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Multi – Objective Optimization for NALGONDA District Crops Irrigated from LAL BAHADUR SHASTRI Canal Using Dynamic Programming

Sandhya Kiran J.K*, S. Vishnuvardha**, M. Yogesh**, V. Varun Kumar**, M. Prithvi Kumar**

Assistant Professor, Student***
Department of Civil Engineering
St. Martin's Engineering College, Hyderabad, India, 500043.
Corresponding Author's email id: *sandhyakir@gmail.com*

Abstract

The pattern of supply of Irrigation water to the crops has significant effect on the agricultural production and effective utilization of water resources. Determining the optimal supply pattern of limited available water resources is done through mathematical optimization. Dynamic programming is a optimization technique used in this study. Dynamic programming is multistage optimization technique applied to solve optimization problems. The study area is Nalgonda district in Telangana. The major crops grown are Maize, Jowar, Bajra, Groundnut, Cotton, etcetera. Nalgonda district receives water from Nagarjuna Sagar dam through left canal (Lal Bahadur Shastri canal). The crops are divided into stages and productivity for different water allocations for each crop is determined and dynamic programming is executed. After applying dynamic programming, the available irrigation water is effectively distributed to the crops.

Keywords*: - Dynamic programming, Optimization, Optimal water supply pattern, Maximum productivity.*

INTRODUCTION

The main aim of irrigation is to supply water effectively to the crops in order to obtain maximum yield. The pattern of supply of water is based on the various considerations such as type of crop and water required for the crops to yield. To determine the pattern of supply mathematical optimization methods such as linear programming, integer programming, robust programming, dynamic programming, etc., are used. In this study we used dynamic programming. It is a multi-stage optimization technique applied to the solving of general optimization problems to permit optimal allocation of available resources at each stage.

Dynamic programming is a method developed by Richard Bellman in 1950s and has numerous applications in various fields such as economics, aerospace engineering, water resources, etc., It refers to breaking down a complicated problem into different stages in order to evaluate each stage in a recursive manner. Dynamic programming allows characterize each stage separately and give optimal value for the available resources in each stage. Dynamic programming provides general framework for variety of problems. DP can be done from up-down or from down-up framework.

Dynamic programming can be classified into 3 types:

- ***Initial value problem:*** In initial value problem, the value of the initial state variable is known

- ***Final value problem:*** In final value problem, the value of the final state variable is known.

- ***Boundary value problem:*** In boundary value problem, the values of both the input and output variables are known.

Dynamic Programming works once a retardant has the subsequent features:

- ***Optimal Substructure:*** If associate optimum resolution contains optimum sub solutions then a retardant exhibits optimum substructure.

- ***Overlapping subproblems:*** once a algorithmic program would visit identical subproblems repeatedly, then a retardant has overlapping subproblems.

OBJECTIVES:

- To irrigate the crops of Nalgonda district from irrigation water available in Nagarjuna Sagar dam reservoir.

- To distribute the available irrigation water effectively to all the crops that are cultivated in Nalgonda district.

- To regulate the input quantity of irrigation water to the crops for efficiency.

LITERATURE REVIEW:

Lily Montarcih Limantara, Sari Narulita (September 2019) have done work on "Optimization of Water Allocation at Irrigation Area of Molek-Kepanjen Regency of Indonesia Using Dynamic Programming" and concluded their results as:

Their study tries to optimize the irrigation water supply at DI Molek. The Dynamic Programming is used to solve this problem. Obtained Result conclude that the benefit of water allocation at DI Molek would be increased by 6.37% for low discharge seasonal year and by 10.86% for dry discharge seasonal year.

Priya.N, Geetha.G (September 2017) have done work on "Dynamic Programming Based Resource Optimization in Agricultural Big Data for Crop Yield Maximization" and discussed their results as follows:

Their study uses Dynamic Programming based Resource Minimization Algorithm (DRMA) to optimize the water, fertilizer, micronutrients requirement based on the availability and requirement in each stage of the crop's growth. The DRMA model optimizes water level, fertilizer and micronutrient requirements based on the type of soil, amount of rainfall and weather data. In addition, the proposed approach can also be extended by supplying the optimized values of the resources to an analytical model to decide on the type of crop to be grown at any given location that would provide a better yield thereby giving higher Return on Investment (ROI).

R. Lalehzari, S. BoroomandNasab, H. Moazed and A. Haghighi (2016) done work on "Multiobjective Management of Water Allocation to Sustainable Irrigation Planning and Optimal Cropping Pattern" and discussed their results as follows:

A multiobjective programming model is proposed for optimal allocation of surface and groundwater resources under water deficits in arid and semiarid regions. This paper considers a biobjective problem in water allocation to agricultural areas by using a nondominated sorting genetic algorithm (NSGAII) as a multiobjective optimization method. Accordingly, there are two maximization objectives:

- net benefit and
- relative water use efficiency.

Moreover, the optimized results of the aforementioned objectives have been determined to verify NSGAII solutions. Groundwater discharge, economic parameters, and evapotranspiration is formulated as three groups of constraints are linked together by the appropriate linear mathematical functions. The applicability of the irrigation scheduling is evaluated in the experimental field located at Baghmalek plain, Khuzestan province, Iran. The values of crop factors for different growth stages were estimated to obtain the production functions of wheat, barley, rice, maize, melon, tomato, onion, vegetable, and bean. The results showed that the model did not suggest deficit irrigation for melon and tomato during the middle stage. Overall, incorporating multiobjective optimization techniques using NSGAII can effectively improve precision in irrigation scheduling.

S. Vedula, D. Nagesh Kumar (April 1996) done work on "An Integrated Model for Optimal Reservoir Operation for Irrigation of Multiple Crops" and explained the following

An integrated model is developed, based on seasonal inputs of reservoir inflow and rainfall in the irrigated area, to determine the optimal reservoir release policies and irrigation allocations to multiple crops. The model is conceptually made up of two modules. Module 1 is an intraseasonal allocation model to maximize the sum of relative yields of all crops, for a given state of the system, using linear programming (LP). The module takes into account reservoir storage continuity, soil moisture balance, and crop root growth with time. Module 2 is a seasonal allocation model to derive the steady state reservoir operating policy using stochastic dynamic programming (SDP). Reservoir storage, seasonal inflow, and seasonal rainfall are the state variables in the SDP. The objective in SDP is to maximize the expected sum of relative yields of all crops in a year. The results of module 1 and the transition probabilities of seasonal inflow and rainfall form the input for module 2. The use of seasonal inputs coupled with the LP-SDP solution strategy in the present formulation facilitates in relaxing the limitations of an earlier study, while affecting additional improvements. The model is applied to an existing reservoir in Karnataka State, India.

STUDY AREA

Here is a brief description about the Nalgonda District and Lal bahadur Shastri Canal.

Nalgonda District

Nalgonda District is in the Southern part of the Telangana Region between 16º25ˈ and 17º50ˈ of the Northern latitude and 78º40ˈ and 80º05ˈ of the Eastern Longitude covering an area of 14,240 sq.Kms. Nalgonda district is located at an Altitude of 421m from Mean sea level (MSL).

In Nalgonda district it has One major irrigation project Nagarjuna Sagar and 2 Medium Irrigation projects i.e. A. Madhav Reddy Project (AMRP) and Musi projects are present in Nalgonda district. Dindi is another medium irrigation project within the district.

The cropping pattern is practiced with based on climatic conditions and availability of irrigation sources. Paddy has been a major crop since ages.

Fig 1: Nalgonda District

Principal crops like jowar, bajra, grams etc., are mostly rain-fed crops. The commercial crops like chilies, cotton and groundnut comes under irrigation.

Nalgonda area ismostlydrained by the River Krishna along with its tributaries like Musi, Aler, Dindi, Halia and Peddavagurivers. The Musi River is the main tributary of river Krishna.

The crops considered for optimization are Maize, Rice, Jowar and Pulses.

Lal Bahadur Shastri canal

Lal Bahadur Shastri canal is the left canal originated from Nagarjuna Sagar Dam Built across Krishna River.

Nagarjuna Sagar has two canals, they are Jawahar canal (Right canal) and other is Lal bahadur Shastri canal (Left canal).

Table 1: land use pattern of Nalgonda District

Land use Pattern of the district	**Area (‘000 ha)**
Geographical Area	1424.0
Forest Area	83.7
Land Under Non-Agricultural Use	114.8
Permanent Pastures	65.9
Cultivable Wasteland	29.4
Land under Misc. Trees, crops and Groves	7.7
Barren and uncultivable land	122.1
Current fallows	320.9
Other fallows	168.2

Fig 2: Satellite image of Nagarjuna Sagar Dam

Table 2: Hydrology of Nagarjuna Sagar Dam

Source	Krishna River
Catchment Area	2,15,185Sq.km (83,083 Sq.miles)
Live Storage	90.58 TMC
Flood Discharge (Observed)	30,050 Cumecs (10.61 Lakh Cusec)
Designed Discharge	58,340 Cumecs (20.60 Lakh Cusec)

Lal bahadur Shastri canal is a major canal in the Telangana state in India which originates from the Nagarjuna Sagar Dam. The designed discharge of Lal Bahadur Main Canal at Head Regulator is 11,000 cusecs

Length of Lal bahadur Shastri canal-284 km

Start point- Nagarjuna Sagar Reservoir

End point- Munneru Acqueduct

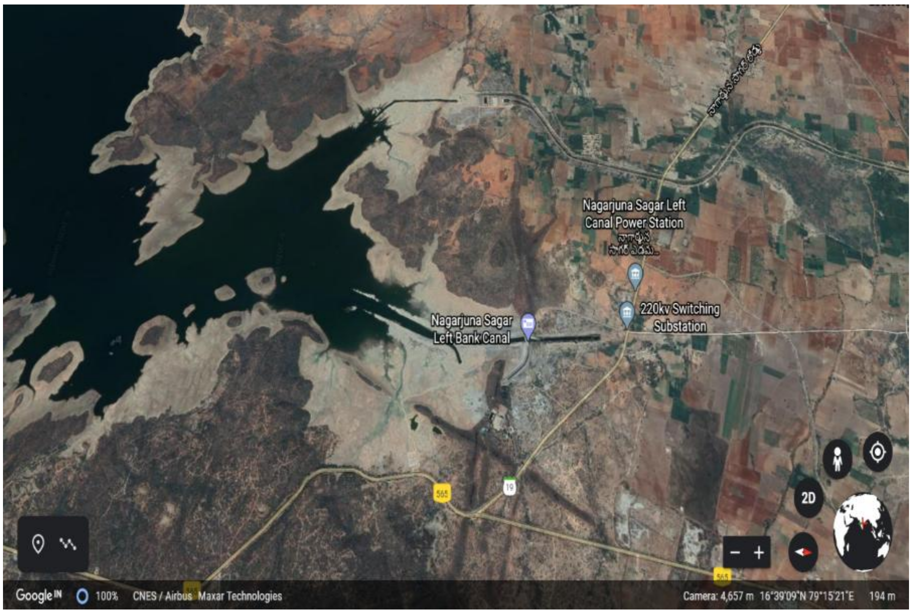


Fig 3: Satellite image of Lal Bahadur Shastri Canal

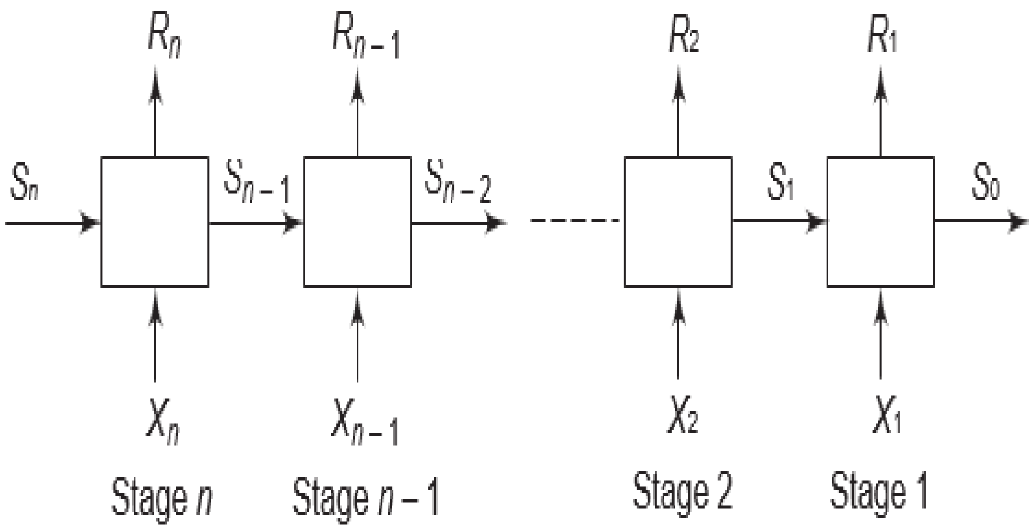


Fig 4: Multistage Decision Problem

METHODOLOGY:

Dynamic programming (DP) is ideally fitted to consecutive decision issues. consecutive (or multistage) decision issues are those within which choices are created consecutive, one after another, based on the state of the system.

The solution procedure for Dynamic programming issues relies on **Bellman's**

Principle of optimality, that states, "An optimum policy (a set of choices) has the property that regardless of the initial state and initial decisions are, the remaining choices should represent an optimum policy with regard to the state resulting from the initial decision."

A typical serial multistage decision problem, consisting of n stages as shown in Fig, S_n is the input to stage n, X_n is the decision taken at stage n, and R_n is the outcome at stage n, with respect to the decision X_n for the input S_n. As a result of this decision, the input S_n gets converted into output S_{n-1}, that forms the input to the next stage n-1.

In serial multistage decision-making problems, the stage numbers may be assigned in increasing order either in the forward direction or in the backward direction.

Forward Recursion

In forward recursion the solution starts from the first user, User 1, and proceeds in the forward direction to the last user, User n.

Let us consider 3 user allocation problem, and the procedure is as explained below.

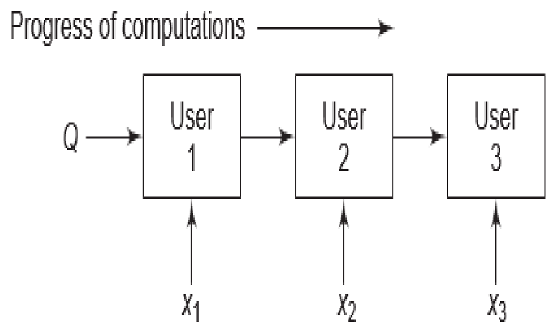


Fig 5: Three user forward recursion

Stage 1: In stage 1 only one user is considered that is User 1. The optimum value is obtained as

$$F_1^*(S_1) = \max [\, R_1(x_1)]$$
$$0 \leq x_1 \leq S_1$$
$$0 \leq S_1 \leq Q$$

Where

$F_1^*(S_1)$: maximum return due to allocation of S1

S_1: Amount of water that is available for allocation at stage 1 (to User 1)

x_1: Amount of water that is allocated to User 1

Stage 2: In second stage, two users are considered (User 1, and 2). The optimum value obtained as

$$F_2^*(S_2) = \max [\, R_2(x_2) + F_1^*(S_2 - x_2)]$$
$$0 \leq x_2 \leq S_2$$
$$0 \leq S_2 \leq Q$$

where

$F_2^*(S_2)$: maximum return due to allocation of S_2

S_2: Amount of water available for allocation to Users 1 and 2 together.

x_2: Amount of water allocated to User 2.

Stage 3: In the third (last) stage, all the three users are included in the optimization. The optimum value is obtained as

$$F_3^*(S_3) = \max [R_3(x_3) + F_2^*(S_3 - x_3)]$$
$$0 \le x_3 \le S_3$$
$$S_3 = Q$$

RESULTS AND DISCUSSIONS:

For proceeding further into applying dynamic programming the data required is gathered. The total quantity of water available for irrigation of crops like Jowar, Maize, Rice, Pulses in Nagarjuna Sagar dam is 10 TMC (10×10x9 Cubic Feet) which is supplied through the left canal (Lal bahadur Shastri canal). Four crops are selected from Nalgonda district to distribute that available irrigation water by applying dynamic programming. In order to proceed the productivity obtained from all the available possibilities of water that can be supplied to each crop is determined. This is predicted by supplying initially 0 TMC of water to all the crops. When no water is distributed obviously there will be no productivity. After that 1TMC of water is allocated to all the crops and productivity is noted. In the same manner all the possibilities such as 2 TMC, 3 TMC, 4 TMC, 5 TMC, 6 TMC, 7 TMC, 8 TMC, 9 TMC and 10 TMC of irrigation water is supplied to all crops and productivity is determined and noted and tabulated below.

Solving Procedure

Stage 1: Iteration of productivity of Maize crop.

By considering the Maize crop the productivity for different inputs of irrigation water in order to determine the Maximum Productivity pattern for each input.

In here,

$\mathbf{S_1}$ = Input irrigation water quantity in TMC for Maize.

$\mathbf{X_1}$= Dividing sub quantities of input S_1.

$\mathbf{R_1(X_1)}$ = Productivity for different inputs in X1.

$\mathbf{F_1^*(S_1)}$ = Maximum of $R_1(X_1)$.

$\mathbf{X_1^*}$= Irrigation water input for which maximum productivity is obtained.

Table 3: Data collected

WATER ALLOCATED (TMC)	MAIZE (Kg/ha)	RICE (Kg/ha)	JOWAR (Kg/ha)	PULSES (Kg/ha)
0	0	0	0	0
1	4500	2200	247	400
2	4700	2600	349	419
3	4750	2700	300	382
4	4800	2714	300	380
5	4978	3369	280	380
6	5303	3300	260	350
7	5400	3000	220	320
8	5300	3000	200	300
9	5200	2800	150	280
10	5000	2000	100	250

Table 4: Iteration table for Stage 1

S_1	X_1	$R_1(X_1)$	$F_1^*(S_1)$ =Max[$R_1(X_1)$]	X_1^*
0	0	0	0	0
1	0 1	0 4500	4500	1
2	0 1 2	0 4500 4700	**4700**	**2**
3	0 1 2 3	0 4500 4700 4750	4750	3
4	0 1 2 3	0 4500 4700 4750		

	4	4800	4800	4
5	0 1 2 3 4 5	0 4500 4700 4750 4800 4978	4978	5
6	0 1 2 3 4 5 6	0 4500 4700 4750 4800 4978 5303	5303	6
7	0 1 2 3 4 5 6 7	0 4500 4700 4750 4800 4978 5303 5400	5400	7
8	0 1 2 3 4 5 6 7 8	0 4500 4700 4750 4800 4978 5303 5400 5300	5400	7

9	0 1 2 3 4 5 6 7 8 9	0 4500 4700 4750 4800 4978 5303 5400 5300 5200	5400	7
10	0 1 2 3 4 5 6 7 8 9 10	0 4500 4700 4750 4800 4978 5303 5400 5300 5200 5000	5400	7

Stage 2: Iteration of productivity of Rice crop along productivity of Maize crop.

By considering the productivity of Rice crop for different inputs of irrigation water along with the maximum productivity obtained for different irrigation water allocations to Maize crop from above Iteration table:1 the maximum productivity of combined Rice and Maize is determined.

In here,

$\mathbf{S_2}$ = Input irrigation water quantity in TMC for Rice.

$\mathbf{X_2}$ **=** Dividing sub quantities of input $\mathbf{S_2}$.

$\mathbf{R_2(X_2)}$ = Productivity for different inputs in $\mathbf{X_2}$.

S_2 - X_2= Remaining water available for Maize crop.

F_1*(S_2 -X_2) = Maximum productivity of Maize for available S_2 -X_2 from iteration table:1.

R_2(X_2)+F1*(S_2-X_2) = Sum of productivity of Rice and Maize from columns $R_2(X_2)$ and F1*(S_2-X_2)

F_2*(S_2) = Maximum of **R_2(X_2) +F_1*(S_2-X_2)**

X_2* = Irrigation water input for Rice crop for which maximum productivity is obtained considering both crops.

Table 5: Iteration table for Stage 2

S_2	X_2	$R_2(X_2)$	S_2 -X_2	$F_1^*(S_2 -X_2)$	$R_2(X_2) +F_1^*(S_2-X_2)$	$F_2^*(S_2)$	X_2^*
0	0	0	0	0	0	0	0
1	0	0	1	4500	4500	4500	0
	1	2200	0	0	2200		
2	0	0	2	4700	4700		
	1	2200	1	4500	6700	6700	1
	2	2600	0	0	2600		
3	0	0	3	4750	4750		
	1	2200	2	4700	6900		
	2	2600	1	4500	7100	7100	2
	3	2700	0	0	2700		
4	0	0	4	4800	4800		
	1	2200	3	4750	6950		
	2	2600	2	4700	7300	7300	3
	3	2700	1	4500	7200		
	4	2714	0	0	2714		
5	0	0	5	4978	4978		
	1	2200	4	4800	7000		
	2	2600	3	4750	7350		
	3	2700	2	4700	7400	7400	3
	4	2714	1	4500	7214		

	5	3369	0	0	3369		
6	0	0	6	5303	5303		
	1	2200	5	4978	7178		
	2	2600	4	4800	7400		
	3	2700	3	4750	7450		
	4	2714	2	4700	7414		
	5	3369	1	4500	7869	7869	5
	6	3300	0	0	3300		
7	0	0	7	5400	5400		
	1	2200	6	5303	7503		
	2	2600	5	4978	5578		
	3	2700	4	4800	7500		
	4	2714	3	4750	7464		
	5	3369	2	4700	8069	**8069**	**5**
	6	3300	1	4500	7800		
	7	3000	0	0	3000		
8	0	0	8	5400	5400		
	1	2200	7	5400	7600		
	2	2600	6	5303	7903		
	3	2700	5	4978	7678		
	4	2714	4	4800	7514		
	5	3369	3	4750	8119	8119	5
	6	3300	2	4700	8000		
	7	3000	1	4500	7500		
	8	3000	0	0	3000		
9	0	0	9	5400	5400		
	1	2200	8	5400	7600		
	2	2600	7	5400	8000		
	3	2700	6	5303	8003		

	4	2714	5	4978	7692		
	5	3369	4	4800	8169	8169	5
	6	3300	3	4750	8050		
	7	3000	2	4700	7700		
	8	3000	1	4500	7500		
	9	2800	0	0	2800		
10	0	0	10	5400	5400		
	1	2200	9	5400	7800		
	2	2600	8	5400	8000		
	3	2700	7	5400	8017		
	4	2714	6	5303	8100		
	5	3369	5	4978	8347	8347	5
	6	3300	4	4800	8100		
	7	3000	3	4750	7750		
	8	3000	2	4700	7700		
	9	2800	1	4500	7500		
	10	2000	0	0	2000		

Stage 3: Iteration of productivity of Jowar crop along with productivity of Maize crop and Rice crop.

By considering the productivity of Jowar crop for different inputs of irrigation water along with the maximum productivity obtained for different irrigation water allocations to Rice crop along with Maize crop from above Iteration table:2, the maximum productivity of combined Jowar, Rice and Maize is determined.

In here,

$\mathbf{S_3}$ = Input irrigation water quantity in TMC for Jowar.

$\mathbf{X_3}$= Dividing sub quantities of input $\mathbf{S_3}$.

$\mathbf{R_3(X_3)}$ = Productivity for different inputs in $\mathbf{X_3}$.

$\mathbf{S_3\text{-}X_3}$= Remaining water available for Rice and Maize crops.

$\mathbf{F_2^*(S_3\text{-}X_3)}$ = Maximum productivity of Rice and Maize for available $\mathbf{S_3\text{-}X_3}$ from iteration table:2.

$\mathbf{R_3(X_3) + F_2^*(S_3\text{-}X_3)}$ = Sum of productivity of Jowar along with Rice and Maize from columns $\mathbf{R_3(X_3)}$ **and** $\mathbf{F_2^*(S_3\text{-}X_3)}$

$F_3^*(S_3)$ = Maximum of $R_3(X_3) + F_2^*(S_3 - X_3)$

X_3^* = Irrigation water input for Jowar crop for which maximum productivity is obtained considering all three crops.

Table 6: Iteration table for Stage 3

S_3	X_3	$R_3(X_3)$	S_3-X_3	$F_2^*(S_3-X_3)$	$R_3(X_3) + F_2^*(S_3-X_3)$	$F_3^*(S_3)$	X_3^*
0	0	0	0	0	0	0	0
1	0	0	1	4500	4500	4500	0
	1	247	0	0	0		
2	0	0	2	6700	6700	6700	0
	1	247	1	4500	4747		
	2	349	0	0	349		
3	0	0	3	7100	7100	7100	0
	1	247	2	6700	6947		
	2	349	1	4500	4849		
	3	300	0	0	300		
4	0	0	4	7300	7300		
	1	247	3	7100	7347	7347	1
	2	349	2	6700	6949		
	3	300	1	4500	4800		
	4	300	0	0	300		
5	0	0	5	7400	7400		
	1	247	4	7300	7547	7547	1
	2	349	3	7100	7449		
	3	300	2	6700	7000		
	4	300	1	4500	4800		
	5	260	0	0	260		
6	0	0	6	7869	7869	7869	0
	1	247	5	7400	7647		
	2	349	4	7300	7649		
	3	300	3	7100	7400		
	4	300	2	6700	7000		

	5	280	1	4500	4760		
	6	260	0	0	220		
7	0	0	7	8069	8069		
	1	247	6	7869	8116	8116	1
	2	349	5	7400	7749		
	3	300	4	7300	7600		
	4	300	3	7100	7400		
	5	280	2	6700	6980		
	6	260	1	4500	4760		
	7	220	0	0	220		
8	0	0	8	8119	8119		
	1	247	7	8069	8316	8316	1
	2	349	6	7869	8218		
	3	300	5	7400	7700		
	4	300	4	7300	7600		
	5	280	3	7100	7380		
	6	260	2	6700	6960		
	7	220	1	4500	4720		
	8	200	0	0	200		
9	0	0	9	8169	8169		
	1	247	8	8119	8366		
	2	349	7	8069	8418	**8418**	**2**
	3	300	6	7869	8169		
	4	300	5	7400	7700		
	5	280	4	7300	7580		
	6	260	3	7100	7360		
	7	220	2	6700	6920		
	8	200	1	4500	4700		
	9	150	0	0	150		

10	0	0	10	8347	8347	8468	2
	1	247	9	8169	8416		
	2	349	8	8119	8468		
	3	300	7	8069	8369		
	4	300	6	7869	8169		
	5	280	5	7400	7680		
	6	260	4	7300	7560		
	7	220	3	7100	7320		
	8	200	2	6700	6900		
	9	150	1	4500	4650		
	10	100	0	0	100		

Stage 4: Iteration of productivity of Pulses along productivity of Maize crop, Rice crop and Jowar crop.

By considering the productivity of Pulses for different inputs of irrigation water along with the maximum productivity obtained for different irrigation water allocations to Jowar crop along with Rice crop and Maize crop from above Iteration table:3, the maximum productivity of combined Pulses, Jowar, Rice and Maize is determined.

In here,

$\mathbf{S_4}$ = Input irrigation water quantity in TMC for Pulses.

$\mathbf{X_4}$= Dividing sub quantities of input $\mathbf{S_4}$.

$\mathbf{R_4(X_4)}$ = Productivity for different inputs in $\mathbf{X_4}$.

$\mathbf{S_4-X_4}$= Remaining water available for Jowar, Rice and Maize crops.

$\mathbf{F_3^*(S_4-X_4)}$ = Maximum productivity of Jowar, Rice and Maize for available S_4-$\mathbf{X_4}$ from iteration table:3.

$\mathbf{R_4(X_4) + F_3^*(S_4-X_4)}$ = Sum of productivity of Pulses along with Jowar, Rice and Maize from columns $\mathbf{R_4(X_4)}$ **and** $\mathbf{F3^*(S_4-X_4)}$

$\mathbf{F_4^*(S_4)}$ **=** Maximum of $\mathbf{R_4(X_4) + F_3^*(S_4-X_4)}$

$\mathbf{X_4^*}$ = Irrigation water input for Jowar crop for which maximum productivity is obtained considering all four crops.

Table 7: Iteration table for Stage 4

S_4	X_4	$R_4(X_4)$	S_4-X_4	$F_3^*(S_4-X_4)$	$R_4(X_4)+F_3^*(S_4-X_4)$	$F_4^*(S_4)$	X_4^*
10	0	0	10	8468	8468		
	1	400	9	8418	8818	**8818**	**1**
	2	419	8	8316	8735		
	3	382	7	8116	8498		
	4	380	6	7869	8249		
	5	380	5	7547	7927		
	6	350	4	7347	7697		
	7	320	3	7100	7420		
	8	300	2	6700	6900		
	9	280	1	4500	4780		
	10	250	0	0	250		

RESULTS OBTAINED AND DISCUSSIONS

After completion of optimization of water allocation for the crops by using Dynamic Programming the following are the results obtained to each crop and their maximum productivity.

The quantity of water that has to be distributed to the Maize, Rice, Jowar and Pulses crops to get maximum productivity from available irrigation water resources is determined by tracing back the optimal productivity values from iteration table 7 and up to iteration table 4

From iteration table 7 the maximum productivity for Pulses is obtained when 1 TMC of irrigation water is distributed to Pulses and remaining 9 TMC of water is further distributed to Jowar, Rice and Maize crops. The maximum productivity obtained from Pulses is 400kg/ha of 1 TMC distribution. The remaining 9 TMC of irrigation water is for Jowar, Rice and Maize crops. From iteration table 6 in 9 TMC distribution the maximum productivity is obtained when 2 TMC of irrigation water is distributed to Jowar and remaining 7 TMC of water is further distributed to Rice and Maize crops. The maximum productivity obtained from

Jowar is 349kg/ha of 2 TMC distribution. The remaining 7 TMC of irrigation water is for Rice and Maize crops. From iteration table 5 in 7 TMC distribution the maximum productivity is obtained when 5 TMC of irrigation water is distributed to Rice and remaining 2 TMC of water is further distributed to Maize crops. The maximum productivity obtained from Rice is 3369kg/ha of 5 TMC distribution. Then the remaining 2 TMC of irrigation water is distributed to the Maize crop. From iteration table 4 when 1 TMC of irrigation water is distributed to Maize crop the maximum productivity obtained is 4700kg/ha.

The total productivity obtained from distribution of 10 TMC of irrigation water to Maize, Rice, Jowar and Pulses crops is 8818kg/ha.

Table 8: Results obtained

Crop	**Obtained Water allocation (TMC)**	**Obtained productivity (Kg/ha)**
Maize	2	4700
Rice	5	3369
Jowar	2	349
Pulses	1	400

Table 9: Comparison between collected Data and obtained results

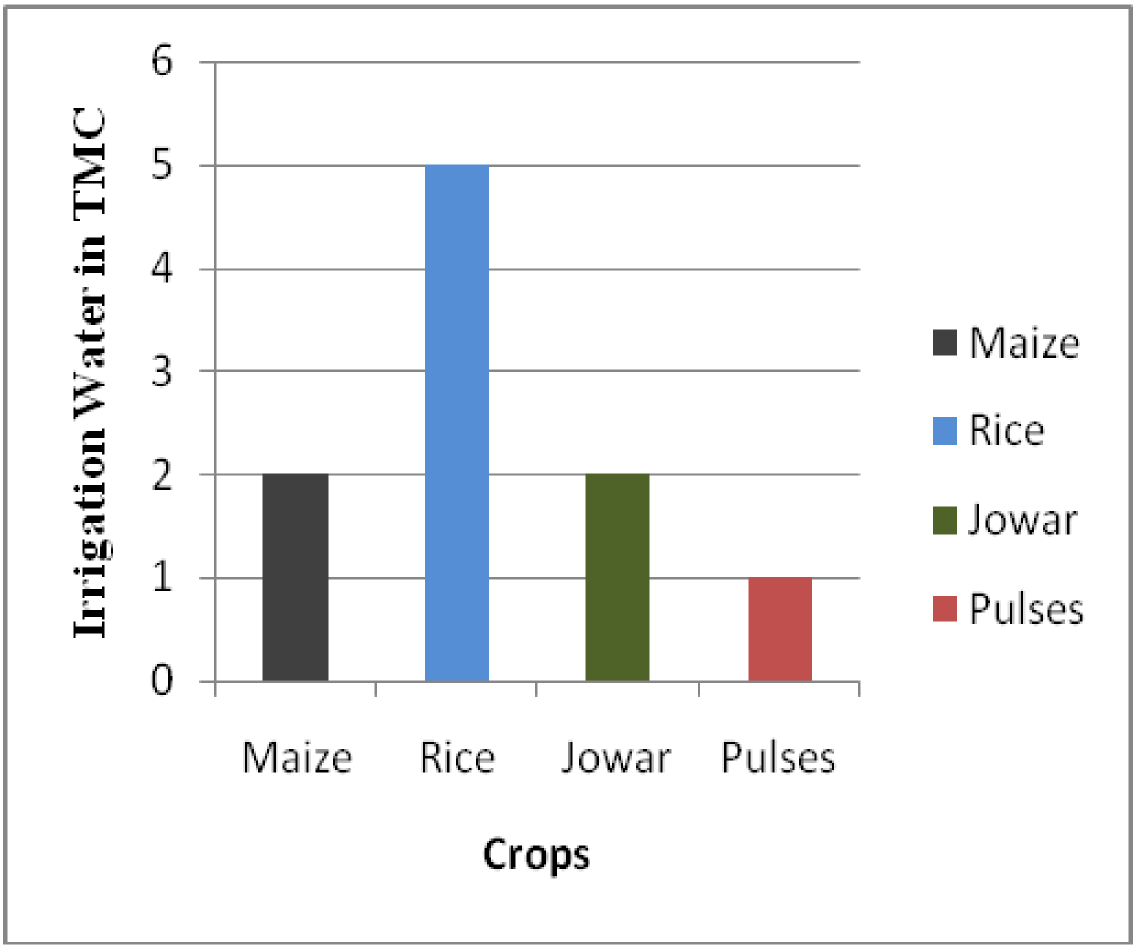
Type of crop	**Total required irrigation water**	**Productivity if required irrigation water is allocated**	**Available irrigation water to supply**	**Productivity for allocated water**
Maize	7 TMC	5400 kg/ha	2 TMC	4700 kg/ha
Rice	5 TMC	3369 kg/ha	5 TMC	3369 kg/ha
Jowar	2 TMC	349 kg/ha	2 TMC	349 kg/ha
Pulses	2 TMC	419 kg/ha	1 TMC	400 kg/ha
Total	**16 TMC**	**9537kg/ha**	**10 TMC**	**8818 kg/ha**

Usually for Maize crop total 7 TMC of irrigation water is required to produce 5400 kg/ha of production. But only 2 TMC of water is allocated to Maize after DP and productivity from allocated irrigation water is 4700 kg/ha.

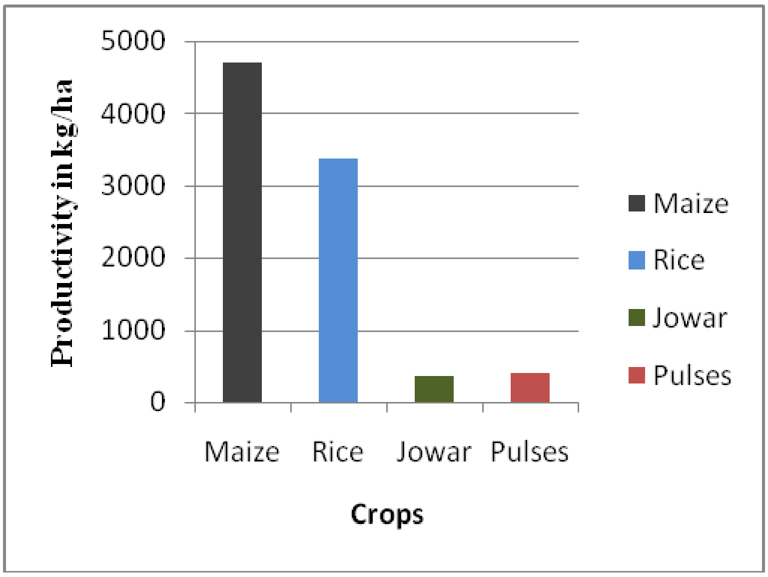
Alongside of Rice crop total 5 TMC of irrigation water is required to produce 3369kg/hectare and is allocated to Rice crop without any changes as per Dynamic Programming.

Jowar crop need 2 TMC of irrigation water to produce 419kg/ha and required irrigation water is allocated to Jowar as given in Dynamic Programming.

At last Pulses needs 2 TMC of irrigation water is required to produce 419kg/ha, whereas only 1 TMC of irrigation water is allocated to Pulses as given by the Dynamic Programming procedure.



Graph 1: Distribution of available irrigation water to crops



Graph 5.2: Productivity of Crops after allocating available irrigation water

CONCLUSIONS OF THE STUDY

From the obtained results after applying Dynamic Programming to the selected crops in Nalgonda district the total quantity of irrigation water required in order to get maximum from all the crops requires 16 TMC of irrigation water. But total available irrigation water is 10 TMC. If total 16 TMC of water is available al total of total productivity would be 9537kg/ha. Instead, we only have 10 TMC of irrigation water. From this 10 TMC of irrigation water the maximum productivity obtained is 8818kg/ha.

Achievements of Objectives:

- By applying Dynamic Programming, the productivity obtained from supply pattern
- is maximum for the available irrigation water resources.
- Different possibilities are analyzed and efficient supply pattern is selected.
- Input quantity of irrigation water for each crop is specified.
- Productivity from each crop is determined.
- Available irrigation water resources are managed effectively.

Scope for future studies:

- Based on above Dynamic Programming procedure, in further cases where available possibilities are altered by considering the available resources.

- This procedure can be computerized by programming it into software.
- Optimization can be mode on weekly basis based on quantity of irrigation water available in canal for usage.

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REFERNCES

I. **Dr. S. Vedula, Dr. P.P. Mujumdar** "Water Resources Systems: Modelling Techniques and Analysis" Indian Institute of Science, Bangalore

II. **Lily Montarcih Limantara, Sari Narulita (September 2019)** "Optimization of Water Allocation at Irrigation Area of Molek-Kepanjen Regency of Indonesia Using Dynamic Programming"

III. **Howell, Terry Allen (1974)** "Optimization of grain sorghum water use efficiency under high frequency irrigation by system simulation and stochastic dynamic programming"

IV. **Kennedy, John O.S (1981)** "Applications of Dynamic Programming to Agriculture, Forestry and Fisheries: Review and Prognosis"

V. **Y. J. Tsai, J. W. Jones, J. W. Mishoe (1987)** "Optimizing Multiple Cropping Systems: A systems Approach"

VI. **Guna N. Paudyal and Henry B. Manguerra (1990)** "Two-Step Dynamic Programming Approach for Optimal Irrigation Water Allocation"

VII. **James E. Epperson, James E. Hook, Yasmin R. Mustafa (1993)** "Dynamic programming for improving irrigation scheduling strategies of maize"

VIII. **Minkang Zhu, Daniel B. Taylor, Subhash C. Sarin (1993)** "A multi-objective dynamic programming model for evaluation of agricultural management systems in Richmond County, Virginia"

IX. **S. Vedula, D. Nagesh Kumar (April 1996)** "An Integrated Model for Optimal Reservoir Operation for Irrigation of Multiple Crops"

X. **Abdallah Ben Alaya, Abderrazek Souissi, Jamila Tarhouni and Kamel Ncib (2003)** "Optimization of Nebhana Reservoir Water Allocation by Stochastic Dynamic Programming"

XI. **Jitka Janova (2011)** "The dynamic programming approach to long term production planning in agriculture"

XII. **Hamid R. Safavi, Mohammad A. Alijanian (June 2011)** "Optimal Crop Planning and Conjunctive Use of Surface Water and Groundwater Resources Using Fuzzy Dynamic Programming"

XIII. **Directorate of Economics and Statistics (2015-14)** "Agricultural Statistics at a Glance Telangana" Hyderabad, Telangana

XIV. **CRIDA (2011)** "Agriculture Contingency Plan for District: NALGONDA"

XV. Performance Overview & Management Improvement Organization Central Water Commission (February, 2016) "Summary Report on Water Use Efficiency Studies For 35 Irrigation Projects"

