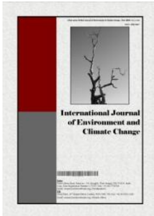

International Journal of Environment and Climate Change

10(12): 224-232, 2020; Article no.IJECC.63834
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Optimum Allocation of Water and Land Resource for Maximizing Farm Income of Jabalpur District, Madhya Pradesh

Vinay Kumar Gautam[1*], M. K. Awasthi[2] and Ayushi Trivedi[2]

[1]Department of Soil & Water Engineering, CTAE, MPUAT, Udaipur, (Raj.), India.
[2]Department of Soil & Water Engineering, CAE, JN Krishi Vishwavidyalaya, Jabalpur, (M.P.), India.

Authors' contributions

This work was carried out in collaboration among all authors. Author VKG designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Author MKA managed and checked the analyses of the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2020/v10i1230299
Editor(s):
(1) Dr. Hani Rezgallah Al-Hamed Al-Amoush, Al al-Bayt University, Jordan.
Reviewers:
(1) Rajesh Kumar, Chhattisgarh Swami Vivekanand Technical University, India.
(2) Diego Peruchi Trevisan, Federal University of São Carlos, Brazil.
Complete Peer review History: http://www.sdiarticle4.com/review-history/63834

Original Research Article

Received 15 October 2020
Accepted 21 December 2020
Published 31 December 2020

ABSTRACT

The continuous decrease and irrational use of water resources is the key issue for the proper application of water resources in tribal areas of Jabalpur district. This study attempts to propose a new aspect of optimum allocation of land & water resources in Jabalpur District. The minimum cultivated area that ensures food requirement and land constraint have a direct impact on water resources allocation. To conduct an accurate program for land and water resource allocation for water deficit area a multi- constraint linear programming model (LPM) was developed by implanting land resource as a constraint on water resources allocation which has to be considered by the demand of water resources in the agriculture sector. The result shows that increase in major crops area like rice, wheat, gram, maize and oilseeds crop areas against the reduction in sorghum, lentil, and sugarcane. Existing cropping intensity of the district was 150 %. To achieve the maximum profit per unit of land i.e. cropping intensity more than 200% for district, therefore an extensive measures was made for district to fix out the water demand supply gap for agriculture. In this study a user friendly Linear programming software was used to develop a model for optimum allocation

**Corresponding author: E-mail: vinaykumargautam24@gmail.com;*

of resources under seasonal and multi-crop condition for Jabalpur district. The net annual profit is increased by 9.1% under optimal allocation conditions. The sensitivity analysis of model parameter shows that the superior price of crop is the most sensitive parameter followed by the crop area. The results obtained from this study will definitely help policy makers to decide how to properly utilize and promote the water and land resources for the available area.

Keywords: Land & water; linear programming; cropping intensity; demand, supply; sensitivity analysis; sustainable plan.

1. INTRODUCTION

In present days the demand of land and water is increasing continuously in India. Increasing population has led to a growing demand for food and agricultural field enlargement, which is not easy to be supported by natural resources. The yield produced from agriculture farms has higher demand and supply is less that may affect the market values. Since past decades, farmers depend on a traditional method for agriculture or utilization of water and land resources to various crops varies depending on the accessible resources. Due to traditional farming for many consecutive years, the available resources are not being utilized properly, due to which no significant change in production has been observed and efficiency of the land is also not giving maximum returns. Alteration of cropping pattern could be responsible for increasing the net return per unit number of land and water resource availability. Linear Programming (LP) can hold an outsized number of constraints and thus, are an efficient operation to feature in optimization process. There is a necessity to have scientific studies on Linear Programming model (LPM) to optimize water resources and to formulate cropping pattern for optimized yield. This study was started with the target to find the optimized cropping pattern forgetting net profit at diverse level of water availability. The requirement of optimized resource allocation to fulfill the requirement of accelerating food demand.

The model objective and constraint functions are formulated as linear equation to find optimized cropping pattern. LP model is an optimization technique which is extensively used for allocation of the limited resources [1].Sustainable use of water and land resources not only affect the ecological system, but also provide stability to the socio-economic activates and environmental system. Modern agricultural operations require improved strategies and management options to address water, land use and productivity. Thus water and land resources should be used efficiently for the purpose of agricultural operations. Model related to LP was applied to examine the chances of combine use of surface and groundwater of canal in Andhra Pradesh [2].

A LP model was introduced for optimization of cropping pattern by providing the maximum permissible profit at diverse water level conditions in the Shahi Distributary canal region, situated in the Bareilly district, UP. The outcomes of this model displayed that farmers should avoid producing a certain crop repeatedly in a particular field and also making necessary changes based on the availability of water and land resources. To achieve maximum economic benefit based on full capacity of available water, the cropping pattern must be altered with an optimized recommended crop of rice, pulses, wheat and chick peas. In addition, it has been observed that production of wheat is beneficial in the study area [3].

Taking in to consideration the reviews of previous works and present requirement as mentioned earlier, this study has used a LP model for optimization of available resources to maximize the annual profit in study area. The optimization of water resources can be attained by using Linear programming model [4-6].

1.1 Study Area

The study for current area was selected as Jabalpur district. The area is located at the latitude 22^0 49’and 23^0 07’ north and meridian of longitude of $79^0$21’ & $80^0$35’ east at an altitude of 425.72 m Fig.1. It covers an area of 5197 km^2. The district has 7 blocks viz, Jabalpur, Patan, Sihora, Kundam, Panagar, Majholi, Shahpura. Jabalpur district situated at the meeting point of Vindhya and Satpura mountain range. The river Narmada and its tributaries viz. Hiran, Sakkar, and Gour River drain the district. The study area features tropical regional condition with an average annual rainfall of 1358 mm.

1.2 Geomorphology and Soil Type

District Jabalpur is a home of Geology since Formation from lower Proterozoic and

Pleistocene age are exposed in the area different types of aquifers are formed by these rocks in the area Jabalpur district can be divided in to three physiographic unit viz.vindhyan tract, the south eastern plateaus of Satpura and Bhitright range & associated hill area. Primary porosity in Gondwana sand stone & vesicular basalt in Deccan trap play an important role in groundwater movement. Districts covers mainly three types of soil viz. loam to sandy loam, medium black and deep black [7].

1.3 Data Needed

For the study area, the following input data were collected, i.e. Suitable crop for the study area and harvesting time and pattern, water requirement of crops, water and land resource availability for agriculture, labor availability, human and animal population, Production cost and selling price of different crops, district statistical data. All the above mentioned data were collected from Department of Agriculture, Jabalpur and District Collector office, Jabalpur. At district the weekly mean ET_0 varied between 21.8 mm/week to 65.1 mm/week. The mean monthly ET_0 surpasses the rainfall value for all the months except August, August and September as shown in Fig.1.

The normal maximum temperature received during December is 10^o C. The normal annual means maximum and minimum temperature of district is 33.2^0 C and 19.2^0 C [8].

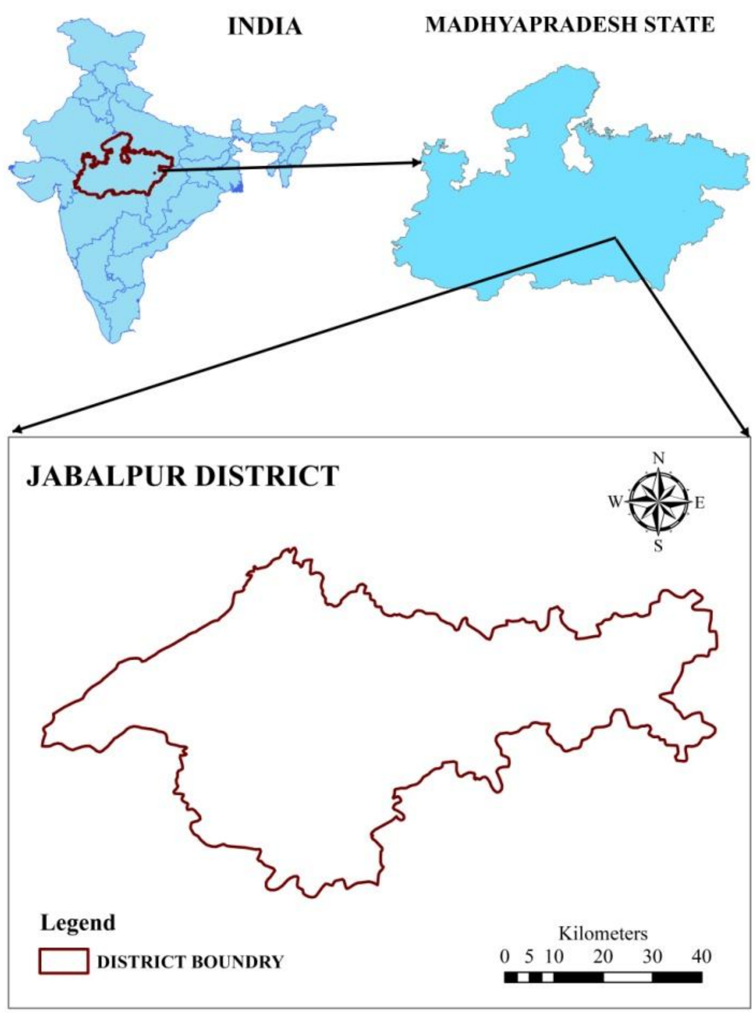

Fig. 1. Study area location

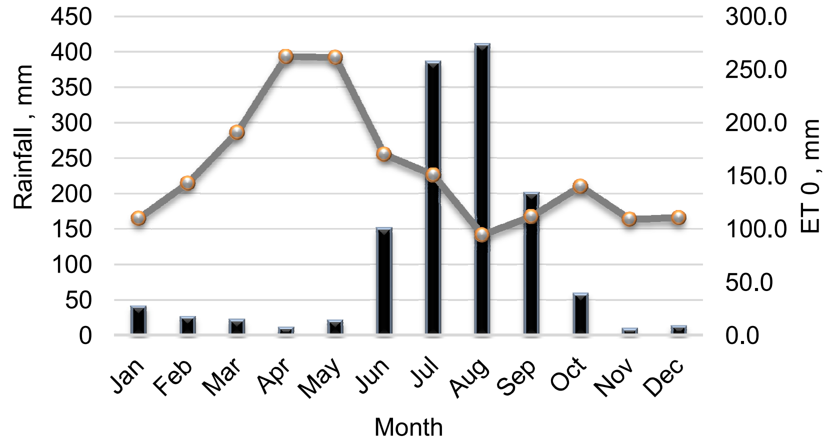

Fig. 2. Distribution of mean monthly rainfall and evaporation

2. MATERIALS AND METHODS

2.1 Availability of Water Resources

The total utilizable water is the addition of utilizable surface and groundwater. The total groundwater resources for unconfined aquifers are taken as annual groundwater recharge with the addition potential recharge in shallow aquifers. The total groundwater resource, thus computed will be available for utilization for agricultural, domestic and industrial purposes. About 85% of total utilizable groundwater is used for only irrigation purpose only. The total water resources available for utilization was estimated based on National commission on Agriculture Guidelines. As per estimation total utilizable water resources availability (including surface and groundwater) was 1820 MCM (million cubic meter). The available surface and groundwater resources presented on graph (Fig.3) [9].

2.2 Irrigation Water Requirement of Crop

Crop grown in the district during. For calculating crop water requirement, potential evapotranspiration is calculated from pan evaporation formula [10].

$$ET_0 = K_p \times E_p$$

Where, ET_0 is potential evapotranspiration (mm/day), E_p = Pan evaporation (mm/day), K_p= pan coefficient (dimensionless).

Crop evapotranspiration can be calculated by using formula,

$$ET_c = Kc \times ET_0$$

Where, ET_c is crop evaporatranpiration (mm/day) and Kc is crop coefficient. Water requirement of different crops are maintained (Table 1).

2.3 Cropping Pattern

The climate of district is congenial for successful cultivation of cereals, pulses, oilseeds and horticultural crops. 28% of total area comes under irrigated area. Gram, pea and wheat is the main Rabi season crop and catches around 70% of total CCA [11]. In kharif and Rabi seasons, lentil, soybean, groundnut, sesame, lentil and sugarcane crops are cultivated in a small manner [8]. Existing seasonal Cropping pattern and crop area in Jabalpur district is presented below in Table 2.

2.4 Model Formulation

An optimization model consists of objective function and set of different resource constraints. The development of optimization models for better implementation of water management practices, extended swiftly in the previous decade. In present days the concept of allocating water and land resources based on a market appliance that is dealing with water as any other commodity allocated according to its demand and supply a mathematical model was formulated to allocate water under different crops to get the maximum revenue out of each unit of it [12-13].

2.4.1 Objective function

The objective function determines the optimal combination of crop production that shows the maximization of net annual return above total costs. It denotes the net profit out of a given cost of crops to be planted, i.e. their cost of production subtracted from their final selling price at the market. In this method use in both condition existing and after proposed resources.

$$\text{Maximize } Z = \sum_{i=1}^{n} P_i A_i, \text{ For i = 1, 2, 3.......N}$$

Where,

Z = Net profit from obtained from crops (Rs)
N= Number of crops
P_i = Net profit from i^{th} (Rs.) and Ai = Crop area under i^{th} (ha)

2.4.2 Model constraints crop

In this study land and water resources were deliberated as model constraints.

2.4.2.1 Land area constraints

Land area is a first constraint for model. Land distributed for different crops must not be greater than the total available cultivable land for kharif and Rabi season. Expression for land constraints is given below:

$$\text{Land area constraints} = \sum_{i=1}^{n} (W_i A_i) \text{ should be less than } (W_w)$$

Where,

W_i=water requirement for i^{th} crop (mm)
W_w = Total water resources availability (surface and ground),ha m

2.4.2.2 Water availability constraints

Water availability constraints should not be greater than the total available water (surface and ground) resources for both seasons.

$$\text{Water Availbility constraints} = \sum_{i=1}^{n} (W_i) \text{ should be less than } (A_c)$$

A_c = availability of cultivable area for kharif and rabi season
W_w = Total water resources availability (surface and ground), ha m

2.4.2.3 Allowable area constraint

To fulfill the food requirement or to meet the local demand in the district, minimum and maximum land acreage must be restrict.

1. Lower limit

$Ai \le \mu_{ij} A_C$

2. Upper limit

$Ai \ge \mu_{ij} A_C$

Where, μ_{ij} = function of agricultural area that can be allotted to i^{th} crop in j^{th} season.

2.4.2.4 Non-negativity constraints

$A_i \ge 0$; $W_w \ge 0$ for all i and j

Ai = Crop area under i^{th}(ha.)
W_w= Total water resources availability (surface and ground), ha m
i = Total 1 to 15 crops

Total 15 crops (Kharif and Rabi) has taken for study under district viz.rice, sorghum, maize, pigeon pea, black gram, soybean, sesame, groundnut, lentil, wheat, sugarcane, pea, gram, lentil and other pulses.

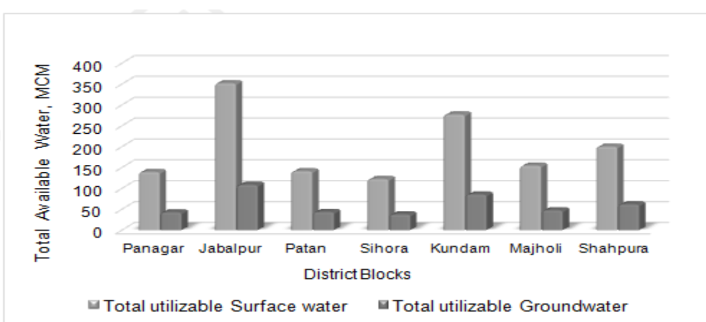

Fig.3. Total water available for utilization at different blocks of district
Sources: District statistical book, Jabalpur

Table 1. Water requirement (WR) of different crops at Jabalpur district

Kharif Crop	WR(mm)	Rabi crop	WR(mm)
Rice	823	Wheat	600
Sorghum	529	Gram	553
Maize	580	Lentil	518
Pigeon pea(Tur)	649	Pea	520
Black gram	518	Sugarcane	1376
Lentil	520	Other pulse	518
Soybean	444		
Sesame	555		
Ground nut	823		

Table 2. Existing seasonal cropping pattern and crop area in Jabalpur district

Kharif crop with area (ha)		Rabi crop with area (ha)	
Rice	87919	Wheat	102793
Sorghum	749	Gram	63676
Maize	5561	Lentil	26954
Pigeon pea(Tur)	12879	Pea	32812
Black gram	19042	Sugarcane	1609
Lentil	3754	Other pulse	1242
Soyabean	14327		
Sesame	1212		
Ground nut	140		

Source: District statistical book, Jabalpur

In this investigation the optimized cropping pattern and cropping area allocation so as to accessibility of water resources (surface and groundwater) were obtained for each Kharif and Rabi seasons by developing an optimization model. The linear programming model was implemented with a single objective function, subjected to a different resource constraint. TORA 2.0 Software was compatible to analyze the model. The model was applied to obtain the optimum allocation of cultivated land area of the selected crops.

3. RESULTS AND DISCUSSION

The development of optimization models for better management of resources is increasing extensively within the previous decade. LP model is used for multiple crop models and dynamic programming for uni-crop model. In irrigated agriculture, where various crops are contending for scanty water and land resources, LP is one of the most effective tools for optimization of water and land resources. The main objective of the model is to maximize the net profit considering the returns from crop.

3.1 Optimum Resources Allocation

The results are presented in the form of graph shows the optimum allocated area plotted together with existing cultivated area for kharif and rabi season crop. It can be seen that under optimal condition rice, maize, sesame and soybean area has increased against decrease in sorghum, pigeon pea, black gram and lentil for kharif crop season, While for rabi season wheat, gram and pea area has increased against decrease in lentil, sugarcane and oilseed crops. The maximum area during kharif and rabi season is increased for rice, maize, soybean wheat, gram pea, and sesame, meanwhile area is decreased for sorghum, pigeon pea, lentil, black gram, lentil, sugarcane and other oilseeds. It has also perceived that exploitation of water has increased under optimized condition. Figs.4 & 5 shows the existing area and optimally allocate area.

The new optimal area allocation graph is plotted together with existing cropping pattern in Figs.4 & 5. In kharif season rice, soyabean and maize cultivation area is increased by 5.65%, 15.85% and 4.66% respectively; while in Rabi season wheat and gram cultivated area is increased by 8.63% and 5.69 %. Minor changes was seen in pea cultivation area under the optimization process sorghum, pigeon pea, lentil, lentil and sugarcane area are reduced by 10%, 12%, 33% and 1.35% respectively. Decrease in sugarcane area is noticed due to higher water requirement.

3.2 Net Annual Income

The differences in net profit of seasonal crops depend on the crop yield, cost of cultivation and current market price [14]. These entire things area place specific, which can hit the net return directly. The net return from cultivation of crops was calculated considering a prospective yield. The Fig.4 and 5 shows the gross seasonal return. The annual profit from district has risen to the net income is increased to Rs. 21.35 Cr when compared to existing income. Fig. 6 & 7 indicates the total profit generated by optimal cropping pattern. Result evidently displays that to retain profit maximum the crop which is having maximum income get increased. In Jabalpur district, the net profit generated after optimization was 6.0 to 9.1% more of existing return.

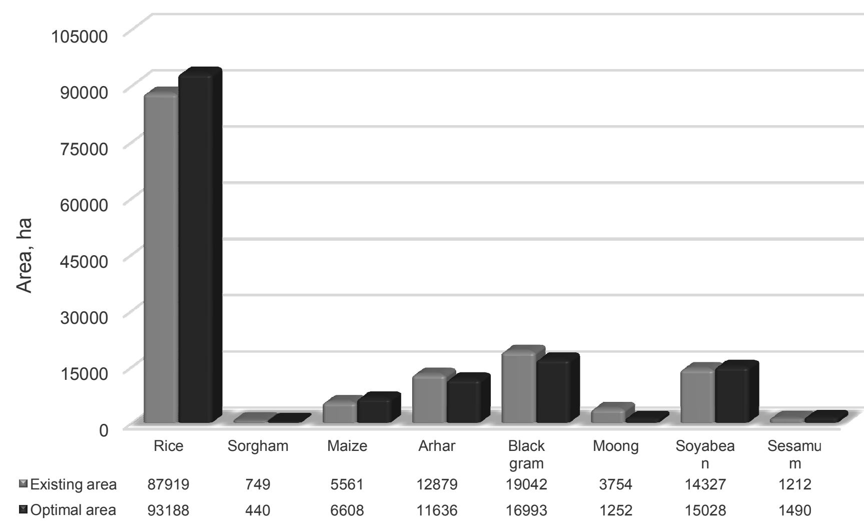

Fig. 4. Comparison of existing and optimal allocated area (ha) for Kharif season crop

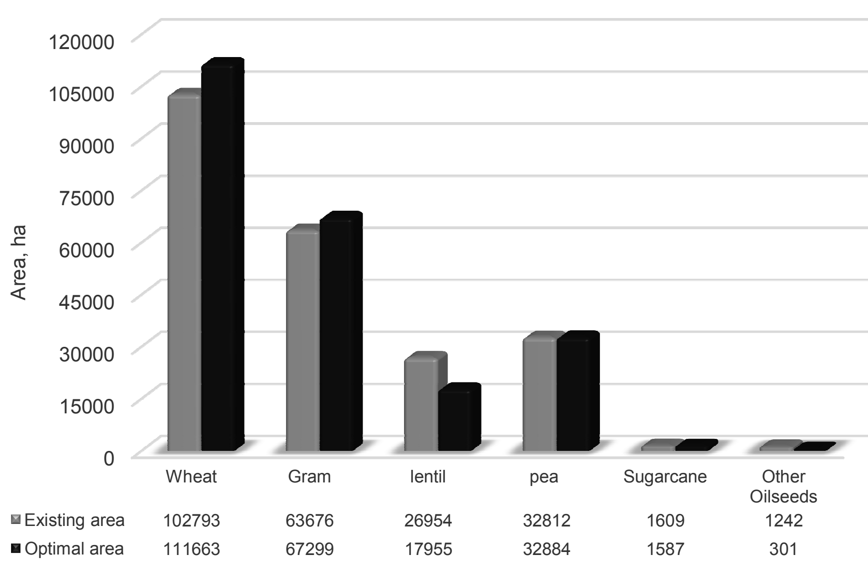

Fig. 5. Comparison of existing and optimal allocated area (ha) for Rabi season crop

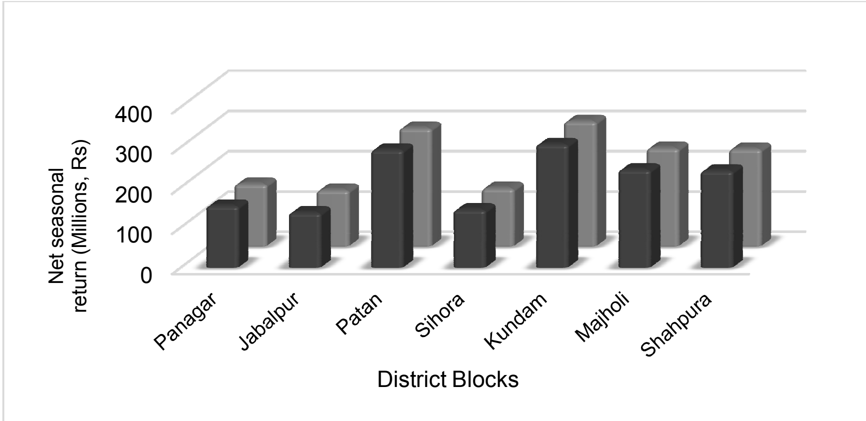

Fig. 6. Comparison of net seasonal return for Kharif crop

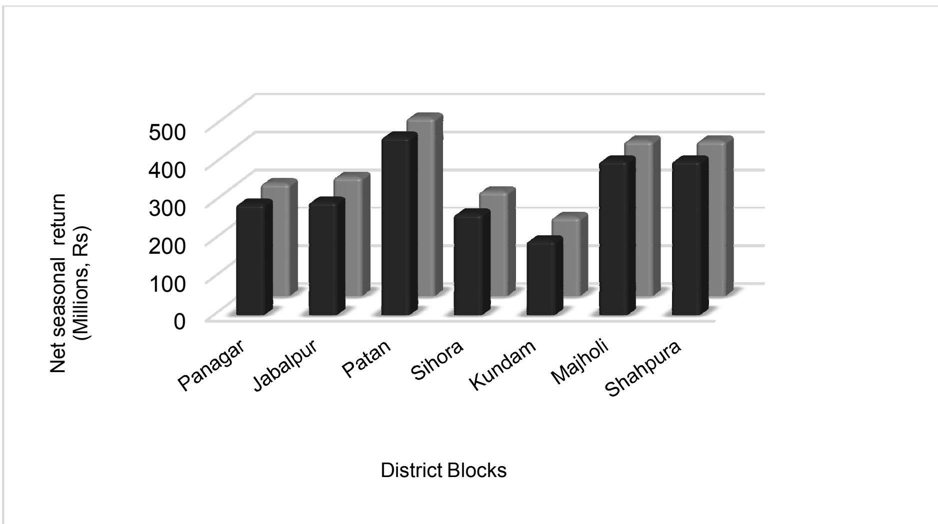

Fig. 7. Comparison of net seasonal return for Rabi crop

4. CONCLUSION

As per estimation total utilizable water resources availability (including surface and groundwater) was 1820 MCM (million cubic meter). Demand of water for achieving 200% cropping intensity can be encountered by conjunctive use of water for entire season. This analysis presents the formulation of model for seasonal land and water resource optimization for maximizing the net annual profit. The optimized land area attained from the model displays a slightly more deviation in yearly profit from the current cropping area by optimally utilization of available water (surface & ground) resources. However, this model can be differing by agro-climatic conditions and availability of good quality and quantity of water resources. The result shows that increase in major crops area like rice, wheat, gram, maize and oilseeds crop areas beside the reduction in sorghum, lentil, and sugarcane. The profit was increased by 9.1 %. The escalation in a land area was noticed due to allocate more area for higher yield and valued crop, which is a tool to boost the farm net profit but these are site specific application, sometimes not acceptable in the field level.

ACKNOWLEDGEMENTS

The authors are thankful to the District agriculture Department, District planning and statistics department and Krishi vigyan Kendra, Jabalpur for their extensive help and support during data collection and field survey. The author expresses their gratitude to the editor of the journal and all the anonymous reviewers for their fruitful and valuable annotations, which have led to a noteworthy perfection to the manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Matanga GB, Marino MA. Irrigation planning cropping pattern. Water Resource. Res. 1979;15(1):672-678.
2. Khar D, Jat MK, Sunder JD. Assessment of water resources allocation options: Conjunctive use planning in a link canal command. Resources, Conservation and Recycling. 2007;51(2):487–506. DOI: 10.1016/j.resconrec.2006.09.011
3. Singh D, Jaiswal C, Reddy K, Singh R, Bhandarkar D. Optimal cropping pattern in a canal command area. Agricultural Water Management. 2001;50(1):1–8. Available:10.1016/s0378-3774(01)00104-4
4. Singh A. Optimization modeling for seawater intrusion management. J. Hydrol. 2014;508(5):43–52. doi:10.1016/j.jhydrol.2013.10.042
5. Dasa Biswadip, Singha Ajay, Pandaa Sudhindra N, Yasuda Hiroshi. Optimal land and water resources allocation policies for sustainable irrigated agriculture. Land Use Polic. 2015;42:527–537.
6. Joodavi A, Zare M, Mahootchi M. Development and application of a stochastic optimization model for groundwater management: Crop pattern and conjunctive use consideration. Stoch Environ Res Risk Assess. 2015;29:1637–1648.
7. CGWB. District ground water information booklet, Jabalpur. A report published by Central Ground Water Board, Bhopal; 2013.
8. Gautam VK, Awasthi MK. Evaluation of water resources demand and supply for the districts of central narmada valley zone. Int.J.Curr.Microbiol.App.Sci. 2020; 9(1):3043-3050. Available:https://doi.org/10.20546/ijcmas.2020.902.350
9. Anonymous. District statistical book. District Statistics and Planning Department, Jabalpur, Govt. of M.P; 2015.
10. James G Larry. Principles of farm irrigation Design, John Willey and Sons Publishers, United Kingdom; 1988.
11. Awasthi MK, Tomar VS, Nema RK, Lodhi AS, Srivastava RN, Sharma SK. A book on water budgeting of Madhya Pradesh, college of agricultural engineering. JNKVV, Jabalpur, Madhya Pradesh. 2018;1-150.
12. Nazarifar MH, Momeni R, Kanani MH, Abolhasani A. Develop a non-linear optimization model for determining optimal cropping pattern under different water regimes. Academia Journal of Biotechnology. 2017;5(9):137-146. Available:10.15413/ajb.2017.0514
13. Sethi Laxmi N, Panda Sudhindra N, Nayak Manoj K. Optimal crop planning and water resources allocation in a coastal groundwater basin, Orissa, India. Agricultural Water Management. 2006; 83(1):209-220.
14. Singh A. Optimal allocation of water and land resources for maximizing the farm income and minimizing the irrigation-induced environmental problems.Stoch Environ Res Risk Assess. 2017; 31(2): 1147–1154.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/63834