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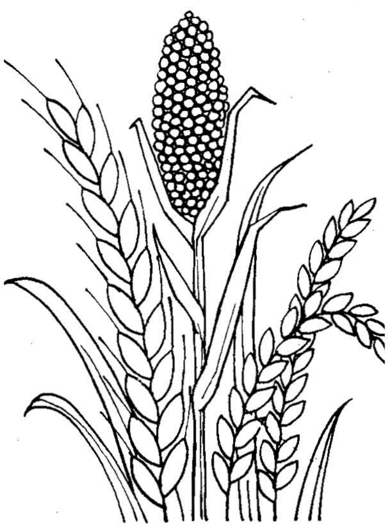

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NET RETURNS OPTIMISATION THROUGH RESOURCE EFFICIENCY ANALYSIS OF CROP-MIXES: AN EXPERIMENT FOR RAYALSEEMA SMALL FARMS[1]

Crop resource compatibility and to that extent, risk minimisation[2] in small farms of semi-arid areas is a necessary base for long-term agro-economic projections. Optimising resource efficiency in small farms[3] with the objective of maximising net returns requires a quantified approach to cropping pattern selection. Market traditions are important critieria in the selection process but high value drought resistant intercrop packages require detailed and quantified resource matching in their growth patterns to ensure economic success. This is more true of rare combinations of short, medium, long-term and perennial varieties of food and non-food crops. The Rayalseema (Southern Andhra Pradesh) small farmers are by tradition habituated to intercrop systems like mango/groundnut (in Chittoor district), mulberry/castor (in Anantapur district), acid lime/groundnut (in Cuddapah district), etc., and to multiple cropping. But they lack flexibility in finding alternate packages to suit market fluctuations. This paper is based on an experiment in selecting alternate cropping patterns in their descending order of net returns applicable over a period of ten years. Essentially, a method study, it is a linear programme analysis with the objective function of maximising net returns in a four-acre plot, simultaneously achieving optimum resource efficiency in the series of crop combinations selected.

METHODOLOGY

A dynamic crop selection programme was formulated on the pattern of crop weather modelling suggested by the ICRISAT scientists.[4] A data matrix was compiled for thirty-seven high value crops traditionally grown by small farmers of semi-arid tropical regions of Andhra Pradesh. These crops include annual, medium duration and perennial varieties.

In the matrix, each crop was studied in its water (consumptive use), cost of cultivation, labour and land use requirements per acre and under restricted conditions of water, land, cash and labour availabilities.

Primary location-specific data were collected in the years 1980 to 1984 from small farms within North latitudes 12 degrees 35 minutes and 13 degrees and East longitudes 78 degrees 10 minutes and 78 degrees 35 minutes, comprising the semi-arid tropical area of Kuppam block in Chittoor district of Andhra Pradesh. The experimental region forms part of India Topographical Maps Nos. 57 L/1, 2, 5 and 6. All the farm management patterns surveyed were traditional and irrigation was through community open wells and borewells. The irrigation water discharges surveyed ranged from 1,500 gallons per hour (GPH) to 8,000 GPH, with an average of about 4,000 GPH or 218 cubic metre/day. The soils surveyed were alfisols with red sandy loam predominance, with a field capacity range from 5 per cent to 15 per cent with a permanent wilting range of 3 per cent to 8 per cent moisture content based on dry weight of soil. Depths of available water per unit of soil were in the range of 4 to 11 cm per metre depth of soil, average wind speeds of 5 to 6 metres per second[5] and relative humidity of 56 per cent.[6] The pan-evaporation rate was 4.88 mm/day.[7] and the potential evapotranspiration (PET) of the area was calculated as 1768.8mm annually.[8]

For the labour and water requirement figures, the crop life was divided into three critical periods of growth, *viz.*, the vegetative phase, the reproductive phase and the ripening phase in both the *kharif* (monsoon) and the *rabi* (winter) sowing seasons. Thus there were seven water-consuming periods and seven labour-consuming periods corresponding to three in *kharif*, three in *rabi* and one in summer.

The gestation periods in the growth of the perennial crops like guava, eucalyptus and papaya were incorporated and the data structure built up for ten years. A period of ten years was selected as the time frame for the model because this is generally the accepted functioning life period of borewells[9] and also because the period of ten years covers the productive periods of all perennials in the matrix, *viz.*, guava gives fruit in the third year and mango in the fourth year and so on.

Actual costs and returns have been adopted for annual crops, whereas for the perennial and bi-annual crops, annuities have been used in the crop selection process to make comparisons realistic. Taking the project life at ten years the process had to optimise a 'highest net return' combination which would be stable for ten years and if such a combination included perennials, then the per year net returns of such perennials had to be worked out and compared with the per year net returns of the annuals in the matrix to have an equal time dimension of comparison. Similarly, the different (unequal) cost patterns of the perennials in their years of gestation had to be averaged and compared on a per year basis with the equal cost patterns of the annual crops. Therefore, for the process, all costs, gross returns and net returns figures were discounted at 12 per cent (assumed lending rate) factors over ten years, *viz.*, they were multiplied by an average (ten years) discount factor of 0.566 and the data constricted to a representative 'X' year figure which substituted for the ten successive years under consideration.[10]

The thirty-seven crops were to be compared in their various requirements against the constraints of resources (limitations) available, to arrive at an optimum mix giving the highest net returns within the constraints of a small farm (in this case restricted to four acres). The resource 'availability' index (row limits) was developed as a hypothetical restriction level under all variables; by structuring water, cash and labour availabilities in four acres and all the resources available in each time frame of reference had to be limited to these four acres. The restrictions envisaged took into consideration the availability of optimum natural and artificial conditions suitable for crop growth. Thus the land and cash variables were considered in a time frame of 365 days. The water and labour variables, on the other hand, had to be directly related to the seven growth stages of the listed crops. For water availability, the field-water-balance equation was applied. This takes into account all climatological and physical factors affecting soil moisture availability at 'field capacity'. This equation pertaining to the data base of the experimental site was applied to derive the row limits under the critical water periods. The irrigaion requirement was calculated as the water required to maintain four acres at 'field capacity' to a depth of one metre. It was presumed that all the crops would require field capacity conditions to achieve optimum growth with nourishment. In the water requirements of crops, application losses were calculated at 85 per cent irrigation efficiency.

THE CROP COMBINATION SELECTION PROGRAMME

With the above data base, selections of suitable crop combinations in four-acre operational units within the row limits were carried out to arrive at the optimum combination which would have the following advantages:

(i) The combination would give the highest net monetary returns to the farmers using amounts of water and labour (man-days) within the row limits.

(ii) There would be water use compatibility in the selected crop combination.

(iii) With the basic objective of optimising net returns, the selected combination would give the optimum land use efficiency.

For the selection process a VAX/11-780 computer was used and the software worked out as a staggered linear programme analysis of a stochastic selection model applicable to similar data bases and row limits. The selections were made for two crop combinations, *viz.*, *(i)* with papaya and stable for ten years giving an average highest net returns of Rs.18,103.25 per acre (discounted at 12 per cent for ten years) and *(ii)* without papaya in a staggered three phase cropping pattern yielding net returns (net per acre) of Rs. 18,021.50 in year 1, Rs. 18,148.75 in year 2 and a steady Rs. 16,352 in years 3 to 10 (discounted figures).

The results suggested intercropping as follows:

(i) Tomato in one acre intercropped with late planted papaya.

(ii) *Kharif* pulses in 0.75 acre intercropped with papaya and/or tomato.

(iii) *Rabi* groundnut in 0.25 acre intercropped with guava in the period of initial canopy spread of guava, *viz.*, two years.

OBSERVATIONS ON THE SELECTION PROCESS

1. Justifying the results of experiments in the field,[11] it is seen that net returns optimisation for small farms (in this case four acres) will always involve multiple cropping of perennials (in this case mulberry, papaya and guava) with short duration (*kharif* pulses, *rabi* groundnut) and long duration (tomato) crops. All sole crop combines are considered and rejected. The six-crop ceiling adopted is based on traditional practice in the drought-prone areas in conditions of minimum irrigation.

2. The results show that if minimum irrigation (2,000 GPH to 4,000 GPH discharge at 85 per cent efficiency) is applied to maintain field capacity (depth of irrigation is a variable depending on the discharge capacity of the source) over the crop period, then traditionally unirrigated crop-mixes can be improved substantially in economic returns.

3. The programme steps adopts mulberry as base for the elimination process because of its commonality with perennials and annuals and also because its net returns (discounted), *viz.*, Rs. 6,311 are the highest per acre among all perennials, long duration and annual crops considered in the comparison matrix. Similar programmes with different data bases pertaining to different areas should also involve the selection of a base (crop) to reduce computer time in the elimination process. This will be practical in field level applications.

4. The programme steps show that net returns from sole cropping of any of the competing crops (except mulberry) will be less than multiple cropping. Mulberry has been pre-allocated a maximum of 2 acres 75 cents (11 units of 0.25 acre) within the row limits in the initial run. This was further restricted to 2 acres (8 units) on the basis of actual field level practice in Rayalseema.[12] Another constraint introduced in the programme was that mulberry cannot be intercropped, due to the productive importance of its 'bush' canopy. The results provide examples of additive mixtures, including crop genotypes yielding throughout the season in vegetative parts (leaves in the case of mulberry, fruits in the case of guava and tomato and the stem in the case of papaya for latex extraction) as also indeterminate phenological groups like pulses and groundnut. The selected combinations also leave no scope for *inter se* competition in the crops for sunlight and water. The selection proves that *(i)* there is no significant competition for environmental facilities among the component crops, *(ii)* the total income from the multiple crop exceeds the total income of the component crops grown separately in the same unit area.

5. This exercise also proves that multiple cropping (including intercropping) is more water use efficient than sole cropping when simultaneously considered for land use efficiency, labour use efficiency and cash use efficiency in a small farm. Both the combinations in the final result are most efficient in water use in the summer period and to that extent, irrigation water can be saved during the most critical water period. These efficiencies will of course change with any modification in the data structure.

6. The results also prove that a combination of tall and short crops will work well, especially if the tall crop is planted later than the short crop thus creating a 'competition free' environment for the intercrop. In both the suggested combinations crops of varying maturing durations (tomato and pulses) have been chosen by the computer in that the

pulses complete their life-cycle before the grand period of the tomato crop starts. These results prove that if net returns are to be maximised then resource efficiencies like land use and water use as also cash and labour use cannot be optimised simultaneously. Thus the highest net return combination (at year 2 in the second combination) leaves balances in row limits. The second highest net returns combination (first combination) leaves balances in row limits, except in *kharif* land. Finally, the least net return combination (at 3 to 10 years in the second combination) leaves no balance in row limits for *kharif* and *rabi* land and land/time use efficiencies but heavy balances under all other variables mainly due to a lack of intercrops. This shows the viability of intercrops in a multiple crop situation in ensuring resource efficiency.

7. The programme results also give the intercrop and sequential components of short duration, medium/long duration and perennial crop combinations for achieving the optimum net returns within economic (cash, land), social (labour) and environmental (water) constraints. This provides the small farmer a long-term market orientation in crop planning. These results also facilitate judicious fixation of input minima in small-scale irrigation, land-levelling and grading and soil conservation technology in small farms, based on a long-term perspective of cropping pattern plan in specific regions. In effect, making the cropping pattern the base for decision-making in farm input technology alternatives and not vice versa as the case is today.

8. Finally, an important aspect which emerges from the matrix and programme step is the market and the relative farm price factor. Changes in the cropping pattern depend on the environment directly and within it, on relative prices operating in the market. It is noticed that majority of the listed crops are not subject to price controls or supports; hence, there is a need to select a series of crop combinations in their net returns potential in a descending order. The list of crops can vary from region to region depending on the relative price factor, but it is important that the descending order of selections should involve all the crops in the list and elimination of any crop from the list can be accepted only when there is a serious fall in demand for it at the local or regional level. This programme suggests only two combinations, *i.e.*, the highest and the highest without papaya. The second combination was introduced arbitrarily due to the unreliability of the papaya (latex) market. However, with papaya, the second highest, the third, the fourth, etc., combinations could be worked out to expand the farmer's alternatives in relation to market fluctuations. This can be done by conducting re-runs of the same programme. This flexibility will not only be economically helpful for the farmer but will introduce healthy changes in resource utility (crop rotation) on the soil thus rejuvenating it. In the instant case, if the Rs. 10,000 acre net return (for papaya latex) every second year adopted as real price to the farmer in the data matrix does not accrue, then the second or third combinations which come out in the programme, should be considered.

CONCLUSION

Whatever be the crop combinations selected, this process will ensure maximum utilisation of the irrigation water applied. For this exercise the water balance at field capacity is maintained throughout the seven growth periods presuming irrigation discharge availability at 4,000 GPH. There is a margin of flexibility, in that if the discharge is lower, then the depth of irrigation applied can be lowered from one metre to correspondingly lesser depths in the *kharif* water 1 (*kharif* water requirement 1: 15th July to 15th September) period. The irrigation utilisation will be maximum in this context also because crop combinations of this nature will require scientific planting patterns. The crops will be in rows and intercrops allowing thicker canopies which will benefit the most from solar radiation (tomato, for example) and shade will weed out of existence. The soil conservation measures, the land shaping and grading will together ensure full irrigation water utilisation. Finally, the field level application of water (through closed pipes preferably) either by drip or sprinkler systems will ensure minimum water loss and maximum utility.

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NOTES

1. Small farms in India are traditional agricultural holding sizes less than 2.5 hectares (5 acres) in extent each but larger than one hectare (2.5 acres), as defined in the Draft Fifth five Year Plan (Government of India, 1974) under the Small Farmers' Development Agency Project. In this paper 'small farms' are considered as 'operational holdings in technical units' which have nothing to do with titles, legal form or location of the plots. 'Technical unit' is defined as "local units under the same management which has the same means of production such as labour force, machinery and animals" (Government of India, 1981).

2. Studying risk attitudes in rubber (small holdings) in Sri Lanka, it is concluded that small income farmers are not necessarily 'present' income oriented, as generally held. Low income farmers showed a tendency towards optimising 'steady' income rather than investing for high income objectives. This is a parallel situation in the south of Andhra Pradesh where 'traditional' and 'known' crops are adopted by the small farmers, more with an intention to maintain steadiness of income than to achieve sudden high incomes (Jayasuria *et al.*, 1981).

3. Small farms can absorb more management inputs than large farms and the economic incentive to increase the management input at high rates of application has directly contributed to the reduction in farm size in tropical Asia. The experience of vegetable farming in Taiwan has shown that small farms are preferred not because of poverty and population pressure on land but because of their potential for intensive multiple cropping on commercial lines (Harwood and Price, 1976, pp. 12-14). Cropping intensities are also more in small farms as shown in research in Bangldesh (Amed, 1965) and hence the potential for high labour use efficiency can be best seen in small operational areas (Ghodake *et al.*, 1981). The irrigation intensity index is also biased in favour of the small farms, especially in Andhra Pradesh where operational holdings of 0 to 2 hectares each have an irrigation concentration of 0.5, holdings of 2 to 5 hectares, 0.3 and those above 10 hectares each, 0.18 (Government of Andhra Pradesh, 1982 *b*, Tables 4.2 and 5.5 co-related). These advantages make for a high potential for market orientation in small farms.

4. Diagrammatically crop weather modelling is shown below:

Essential data is fed into the computer (input) on

↓

Climate, Rainfall Temperature		Land, Labour, Capital		Location of experimental region		Soils-class/types, M-R-C etc.		Crop Traits

↓

Varying combinations of relevant data are assembled, assessed and predictions received (output) on:

↓

Types of crops with areas within restricted plots that can be grown economically given the constraints of land, labour, cash and water availability over a long period.

Source: ICRISAT, 1984, p. 32.

5. From Andhra Pradesh Planning Atlas 1974: wind map on p. 9 compared to international scale of wind force of 3.

6. From Andhra Pradesh Planning Atlas 1974: climograph at p.8. Percentage figures cross-compared with data supplied by the Arogyavaram meteorological station at Madanapalli in Chittoor district in 1983, *viz.*, 67 per cent RH at 0830 hrs. IST and 45 per cent RH at 1730 hrs. IST as annual average for the Kuppam area.

7. Mean annual rate from the Indian Meteorological Observation Station at Bangalore, 90 km. from the test site.

8. Raju *et al.*, 1980, Appendix IV.

9. The Andhra Pradesh State Irrigation Development Corporation adopts ten years as the life period of borewells (Reddy, 1983).

10. Discounted factor tables have been used for ten years at 12 per cent. This percentage is adopted as the agricultural lending rate as per the World Bank criterion (Gittinger, 1972). Twelve per cent is a higher figure adopted than the 9.5 per cent interest rate being charged at present by rural banks in India (NABARD, 1985, p. 24) taking into account possible hikes in rates upto a maximum of 12 per cent.

11. As concluded by Singh and Nair (1972).

12. As provided by the Department of Sericulture, Government of Andhra Pradesh, 1984.

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