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Development of optimum crop plan through area allocation, income distribution and employment in case of finger millet (*Eleusine coracana*) using linear programming technique

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ABSTRACT

The present study is an attempt to assess the ragi (*Eleusine coracana* L.) production system with special reference to allocation of area, income distribution and employment in Tumakuru and Hassan districts of Karnataka. Farm survey method was used to collect data in order to develop linear programming representative farm models. The analysis takes into account crop activities, inputs used, farm size, etc. Out of total area allocation, the major area was allocated to maize (37.06%) followed by ragi (28.93%). The negative net returns from ragi (₹ 1342) was attributed to higher cost of cultivation and low crop yield coupled with low market price. The optimum crop plan per farm in the study area under rainfed situation indicated that, optimum allocation of the land, labour and variable capital among ragi, maize and redgram would yield net returns of ₹ 13442. The net returns under irrigated crop plan was three fold higher than the rainfed crop plan because of effective contribution of groundwater for increased productivity of commercial crops namely potato and maize. Ragi is best suited crop under the emerging climate change, groundwater exploitation and food scarcity issues. Therefore, there is a need to increase incentives which in turn helps the farmers to grow more ragi and enhances the farm income of farmers.

Key words: Incentive, Linear programming, Net returns , Optimum crop plan, Ragi

Efficiency in food production largely depends upon improvement in management of different resources. Hence the question of allocation and distribution of resources needs to be considered for sustainability, resource use efficiency and optimization of crop plans across regions and production environments. With the increasing population coupled with progressive shrinkage of land reducing the per capita agricultural land availability, crop intensification becomes a rule than an exception. Rising stress on water availability, commercialization of production, higher use of energy and other purchased inputs in agriculture necessitates optimum use of resources and reallocation of production choices. Cropping pattern is influenced by extent of irrigation, resource endowments, land type, rainfall, production technology, price expectation, rainfall, markets in addition to soil, climate, rainfall and cropping pattern which is influenced by irrigation water and the market opportunities.

Millet is a collective term referring to a number of small-seeded annual grasses that are cultivated as grain crops, primarily on marginal lands in dry areas in temperate, subtropical and tropical regions. Very limited quantities of millet are produced in the developed countries, primarily for a high-value specialty market as bird seed. Correspondingly, only limited quantities of millet are recorded in international trade.

In most parts of the world, millet is grown as a subsistence crop for local consumption. Commercial millet production is risky, especially in Africa, because there is a absence of large market outlets. Apart from grain production, millet is also cultivated for grazing, green fodder or silage. Millets are better adapted to dry, infertile soils than most other crops, and are therefore often cultivated under extremely harsh conditions - for example, high temperatures, low and erratic precipitation, short growing seasons and acidic and infertile soils with poor water-holding capacity. Livestock are an important component of most millet production systems, and millet crop residues contribute significantly to fodder supplies.

Some popular land race millet varieties in India, for example, are over 3-m tall, and are valued for the large amount of fodder they provide, even though grain yields are relatively low. Millets are often termed "coarse cereals". Millets are one of the best-kept secrets of our ancient ancestors. Traced back to its origin in China, millets has been used throughout the ages and across many countries.

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For centuries millets have been prized crops in China, India, Greece, Egypt and Africa, used in everything from bread to couscous and as cereal grains.

Millets contain high amount of fat, fibre and minerals compared to wheat and rice. The protein content in millets like jowar (10.4g), bajra (11.8 g), proso millet (12.5g), foxtail millet (12.3g), finger millet (6.8g) and barnyard millet (11.6g) are comparable with wheat (11.8g) and rice (6.8g). Finger millet contains lesser protein, but rich in mineral matter and calcium than rice and wheat (Anonymous 2014). All the millets contain more fiber than fine cereals.

Finger millet (*Eleusine coracana* L.) also is known to have several potential health benefits and some of the health benefits are attributed to its polyphenol contents (Chethan and Malleshi 2007). It has a carbohydrate content of 81.5%, protein 9.8%, crude fiber 4.3%, and mineral 2.7%, that is comparable to other cereals and millets. Its crude fiber and mineral contents are markedly higher than those of wheat (1.2% fiber, 1.5% minerals) and rice (0.2% fiber, 0.6% minerals); its protein is relatively better balanced; it contains more lysine, threonine, and valine than other millets (Ravindran 1991, Sripriya *et al.*1997).

MATERIALS AND METHODS

Tumakuru and Hassan districts of Karnataka were selected for the study, as they are the major ragi; one of the important millets growing districts of Karnataka. For this study, 80 sample farmers were selected randomly in each district. Eighty sample farmers comprise 40 rainfed and 40 irrigated ragi growing farmers. Data was collected from total 160 ragi growing farmers from the two districts.

In linear programming analysis, the linear function of a number of variables (objective function) is maximized (or minimized) subjected to number of constraints in the form of linear equalities or in-equalities. In this study, it was employed to develop the optimum crop plan under rainfed and irrigated conditions. The activities considered for developing the optimum crop plan under rainfed and irrigated condition in Tumakuru and Hassan district are as follows: per farm area under rainfed cultivation, labour availability for the farm, variable capital requirement for cultivation of crops in the farm area under food crops namely ragi and redgram as to meet minimum food consumption requirement. Similarly, for optimum crop plan under irrigated situation the following activities were considered; area under borewell irrigation in the farm, labour availability of the farm, variable capital requirement for cultivation of crops in the farm, area under food crops namely paddy and ragi as to meet minimum food consumption requirement.

The average area under different crops (ha), labour utilization (mandays), water applied to crops (acre inch), capital expenditure (₹) excluding labour cost incurred and net returns realized by farmers with borewell irrigation and rainfed were calculated, averaged and used for development of the optimum regional crop plan. The computational procedure is as follows.

In mathematical form, one year linear program can be expressed in the following way

Maximize Z for i=1, 2, 3, 4 …. N is the number of crops

Subject to the constraints

1. (i =1, 2, 3, 4…….N)
2. (i =1, 2, 3, 4…….N)
3. (i=1, 2, 3, 4…...…N)
4. (i=1, 2, 3, 4…….N)
5. (i=1, 2, 3, 4…….N)

where,Z= Net return (₹) from all crops grown by the farmer, N_i = Net return from the i^{th} crop (₹ /ha), X_i= Crop area under i^{th} crop (ha) (decision variable) , R= Rainfed area available for cultivation in the region (ha), I= Area under irrigation available for cultivation in the region (ha), W_i= Water requirement for i^{th} crop (ha cm), W_u= Total ground water availability (ha cm) , F_i= Food requirement of i^{th} crop in terms of area (ha), D_i=Labour requirement for i^{th} crop (mandays/ ha), L= Total agricultural labour availability per year for average farm (mandays), T_i= Variable capital required to produce i^{th} crop (₹ /ha), B= Total budget availability with the farmer (₹).

Objective function was to maximize aggregate net income from crops grown in the average farm in Tumakuru and Hassan districts. The objective function was subject to linearity and non-negativity constraints.

Land is one of the limiting resources on all farm situations. It is defined as operational area, which was equal to owned-land plus leased-in land minus leased-out land. The average size of operational holding in Tumakuru and Hassan districts was 1.57 ha and 1.90 ha under rainfed and irrigated conditions, respectively.

Ragi and readgram are important food grain crops under rainfed condition. Some area under ragi and readgram is required to fulfil the minimum food consumption requirement, therefore the minimum area for ragi and redgram was fixed. The average family size in Tumakuru and Hassan district was estimated at 5 members from the data collected. The average yield of ragi per ha was 17 q, minimum ragi required per family per year was 5 q. Hence, the minimum area under ragi was calculated as 0.3 ha. Similarly, minimum area required for redgram was 0.2 ha, where the average family requirement and yield per ha was 1 q and 5 q, respectively. In case of irrigated situation, maize is an important cash crop and paddy is the main food crop under bore well irrigated condition. Whereas, ragi is other important minor millet and staple food crop grown under irrigated conditions.The average family size in the study area was estimated at 5 members from the data samples. The average yield of ragi per hectare was 28 q, therfore minimum ragi required per family per year was 5 q. Hence, the minimum area under ragi was calculated as 0.2 ha. Similarly, minimum area required for the paddy was 0.1 ha, where the average family requirement and yield per ha was 5.5 q and 55 q, respectively.

The average family size was 5 members in Tumakuru and Hassan districts. Out of 5 members in a family two members were working in the agriculture. The labour availability for agriculture work per family was two

mandays per farm from the data 2014, multiplied with 125 days (average working days of agricultural labour per year**)**. The total agricultural labour availability was 250 days/year/farm.

To calculate capital use on the farm, the costs of seed, manures, fertilizers, pesticides, insecticides, hiring of bullocks and machinery, irrigation charges, etc. were added up and the cash requirements for cultivation of crops under rainfed situation. For estimating capital availability on the farm, it was assumed that, the expenditure incurred on variable inputs was taken as per data collected from sample farmers from the respective crops and it was ₹ 84623 and ₹ 174277 under both rainfed and irrigated situations, respectively. The farmers under rainfed situation were capital constrained, it has assumed that, available capital with farmers at least constrained by 10% than the required one. Total available capital with the farmer per average farm was nearly ₹ 75000 and farmers under irrigated situation were better in financial condition than the rainfed ones. Therefore, it was assumed that, capital available with the irrigated farmers is 25% more than the rainfed situation. The cash available with the irrigated farmers for spending on variable input was ₹ 100000.

Water is an important input for crop cultivation. Groundwater is the source for irrigation in the study area. The average borewell yield in the study area was 3 inch. The average hours of pumping per day was 4 and average pumping days per year was 250. By this, the groundwater available per farm per year was calculated as 110.48 acre inch.

The variables in the linear programs must be greater than or equal to zero and the returns or inputs should not be negative.

RESULTS AND DISCUSSION

Ragi production system under both rainfed and irrigated situations

The ragi production system with special reference to area allocation, income distribution and employment are presented in Table 1. The results revealed that, the average land holding in rainfed and irrigated situation was 3.94 acre and 4.75 acre, respectively.

In case of rainfed condition, out of total area allocation, the major area was allocated to maize (37.06%) followed by ragi (28.93%). Maize was a predominant crop and more area was under cultivation by rainfed farmers in the study area. This is also due to the fact that, maize gives higher net returns with low risk (pest and disease incidence). The next important crop in the study area under rainfed condition was ragi, it is a staple food crop of southern Karnataka, the farmers grow ragi mainly for the subsistence of their family and to meet fodder requirement. These findings are in confirmatory with the results of Varalakshmi *et al.* (2011).

With respect to income distribution and employment opportunities, the major chunk was from maize. The farmers growing maize has realized higher net returns (₹ 6579) and created more employment opportunities (42 mandays) in the study area. As, maize is one of the important cash crop grown extensively in order to reap more benefits. The next major crop grown by farmers in order to get higher net returns was redgram (30.57%). The negative net returns from ragi (₹ 1342) was attributed to higher cost of cultivation and low crop yield and less market price, even though it created more employment opportunities (31 mandays) in the study area.

Table 1 Production system of ragi in terms of area allocation, income distribution and employment

Crops	Area allocation (acre)	Net income (₹)	Employment (mandays)
Rainfed			
Ragi	1.14	-1342	31
	(28.93)	(-12.75)	(27.19)
Redgram	0.50	3219	15
	(12.69)	(30.57)	(13.16)
Maize	1.46	6579	42
	(37.06)	(62.48)	(36.84)
Groundnut	0.84	2074	26
	(21.32)	(19.70)	(22.81)
Total	3.94	10529	114
	(100.00)	(100.00)	(100.00)
Irrigated			
Ragi	0.98	2609	36
	(20.63)	(4.98)	(19.05)
Paddy	1.05	13636	40
	(22.11)	(26.03)	(21.16)
Maize	1.26	15462	38
	(26.53)	(29.52)	(20.11)
Potato	1.20	18620	63
	(25.26)	(35.55)	(33.34)
Groundnut	0.26	2050	12
	(5.47)	(3.91)	(6.35)
Total	4.75	52378	189
	(100.00)	(100.00)	(100.00)

Figures in parentheses indicate percentage to total

The predominant crops grown under irrigated condition in the study area are ragi, paddy, maize, groundnut and potato. The average size of land holding was 4.75 acres. The results showed that, the total allocation of area was 4.75 acre, the major area was devoted to maize and potato (1.26 acre and 1.20 acre), respectively. Farmers realized higher net returns from potato, as potato is versatile vegetable whose yields depend upon variety, planting and growing techniques, as well as weather conditions and increased yields come from achieving the optimum tuber numbers attributed to higher yield inturn gives more returns to farmers (₹ 18620) followed by maize (₹ 15462). The potato cultivation created more employment opportunities (63 mandays) followed by paddy (40 mandays). A study (Kaur *et al.* 2010) of similar kind has reported that, the changes in the cropping pattern

resulted in four per cent increase in net returns and 27% of ground water savings in case of *Bt* cotton.

Further, an attempt was made to estimate the optimum crop plan to be followed in the study area under both rainfed and irrigated conditions through linear programming technique.The linear programming technique was employed to assess area allocation, income distribution and employment for each crop grown under rainfed and irrigated situations.

Optimum crop plan under rainfed situation

The major crops cultivated in Tumakuru and Hassan districts under rainfed situation and the activities considered for crop plan were constrained and subjected to linear programming in order to obtain economic optimum cropping plan under rainfed condition per average farm.

The activities considered for optimum crop plan are given in Table 2. The optimal crop plan includes ragi, redgram, maize and groundnut under rainfed situation. Ragi is a important food grain crop, mainly grown under rainfed condition. Whereas, maize and groundnut were the important commercial crops grown both under rainfed and irrigated conditions and redgram was the important legume crop grown purely under rainfed condition.

The optimum crop plan per farm in the study area under rainfed situation indicated that, optimum allocation of the land, labour and variable capital among ragi, maize and redgram would yield a net return of ₹ 13442. The area allocated under ragi, redgram, and maize was 0.3 ha, 0.2 ha, and 1.07 ha, respectively (Table 3). Interestingly no area was allocated for groundnut because of high variable capital (₹ 18400/ha) demand compared to other crops namely, maize (₹ 14540/ha), redgram (₹ 12052/ha) and ragi (₹ 14441/ha). The most of the area allocation in rainfed situation was for maize (₹ 10570/ha) because, the net returns from maize was more compared to ragi (₹ 2392/ha) and redgram (₹ 7073). The total labour available per farm was 250 mandays out of which, the labour used was 90 mandays, which indicates more than half of the labour available was idle because of land and variable capital constraint. The area under ragi (₹ 2392/ ha) and redgram (₹ 7073/ha) is 0.3 ha and 0.2 ha, respectively because of low net income compared to other rainfed crops. The findings are in line with the results of Dey (2011).

Table 2 Resource allocation and constraints framed for the optimum allocation under rainfed situation

Activity	Constraints	Resource available	Resource allocated
Land (ha)	=	1.57	1.57
Human labour (mandays)	≤	250	89
Variable capital (₹)	=	75000	75000
Minimum area under ragi (ha)	≥	0.3	0.04
Minimum area under redgram (ha)	≥	0.2	0.67

Table 3 Distribution of net income among rainfed crops under optimum allocation of land and labour

Crop	Land (ha)	Labour (mandays)	Net income (₹)
Ragi	0.30	15	718
Redgram	0.20	10	1415
Maize	1.07	64	11310
Groundnut	0.00		
Total	1.57	89	13442

The variable capital of ₹ 75000 was fully utilized. The farmers were capital constrained indicated that, they do not have enough cash in hand to spend on the critical inputs required for the crop cultivation and it may also because of farmers were more evade from financial inclusion in the rural areas. The major area is devoted to maize, as it is a commercial crop and well known as lazy man easy crop requiring less variable capital (₹ 14540/ha) compared to groundnut (₹ 18400/ha). The variable capital requirement was more are less equal in maize (₹ 14540/ha) and ragi (₹ 14441/ha) but area allocated for the ragi was merely to fulfil the minimum consumption requirement attributed to the net returns (₹ 2392/ha) is thrice less than the maize (₹ 10570/ha). Similar type of findings were reported by Hamsa (2016). The results showed that, there is a need to reallocate the land and labour in order to get economic net returns by fulfilling the family consumption requirement from ragi and redgram. Finally, there is a need to devote more area to maize rather than groundnut in order to overcome the capital constraint.

Optimum crop plan under irrigated situation

The major crops cultivated in Tumakuru and Hassan districts under irrigated situation and the activities considered for crop plan were constrained and subjected to linear programming in order to obtain the economic optimum cropping plan per average farm. The activities considered for the optimum crop plan is presented in Table 4.

The optimum crop plan, allocation of land and labour for different crops is represented in Table 5. The optimal

Table 4 Resource allocation and the constraints framed for the optimum allocation under irrigated situation

Activity	Constraints	Resource available	Resource allocated
Land (ha)	=	1.90	1.90
Human Labour (mandays)	≤	250	146
Variable capital (₹)	=	100000	74554
Ground water (acre inch)	≤	110	80
Minimum area under ragi (ha)	≥	0.20	0.20
Minimum area under paddy (ha)	≥	0.10	0.10

Table 5 Distribution of net income among irrigated crops under optimum allocation of land and labour

Crops	Land (ha)	Labour (mandays)	Net income (₹)
Ragi	0.89	13	2305
Potato	0.48	72	31929
Maize	0.91	56	4552
Paddy	0.04	06	2409
Groundnut	-0.41	00	00
Total	1.90	147	41194

crop plan includes ragi, paddy, maize, potato and groundnut under irrigated situation. Ragi and paddy are the important food grain crops grown under irrigated condition. Whereas maize, groundnut and potato are the important commercial crops grown under irrigated situation. Highly remunerative cash crops like maize and potato entered into the optimal plans.

The optimum crop plan per average irrigated farm in the study area indicated that, the area allocated for ragi, potato, maize and paddy was 0.89 ha, 1.10.48 ha, 0.91 ha, 0.1 ha, respectively (Table 5). The optimum allocation of land, labour, variable capital among ragi, maize, potato, paddy and groundnut would yieldnet returns of ₹ 41194. The net returns under irrigated crop plan was three crimp higher than the rainfed crop plan because of effective contribution of groundwater for increased productivity of commercial crops namely potato and maize. The total labour available was 250 mandays, out of which, 147 mandays were utilized and remaining labours were kept idle because of land constraint. The results showed that, irrigated farmers were not bound by capital constraint but land was the main impede for utilization of available labour.

The variable capital available per farm of ₹ 100000 was not fully utilized. The area under groundnut (₹ 35082/ha) was diverted to potato and maize crops because variable capital requirement was more than other crops such as maize (₹ 27084/ha). The variable capital requirement was more for potato (₹ 45042/ha) than groundnut (₹ 35082/ha) but the area allocated under potato was more. Since, net returns/ha of groundnut (₹ 13704/ha) which was half of the net returns in potato (₹ 26310/ha). The allocated area under maize was higher than paddy since net returns/ha was more in maize (₹ 4552/ha) than in paddy (₹ 2409/ha). Paddy is a water intensive crop but the supply of groundwater was limited and capital requirement was more than the other crops except potato.These findings are in confirmatory with the results of Rashmi (2015).

The crop plan for an average farm in the study area indicated that, more area was allocated for potato followed by maize, ragi and paddy under irrigated situation. Ragi and maize requires less variable capital and water for cultivation besides, they are part of sustainable crop plan in order to fulfill the requirement of food for family and fodder for livestock.The crop plan under irrigated condition showed sustainable as usage of groundwater was less than the available by fulfilling the minimum consumption requirement and gain in net returns of ₹ 41194 form the average farm. Similar type of findings were reported by Shinde *et al*. (2014).

When we compare with actual allocation, the optimum allocation results showed that, in case of rainfed condition all crops were retained but groundnut was replaced with potato due to higher net returns realized by farmers under irrigated situation. This shows a mis-allocation of existing resources on both situations and considerable scope for increasing farm income by reallocation of the existing resources. Varalakshmi *et al*. (2011) and Gadge *et al.* (2011) supports this finding. The results suggest that by reallocating existing resources, farmers can increase their farm income more significantly. Thus, the optimal plan achieved the economic goal which is *prima facie* for the development of optimum crop plan in the region.

Conclusion and policy recommendations

The actual allocation of crops in the study area showed that, the major area was allocated towards maize (37.06%) followed by ragi (28.93%) under rainfed condition. In case of irrigated condition, major area was devoted to maize and potato (1.26 acre and 1.20 acre reported). The optimal crop plan includes ragi, redgram, maize and groundnut under the rainfed situation and in irrigated situation ragi, paddy, maize, potato and groundnut were included in the optimum crop plan.

Optimum allocation of the land, labour and variable capital among ragi, maize, redgram and groundnut would yield a net returns of ₹ 25953. The area allocated for ragi, redgram, maize and groundnut was 0.04 ha, 0.67 ha, 0.09 ha and 0.78 ha, respectively in rainfed condition.In case of irrigated condition, the area allocated under ragi, potato, maize and paddy was 0.89 ha, 0.48 ha, 0.91 ha, 0.04 ha, respectively and area under groundnut has decreased by 0.41 ha giving a net returns of ₹ 63940.

Based on the above findings, it was suggested that, as there is a good potential for ragi production in India particularly in Karnataka as rainfed crop, this may be encouraged through proper incentives.The ragi may also be distributed through Public Distribution System (PDS) in all parts of the nation, as ragi is very rich source of minerals and higher protein content and consumption of ragi has many health benefits; controls dibetes, anti-cancer potential, prevents cardiovascular disease, etc. Considering all these benefits, it is extremely surprising that in a world desperate for health foods and miracle cures, most people have never heard of ragi. In many places where it is grown, it is looked upon as a *"poor person's crop"* or a *"famine food"*.

Ragi is often growing on skeletal soils that are less than 15 cm deep. It does not demand rich soils for their survival and growth. Hence, for the vast dryland area, this is a boon and production of ragi is not dependent on the use of synthetic fertilizers. Majority ragi farmers uses more farmyard manures and in recent times, household produced

biofertilisers. Therefore, they can significantly reduce the huge burden of fertilizer subsidy borne by the government. Ragi is grown under traditional method and pest free crop. Thus, they are a great boon to the agricultural environment. Therefore, the policy makers can make use of optimum crop plan suggested to limit the production of output of other crops which face the problem of over production through different support schemes and other fiscal incentives or disincentives.

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