Evading Cyclonic Risks in Perennial Crops Dominated Farm Belt- An Alternative Strategy

Idemakanti Chandrakanth Reddy and C. Prabakar

Research Journal of Agricultural Sciences
An International Journal

P- ISSN: 0976-1675
E- ISSN: 2249-4538

Volume: 13
Issue: 04

Res. Jr. of Agril. Sci. (2022) 13: 1185–1190

CARAS

Res. Jr. of Agril. Sci. (Jul-Aug 2022) 13(4): 1185–1190

www.rjas.org

ISSN: 0976-1675 (P)
ISSN: 2249-4538 (E)

Full Length Research Article

Evading Cyclonic Risks in Perennial Crops Dominated Farm Belt- An Alternative Strategy

Idemakanti Chandrakanth Reddy[1] and C. Prabakar*[2]

Received: 01 Apr 2022 | Revised accepted: 28 Jul 2022 | Published online: 02 Aug 2022

ABSTRACT

Historically, Tamil Nadu is one of the most vulnerable states to the tropical cyclones. Also, evidences show that farm belts dominated with perennials as monocrop are worst hit during larger cyclonic havocs. Cuddalore district of Tamil Nadu is one among such perennial dominated districts which often faces similar havocs. Hence, this study was conceived with the objective to assess the existing degree of farm level crop diversification in the cyclone prone district of Cuddalore and to evolve at a risk tolerant, havoc resilient, alternative cropping system, embedded with the annual – perennial crop mix capable of enhancing the livelihood security of farmers. In the study, certain econometric analyses were undertaken using primary data. Stratified random sampling technique was adopted for collection of primary data from farmers. The estimated diversification indices vividly revealed that, in general, the concept of crop diversification was much less pronounced in the study area. Hence efforts need to be enhanced by Institutional authorities to promote awareness, among the farmers of coastal blocks, on the merits of crop diversification and make them realize that, crop diversification is an effective tool for mitigating production risks arising out of cyclones, storms and floods. The study had evolved farm size specific, risk optimized, crop plans, vide MOTAD analyses, which needs to be popularized among farmers in the study area.

Key words: Crop diversification, Herfindahl index, MOTAD analysis, Risk mitigation

Tamil Nadu which has a coastal line of 1,076 kms, is one among the most vulnerable states to the tropical cyclones. During certain years, the coast has been hit by cyclones even more than once. The state is multi- hazard prone, the major natural hazards being cyclonic storms, urban and rural floods and periodic droughts. Some of the tropical cyclones that hit Tamil Nadu in recent years were; Gaja (2018), Ockhi (2017), Vardha (2016), Nilam (2012), Thane (2011), Jas (2010) and Nisha (2008) [1]. Among these, Thane, Nilam and Gaja cyclones made severe damages to the coastal agriculture of Tamil Nadu. Especially, the Cuddalore district which accommodates vast stretches of perennials like Cashew and Jack, was worst hit by these cyclones. During Thane cyclone, about 23,500 ha of cashew and major portion of Jack in Cuddalore district were either completely uprooted or partially uprooted [2]. Nilam cyclone hit the Tamil Nadu coast on 31st October 2012 and the flood water totally inundated 51,486 ha of directly sown farmland [3]. Gaja cyclone had the land fall on 11th November 2018, which uprooted a large number of trees and the total agricultural area affected by flood stood at 1,22,063 ha. Coconut trees spread over 69,358 ha were uprooted [1].

Eventually, it is also a fact that the damage became intolerable since majority of the farmers were adopting a monocropping system of farming. Crop diversification almost remained a forgotten concept in the region, and farmers are unaware of the alternative crops which could be cultivated in their land, since the present system has been followed for decades together. Crop diversification has been recognized as an effective strategy for achieving objectives of food security, nutrition security, poverty alleviation, production risk management, sustainable agricultural development and environmental improvement [4]. But the micro level-details on the study area, reveal only a very negligible level of crop diversification. The reason for which has to be explored and set right, since in such cyclone prone areas, crop diversification could serve as an effective remedy.

The lessons learnt from previous cyclones also revealed tragical scenarios. During larger cyclonic devastations when even bigger trees were uprooted, the farms growing perennials like Cashew and Jack as monocrop were worst hit. The resilience of those farmers were very poor because of the larger gestation/recovery period of tree crops. A minimum of four to five years is required for the complete recovery. Had there a

* **C. Prabakar**
prabakarcagrieco@gmail.com

1 MSSSoA, Centurion University of Technology and Management, Paralakhemundi - 761 200, Odisha, India

2 Department of Agricultural Economics, Faculty of Agriculture, Annamalai University, Annamalai Nagar - 608 002, Tamil Nadu, India

small portion of land been allocated for annuals like paddy or vegetable, the farmer would have begun his cultivation in the next season at least and earned a little for his livelihood. Under this background, an attempt was made to evolve at a risk tolerant, havoc resilient cropping system accommodating the concept of crop diversification probably with an annual-perennial crop mix considering the socio-economic and agronomical factors prevailing at micro level. Hence, the specific objectives are as follows:

- To assess the existing degree of farm level crop diversification, in the cyclone prone, perennials dominated district of Cuddalore.
- To evolve at a risk tolerant, havoc resilient, alternative cropping system, embedded with the annual – perennial crop mix capable of enhancing the livelihood security of farmers.

MATERIALS AND METHODS

Cuddalore district formed the universe of the study. In accordance with the Stratified random sampling technique, as the first stage of sampling, all the four coastal blocks of the district viz., Cuddalore, Kurinjipadi, Panruti and Parangipettai were purposively selected since these are the blocks cultivating perennials viz., Cashew and Jack in large stretches and also were encountered with higher number of cyclonic land falls in the recent decades. As the second stage of sampling, from each block, 60 farmer respondents were selected at random. The ultimate sample size in total was 240. The 60 farmers from each block were post stratified into small farmers (<2.5 ha) and large farmers (> 2.5 ha) for analytical convenience.

The collection of primary data forms a vital part of this study. In accordance with the adopted, stratified random sample technique, sixty respondents from each of the four blocks were selected and data were obtained, by personal enumeration method. A well-structured interview schedule was prepared and pre-tested during pilot survey and was used for enumeration of data. The interview schedule was constructed in such way that it accommodated questions capable of culling out all data required for the two analyses viz., Estimation of Herfindahl and Simpson indices and MOTAD analysis. The primary data related to the socio-economic demography of the region, degree of farm level crop diversification, cultivation details of suitable crops, awareness of farmers on crop diversification, opinion on annual-perennial crop mix and suggestions to mitigate risk in agriculture had been collected from sample farmers in the study area.

The general information about the districts and blocks, such as, demographic details, crop coverage, rainfall, occupational status, land utilization pattern, sources of irrigation, area irrigated, operational land holdings, livestock population and disaster vulnerability were collected from the secondary sources. The data collected were tabulated, processed and subjected to statistical analyses to draw meaningful inferences. The reference year for the study is the agricultural year 2019-20.

Assessment of crop diversification

Herfindahl index (HI)

The Herfindahl index is a measure of concentration. The degree of crop diversification in a farm/ region could be assessed using the Herfindahl index. It is an economic concept widely applied in competition law in USA [5].

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:

$$\text{HI} = \sum_{i=1}^{N} \text{P}_i^{\,2}$$

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.

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:

$$\text{SI} = 1 - \sum_{i=1}^{N} \text{P}_i^{\,2}$$

Where,
$P_i = A_i / \Sigma A_i$ is the proportion of the i^{th} 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.

Herfindahl index and Simpson index were calculated separately for each sample farm and the average value of the farm level indices was considered for further interpretation. The Indices were estimated for small (<2.5 ha) and large farms (>2.5 ha) separately for the agricultural years, 2017-18, 2018-19 and 2019-20. The indices were estimated using the collected primary data on the proportion of area under different crops in gross cropped area at farm level.

Evolution of risk optimized crop plan using MOTAD Model

To suggest appropriate 'risk optimized – crop diversified' alternative plans for the farmers in the study area, MOTAD (Minimization of Total Absolute Deviation) model was used in the study. In agricultural planning at micro level, the farmers face multiple objectives, often conflicting in nature. In situations where multiple objectives are involved, the farmer is interested not in optimizing a single objective, but would find a compromise among several objectives. In general, two conflicting objectives, viz., profit maximization and risk minimization, are attempted to be solved. Profit maximizing linear programming models based on the data of representative farms has been frequently used for finding the optimum use of farm resources. However, due to the risk involved in different profit outcomes, some method of incorporating risk considerations into the analytical framework is desirable. Quadratic Programming (QP) has been suggested as the most useful tool for incorporating risk in farm planning. But certain limitations of QP itself necessitated a linear rather than a QP approach.

In line with this understanding, Hazell [6] proposed the use of MOTAD (minimization of total absolute deviation from mean) as an alternative for planning under risk. It attracted the attention of researchers in India and abroad as it can be solved on conventional linear programming code and also enables better post optimal analysis. Sirohi [7], Singh and Jain [8], Randhir and Krishnamoorthy [9], Jha [10] and Boruah [11] 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:

$$\text{M} = \text{S}^{-1} \sum_{t=1}^{s} \left| \sum_{j=1}^{n} (C_{tj} - \overline{C}_j)\text{x}_j \right| \qquad \ldots\ldots\ldots\ldots (1)$$

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 j^{th} crop activity in the t^{th} year (unit is hectare)
$\bar{C}_j$ = Sample mean gross margin per unit of j^{th} crop activity.
X_j = Level of j^{th} crop activity to be obtained from the solution of the model.
J = Refers to j^{th} activity (j = 1 to n activities)
t = Refers to t^{th} 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 t^{th} year of sample data were defined by a new variable, $\bar{Y}_t$ and it was defined as:

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

J = 1 to n crop activities,
C_{tj} = Gross margin from j^{th} crop activity in the t^{th} year
$\bar{C}_j$ = Mean gross margin of j^{th} crop activity.

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

Minimize $\bar{Y}_t$
Subject to:

$$\sum_{i=1}^{n} a_{ij}X_j(\geq = \leq)b_i\,,\; i = 1 \text{ to m contraints} \quad \dots\dots\dots (3)$$

$$\sum_{j=1}^{n}(C_{tj} - \bar{C}_j)X_j + \bar{Y}_t \geq 0 \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

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

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

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

$\bar{Y}_t$ = 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 j^{th} activity for the i^{th} resource or constraint
X_j = Level of j^{th} crop activity to be obtained from the solution of the model
b_i = The i^{th} constraint level
C_{tj} = Gross margin from j^{th} crop activity in the t^{th} year
$\bar{C}_j$ = Mean gross margin of j^{th} crop activity
n = Number of activities
m = Number of constraints
λ = A parameter to be parameterised to the maximum level of expected income.

The Standard Deviation (S.D.) of each risk efficient crop production plan, generated by the MOTAD model were calculated by the following statistic:

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

Where,
S.D = Standard Deviation
d = Estimated Mean Absolute Deviation

$$\pi = \frac{22}{7}$$

s = Number of observations

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 minimizing risk, subject to the constraints listed already. 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.

Requirements and constraints

The values of factor requirements, viz., labour, 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 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 were considered as the constraint limit for land availability. With regard to labour, 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 variance, in the most understandable 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 these above considerations and assumptions, the MOTAD analysis was employed in the study for evolving at ‘risk optimized- crop diversified’ alternative cropping systems. The analysis was undertaken separately for small farms (<2.5 ha) and large farms (>2.5 ha) in the cyclone prone Cuddalore district of Tamil Nadu.

RESULTS AND DISCUSSION

Crop diversification

The degree of farm level crop diversification for both small and large farms were assessed and quantified using Herfindahl Index and Simpson Index for the three recent years viz., 2017-18, 2018-19 and 2019-20. The indices were estimated for each farm separately and the average value 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 observed that, the estimated Herfindahl indices were 0.701, 0.631 and 0.661 for small farms and 0.609, 0.621 and 0.620 for large farms, respectively. It could be inferred from the indices that; the concept of crop diversification was much less pronounced in the study area. This might be because of the lack of awareness on the merits of crop diversification. The corresponding Simpson indices also replicate the similar trend in the referred years.

Another observation which could be derived from the value of indices was that the degree of adoption of crop diversification was more with large farms than small farms in the study area, but practically seemed to be insignificant. As mentioned earlier, the study area is dominated by perennial crops especially Cashew and Jack. Obviously growing perennials as Monocrop would invite all sorts of production risks which needs to be addressed [12].

Table 1 Farm level crop diversification in the study area

Particulars		Herfindahl index			Simpson index		
		2017-18	2018-19	2019-20	2017-18	2018-19	2019-20
Cuddalore district	Small farms	0.701	0.631	0.661	0.299	0.369	0.339
	Large farms	0.609	0.621	0.620	0.391	0.379	0.380

Small farms- <2.5 ha; Large farms- > 2.5 ha

Risk optimized cropping plan

The lessons learnt from cyclones, viz., Thane, Nilam and Gaja in the study area has clearly spelt out an inference that the prevailing system of monocropping with perennials has lessened the resilience of farmers during cyclonic havocs. Crop diversification is understood to be an effective tool in mitigating risk during such disasters. MOTAD analysis was employed to arrive at a 'Risk optimized cropping plan' in the study area. The MOTAD analyses were undertaken separately for small farms (<2.5 ha) and large farms (>2.5 ha), respectively.

Table 2 Risk optimized crop plan for small farms with MOTAD analysis

Particulars	Paddy	Maize	Brinjal	Tapioca	Jack	Cashew	Z_1^-	Z_2^-	Z_3^-	≈	Constraint limits	Optimum plan
Minimize							1	1	1			
Expected gross margin	90123	89331	323082	198117	959534	201912				≥	421498	421498
Area (in hectares)	1	1	1	1	1	1				=	1.9	1.9
Men Labour (hours/ha)	224	268	906	1055	558	183				≤	1446	845.2633
Women Labour (hours/ha)	485	286	2756	712	806	3098				≤	4502	3204.942
Machine hours (hours/ha)	15.5	5.7	7.5	7.3	0	0				≤	11	11
Farm yard manure (ton/ha)	7.5	9.7	12.5	12	4.7	6.5				≤	17	15.361
Nitrogen (kg/ha)	116	58	210	86	76	103				≤	476	191.7324
Phosphorus (kg/ha)	36	25	92	85	38	78				≤	384	126.9816
Potash (kg/ha)	37	16	110	218	52	25				≤	372	151.2291
Pesticides (Rs.)	2552	816	409	2533	512	1020				≤	3559	3329.055
Water requirement (mm/ha)	1200	500	450	1500	800	745				≤	2000	2000
Minimum	1				1	1				≥	1.4	1.4
Capital	49522	37681	143234	104055	252626	79744				≤	184886	170595.1
Crop rotation	-1	-1	-1	-1	1	1				-	0	-0.04832
Year- 1	11466	1012	17406	7286	-63572	-1925	1			≥	0	5.91E-12
Year- 2	-2730	6212	-29445	6236	-27326	-21171		1		≥	0	0
Year- 3	-8736	-7224	12039	-13522	90898	23096			1	≥	0	18995.65
Optimized solution on area allocation	0.47	0.00	0.02	0.48	0.12	0.81	0	18995	0			
Statistical parameters	Mean Absolute Deviation- 18995				Standard Deviation-29149					Coefficient of Variation- 6.91		

In the study area, most of the region was covered with fertile red loamy soil, which was suitable for all annual and perennial crops. The availability of ground water was also good and hence majority of the farmers used borewell for irrigation, especially with large farms [13]. In case of small farms, borewell irrigation was less in number when compared to large farms. The labour wages were found to be high, but scarcity in labour availability was not observed. Pesticide and fertilizer usage were found to be less, since most of the area was cultivated with perennials. Considering these existing agronomical aspects, suitable crops were included in MOTAD analysis.

Small farms

The MOTAD results pertaining to small farms are presented in (Table 2). The crops suggested for the 'risk optimized- crop diversified new plan' were, Paddy, Maize, Brinjal, Tapioca, Jack and Cashew. Paddy and Tapioca were two crops which required more water. Brinjal was the most labour-intensive crop among these crops. It required 906 hours of men labour and 2756 hours of women labour for cultivation, closely followed by Cashew (men-183 and women- 3098 hours/ha). The two important perennials of this region, Jack and Cashew were included. Jack was the crop which had the highest gross margin (Rs. 9,59,534). The crops with less water requirement were Brinjal (450 mm), Maize (500 mm) and Cashew (745 mm). With regard to capital requirement, Jack stood first with Rs. 2,52,626, followed by Brinjal (Rs. 1,43,234) and Tapioca (Rs. 1,04,055). The optimum plan arrived vide MOTAD analysis confirmed a gross margin of Rs. 4,21,498/- from a farm which had the size of 1.90 ha (Small farm). The capital required as per new plan was Rs. 1,70,595/-. The recommended area allocation under different crops was as follows: Paddy-0.47ha; Brinjal-0.02ha; Tapioca-0.48 ha; Jack-0.12ha and Cashew-0.81 ha. The comparative lower values of Mean Absolute Deviation (18995), Standard Deviation (29149) and Coefficient of Variation (6.91) guaranteed the genuineness and reliability of the new crop plan [14].

Table 3 Risk optimized crop plan for large farms with MOTAD analysis

Particulars	Paddy	Brinjal	Watermelon	Jack	Cashew	Z_1^-	Z_2^-	Z_3^-	≈	Constraint limits	Optimum plan
Minimize						1	1	1			
Expected gross margin	90546	332588	320452	965512	203418				≥	1850102	1850102
Area (in hectares)	1	1	1	1	1				=	6.86	6.86
Men Labour (hours/ha)	231	952	552	550	196				≤	3462	2766.595
Women Labour (hours/ha)	498	2672	506	816	3259				≤	18014	17970.06
Machine hours (hours/ha)	16.5	7	7.5	0	0				≤	24	24
Farm yard manure (ton/ha)	8	15.1	10.3	5	8.2				≤	79	66.0384
Nitrogen (kg/ha)	124	204	55	75	112				≤	1017	894.4733
Phosphorus (kg/ha)	34	96	52	42	75				≤	778	500.7644
Potash (kg/ha)	35	118	54	54	27				≤	475	349.5791
Pesticides (Rs.)	2632	525	714	616	1220				≤	8513	7924.671
Water requirement (mm/ha)	1200	450	500	800	745				≤	5000	4940.885
Minimum	1								≥	0.7	0.7
Capital	49937	149518	67492	255465	82546				≤	715228	715228
Crop rotation	-1	-1	-1	1	1				-	0	1.931244
Year- 1	-8900	-21029	18744	-60309	20943	1			≥	0	23771.38
Year- 2	-1546	-9513	17492	78826	-9755		1		≥	0	-3.6E-12
Year- 3	10446	30542	-36236	-18517	-11188			1	≥	0	-1.2E-11
Optimized solution on area allocation	0.70	1.56	0.20	0.40	4.00	0	19560	4211			
Statistical parameters	Mean Absolute Deviation- 23771			Standard Deviation-36479				Coefficient of Variation- 1.97			

Large farms

With regard to the large farms, the MOTAD results are presented in (Table 3). The crops suggested for the 'risk optimized- crop diversified new plan' were, Paddy, Brinjal, Watermelon, Jack and Cashew. Paddy was the only water-intensive crop proposed in the crop plan. Jack and Cashew were the two perennials, which were present already in almost all farms. Brinjal and Watermelon were also proposed, which are crops requiring only less water for cultivation. With regard to labour requirement, two crops were much labour intensive, viz., Brinjal (men-952 hours and women-2672 hours of labour) and Cashew (men- 196 hours and women- 3259 hours of labour). As far as capital requirement was concerned, Jack (Rs. 2,55,465) and Brinjal (Rs. 1,49,518) seemed to be more capital-intensive than the other crops [15-16].

The optimum plan arrived vide MOTAD analysis ensured a gross margin of Rs. 18,50102/- from a farm which had the size of 6.86 ha (Large farm). The capital required as per new plan was Rs. 7,15,228/-. The recommended area allocation under different crops was as follows: Paddy- 0.70 ha; Brinjal-1.56 ha; Watermelon- 0.20 ha; Jack- 0.40 ha and Cashew- 4.00 ha.

The comparative lower values of Mean Absolute Deviation (23771), Standard Deviation (36479) and Coefficient of Variation (1.97) guaranteed the genuineness and reliability of the new crop plan.

In both the crop plans, a major portion of area (approximately 50 per cent) was allotted to the existing dominant principal crop and rest of the area was allotted to less water intensive crops and perennials. The cropping systems arrived at, were complemented with increased level of diversification aiding for minimization of risk, when compared to the existing monocropping system [17]. The mean absolute deviation of the two risk optimized plans were observed to be rational.

Policy implications

The estimated diversification indices vividly revealed that, in general, the concept of crop diversification was much less pronounced in the study area. Hence efforts need to be enhanced by Institutional authorities to promote awareness, among the farmers of coastal blocks of Cuddalore district, on the merits of crop diversification and make them realize that, this is an effective tool for mitigating production risks arising out of cyclones, storms and floods.

In the study area, most of the farmers cultivate perennials as monocrop. Monocropping would reduce the resilience of farmers. A diversified crop plan with a balanced annual perennial mix would be ideal for mitigating risk in cyclone prone areas. The evolved "Risk optimized, Crop diversified plans" obtained vide MOTAD analyses, needs to be popularised among farmers in the study area.

Acknowledgement

The author acknowledges with gratitude, the Indian Council of Social Science Research (ICSSR), New Delhi, for the award of the Doctoral fellowship for the conduct of this Research.

LITERATURE CITED

1. NMDA. 2019. National Disaster Management Authority (NDMA), 2019. https://ndma.gov.in/images/guidelines/Study-Report-Gaja-Cyclone-2018.pdf
2. Damodaran K. 2015. Thane cyclone and rehabilitation cost of cashew cultivation in Panruti Block, Cuddalore District, Tamil Nadu. *International Journal of Advanced Research in Management and Social Sciences* 4(4): 23-31.
3. IMD. 2020. India Meteorological Department (IMD). mausam.imd.gov.in
4. Hedge DM, Tiwari Sp, Rai M. 2003. Crop diversification in Indian agriculture. *Agricultural Situation in India* 2003: 351-354.

5. Brown, Donald M, Warren-Boultan, Frederick R. 1988. Testing structure-competition relationship on cross-sectional firm data. Discussion Paper 88-6, Economic Analysis Group, U.S. Department of Justice.
6. Hazell, Peter BR. 1971. A linear alternative to quadratic and semivariance programming for farm planning under uncertainty. *American Journal of Agricultural Economics* 53(1): 53-62.
7. Sirohi AS. 1976. An economic analysis of risk on drought prone farms in Bijapur district, Karnataka. Indian Agricultural Research Institute, Division of Agricultural Economics.
8. Singh AJ, Jain KK. 1983. Farm planning under risk and uncertainty: An application of parametric linear programming. *Indian Journal of Agricultural Economics* 38(2): 208-216.
9. Randhir, Timothy O, Krishnamoorthy S. 1993. Optimal crop planning under production risk in Tankfed south Indian farms. *Indian Journal of Agricultural Economics* 48(4): 678-686.
10. Jha BK. 1996. Risk return trade off in the farms in the greenbelt, India. *Agricultural Situation in India* 53: 501-506.
11. Boruah LK. 2014. An economic analysis of crop production risks and measures adopted by farmers of Riverine area in the upper Brahmaputra valley zone of Assam. *Unpublished Thesis*, Assam Agriculture University, Jorhat, Assam.
12. Mugendi NE. 2013. Crop diversification: A potential strategy to mitigate food insecurity by smallholders in sub-Saharan Africa. *Journal of Agriculture, Food Systems, and Community Development* 3(4): 63-69.
13. Ho, Shuay-Tsyr, Ifft, Jennifer E, Rickard, Bradley J, Turvey, Calum G. 2016. Alternative strategies to manage weather risk in perennial fruit crop production. Working Papers 250036, Cornell University, Department of Applied Economics and Management.
14. Roushon J, Paul K, Kabir M, Lobry de Bruyn L. 2022. Cropping systems intensification and diversification: risk, vulnerability and adaptation in southwest coastal Bangladesh. *International Journal of Sustainable Development and World Ecology*. doi: 10.1080/13504509.2022.2073615
15. Yuen KW, Switzer AD, Teng PPS, Lee JSH. 2022. Assessing the impacts of tropical cyclones on rice production in Bangladesh, Myanmar, Philippines, and Vietnam. *Natural Hazards and Earth System Science Discussions*. https://doi.org/10.5194/nhess-2022-4
16. Fritz HM, Blount CD, Thwin S, Thu MK, Chan N. 2009. Cyclone Nargis storm surge in Myanmar. *Nature Geoscience* 2: 448-449.
17. Blanc E, Strobl E. 2016. Assessing the impact of typhoons on rice production in the Philippines 55: 99-1007. https://doi.org/10.1175/JAMC-D-15-0214.1.