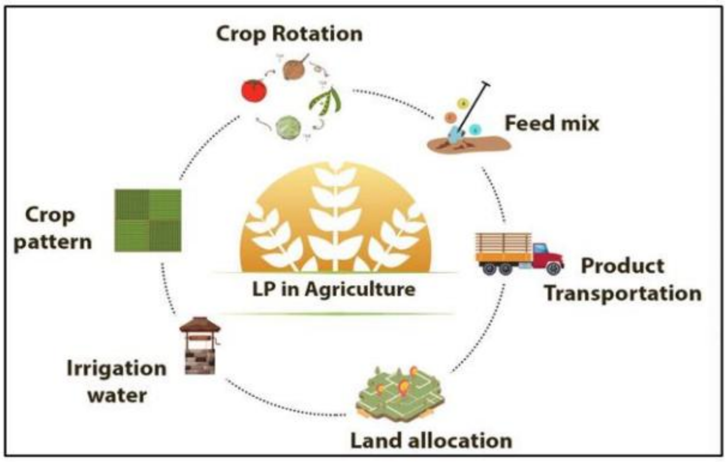

Figure 1 Linear programming applications in agriculture

[4] Uses of LP model

The model can be used to determine which agricultural projects should be chosen or combined in order to increase revenue or cut costs while staying within a given budget. It's an alternative to the traditional approach, which farmers were utilising to their detriment and involved "trial and error." The majority of issues that arise in farms are typically resolved utilising the LP model for three reasons:

1. Encouraging small farmers to use natural resources while increasing the profitability of their agricultural production and helping them meet the demand for food crops.
2. Applied to determine whether profit grew after the model was implemented and to maximise profit.
3. A lot of studies have been employing the LP model types, including fuzzy goal programming, to address issues in the agricultural sector, where ambiguity and vagueness have an impact on decision-making.

Table 2 Objectives formulated in the LP model [↓ Minimization, ↑ Maximization]

Categories	**Software Used**	**Objectives**
Optimal feed formulation	CPLEX Studio IDE, TORA software	↓: Cost of mixing the feeds.
Optimal crop rotation	MS Office Excel	↑: Total net income ↓: Costs per crop rotation
Optimum land utilization of food crops	LINGO software	↑: Agriculture production, Net Profit, Net Present Value (NPV)
Optimal crop combination	LINGO, MS Office Excel, LINDO software	↑: Profit, Revenue, Net returns.
Economic distribution of crop water per month	LINDO software	↑: Net profit, Water productivity. ↓: Minimize the demand at the head of the channel

[5] LP Model formulation

In order to recommend the cropping strategy that will yield the greatest net benefit at various reservoir water availability, a linear programming model is developed. Water availability, crop land requirements, human labour costs, animal and machine power costs, seed costs, fertilisers and manure costs, fixed costs, etc. are among the limitations that affect the model's objective function.

Table 3 Maximization Function

Objective $Max\ Z = \sum Y_i A_i (R_i - C_i)$	**Subject to constraint** $\sum NIR_i A_i \le WA$ - Water Availability $\sum A_i \le CCA$ - Crop land requirement $\sum CHL_i A_i \le CHL$ - Human labour cost $\sum CAMP_i A_i \le CAMP$ - Animal and Machine power cost $\sum CS_i A_i \le CS$ - seed cost $\sum CFM_i A_i \le CFM$ - Fertilizer and Manure cost $\sum CUFE_i A_i \le CUFE$ - Unforeseen Expenditure

The average monthly precipitation data over the previous 30 years and the hydrometeorological data over the last 10 years are both utilised to determine the net irrigation needs for each crop in the research area. Using the software LINGO, the LP model created for the research region is run to maximise net benefits. The model's objective function is subject to the following limitations: the availability of water, the need for crop land, the cost of human labour, the cost of animal and machine labour, the cost of seeds, fertilisers, and manure, the cost of fixed costs, etc. The linear programming model is run with the lowest water availability set to 2000 Ha-m, and it is then run with the water availability increased in 500 Ha-m steps. The LP model's recommended acreage for each crop is less than or equal to the total area of land allowed to each crop as reported by the Irrigation department, achieving the goal of maximum net benefit.

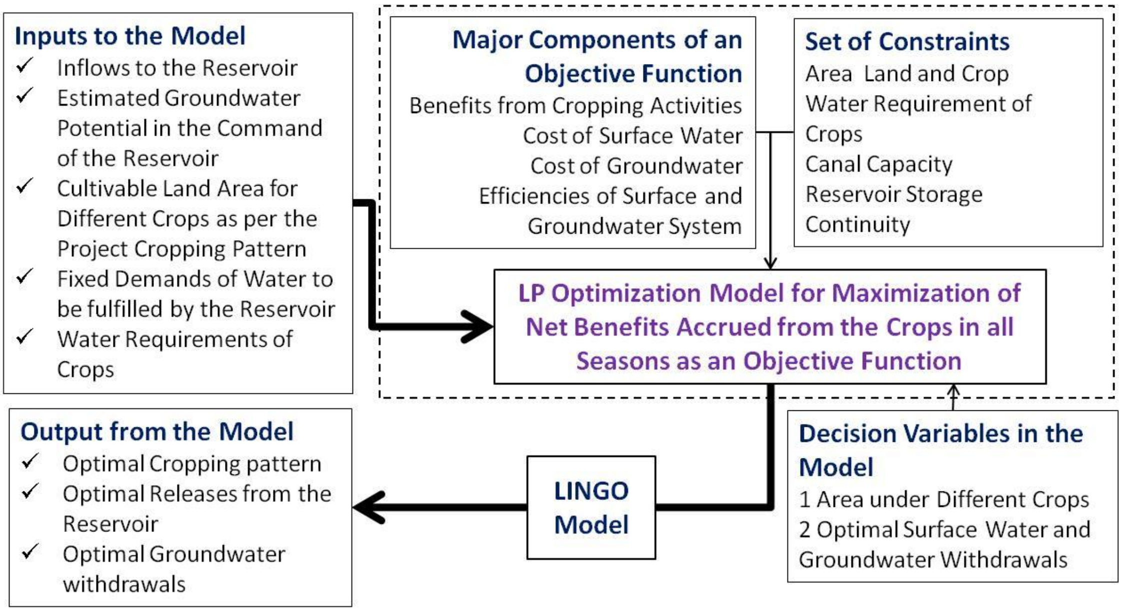

Figure 2: Methodology for LP Model (Source: Regulwar)

[6] Conclusion:

The paper has thoroughly discussed the primary goals of this research in relation to LP and how it can be very helpful in optimising issues in the agriculture sector. Whenever achieving efficiency is the primary objective, LP is frequently relevant. This is advantageous for farmers since it eliminates the need for trial and error when allocating resources and making decisions. This review examined the applicability of the LP model in the agriculture sector in several domains because there was a dearth of survey papers on the themes. According to earlier research, there are three basic justifications for employing the LP model to address the majority of farm challenges. One of them is to encourage small farmers to use environmental resources, boost the profitability of their crop production, and assist them in meeting the need for food crops. The majority of research demonstrated the effectiveness of LP in resolving practical issues and delivered trustworthy outcomes. Future research will conduct in-depth analyses of further LP applications, compare several models, and then list the benefits and drawbacks of each model.

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