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Remodelling of Existing Cropping System towards Risk Optimization in Cauvery Delta Zone of Tamil Nadu

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ABSTRACT

This study explores the challenges faced by farmers in the cauvery delta zone of Tamil Nadu, an area highly vulnerable to drought and flooding. The traditional reliance on mono-cropping, especially paddy, has made farmers more susceptible to risks posed by uncertain water availability and climate variability. The study aims to develop a risk-optimized, crop-diversified alternative cropping system using the Minimization of Total Absolute Deviation (MOTAD) model. Through a stratified random sampling, 600 farmers were selected across five agronomically and socio-economically homogeneous village clusters, to capture the diversity of cropping patterns and irrigation sources. The results revealed that, the degree of farm-level crop diversification was much low in the study area. The MOTAD model integrates risk considerations into farm planning by balancing profit maximization and risk minimization. The findings suggest alternative cropping systems, which include combinations of Paddy, Banana, Coconut-Pepper and low-water-intensive crops such as Brinjal, Bhendi, Maize, Cotton, Marigold and Tuberose. The findings emphasize the need for awareness among farmers about crop diversification as a risk mitigation strategy and suggest that agricultural extension agencies should promote the adoption of these diversified cropping systems. By evolving cluster-specific cropping plans, the study proposes a sustainable approach to enhance the resilience of farming in the Cauvery delta zone.

Keywords Agricultural risk, Crop diversification, MOTAD model, Cropping system.

INTRODUCTION

The cauvery delta zone which is regarded as the rice bowl of Tamil Nadu, encounters many problems in recent decades, ultimately impacting the livelihood security of the farming community. The Cauvery river irrigates Trichy, Thanjavur, Thiruvarur, Nagapattinam and part of Pudukkottai district. The conventional water release date for irrigation from Mettur dam is 12th June of every year. This convention is not been adhered with, in most of the years because of the low water storage in the dam, which is the result of certain political and climatic attributes. This sort of uncertainty in the release of Mettur dam

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water affects the planning process of the farmers, ultimately ruining away their confidence in farming. Moreover, contrarily the Cauvery delta region often experiences torrential rains during North East monsoon causing inundations in larger patches of low-lying areas. Thus, the Cauvery delta region is a vulnerable zone, prone to drought and flood. Like adding fuel to fire, the vast stretch of mono-cropping system of paddy practiced in the Cauvery delta zone has made the farmers less resilient to monsoon vagaries and crop failure. The awareness of farmers on risk-mitigating strategies like crop diversification is also perceived to be very much limited. Though district-level data reveals a certain degree of crop diversification, the diversification at the farm level is found to be very low, which needs to be addressed with. The cropping pattern in the region is understood to be much more stable over many decades despite many crop failures, as experienced by the farmers. The reason for the reluctance of farmers to attempt to less water-intensive crops and perennials needs to be probed in. Under this background, the present study has been undertaken with an overall objective to evolve at a Risk optimized-crop diversified alternative cropping system for the farmers of the Cauvery delta zone.

MATERIALS AND METHODS

Sampling technique

A stratified random sampling technique was employed for selecting respondent farmers from erstwhile Tanjore district, the universe of the study, which is currently represented by Thanjavur, Mayiladuthurai, Nagapattinam and Tiruvarur districts. The primary data collected pertained to 1,867 villages, classified into five homogeneous clusters based on agronomic, socio-economic, and conjunctive water use aspects. Cluster I consists of 56 villages with a cropping pattern of Paddy+Paddy+Paddy, irrigated by borewells and canals on clay loam soil. Cluster II includes the 1,210 villages growing Paddy+Paddy+Black Gram/ Green Gram, using borewell and canal irrigation on sandy loam and alluvium soil. Cluster III has 262 villages with a Paddy+Paddy+Groundnut/Gingelly cropping pattern, irrigated by borewells and canals on sandy loam and red sandy soil. Cluster IV comprises of 236 villages cultivating Paddy + Cotton/ Groundnut, with canal and borewell irrigation on black, clay loam and sandy clay alluvium soil. Cluster V has 103 villages with a Paddy+Pulses cropping pattern, utilizing canal, borewell and rainfed irrigation on black, clay loam, and sandy clay alluvium soil.

In the first stage, village clusters were identified, followed by selection of 30 sample villages in the second stage, distributed among the clusters based on probability proportionate to the number of villages in each cluster. A total of 600 farmers were randomly selected at rate of 20 farmers from each sample village. This sampling design ensured that the analyses undertaken captured the agronomic and socio-economic diversity across the study region.

Tools for analyses

The degree of crop diversification in the region was measured with Herfindhal Index and Simpson Index. These indices pertaining to agricultural years 2019-20, 2020-21 and 2021-22 were estimated.

Herfindhal index (HI)

The Herfindhal index is a measure of concentration. The degree of crop diversification in a farm/ region could be assessed using the Herfindhal index. It is an economic concept widely applied in competition law in USA (Brown and Warren-Boulton 1988). The index was computed by taking the sum of square of proportion of area under each crop to the gross cropped area of the farm. This index was worked out by the following formula :

$$HI = \sum_{i=1}^{N} P_i^2$$

Where,

N = Total number of crops, P_i = Average proportion of the i^{th} crop in gross cropped area of the farm.

With increase in diversification, the index decreases. The index takes a value of one when there is a complete specialization and approach to zero as N is large, i.e., diversification is perfect. Herfindahl index was estimated separately for each sample farm and the average was arrived at, for the study area.

Simpson index (SI)

The Simpson Index (SI) is also a suitable index of measuring diversification in a particular farm/region. Mathematically, SI is defined as

$$SI = 1 - \sum_{i=1}^{N} P_i^2$$

Where,

$P_i = A_i / \Sigma A_i$, is the proportion of the ith crop acreage.

If Simpson Index is nearer to zero, it indicates that the farm or region is nearer to complete specialization, growing a particular crop and if it is close to one, it indicates that the farm or region is fully diversified in terms of crops. Simpson index was also calculated separately for each sample farm and the average was arrived at, for the study area.

Evolution of risk optimized crop plan using MOTAD model

MOTAD (Minimisation of Total Absolute Deviation) model was employed to suggest appropriate 'Risk optimized - Crop diversified' alternative plans for the farmers in the study area. Hazell (1971) proposed the use of MOTAD (Minimization of total absolute deviation from mean) for planning under risk. It attracted the attention of researchers in India and abroad as it can be solved on conventional linear programing code and also enables better post optimal analysis. Sirohi (1976), Singh and Jain (1983), Randhir and Krishnamoorthy (1993), Jha (1996), and Boruah (2014) used MOTAD to formulate risk efficient farm plans. Risk is incorporated in the model as mean absolute deviation of expected income.

In matrix notation, the MOTAD model is specified as:

$$M = S^{-1} \sum_{t=1}^{s} \left| \sum_{j=1}^{n} (C_{tj} - \overline{C}_j) X_j \right| \quad ......(1)$$

Where,

M = Mean absolute deviation that can be minimized for a given level of expected income, S = Number of years, C_{tj} = Gross margin per unit of jth crop activity in the tth year (unit is hectare), $\overline{C}_j$ = Sample mean gross margin per unit of jth crop activity, X_j = Level of jth crop activity to be obtained from the solution of the model, J = Refers to jth activity (j = 1 to n activities), t = Refers to tth year (t =1 to S years), | | = Modulus denotes absolute value of the figures, i.e., ignoring the signs within the two vertical bars.

The negative deviations of gross margin from their mean in the tth year of sample data were defined by a new variable, $\overline{Y}_t$ and it was defined as:

$$\overline{Y}_t = \sum_{j=1}^{n} (C_{tj} - \overline{C}_j) X_j \quad ....(2)$$

j = 1 to n crop activities, C_{tj} = Gross margin from jth crop activity in the tth year, $\overline{C}_j$ = Mean gross margin of jth crop activity.

The LP problem is formulated as minimization of $\overline{Y}_t$ in the objective function subject to usual technical constraints and parametric constraints on expected income from crops. The MOTAD model was formulated as :

Minimize $\overline{Y}_t$

Subject to,

$$\sum_{i=1}^{n} a_{ij} x_j \ (\geq = \leq)\ b_i,\ i = 1 \text{ to m constraints} \quad ......(3)$$

$$\sum_{j=1}^{n} (C_{tj} - C_j) + x_j + \overline{Y}_t \geq 0 \quad ......(4)$$

$$\sum_{j=1}^{n} \overline{Y}_t \leq \lambda \quad ......(5)$$

$$X_j \geq 0,\ \overline{Y}_t \geq 0 \text{ for j= 1 to n activities, t = 1 to S years} \quad ......(6)$$

Equation (3) is technical constraint,
Equation (4) is deviation constraint,
Equation (5) is parametric constraint and
Equation (6) is non-negativity constraint,

$\overline{Y}_t$= The negative deviation of total gross margin from mean of crops for each year, T =1 to S years, a_{ij} = The technical requirements of the jth activity for the ith resource or constraint, X_j = Level of jth crop activity to be obtained from the solution of the model, b_i = The ith constraint level, C_{tj} = Gross margin from jth crop activity in the tth year, C_j = Mean gross margin of jth

crop activity, N = Number of activities, M = Number of constraints, Λ = A parameter to be parameterized to the maximum level of expected income.

The Standard Deviation (SD) of each risk efficient crop production plan, generated by the MOTAD model was calculated by the following statistic:

$$SD = d\,(\pi s/2(s-1))^{1/2}$$

Where,

SD = Standard deviation, d = Estimated mean absolute deviation, $\pi = \frac{22}{7}$, S = Number of observations.

Objective function

The objective function of the model is the maximization of the annual returns to owned resources. The gross returns per hectare of the crop were calculated by using the data of sample farmers. The maximization of returns is subjected to the assumptions and resource constraints imposed in the model. It is assumed that product and factor markets are perfectly competitive.

Basic assumptions

Besides the general assumptions of linearity, divisibility, additivity, and finiteness, the following assumptions were made in developing the model. In this study, the problem of resource allocation is dealt by considering the average farm level. Each farm is assumed to be an economic decision-making unit. The farm operator is free to make decisions regarding business, limited only by legal and contractual arrangements. The concept of time in production process is short-run in nature. The model has an operational period of 12 months. It is also assumed that each farm is operated with the objective of maximizing farm returns, subject to the constraints. Closely related to the above assumption, the study to start with, is in the static frame work. It is assumed that the yield and price expectation of the farmers are single valued.

Factor requirements and constraints

The values of factor requirements, viz., labor, manures and fertilizers, pesticides and capital, relevant to the different crop activities specified in the models, were arrived at, by considering the primary data collected from Cluster specific sample farmers. For the factor, water requirement alone, the book values of the respective crops were considered, taking into account the difficulty in quantifying the water used, in terms of measurable units at farm level.

Simultaneously, the upper limits of availability of these factors for the considered crop activities, technically termed as constraint limits had also been defined and quantified. As far as the constraint on land is considered, the average farm size of the sample farms of the respective categories was considered as the constraint limit for land availability. With regard to labor, manure and fertilizer, pesticide, water requirement and capital, the upper limits of availability were assessed and fixed by certain subjective means utilizing the expertise of the farmer as well as the researcher. In order to cull out the constraint limits in quantitative terms from the respondents, subjective questions were posed to the farmers considering the nature of variables, in the most under standable and palatable way and responses were obtained. The responses obtained were judged, edited and the averages were accommodated in the model for further estimations.

With regard to the crops accommodated in the MOTAD analyses undertaken for the different Clusters, the following aspects were considered in the selection of crops.

i. The unconventional but potential crops tried and cultivated successfully by innovative farmers in the referred Cluster, if any, were given preference.

ii. Opinion of the innovative and experienced farmers on the suitability of the crops.

iii. Opinion of the local Agricultural officers of department of agriculture, Tamilnadu on the reliability of the crop.

With these above considerations and assumptions, the MOTAD analysis was employed in the study for evolving at "Risk optimized - Crop diversified" alternative cropping systems.

Garrett ranking technique

Garrett ranking technique was employed to rank the reasons for non-adoption of crop diversification, as perceived by the farmers has been ranked and analysed (Garrett and Woodworth 1969). The order of merit assigned by the respondents were converted in to ranks using the formula,

$$\text{Percent position} = 100 \times \frac{R_{ij} - 0.5}{N_j}$$

Where,

R_{ij} = Rank given for i^{th} reasons by the j^{th} individual,

N_j = Number of reasons ranked by j^{th} individual

By referring to Garrett's table, the percentage positions estimated were converted in to scores and then for each factor the scores of various respondents were added and mean value was arrived at. These means were arranged in descending order. The problem having the highest mean value was considered as the most important and was given the highest rank and vice versa.

RESULTS AND DISCUSSION

Level of crop diversification

The degree of farm level crop diversification in the study area was calculated using Herfindahl index and Simpson index for the three consecutive years viz., 2019-20, 2020-21 and 2021 - 22. The indices were estimated for each farm separately and the average values of these farm level indices are presented in Table 1. The Herfindahl index would decrease with increase in diversification, whereas Simpson index would increase with increase in diversification.

It could be found that the calculated values of the Herfindahl index were relatively high and gradually increasing over the referred three years for both small and large farms, i.e., 0.801, 0.835, 0.867 and 0.779, 0.792, 0.802 respectively. The corresponding Simpson indices for the three years 2019-20, 2020-21 and 2021-22 were 0.199, 0.165 and 0.133 for large farms and 0.221, 0.208, and 0.198 for small farms respectively.

Note :
Small Farms - < 2.5 ha, Large Farms - > 2.5 ha.

The values of indices revealed that degree of crop diversification are very minimal over years. It could also be observed that, the differences in the degree of crop diversification between small and large farms was very less. From the above results, it is evident that farmers in the study area were reliant on mono cropping i.e., paddy even though they encounter several crop failures.

Reasons for non-adoption of crop diversification

Garrett ranking techniques was employed to rank the reasons for non-adoption of crop diversification in the study area and the cluster wise results are presented in Table 2. The Garrett analysis results are presented cluster wise since there were obvious differences in perception on crop diversification among clusters. In Cluster I & II, the reasons quoted for non-adoption were in the order viz., 'Lack of awareness on suitable alternative crops', 'Fear of production failure', 'Highly experienced with existing cropping pattern', 'Fear due to marketing risk', and 'Present system is more profitable'. As far as the first and second reasons are concerned, they might have been quoted since farmers are more accustomed with only paddy cultivation which they consider as respectable and even sacred.

With regard to the Cluster III & IV, the foremost reason as ranked by the respondents for non-adoption of crop diversification was 'Lack of awareness on suitable alternative crops', followed by other reasons, viz., 'More attached with the conventional wisdom on cropping pattern', 'Fear of production failure',

Table 1. Farm level crop diversification. Note: Small farms - < 2.5 ha, Large farms - > 2.5 ha.

	Herfindahl index			Simpson index		
	2019-20	2020-21	2021-22	2019-20	2020-21	2021-22
Large farm	0.801	0.835	0.867	0.199	0.165	0.133
Small farm	0.779	0.792	0.802	0.221	0.208	0.198

Table 2. Reasons for non - adoption of crop diversification.

Sl. No.	Clusters	Reasons	Garrett score	Rank
1	Cluster-I & II	Lack of awareness on suitable alternative crops	81.52.	I
		Fear of production failure	80.02	II
		Highly experienced with existing cropping pattern	76.21	III
		Fear due to marketing risk	62.05	IV
		Present system is more profitable	57.74	V
2	Cluster- III & IV	Lack of awareness on suitable alternative crop	86.64	I
		More attached with the conventional wisdom on cropping pattern	81.52	II
		Fear of production failure	79.12	III
		Fear due to marketing risk	71.38	IV
		Present system is more profitable	64.00	V
3	Cluster-V	Sense of frustration due to scarcity of resources	80.62	I
		Lack of awareness on crop diversification	76.13	II
		Fear of production failure	68.43	III
		Fear due to natural calamities	65.01	IV
		Lack of financial backup	60.03	V

'Fear due to marketing risk', and 'Present system is more profitable'. The farmers in this cluster are also mostly accustomed to grow only Paddy. Every farmer is used to a specific marketing channel in which they are comfortable. It could be understood, that the production risk dominates more in farmers mind.

The Cluster V is the most disadvantageous

Table 3. Risk optimized crop plan for cluster I with MOTAD analysis.

Particulars	Paddy	Banana	Brinjal	Bhendi	Coconut & Pepper
Minimize					
Expected gross margin (Rs.)	304322	565311	355966	173831	538219
Land (ha)	1	1	1	1	1
Men labor (in man-hours/ha)	621	1332	936	511	1476
Women labor (in man- hours/ha)	1458	2665	2498	1292	699
Machine hours (in hours/ha)	53.65	21.75	6.25	7.37	4.5
Farm yard manure (in ton/ha)	20.5	8.5	5.5	8.5	14
Nitrogen (in kg/ha)	354	586	186	197	93
Phosphorus (in kg/ha)	122	543	180	162	69
Potash (in kg/ha)	124	712.5	116	129	191
Pesticides (in Rs.)	9501	6728	15320	586	4112
Water requirement (in mm/ha)	3600	1200	450	560	1350
Minimum	1				
Capital (Rs)	138864	273487	142586	52866	104856
Crop rotation	1	1	1		1
Year- 1	-9857	-7412	11726	-13895	-38432
Year- 2	-11966	-6245	-2881	26262	69062
Year- 3	-2109	13657	-8845	-12367	-30580
Optimized solution on area allocation	**2.21**	**0.25**	**1.21**	**0.00**	**0.38**
Statistical parameters	**Mean absolute deviation - 63772**		**Standard deviation - 98472**		**Coefficient of ariation – 5.89**

Table 3. Continue.

Particulars	Tuberose	Z 1-	Z 2-	Z 3-	Constraint limits	≈	Optimum plan
Minimize		1	1	1			
Expected gross margin (Rs.)	300327				1649995	≤	1649995
Land (ha)	1				4.7	=	4.7
Men labor (in man-hours/ha)	697				5078	≥	3847.081
Women labor (in man- hours/ha)	254				7247	≥	7247
Machine hours (in hours/ha)	6				139	≥	139
Farm yard manure (in ton/ha)	9.5				101	≥	84.086
Nitrogen (in kg/ha)	223				1642	≥	1329.765
Phosphorus (in kg/ha)	212				1836	≥	772.543
Potash (in kg/ha)	319				1876	≥	853.547
Pesticides (in Rs.)	4247				51578	≥	46123.82
Water requirement (in mm/ha)	600				17280	≥	10640.61
Minimum					2.4	≤	2.4
Capital (Rs)	101343				1036899	≥	658244.9
Crop rotation	1				0	-	4.8
Year- 1	23865	1			0	≤	0
Year- 2	-16321		1		0	≤	35050.798
Year- 3	-7544			1	0	≤	0
Optimized solution on area allocation	**0.65**	**31534**	**16434**	**17125**			
Statistical parameters	**Mean absolute deviation - 63772**		**Standard deviation - 98472**			**Coefficient of ariation – 5.89**	

Cluster, where paddy is grown mostly in only one season especially with the help of rainfall and Cauvery water. The foremost reason for non-adaptation of crop diversification as ranked by farmers of this Cluster was, 'Sense of frustration due to scarcity of resources'. Scarcity of water always exists in this cluster since most of the area of this cluster falls in the tail end region of Cauvery river. Labor scarcity is also prevalent in this cluster. The local labors intend to migrate, since job availability is much seasonal in this region. The second reason quoted was 'Lack of awareness on crop diversification', followed by the reasons 'Fear of production failure', 'Fear due to natural calamities', and 'Lack of financial backup'.

Risk optimized cropping plan

As far as the 'Cauvery delta zone' farming scenario is concerned, the area is dominated by cultivation of high-water intensive Paddy crop alone, especially as a mono - crop. Contradictorily, the 'Cauvery delta zone', of late experiences water scarcity due to undulations in the Cauvery river water release from Mettur dam and fluctuations in the receipt of North East monsoon. The farmers, hence often encounter with production risk which needs to be addressed with. Crop diversification with perennials and less water intensive garden land crops are understood to be an effective way out, for risk mitigation. Using MOTAD model village-cluster specific 'Risk optimized-crop diversified new plans' have been evolved at and are presented below.

Cluster I

The MOTAD results for Cluster I, are presented in Table 3. The crops advocated for the 'Risk optimized - Crop diversified new plan' were, Paddy, Banana, Brinjal, Bhendi, Coconut-Pepper and Tuberose. Paddy is the crop which required more water (3600 mm for three seasons). The other water intensive crops in the combination were Banana (1200 mm) and Coconut (1350 mm). The crops with less water requirement were Brinjal (450 mm), Bhendi (560 mm) and Tuberose (600 mm). Banana was the most labor-intensive crop among this combination. It required 1,332 hrs/ha of men labor and 2,665 hours/ha of women labor, followed by Brinjal (men- 936 hours/ha: women - 2,498 hours/ha) and Coconut (men -1476 hours/ha; women - 699 hours/ha). The perennials like coconut-pepper and semi perennial like Tuberose also proposed. Banana was the crop which had the highest gross margin (Rs. 5,65,311/-), followed by coconut-pepper (Rs. 5,38,219/-). With regard to capital requirement, banana stood first with Rs. 2,73,487/- followed by brinjal (Rs. 1,42,586/-). The optimum plan arrived vide MOTAD analysis ensured a gross margin of Rs. 16,49,995/- from a farm which has the size of 4.7 ha. The capital required as per new plan was Rs. 6,58,244.9/-. The recommended area allocation under different crops are as follows; Paddy - 2.21 ha, Banana - 0.25 ha, Brinjal 1.21 ha, Coconut- 0.38 ha and Tuberose - 0.65 ha. The comparative lower values of Mean Absolute Deviation (63772), Standard Deviation (98472) and Co-efficient of Variation (5.89) guarantee the genuineness and reliability of the new crop plan.

Cluster II

The MOTAD results of Cluster II, are presented in Table 4. The crops advocated for the 'Risk optimized - Crop diversified new plan' were Paddy, Banana, Brinjal, Marigold, Coconut-pepper, and Mango. Since water availability was perceived to be moderate in the farm, crops with less water requirement viz., Brinjal and Marigold would be a good choice to farmers. In this combination Paddy is the crop which required more water for cultivation (2400 mm for two seasons). Banana was the most labor-intensive crop

Table. 4. Risk optimized crop plan for cluster II with MOTAD analysis.

Particulars	Paddy	Banana	Brinjal	Marigold	Coconut & Pepper
Minimize					
Expected gross margin (Rs)	225966	546923	354896	181114	535648
Land (ha)	1	1	1	1	1
Men labor (in man- hours/ha)	421	1354	923	316	1465
Women labor (in man- hours/ha)	986	2642	2355	851	682
Machine hours (in hours/ha)	38	19.55	4	8.5	5
Farm yard manure (in ton/ha)	21	8	5	9.5	14
Nitrogen (in kg/ha)	235	570	176	194	97
Phosphorus (in kg/ha)	92	529	168	132	71
Potash (in kg/ha)	86	722	109	68	196
Pesticides (in Rs.)	6386	6634	14975	4512	3815
Water requirement (in mm/ha)	2400	1200	450	700	1350
Minimum	1				
Capital (Rs)	104675	253673	137844	43885	103457
Crop rotation	1	1	1		1
Year- 1	11855	-37187	-29659	-23621	-37234
Year- 2	-1956	106393	-2641	36750	-29815
Year- 3	-9899	-69206	32300	-13129	67049
Optimized solution on area allocation	**1.95**	**0.00**	**0.72**	**0.19**	**0.61**
Statistical parameters	**Mean absolute deviation - 39990**		**Standard deviation - 61972**	**Coefficient of variation - 5.01**	

Table 4. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Constraint limits	≈	Optimum plan
Minimize		1	1	1			
Expected gross margin (Rs)	293466				1193788	≤	1193788
Land (ha)	1				3.7	=	3.7
Men labor (in man- hours/ha)	674				2765	≥	2752.344
Women labor (in man- hours/ha)	229				4988	≥	4525.186
Machine hours (in hours/ha)	5				126	≥	82.50
Farm yard manure (in ton/ha)	8.5				62	≥	49.10
Nitrogen (in kg/ha)	205				1186	≥	764.53
Phosphorus (in kg/ha)	210				966	≥	422.16
Potash (in kg/ha)	314				464	≥	464
Pesticides (in Rs.)	4019				29854	≥	29854
Water requirement (in mm/ha)	1100				9360	≥	6417.494
Minimum					2	≤	2
Capital (Rs)	101345				536752	≥	426778.5
Crop rotation	1				0	-	3.561335
Year- 1	19530	1			0	≤	-4678.49
Year- 2	-12058		1		0	≤	-20995
Year- 3	-7022			1	0	≤	66730.53
Optimized solution on area allocation	**0.23**	**16925**	**0**	**24876**			
Statistical parameters	**Mean absolute Deviation - 39990**		**Standard deviation - 61972**		**Coefficient of variation - 5.01**		

among this combination. It required 1,354 hours/ha of men labor and 2,642 hours/ha of women labor. Banana had the highest gross margin (Rs. 5,46,923/), followed by Coconut-pepper (Rs. 5,35,648/-) and Brinjal (Rs. 3,54,896/-).

The crops with less water requirement were Brinjal (450 mm) and marigold (700 mm). With regard to capital requirement, banana stood first with Rs. 2,53,673/-, followed by brinjal (Rs. 1,37,844/-). The optimum plan arrived vide MOTAD analysis ensured a gross margin of Rs. 11,93,788/- from a farm which has the size of 3.7 ha. The capital required as per new plan was Rs. 4,26,778.5/-. The recommended area allocation under different crops are as follows, Paddy – 1.95 ha, brinjal - 0.72 ha, marigold - 0.19 ha, coconut-pepper - 0.61 ha and Mango - 0.23 ha. The comparative lower values of Mean Absolute Deviation (39990), Standard Deviation (61972) and Co-efficient of variation (5.01) guarantee the genuineness and reliability of the new crop plan.

Cluster III

With regard to Cluster III, the MOTAD results are presented in Table 5. The crops advocated for the 'Risk optimized-crop diversified new plan' were Paddy, tuberose, brinjal, cotton, coconut and mango. The water availability was moderate in this cluster and hence to suggest a judicious optimal plan, less water intensive crops viz., Tuberose (600 mm) brinjal (450 mm) and cotton (700 mm) would be suitable choices. With regard to capital requirement Tuberose stood first with Rs. 2,49,497/- followed by Brinjal (Rs. 1,24,298/-).

The optimum plan arrived vide MOTAD analysis ensured a gross margin of Rs. 4,41,646.81/- from a farm which has the size of 1.9 ha. The capital required as per new plan was Rs. 1,72,087.24/-. The recommended area allocation under different crops are as follows; Paddy - 0.89 ha, Tuberose - 0.21 ha, Brinjal - 0.25 ha, Cotton - 0.31 ha and coconut - 0.24

Table 5. Risk optimized crop plan for cluster III with MOTAD analysis.

Particulars	Paddy	Tuberose	Brinjal	Cotton	Coconut & pepper
Minimize					
Expected gross margin (Rs)	216324	545128	358758	180345	539698
Land (ha)	1	1	1	1	1
Men labor (in man- hours/ha)	412	1312	912	321	1470
Women labor (in man- hours/ha)	969	2614	2257	842	678
Machine hours (in hours/ha)	34	19	6	9	6
Farm yard manure (in ton/ha)	19	9	6	9	14
Nitrogen (in kg/ha)	223	569	178	198	97
Phosphorus (in kg/ha)	82	514	176	130	64
Potash(in kg/ha)	81	678	105	78	194
Pesticides (in Rs.)	6327	6638	14023	4675	3646
Water requirement (in mm/ha)	2400	600	450	700	1350
Minimum	1				
Capital (Rs)	104724	249497	124298	67259	102975
Crop rotation	-1	1	1	-1	1
Year- 1	-12748	-18952	-8485	23653	-9628
Year- 2	22509	-16586	-18002	-13416	32782
Year- 3	-9761	35538	26487	-10237	-23154
Optimized solution on area allocation	**0.89**	**0.21**	**0.25**	**0.31**	**0.24**
Statistical parameters	**Mean absolute Deviation - 3989**	**Standard deviation - 5542**		**Coefficient of variation - 1.29**	

Table 5. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Con-straint limits	≈	Optimum plan
Minimize		1	1	1			
Expected gross margin (Rs)	288295				415783	≤	441646.81
Land (ha)	1				1.9	=	1.9
Men labor (in man- hours/ha)	682				1032	≥	931.45
Women labor (in man- hours/ha)	223				2489	≥	2295.46
Machine hours (in hours/ha)	5				61	≥	39.24
Farm yard manure (in ton/ha)	8.5				36	≥	21.48
Nitrogen (in kg/ha)	215				547	≥	356.89
Phosphorus (in kg/ha)	221				557	≥	219.36
Potash(in kg/ha)	299				636	≥	156.78
Pesticides (in Rs.)	3795				15846	≥	14362.67
Water requirement (in mm/ha)	1100				4320	≥	2667.4766
Minimum					0.9	≤	0.9
Capital (Rs)	99336				209593	≥	172087.24
Crop rotation	1				0	-	-0.819813

Table 5. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Con-straint limits	≈	Optimum plan
Year- 1	12511	1			0	≤	0
Year- 2	-6030		1		0	≤	5936.1304
Year- 3	-6481			1	0	≤	0
Optimized solution on area allocation	**0.00**	**4280**	**0**	**0**			
Statistical parameters	**Mean absolute deviation - 3989**		**Standard deviation – 5542**		**Coefficient of variation - 1.29**		

ha. The comparative lower values of Mean Absolute Deviation (3989), Standard deviation (5542) and Co-efficient of variation (1.29) guarantee the genuineness and reliability of the new crop plan.

Cluster IV

With regard to the Cluster IV, the MOTAD results are presented in Table 6. The crops advocated for the 'Risk optimized - Crop diversified new plan' were Paddy, Brinjal, Cotton, Maize, Coconut-Pepper and Mango. Out of the six crops considered for MOTAD analysis, Paddy is more water intensive crop. Coconut also required more water but its consumption was staggered and spread over the entire year. Three crops with less water requirements viz., Brinjal (450 mm), Cotton (700 mm) and Maize (500 mm) were accommodated. As far as labor requirement is concerned Brinjal required more labor. It required 923

Table 6. Risk optimized crop plan for cluster IV with MOTAD analysis.

Particulars	Paddy	Brinjal	Cotton	Maize	Coconut & Pepper
Minimize					
Expected gross margin (Rs)	106856	348428	179276	89678	532178
Land (Rs)	1	1	1	1	1
Men labor (in man- hours/ha)	216	923	298	232	1586
Women labor (in man- hours/ha)	495	2374	842	259	685
Machine hours (in hours/ha)	19	7	8	5.5	5
Farm yard manure (in ton/ha)	11	5	9	8.5	14
Nitrogen (in kg/ha)	127	166	183	61	92
Phosphorus (in kg/ha)	49	164	131	29	71
Potash(in kg/ha)	48	119	61	21	198
Pesticides (in Rs.)	3301	13978	4278	1948	3684
Water requirement (in mm/ha)	1200	450	700	500	1350
Minimum	1				
Capital (Rs)	48857	125783	41958	31431	101573
Crop rotation	-1	1	-1	-1	1
Year- 1	-11466	-16952	-12896	15435	54435
Year- 2	-7923	31441	-12709	-4819	-31783
Year- 3	19389	-14489	25605	-10616	-22488
Optimized solution on area allocation	**1.96**	**0.30**	**0.33**	**0.44**	**1.17**
Statistical parameters	**Mean absolute deviation - 13980**	**Standard deviation - 21402**		**Coefficient of variation - 2.25**	

Table 6. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Con-straint limits	≈	Optimum plan
Minimize		1	1	1			
Expected gross margin (Rs)	281895				524892	≤	958943.5
Land (Rs)	1				4.2	=	4.2
Men labor (in man- hours/ha)	663				2331	≥	2342
Women labor (in man- hours/ha)	235				3982	≥	2721.84
Machine hours (in hours/ha)	5				69	≥	49.78
Farm yard manure (in ton/ha)	8				42	≥	42
Nitrogen (in kg/ha)	208				675	≥	451.83
Phosphorus (in kg/ha)	202				549	≥	256.83
Potash(in kg/ha)	291				585	≥	323.68
Pesticides (in Rs.)	3928				19591	≥	16981.49
Water requirement (in mm/ha)	1100				4920	≥	4335.011
Minimum					2	≤	2
Capital (Rs)	98891				332185	≥	278432.8
Crop rotation	1				0	-	-1.51922
Year- 1	-12796	1			0	≤	27714.9
Year- 2	-18673		1		0	≤	-43748.6
Year- 3	31469			1	0	≤	30208.5
Optimized solution on area allocation	**0.00**	**0**	**0**	**1414**			
Statistical parameters	**Mean absolute deviation- 13980**		**Standard deviation - 21402**		**Coefficient of variation - 2.25**		

hours/ha of men labor and 2,374 hours/ha of women labour. Coconut-pepper was the crop with the highest gross margin (Rs. 5,32,178/-). With regard to capital requirement Brinjal stood first with Rs. 1,25,783/- followed by Coconut (Rs. 1,01,573/-).

The optimum plan arrived vide MOTAD analysis ensured a gross margin of Rs. 9,58,943.5/- from a farm which has the size of 4.2 ha. The capital required as per new plan was Rs. 2,78,432.8/-. The recommended area allocation under different crops are as follows; Paddy-1.96 ha, Brinjal - 0.30 ha, Cotton - 0.33 ha, Maize - 0.44 and coconut-pepper-1.17 ha. The comparative lower values of Mean Absolute Deviation (13980), Standard Deviation (21402) and Co-efficient of Variation (2.25) guarantee the genuineness and reliability of the new crop plan.

Cluster V

The MOTAD results for the Cluster V, are presented in Table 7. This cluster is the one which depends on canal water and North East monsoon. Irrigation with bore wells is much limited, since underground water is saline in nature. It could be observed at field level that the agronomical conditions were almost similar for the small and large farm. Difference may exist with economies of scale and capital mobilization, which may have some impact on the cropping systems. The crops advocated for the 'Risk optimized - Crop diversified new plan' were Paddy, Brinjal, Cotton, Maize, Coconut-Pepper, and Mango. Cultivation of perennials like Coconut seemed to have scope in this Cluster. Brinjal, Maize and Cotton were also accommodated.

The optimum plan arrived vide MOTAD analysis, ensured a gross margin of Rs. 4,25,736.56/- from a farm which has the size of 2.2 ha. The capital required as per new plan was Rs. 1,16,894/-. The recommended area allocation under different crops

Tabel 7. Risk optimized crop plan for cluster V with MOTAD analysis.

Particulars	Paddy	Brinjal	Cotton	Maize	Coconut & pepper
Objective function					
Expected gross margin (Rs)	102345	345673	178459	89271	529462
Land (ha)	1	1	1	1	1
Men labor (in man- hours/ha)	211	882	271	201	1421
Women labor (in man- hours/ha)	493	2185	824	242	662
Machine hours (in hours/ha)	19	7	7.5	5	5
Farm yard manure (in ton/ha)	10	5	8	7.5	12
Nitrogen (in kg/ha)	123	164	173	52	89
Phosphorus (in kg/ha)	45	158	124	29	72
Potash (in kg/ha)	46	103	59	21	175
Pesticides (in Rs.)	3227	13367	4165	812	3502
Water requirement (in mm/ha)	1200	450	700	500	1350
Minimum	1				
Capital (Rs)	48256	124674	40522	32785	100456
Crop rotation	-1	1	-1	-1	1
Year- 1	32307	-19554	-12818	14841	-19402
Year- 2	-17681	-15124	23887	-9625	-29272
Year- 3	-14626	34687	-11059	-5216	48674
Optimized solution on area allocation	**1.08**	**0.00**	**0.17**	**0.45**	**0.50**
Statistical parameters	**Mean absolute deviation - 6872**	**Standard deviation - 9979**		**Coefficient of variation - 2.53**	

Table 7. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Con-straint limits	≈	Optimum plan
Objective function		1	1	1			
Expected gross margin (Rs)	282592				244285	≤	425736.56
Land (ha)	1				2.2	=	2.2
Men labor (in man- hours/ha)	297				1195	≥	1005.6
Women labor (in man- hours/ha)	211				1486	≥	1033.62
Machine hours (in hours/ha)	6				41	≥	26.72
Farm yard manure (in ton/ha)	8				29	≥	21.32
Nitrogen (in kg/ha)	194				474	≥	215.64
Phosphorus (in kg/ha)	192				278	≥	102.37
Potash (in kg/ha)	273				234	≥	142.86
Pesticides (in Rs.)	3632				8356	≥	5855.63
Water requirement (in mm/ha)	1100				2520	≥	2185.194
Minimum					1	≤	1
Capital (Rs)	99397				126492	≥	116894
Crop rotation	1				0	-	-1.15102

Table 7. Continued.

Particulars	Mango	Z_1^-	Z_2^-	Z_3^-	Con-straint limits	≈	Optimum plan
Year- 1	-16994	1			0	≤	27975.4
Year- 2	-13862		1		0	≤	-32249
Year- 3	30856			1	0	≤	11252.43
Optimized solution on area allocation	**0**	**0**	**0**	**6977**			
Statistical parameters	**Mean absolute deviation - 6872**		**Standard deviation - 9979**			**Coefficient of variation - 2.53**	

are as follows, paddy - 1.08 ha, cotton - 0.17 ha, maize - 0.45 ha and coconut-pepper - 0.50 ha. The comparative lower values of Mean Absolute Deviation (6872), Standard Deviation (9979) and Co-efficient of variation (2.53) guarantee the genuineness and reliability of the new crop plan.

Conclusion and policy implication

The estimated Diversification indices reveal that, the concept of crop diversification is much less pronounced in the study area. Hence efforts need to be enhanced by the concerned authorities, to promote awareness among the Cauvery delta farmers, on the merits of crop diversification as a tool for risk mitigation in agriculture. Parallel care should also be there to protect Cauvery delta zone as the Rice bowl of Tamil Nadu by restoring the reasonable dominance of Paddy crop in the area.

Needed efforts may be put forth by the authorized Governmental agri-extension agencies to educate the target farmers on the concept of crop diversification by conducting a series of meetings/workshops. The Cluster specific 'Risk optimized - Crop diversified alternative cropping systems' evolved at, vide MOTAD analyses in this study may be popularized among the farmers of Cauvery delta region.

The Garrett analyses for the different clusters vividly portray that 'Lack of awareness on crop diversification' and 'Fear of production failure' with new crops are the major reasons for non-adoption of crop diversification in the study area. Hence, while popularizing the advocated alternative model, due care should be accorded to impart the target farmers, the needed production techniques of the new crops.

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