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Optimization of landuse of Patapur Goladinni-nala watershed of Manvi Tq., Dist. Raichur, Karnataka

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ABSTRACT : Managing a watershed for satisfying the inhabitant's demand is a difficult task if one has to maintain a reasonable balance between usually conflicting environmental flows and demands. The solution to these complex issues requires the use of mathematical techniques to take into account conflicting objectives. Many optimization models exist for general management systems but there is a knowledge gap in linking practical problems with the optimum use of all land resources under conflicting demands in a watershed. In the present study, an optimization problem has been formulated for the Patapur Goladinni nala watershed of Manvi Tq. Raichur Dist. Karnataka, India. Comprising 446 ha to find out the most suitable crops allocation to different land covers, *viz.*, bajra, cotton, pigeonpea, sunflower and green gram fallowed with sorghum are the major crops, rainfall considered as a constraints and targeting maximization of profit. Considering average rainfall of 35 years and average 3 year cropping pattern considered as constraints, maximizing the net benefit and area under cultivation, benefit under crop and cost of cultivation to the crops are provided as inputs to formulate the objective functions and governing constraints in a multi-objectives linear optimization problem. The problem was then solved using the simplex method with the help of MS Excel solver software package and the optimal solution was ultimately determined. The results of the study revealed that the amount of net benefit increased to considering the existing cropping pattern of area 446 ha with profit worth Rs. 29,645 per ha. After optimization of land use based on crop water requirement and rainfall net profit increased to Rs. 31,429 per ha. The results of sensitivity analyses also showed that the objective functions were strongly susceptible to the constraint of maximum profit considering suggested cropping pattern without affecting to the existing land use pattern.

KEY WORDS : Watershed management, Optimization, Land use allocation, Linear programming, Patapur Goladinni- nala watershed

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The general goal of optimization of land use is to get continuously increasing and integrative benefits with social, economic and ecological features. Spatial land-use patterns affect the ecological, physical and socio-economic processes of a region in various ways (Brookes, 2001; Forman, 1995; Turner *et al.*, 2001). Therefore, a thorough understanding of land-use dynamics is necessary to predict future changes accurately, and to facilitate the development of sustainable management practices designed to preserve essential landscape functions (Hietel *et al.*, 2004; Lin *et al.*, 2007). Land use planning must be carried out according to the demands of social and economic development and environment protection to realize the optimal allocation of land resources. Optimization of land use means to find the best land use structure (Components and proportions of all kinds of land uses) which can bring better or best social, economic and ecological benefits by some methods. The conflict between environmental protection and the economic development by different land uses within a watershed are challenges facing land use planners in many developing countries (Peel and Lloyd, 2007; Gezelius and Refsgaard, 2007). Therefore, when we deal with land use decision making, we should make overall plan and take all factors into consideration and harmonize the correlations of all kinds of land use in the light of developmental planning of regional economy and society. Only in this way, sustainable land use

and regional development can be guaranteed.

In recent years, with the rapid growth of the economy and the population, and the continuous development of industrialization and urbanization, the problem in land use is getting more and more rigorous, especially as a populous country with relatively short of land use. Therefore, optimization of land use structure is the key point to enhance land management, as well as the hot point for the research of land use.

METHODOLOGY

The present study was taken up in a Patapur Goladinni nala watershed having an area of 481.60 ha which is located about 63 km from the Raichur city on Raichur-Lingasugur road (Fig. A). The study area is situated in the North-Eastern dry zone (Zone-2 of Region-1) of Karnataka and lies between 16^0 07'35.9" North latitude and 76^0 51'33.3" East longitudes to 16^0 08'22.3" North latitude and 76^0 53'27.7" East longitudes with an average elevation of 447 m above the mean sea level (MSL). The watershed fields are cultivated both under rainfed cultivation and with well irrigation. Agriculture land occupies the major area covering about 93 per cent of total geographical area of watershed and remaining 7 per cent of geographical area of watershed is covered by shrubs and fallow land. The Raichur district on whole has a dry climate. 35 years average rainfall of the region was 650 mm.

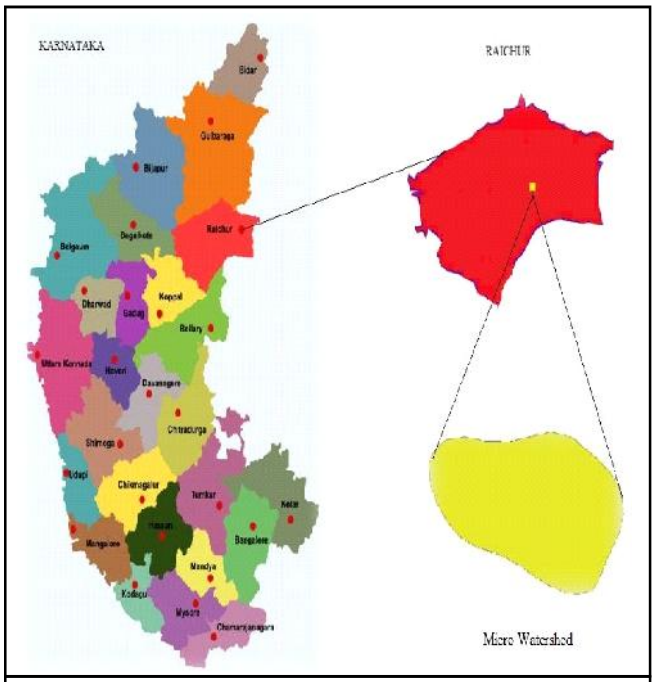

Fig. A : Location map of study area

Optimization of land use:

Maximizing returns from the watershed requires appropriate planning. In order to assess extent of net returns, the decision making factors will be the availability of rainfall quantity during the season and land resources. The methods adopted to make these decisions are explained below.

Optimization model:

It is necessary to work out optional plan of allocating crop area. While optimizing the area under various crops, the cost of cultivation and returns per ha were worked out based on the prevailing market rates.

The objective function of the model was to maximize the net returns considering the following:

– The cost of cultivation per ha under each crop.

– The returns obtainable from the each crop per ha considering prevailing market rates.

The constraints are as follows:

– Consumptive use of each crop during its growth period including losses.

– The maximum cultivable area.

The optimization process was attempted with the objective of verifying the possibility of land allocation for different crops when subjected to varied quantity of rainfall.

The algorithm of the model is as follows:

Objective function:

$$\textbf{Max NB} = \sum_{i=1}^{n} \mathbf{B_i A_i} - \sum_{i=1}^{n} \mathbf{C_i A_i}$$

Subject to

$$\sum_{i=1}^{n} \mathbf{G_{WR} A_i} \leq \sum_{j=1}^{n} \mathbf{Q_j}$$

$$\sum_{i=1}^{n} \mathbf{A_i} \leq \mathbf{A_c}$$

$$\sum_{i=1}^{n} \mathbf{A_i} \geq \mathbf{0}$$

where,

NB = Net benefit, Rs. ha^{-1}

A_i = Area under i^{th} crop

B_i = Benefit under i^{th} crop

C_i = Cost of cultivation i^{th} crop, Rs. ha^{-1}

i = 1,2,3…….. n

n = Total number of crops considered for optimization

Q_j = Quantity of water received from the rainfall.

j = 1,2,3…….. m

G_{WR} = Gross water requirement for each crop, m^3

A_C = Total cultivable area under consideration, ha

RESULTS AND DISCUSSION

The method optimization of land use was used to allocate cultivable area under the different crops using available rainfall subjected to water and land constraints. It could be observed

from the Table 1 that 446 ha area could be grown under 5 crops / crop groups when the area receives assured water supply from the rainfall. The existing cropping pattern in the watershed consists of cultivable crops namely, cotton (99 ha) followed by pigeonpea (90 ha), sunflower (94 ha), bajra (81 ha), sorghum (82 ha) and with waste land of (35.6 ha). This privilege pattern yields profit of Rs. 1,32,21,695 in a year.

Among these field crops, the net water demand for sunflower (237 mm) is less than that of Cotton (566.37 mm) and Pigeonpea (447.48 mm), with respective of net returns Rs. 28,000, Rs 29,500 and Rs. 39,705 (Market rates are considered in the year 2012-13). In the case less water consuming crops like sunflower and greengram a profit share would be 19.91 and 24.16 per cent. During *Kharif* greengram crop could be grown fallowed by sorghum crop, with assured income from the cultivation. However, cotton and pigeonpea being a major bi-seasonal crop of this agro-climatic zones (Zones-1 and 2 of Region-II, Karnataka), even under water-constrained conditions also an area of 99 ha would be grown. The cotton crop has a good returns of Rs. 39,705 per ha with profit share of 29.73 per cent. Though pigeonpea being equally important major bi-seasonal crop of the region, its average growing area is about 90 ha and net returns of Rs. 29,500 per ha. The bajra crop is also grown in this area for fodder purpose and as micro millets, considering the average cultivable area of 81 ha bajra yields net returns of Rs. 10,000 per ha with less profit share of 6.13.

Projected optimized cropping pattern in watershed area is presented in the Table 2. In this case, priority is given to the crops of less water requirement namely sunflower and sorghum. In order to maximize the profit by considering the average rainfall of the region 650 mm, it is proposed to grow greengram in an area of 108 ha, sorghum 108 ha, cotton 95 ha, pigeonpea 90 ha and Bajra 50 ha. The net returns from all crops with optimal allocation area in the watershed could set profit of Rs.1,40,17,575 as against a correspondence profit margin of Rs. 1,32,21,695 in the existing cropping pattern (Sadeghi *et al.*, 2009). The increased in the profit Rs. 7,95,880 could be achieved and of decreasing bajra (81 ha) by 31 ha and cotton (99 ha) by 4 ha. Whereas the proposed area under sunflower (94 ha) could be increased by 9 ha and sorghum (82 ha) 26 ha. The area under pigeonpea could be maintained at 90 ha area. The proposed optimization analysis at increasing the profit marginally by the cropping pattern sustainably.

Conclusion:

The optimization models were considered subject to constraints namely, quantity of rainfall available to the cultivable area of 481.60 ha and seasonal consumptive use of each crop water requirement. Considering the existing cropping pattern of area 446 ha with profit worth Rs. 29,645 per ha. After optimization of land use based on crop water requirement and rainfall net profit increased to Rs. 31,429 per ha.

Table 1 : Existing cropping pattern by considering the average cropping pattern in watershed area

Sr. No.	Crop	Area (ha)	Per cent crop area (%)	Cost of cultivation per ha (Rs ha^{-1})	Gross returns per ha (Rs ha^{-1})	Net returns per ha (Rs ha^{-1})	Total profit	B:C ratio	Per cent profit share
1	Cotton	99.00	22.20	26595	66300	39705	3930795	2.49	29.73
2	Pigeonpea	90.00	20.18	20000	49500	29500	2655000	2.48	20.08
3	Sunflower	94.00	21.08	14000	42000	28000	2632000	3.00	19.91
4	Bajra	81.00	18.16	8000	18000	10000	810000	2.25	6.13
5	Greengram followed with sorghum	82.00	18.39	26050	65000	38950	3193900	2.50	24.16
	Total	446.00	100.00				13221695		100.00

Table 2 : Proposed optimal cropping pattern in watershed area

Sr. No.	Crop	Optimized area (ha)	Per cent crop area (%)	Cost of cultivation per ha (Rs ha^{-1})	Gross returns per ha (Rs ha^{-1})	Net returns per ha (Rs ha^{-1})	Total profit	B:C ratio	Per cent profit share
1.	Cotton	95.00	21.30	26595	66300	39705	3771975	2.49	26.91
2.	Pigeonpea	90.00	20.18	20000	49500	29500	2655000	2.48	18.94
3.	Sunflower	103.00	23.09	14000	42000	28000	2884000	3.00	20.57
4.	Bajra	50.00	11.21	8000	18000	10000	500000	2.25	3.57
5.	Greengram followed with sorghum	108.00	24.22	26050	65000	38950	4206600	2.50	30.01
	Total	446.00	100.00				14017575		100.00

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