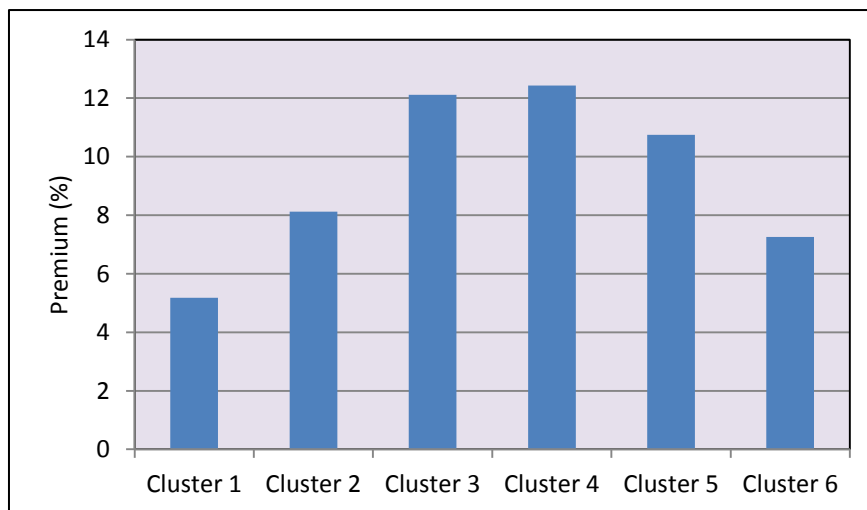
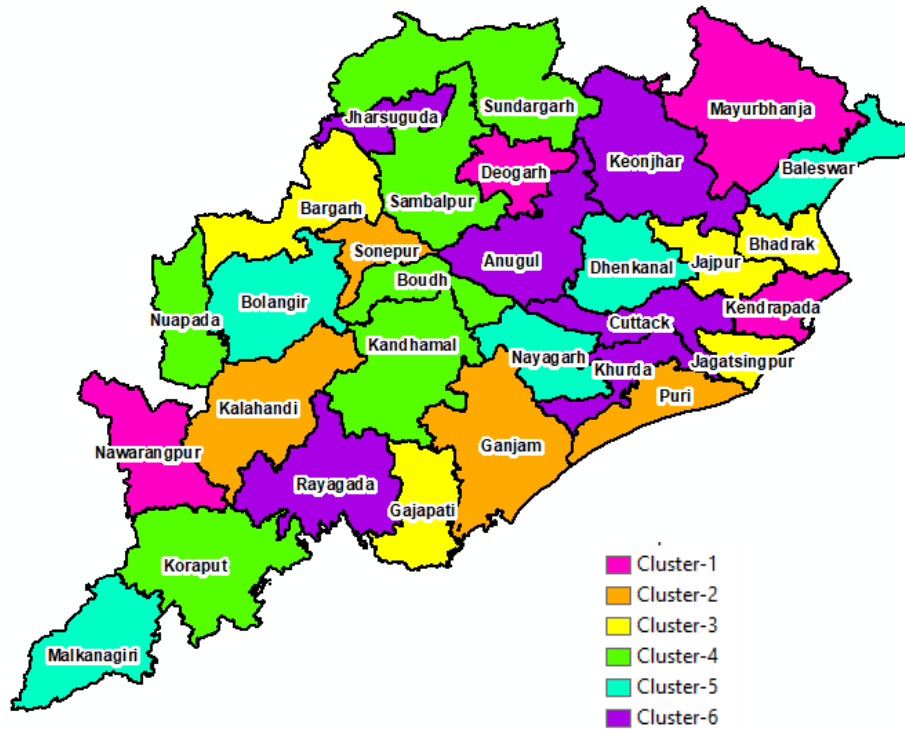


Agriculture Risk Index for Crop Insurance Pricing

(Crop Insurance Decision Support System Project for Department of Agriculture and Farmers Empowerment, Government of Odisha)



July 2018

Agricultural Sciences and Applications, Remote Sensing Applications Area,
National Remote Sensing Centre, ISRO, Hyderabad

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14.	Abstract	<p>This report focuses on improving the clustering mechanism of crop insurance pricing process under PMFBY by including multiple risk indices generated from satellite data and other datasets. This work represents a part of the on-going Crop Insurance Decision Support System (CIDSS) project for Odisha state. An innovative approach is adopted to develop Agriculture Risk Index (ARI) for different districts of Odisha state, by combining multiple risks representing flood, drought and weather/crop management effects and insurance history. Using the ARI and crop area data, the state is divided in to six clusters, representing uniform risk exposure levels and business opportunities. The clusters suggested by NRSC have been adopted by Odisha for insurance rate making in kharif 2018, thus setting a model for technology utilisation in the pricing segment of crop insurance value chain. This improved clustering mechanism can be replicated in other states also. As a way forward, scope for integrating the risk indices with the pricing models of the insurance companies needs to be explored in order to arrive at optimal premiums for different crops in a cluster.</p> <p>Key words: Crop insurance, rate making, crop risks, PMFBY, agriculture, flood, drought</p>			

Executive Summary

Crop insurance pricing or rate making is a procedure to determine the price of the insurance contract i.e. premium amount to be charged for a crop in a given district.

One of the important challenges in PMFBY is to arrive at optimal premium rates for different crops. It is well recognised that there is a need to improve the pricing mechanism to make it more scientific, transparent and competitive, for increasing farmer subscriptions.

The first step in the process of rate making is dividing the state into clusters of districts in such a way that risk exposure levels and business opportunities among the clusters are more or less uniform. This is done by State department dealing with crop insurance. The second step is to compute the premiums for each crop, season and district within each cluster. This is done by the empanelled insurance companies in the state. The actuarial premium rates include loss cost during recent years, non-parametric crop risks and expenses towards management. The last step is assigning clusters to insurance companies on the basis of competitive premium rates for implementation of the scheme for all notified crops in all districts of each cluster.

The current approach of clustering uses limited risk information either due to non-availability or due to lack of expertise with stakeholders for generating such information. This report focuses on improving the clustering mechanism of rate making process by including multiple risk information generated from satellite data and other datasets. This work was carried-out as a part of the on-going Crop Insurance Decision Support System (CIDSS) project for Odisha state.

An innovative approach is adopted here to develop Agriculture Risk Index (ARI) for different districts of Odisha state, by combining multiple risks. Indices related to flood and drought risks are generated from satellite data and the other two risk indices representing weather & crop management effects and insurance history are generated using secondary data. These four risk indices are then synthesised in to a composite index named as 'Agriculture Risk Index

(ARI)' for each district. Using the ARI and crop area data, the state is divided in to six clusters, representing uniform risk exposure levels and business opportunities.

The six clusters suggested by NRSC have been adopted by Odisha for insurance rate making in kharif 2018, thus setting a model for technology utilisation in the pricing segement of crop insurance value chain. District wise ARI values and crop statistics are made available to the participating insurance companies.

As a way forward, the improved clustering mechanism for insurance rate making adopted by Odisha can be replicated in other states also, subject to data availability.

Further, the scope for integrating the risk indices with the pricing models of the insurance companies needs to be explored in order to arrive at optimal premiums for different crops and districts in a cluster. Such improvements would make the premium rates more objective and realistic.

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1. Introduction

Crop insurance acts as farm safety net and stabilises farm income. Agricultural risk sharing through crop insurance has been in existence in many countries, in many forms for more than many decades (Skees et al. 2005) but most of these products are being supported by huge subsidies from the Governments (Ibarra and Skees 2007). The need for developing innovative crop insurance products that are actuarially stronger, has been largely recognized by both developed and developing nations in recent years (Anonymous 2014, Leblois and Quiron 2013). Index based insurance products (yield or weather) have been widely promoted since 1990s as efficient contracts in agricultural insurance (Binswanger-Mkhize, 2012).

India has a long history in the design, development and implementation of various crop insurance schemes signifying improvements from time to time, to insulate the farming community against various cultivation risks (Mishra 1996). Traditional crop insurance was introduced in the country in the year 1965 followed by Comprehensive Crop insurance scheme (CCS) in 1980's and 1990's, weather based insurance schemes in 2003 and National Agricultural Crop Insurance Scheme (NAIS) in 2004 and Modified NAIS (MNAIS) in 2010 (Anonymous 2014). In the existing crop insurance schemes, estimation of loss and indemnity payment are decided by weather index or crop yield index over an area. Weather based crop insurance is seriously limited by (1) complex relations between weather and crop yield, (2) inadequate representation of spatial variability in weather conditions, (3) lack of representation to the hazards (pests and diseases) not related to weather etc. (Leblois and Quirion (2013). NAIS and MNAIS, the most popular area-yield crop insurance schemes, faced serious limitations – subjective crop yield measurements, inadequate coverage, accuracy and transparency (Anonymous 2014). Increasing crop production risks in agriculture coupled with the alarmingly low growth reaffirm the relevance of and huge potential for crop insurance in India.

A new scheme of crop insurance namely Pradhan Mantri Fasal Bima Yojana (PMFBY) is being implemented all over the country from kharif 2016. It is an important step towards improving agriculture insurance system in the country. PMFBY, primarily an area-yield insurance contract, has many positive features to compensate for multiple risks during the entire life cycle of the crop season. Use of technologies viz. remote sensing, mobile and data analytics is strongly recommended for effective implementation of the scheme.

One of the key challenges in PMFBY is to arrive at the actuarial price of insurance i.e., premium rate for a given crop in a given district. Sustenance of crop insurance in the long run is closely linked to farmers participation which in turn is dependent on premium rates. Considering the unique features of Indian Agriculture – small field sizes, dominance of small and marginal farmers, subsistence farming etc, the insurance premiums should always be on lower side. Affordability for farmers and objectivity in the determination of premiums are the most important requirements. Thus, accurate pricing of crop insurance is the fundamental requirement for enhanced participation of farmers.

In PMFBY actuarial premium rates are computed by insurance companies. There is no cap on premium rates. Farmers pay only 2 per cent of the sum insured or actuarial rate, whichever is less, as the premium. Actuarial premium over and above 2% of sum insured is shared by State and Central Governments in equal proportions. Thus, the crop insurance premiums are highly subsidized. During 2016-17 which is a normal year, total sum insured is Rs.2,02,551 Crores, premiums collected Rs. 22,337 Crores (shares of farmer, Central Govt and State Govt are Rs. 4411, 8867, 9056 crores respectively), and the claims disbursed is Rs.13,500 Crores. On an average at nation level, the premium rate is 12% of the sum insured (Source: websites and documents of Ministry of Agriculture and Centre for Science and Environment)

This report deals with improving crop insurance pricing mechanism by using agriculture risk information products generated using satellite data and other datasets. Innovative method of analysis with different input datasets related to risk is presented.

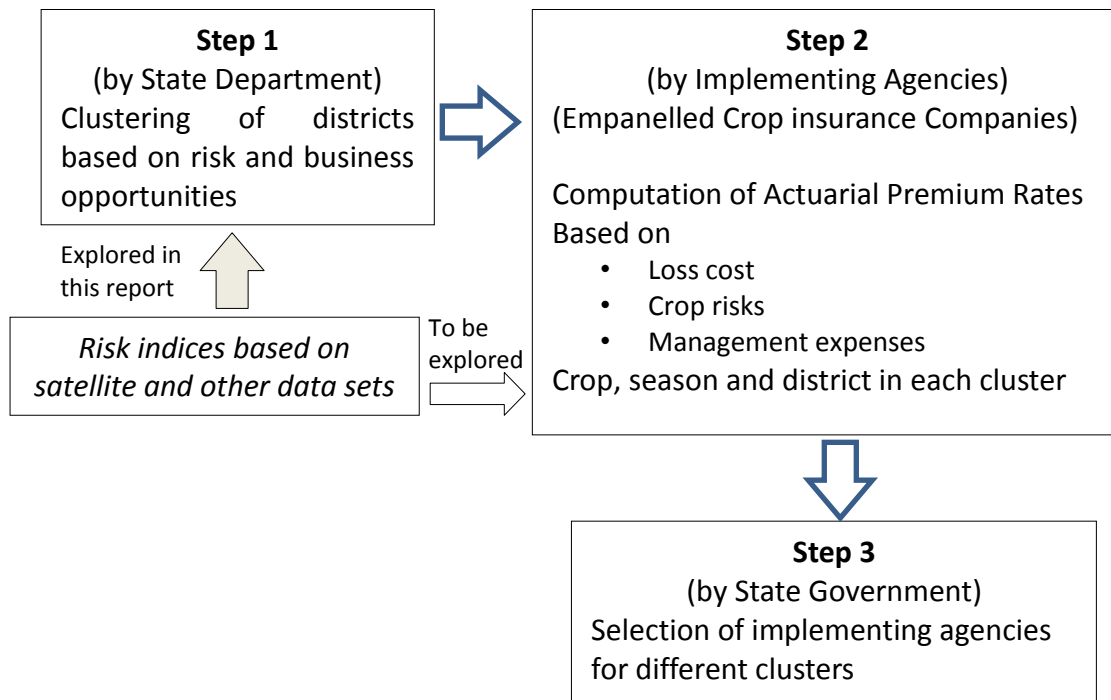
2. Rate making or insurance pricing

The procedure followed for arriving premiums is called rate making or insurance pricing. Accurate pricing of crop insurance is the fundamental requirement particularly for India, because of dominance small and marginal farmers and subsistence farming. There are three steps in the process of insurance rate making or pricing under PMFBY (Fig. 1).

The first step involves dividing the state in to groups of districts, using the available risk information. State departments undertake this exercise of clustering. The clusters of districts represent bunch of high and low risk districts. The clusters are generated in such a way that risk exposure and business opportunities among the clusters are uniform. If the clustering procedure is defective either due to methodology or due to inadequate input data, it would lead to generating the clusters with differential risk levels. In such case, clusters with high risk levels are not preferred by insurance companies to implement the contract. This leads to reduced coverage of insurance. Adoption of clustering approach has certain specific advantages; (a) ensures participation of many implementing companies in the state and hence risk is distributed among these entities, (b) enables discovering competitive premium rates.

The second step is to compute the premiums, crop wise, season wise and district wise for each cluster. This is done by the empanelled insurance companies in the state. Non-parametric techniques are generally adopted for rating crop insurance (Ker and Goodwin, 2000, Racine and Ker, 2006). The actuarial premium rates include loss cost claims as % of sum insured during recent 10 years, non-parametric crop risks and expenses towards management. In the third step of the process, State Department selects the Insurance Company that has quoted lesser premium rate for a given cluster for scheme implementation. There is only one implementing company in a cluster.

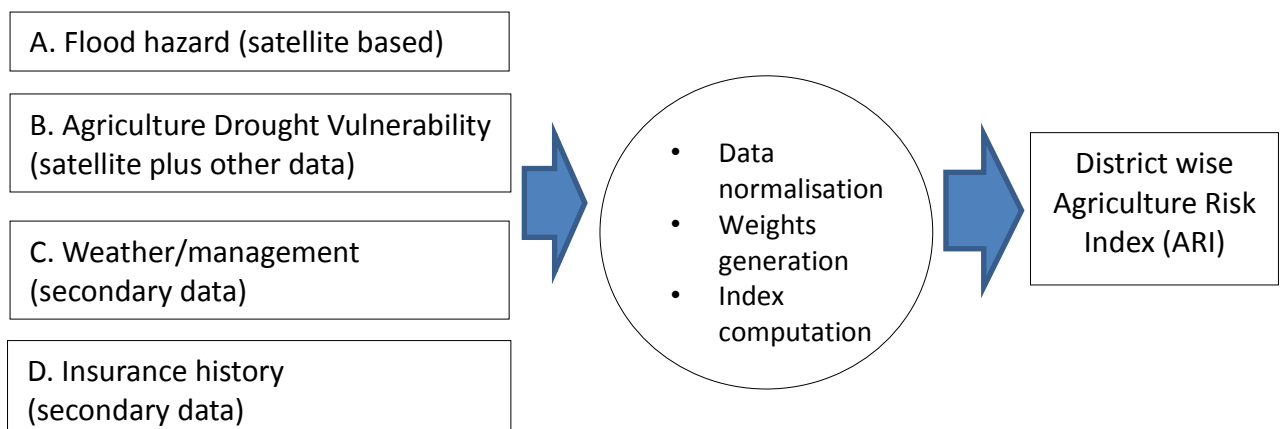
Fig. 1 Insurance rate making process and scope of the current study



This report focuses on improving the clustering mechanism in the rate making process by including multiple risks (Fig. 2). Crop generic risk indices of flood and drought using satellite data and weather/ environment risk on crop using time series yield data are developed. All these risk data are synthesised in to a composite index named as Agriculture Risk Index (ARI). The values of ARI are generated for each district.

Using ARI and crop area data, districts are grouped in to clusters. ARI provides integrated risk information and crop area data provides insurance business opportunities. Thus, by combining these two, the resultant clusters would be with similar levels of risk exposure and business opportunities. Three different ways of clustering was done and presented to the State Department.

Fig. 2 Methodology framework

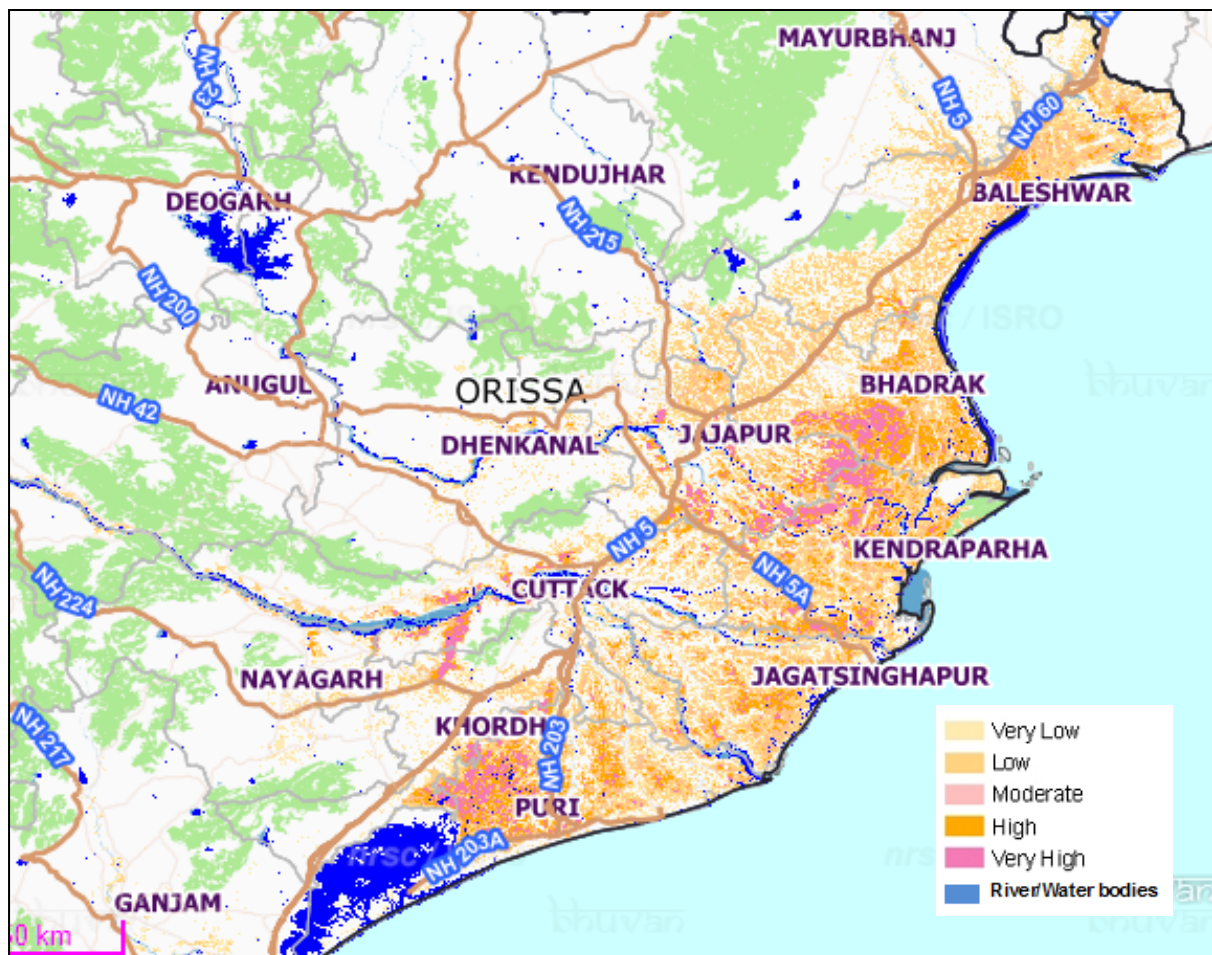


3. Flood risk

Flood risk information for different districts is derived from the flood hazard atlas generated by NRSC using time series flood layers. Flood hazard zonation layer for Odisha State (Fig. 3) was prepared based on the analysis of the annual flood inundation layers derived from 13 years of multi-temporal satellite data (2001- 2013). The map has been generated by Disaster Management Support Division of Remote Sensing Applications Area of National Remote Sensing Centre.

By intersecting flood hazard map with satellite derived kharif agriculture area, district wise % area under moderate to very high hazard class was generated as shown in Fig. 4. It is evident from the Figure that North coastal districts are under flood hazard. Large proportion of agriculture area in Kendrapara district is exposed to flood hazard followed by Bhadrak, Jagatsinghpur and Puri districts with 30-40 % of agriculture area under flood hazard.

Fig. 3 Flood hazard map

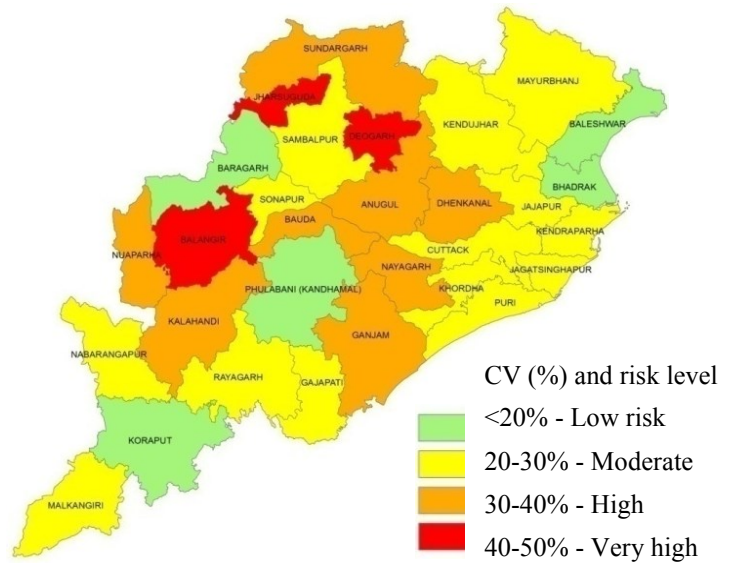


5. Weather/environmental risks on kharif paddy yield

District wise, time series yield data of kharif paddy crop (1993-2014) was the input in the analysis. The data was provided by the Department of Agriculture and Farmers Empowerment, Government of Odisha. Time series yield data for kharif paddy crop in each district was de-trended by fitting linear regression equation and the trend component was removed by taking the ratio of actual yield to the estimated yield. The procedure for regression analysis and de-trending is available in Cooper and Weeks 1983.

Thus, time series yield data gave rise to time series de-trended yield data. The CV of de-trended yield was taken as a direct indicator of crop's sensitivity to weather/environmental risks. Higher the CV value higher is the risk (more sensitivity to weather/environmental effects). The CV values are grouped in to four risk levels, with <20 % representing low risk and >40% representing very high risk as shown in Fig.6. Since paddy is the main crop in the state, the analysis is restricted to this crop only.

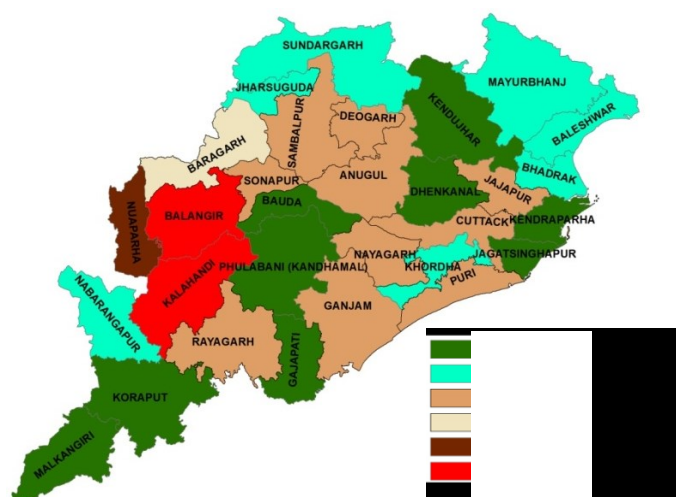
Fig. 6 Weather and environmental risks on kharif paddy crop



6. Risk based on insurance history

Crop insurance data of last 15 years related to premiums collected and claims paid for each district was collected from the Department of Agriculture. Claims paid as per cent of insurance premium collected averaged over the time period for a district indicates the risk level. The risk index based on insurance history thus computed is depicted in Fig.7. Higher the proportion of claims paid in the premium collected, higher is the risk associated with crops.

Fig. 7 Claims paid as per cent of sum insured in different districts



7. Agriculture Risk Index

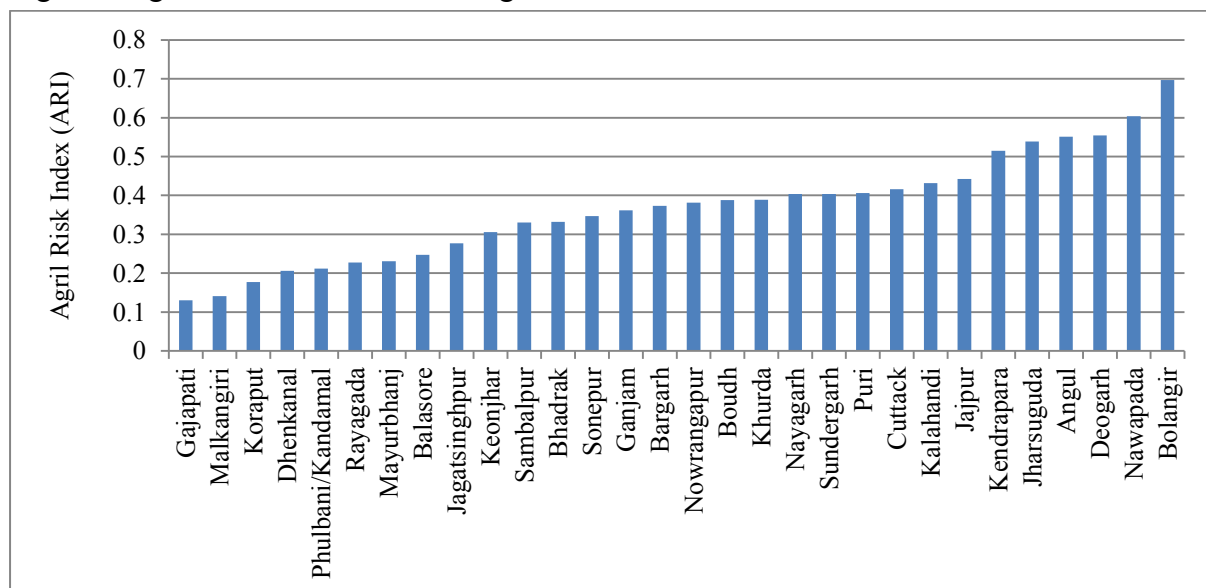
Agriculture Risk Index is a composite index synthesised from four input indicators namely

- % agri area under flood hazard
- Agriculture drought vulnerability index
- Weather / environmental risk index
- Insurance history index (Claims as % of sum insured)

All these four input indicators are directly related to Agriculture risk. The data matrix consisting of four input indicators for 30 districts, is subjected to data normalisation, weights generation based on inverse variance approach to synthesize into Agriculture Risk Index (Iyengar and Sudarshan1982). The ARI values range from 0 to 1 and are sliced in to five categories with 0.2 interval. The procedural aspects of ARI generation and its grouping are same as that adopted for Agriculture Drought Vulnerability which is shown in Annexure. This methodology has been peer-reviewed and published in International Journals (Murthy et al, 2015).

District wise ARI values are depicted in Fig.8. It is observed that the agriculture risk is less in Gajapati and Malkangiri districts with ARI values less than 0.2 and it is highest in Nawapada and Bolangir districts with ARI values >0.6.

Figure 8 Agriculture Risk Index among the districts



8. Agriculture-risk based clustering of districts

The districts of the state are grouped in to clusters on the basis of ARI and paddy area. Since paddy is the predominant crop, it is assumed that paddy area represents the business opportunities. The resultant clusters show uniform risk exposure levels and almost equal business opportunities. There are multiple ways of combining the districts in to clusters.

Three different combinations of clustering are presented here as Option-1, Option-2 and Option-3 to the State Department of Agriculture.

- Details of clusters under Option-1 are shown in Fig. 9, 10 and Table 1
- Details of clusters under Option-2 are shown in Fig. 11, 12 and Table 2
- Details of clusters under Option-3 are shown in Fig. 13, 14 and Table 3 (adopted by the State for rate making in kharif 2018).

Fig. 9 Clusters of Option-1

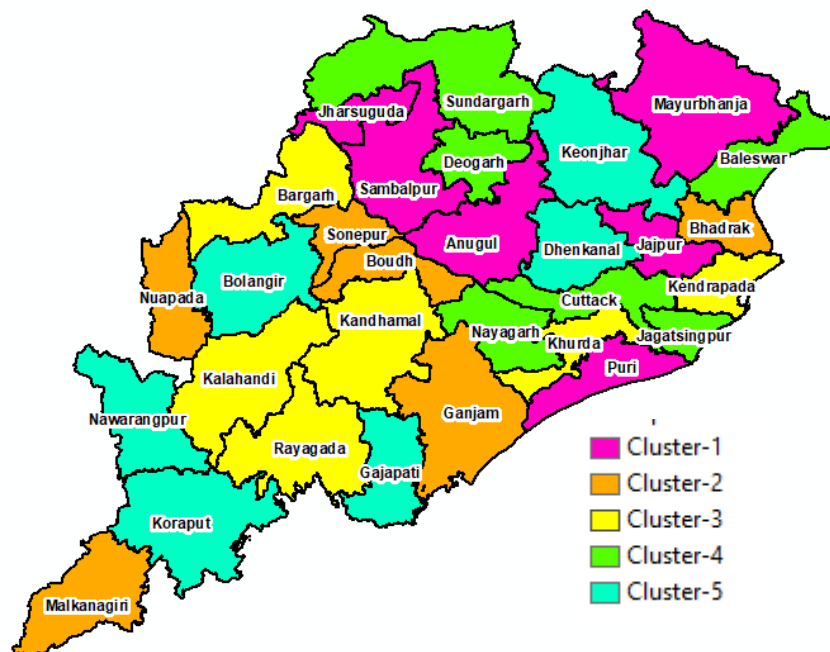


Fig. 10 Average risk index and total paddy area of different clusters of Option-1

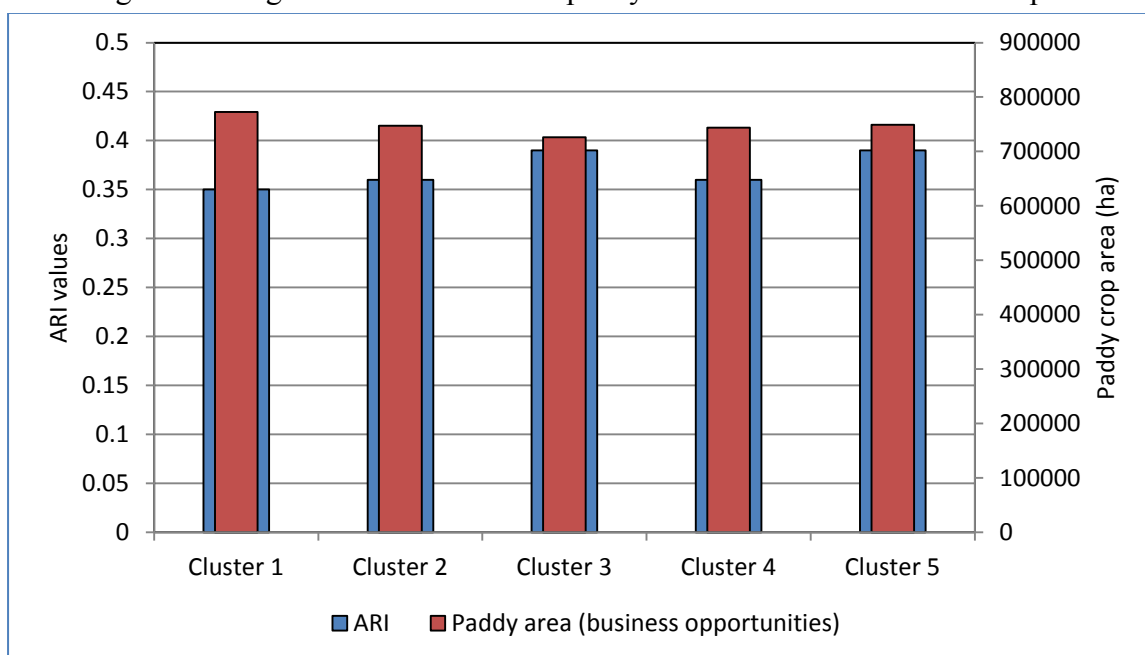


Table 1 Clustering Option-1 – details of cluster members and risk levels

Cluster details	Agriculture Risk index	Paddy area ha
Cluster 1		
Mayurbhanj	0.231	302469
Sambalpur	0.33	149776
Jajpur	0.442	102303
Puri	0.406	92956
Angul	0.551	78600
Jharsuguda	0.539	46719
Area Weighted Risk Index	0.35	
Cluster 2		
Ganjam	0.362	243620
Bhadrak	0.332	155518
Sonepur	0.347	103813
Nawapada	0.604	93712
Malkangiri	0.141	95730
Boudh	0.388	55125
Area Weighted Risk Index	0.36	
Cluster 3		
Bargarh	0.373	217771
Kalahandi	0.432	189499
Kendrapara	0.515	124367
Khurda	0.389	94785
Rayagada	0.227	59497
Phulbani/Kandamal	0.212	40415
Area Weighted Risk Index	0.39	
Cluster 4		
Sundergarh	0.404	200472
Balasore	0.247	190938
Cuttack	0.416	130915
Nayagarh	0.404	91679
Jagatsinghapur	0.277	87726
Deogarh	0.554	41749
Area Weighted Risk Index	0.36	
Cluster 5		
Bolangir	0.697	195867
Keonjhar	0.306	191821
Nowrangapur	0.381	145990
Koraput	0.177	98517
Dhenkanal	0.206	75240
Gajapati	0.13	41522
Area Weighted Risk Index	0.39	

Fig. 11 Clusters of Option-2

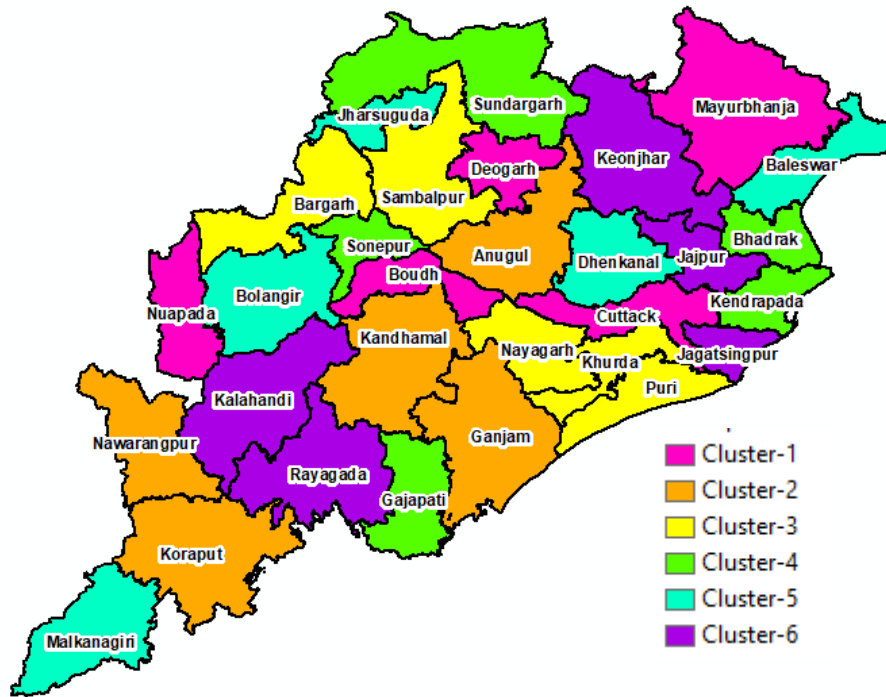


Fig. 12 Average risk index and total paddy area of different clusters of Option-2

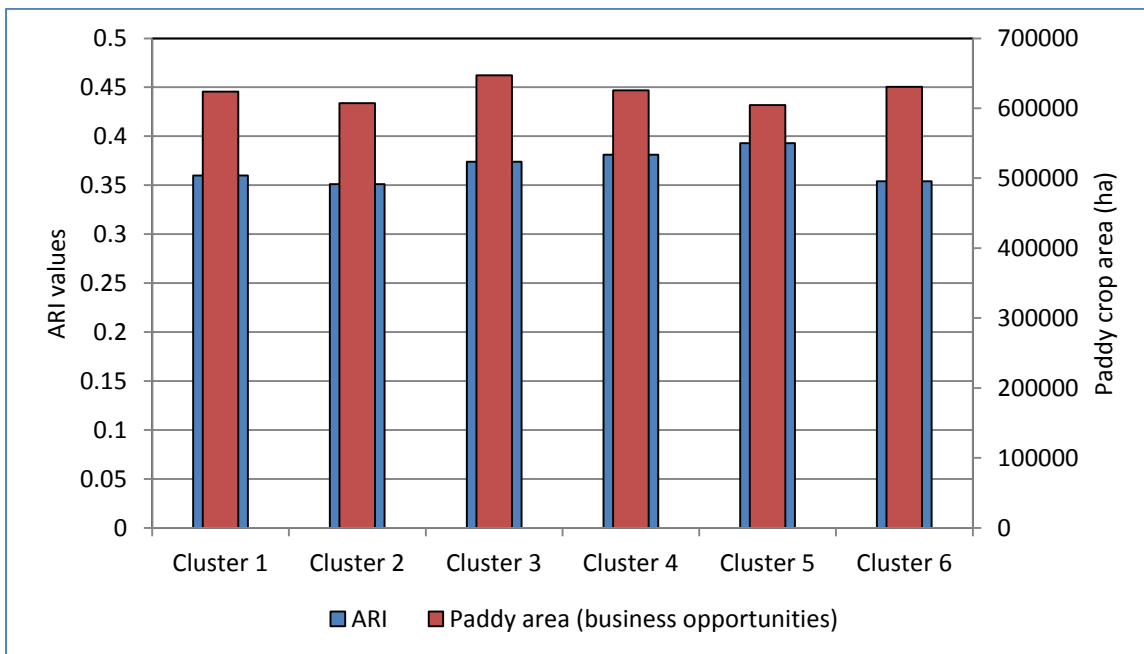


Table 2 Clustering Option-2 – details of cluster members and risk levels

Cluster details	Agriculture Risk index	Paddy area ha
Cluster 1		
Mayurbhanj	0.231	302469
Cuttack	0.416	130915
Nawapada	0.604	93712
Boudh	0.388	55125
Deogarh	0.554	41749
Area Weighted Risk Index	0.36	623970
Cluster 2		
Ganjam	0.362	243620
Nowrangapur	0.381	145990
Koraput	0.177	98517
Angul	0.551	78600
Phulbani/Kandamal	0.212	40415
Area Weighted Risk Index	0.35	607142
Cluster 3		
Bargarh	0.373	217771
Sambalpur	0.33	149776
Puri	0.406	92956
Khurda	0.389	94785
Nayagarh	0.404	91679
Area Weighted Risk Index	0.37	646967
Cluster 4		
Sundergarh	0.404	200472
Bhadrak	0.332	155518
Kendrapara	0.515	124367
Sonepur	0.347	103813
Gajapati	0.13	41522
Area Weighted Risk Index	0.38	625692
Cluster 5		
Bolangir	0.697	195867
Balasore	0.247	190938
Malkangiri	0.141	95730
Dhenkanal	0.206	75240
Jharsuguda	0.539	46719
Area Weighted Risk Index	0.39	604494
Cluster 6		
Keonjhar	0.306	191821
Kalahandi	0.432	189499
Jajpur	0.442	102303
Jagatsinghapur	0.277	87726
Rayagada	0.227	59497
Area weighted risk	0.35	630846

Fig. 13 Clusters of Option-3
(adopted by the State for rate making in kharif 2018)

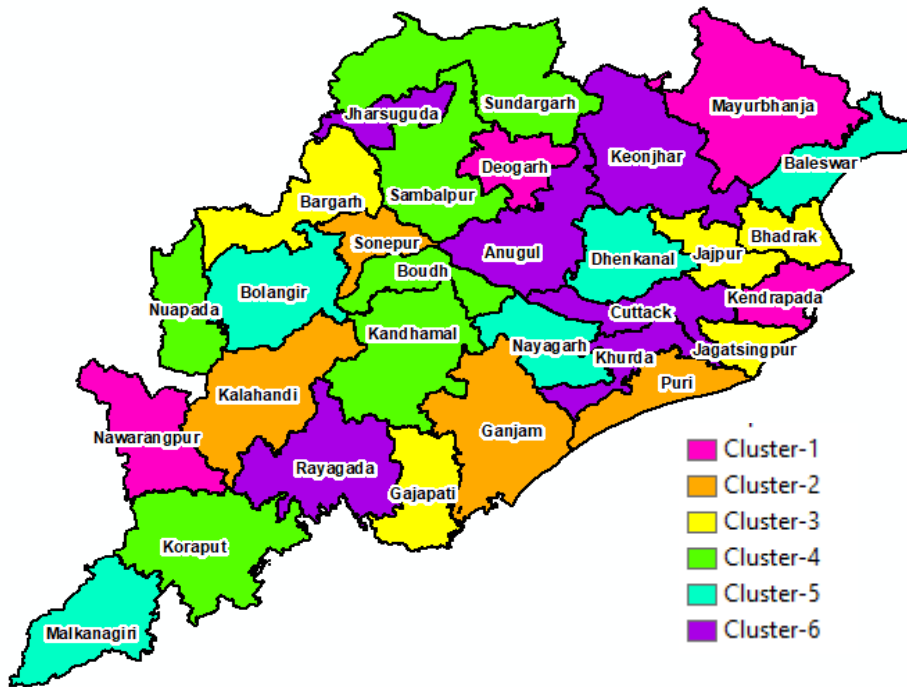


Fig. 14 Average risk index and total paddy area of different clusters of Option-3

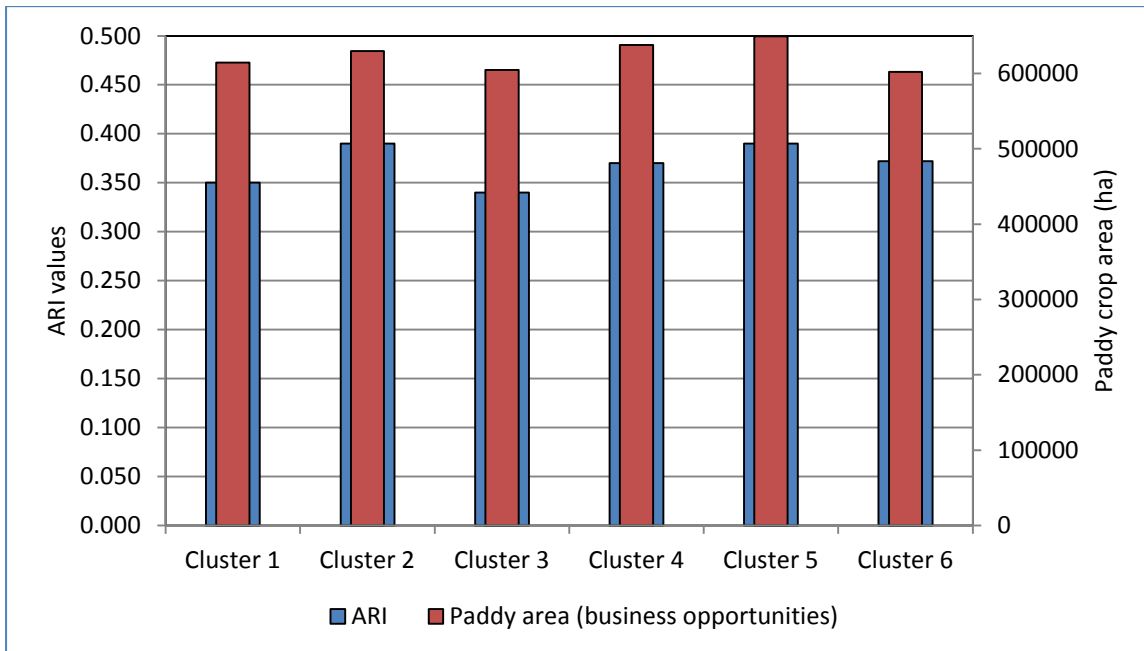


Table 3 Clustering option-3 – details of cluster members and risk levels

Cluster details	Agriculture Risk index	Paddy area ha
Cluster 1		
Mayurbhanj	0.231	302469
Nowrangapur	0.381	145990
Kendrapada	0.515	124367
Deogarh	0.554	41749
Area Weighted Risk Index	0.35	614575
Cluster 2		
Ganjam	0.362	243620
Kalahandi	0.432	189499
Sonepur	0.347	103813
Puri	0.406	92956
Area Weighted Risk Index	0.39	629888
Cluster 3		
Bargarh	0.373	217771
Bhadrak	0.332	155518
Gajapati	0.13	41522
Jajpur	0.442	102303
Jagatsinghapur	0.277	87726
Area Weighted Risk Index	0.34	604840
Cluster 4		
Sundergarh	0.404	200472
Sambalpur	0.33	149776
Koraput	0.177	98517
Nawapada	0.604	93712
Phulbani/Kandamal	0.212	40415
Boudh	0.388	55125
Area Weighted Risk Index	0.37	638017
Cluster 5		
Bolangir	0.697	195867
Balasore	0.247	190938
Malkangiri	0.141	95730
Nayagarh	0.404	91679
Dhenkanal	0.206	75240
Area Weighted Risk Index	0.39	649454
Cluster 6		
Keonjhar	0.306	191821
Cuttack	0.416	130915
Khurda	0.389	94785
Rayagada	0.227	59497
Angul	0.551	78600
Jharsuguda	0.539	46719
Area Weighted Risk Index	0.37	602337

The average premium rates for different clusters computed by the empanelled insurance companies for kharif 2018 are shown in Table 4. Premium rates finalised for each cluster are shown in bold letters in the Table.

Table 4 Premium rates (% of sum insured) quoted for kharif 2018
(Clusters of Option-3 are adopted by the State)

S.No	Insurance Company	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6
1	IL	8.48	11.03	33.44	13.93	35.06	11.71
2	Chola	5.18	8.27	20.17	12.94	13.87	7.26
3	Future	9.27	31.4	41.9	40.06	43.79	12.24
4	Universal	23.02	11.99	25.56	26.12	26.09	12.51
5	TATA-AIG	10.05	31.39	29.01	15.25	17.65	13.13
6	IFFCO	10.53	12.58	22.08	15.73	22.3	12.58
7	Royal	5.68	8.12	16.16	13.29	10.75	8.48
8	AIC	10.57	21.06	22.95	20.57	22.47	11.08
9	HDFC	6.59	17.8	25.72	14.82	22.23	9.21
10	AXA	10.68	25.68	34.18	30.02	32.15	11.24
11	Reliance	8.06	11.63	12.12	12.43	16.98	8.84
12	SBI	11.44	11.87	19.28	15.36	17.52	13.5
13	Oriental	10.11	1.03	12.11		14.62	11.37
14	National	8.64	13.64	30.18	19.64	26.30	10.9
15	UIIC	27.43	35.29	44.18	39.02	43.07	10.81

Source of data: Department of Agriculture and Farmers Empowerment, Government of Odisha

9. Conclusion and way forward

Accurate pricing of crop insurance is the fundamental requirement for enhanced participation of farmers and sustenance of the scheme. Technology based information products and innovative approach of data analysis for crop insurance pricing are showcased in this report.

Risk based clustering is the first step in the rating process of PMFBY. Cluster approach is adopted in all the states in order to encourage participation of multiple insurance companies and to arrive at competitive premium rates. Clustering of the districts of Odisha state with multiple risk indices for crop insurance rating is showcased in this report. Risks due to droughts, floods and other environmental factors have been accounted to make realistic assessment of crop risks of districts. Agriculture Risk Index developed in this project, is synthesized from four risk indices - droughts, floods and other environmental factors and this integrated index provides comprehensive risk information of the districts to the stake holders of crop insurance.

This work was carried-out as a part of the on-going CIDSS project for Odisha state. The clusters suggested by NRSC on the basis of multiple risks have been adopted by the State for

crop insurance rate making in kharif 2018, thus setting a model for technology utilisation in crop insurance pricing.

The improved clustering mechanism for insurance rate making implemented in Odisha can be replicated in other states also, subject to data availability. As a first step towards improving the rating process, the states may adopt improved clustering mechanism. This is the starting point of technology infusion in to the crop insurance rating process.

Insurance companies determine the premium rates for different crops and districts of a cluster through pricing models. The scope for using the risk indices developed in this project in the pricing models need to be explored, in order to arrive at optimal premiums for different crops and districts in a cluster. Such improvements would make the premium rates more objective and realistic.

10. Acknowledgements

We express our sincere gratitude to Sri Santanu Chowdhury, Director, National Remote Sensing Centre for his constant encouragement and guidance. We are grateful to the Department of Agriculture and Farmers Empowerment, Government of Odisha, for the collaborative project with NRSC to develop technology based solutions for crop insurance.

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Agricultural drought vulnerability index

Agricultural drought vulnerability is defined as exposure, sensitivity and adaptive capacity of an agricultural area to the situation of inadequate soil moisture availability during the season. Crop areas are exposed to hazardous weather –low rainfall, high temperature etc. The sensitivity and coping ability of the agricultural area, when exposed to drought situation or potentially harmful crop stress situations determines the vulnerability of the area. Exposure, sensitivity and adaptive capacity together determine the agricultural drought vulnerability which is a relative term and can be represented in a predefined scale. The coping ability or adaptive capacity of agricultural area to agricultural drought is determined by a number factors related to crop growing environment. Thus, agricultural drought vulnerability differs from place to place. In this study, agricultural drought vulnerability index was derived from the composite indices constructed for each of the three components of vulnerability – exposure, sensitivity and adaptive capacity with the input data shown in the Table below.

The indicators of the model are in different units with different functional relationships respective component indices. In order to make these indicators free of their units and to standardize their values, data normalization was done. In case of the variables that have a positive relationship with its respective component index, the normalization was done using the formula:

$$x_{ij} = \frac{X_{ij} - \text{Min}\{X_{ij}\}}{\text{Max}\{X_{ij}\}_i - \text{Min}\{X_{ij}\}} \text{-----} (1)$$

In the case of variables that have negative relationship with its respective component index, the normalization was done using the formula:

$$x_{ij} = \frac{\text{Max}\{X_{ij}\} - X_{ij}}{\text{Max}\{X_{ij}\}_i - \text{Min}\{X_{ij}\}} \text{-----} (2)$$

After normalization, all the indicators were ranging from 0 – 1, and having positive relationship concerned component index.

Construction and use of composite indices from multi-dimensional data for measuring spatial differentials in social and economic development issues has been widely practiced (Iyengar and Sudershan 1982). Assignment of weights to selected indicators is a key issue in the vulnerability assessment model (Brooks et al., 2005).

Table Parameters and contributing indicators of exposure, sensitivity and adaptive capacity components

Parameter	Details and Source of data	indicator with its functional relationship with the respective component index in parenthesis
I. Exposure component		
1. Total season rainfall	Daily rainfall data at block level from June to October for different years collected from the Dept. of Agriculture, Government of Odisha	(a) Mean (-ve) (b) CV (+ve) (c) Drought frequency (+ve)
2. Sowing period rainfall		(a) Mean (-ve) (b) CV (+ve) (c) Drought frequency (+ve)
3. Total season rainy days		(a) Mean (-ve) (b) CV (+ve) (c) Drought frequency (+ve)
4. Sowing period rainy days		(a) Mean (-ve) (b) CV (+ve) (c) Drought frequency (+ve)
II. Sensitivity component		
1. Season's Integrated NDVI (SIN)	Satellite data - Terra MODIS 250 m 8-day NDVI composites generated under the NADAMS* project of NRSC**	(a) CV (+ve) (b) Drought frequency (+ve)
2. Season's Maximum NDVI (SMN)		(a) CV (+ve) (b) Drought frequency (+ve)
3. August NDVI		(a) CV (+ve) (b) Drought frequency (+ve)
III. Adaptive capacity		
1. Soil	1: 50000 scale soil map of NBSS and LUP, India	Available Water Content (+ve)
2. Irrigation support	Mandal wise data on irrigated area collected from BES, GOAP	% crop area irrigated (+ve)

In this study, the method given by Iyengar and Sudarshan (1982) to construct a statistically sound composite index from multivariate data was used. Hiremath and Shiyani (2012) used this method for evaluating vulnerability to climate change.

It is assumed that there are N Blocks, K indicators and $x_{ij}, i=1, 2, \dots, M; j=1, 2, \dots, K$ are the normalized scores. The level or stage of development of i^{th} zone, \bar{y}_i , is assumed to be a linear sum of x_{ij} as

$$\bar{y}_i = \sum_{j=1}^K w_j x_{ij} \text{-----} (3)$$

Where w_j 's ($0 < w_j < 1$ and $\sum_{j=1}^K w_j = 1$) are the weights. In Iyengar and Sudharshan's method the weights are assumed to vary inversely as the variance over the regions/blocks in the respective indicators of vulnerability. That is, the weight w_j is determined by

$$w_j = \frac{c}{\sqrt{\text{var}(x_{ij})}} \text{-----} (4)$$

Where c is a normalizing constant such that

$$c = \left[\sum_{j=1}^K \frac{1}{\sqrt{\text{var}_i(x_{ij})}} \right]^{-1} \text{-----} (5)$$

By assigning the weights in this manner, the large variation in any of the indicators will not unduly dominate the contribution of the rest of the indicators or distort inter-regional comparisons. The resulting index ranges between 0 and 1, with 1 indicating maximum and 0 indicating minimum intensity of respective index.

Using this method three composite indices, namely Exposure Index (EI), Sensitivity Index (SI) and Adaptive capacity Index (AI) were computed. Agricultural Drought Vulnerability Index (ADVI) was computed as under

$$\text{ADVI} = \text{EI} + \text{SI} - \text{AI} \text{-----} (6)$$

The ADVI and component indices reflect relative differences among the Mandals, rather representing specific conditions of a crop growing environment. Categorization based on ADVI in to drought vulnerability classes was done by fitting a statistical distribution to ADVI. Beta distribution, which is generally skewed and takes values in the interval (0,1), was fitted to ADVI, as followed by Iyengar and Sudarshan (1982). This distribution has the probability density given by

$$f(z) = \frac{z^{a-1}(1-z)^{b-1}}{\beta(a,b)}, 0 < z < 1, \text{ and } a, b > 0 \text{-----} (7)$$

Where $\beta(a, b)$ is the beta function defined by

$$\beta(a, b) = \int_0^1 x^{a-1}(1-x)^{b-1} dx \text{-----} (8)$$

The two parameters a and b of the distribution were estimated by maximum likelihood approach. The ADVI converted to Beta probabilities was divided into five classes of vulnerability. Let $(0, z_1)$, (z_1, z_2) , (z_2, z_3) and (z_3, z_4) be the linear intervals such that each interval has the same probability weight of 20 per cent. These fractal intervals can be used to characterize the various stages of vulnerability as given below;

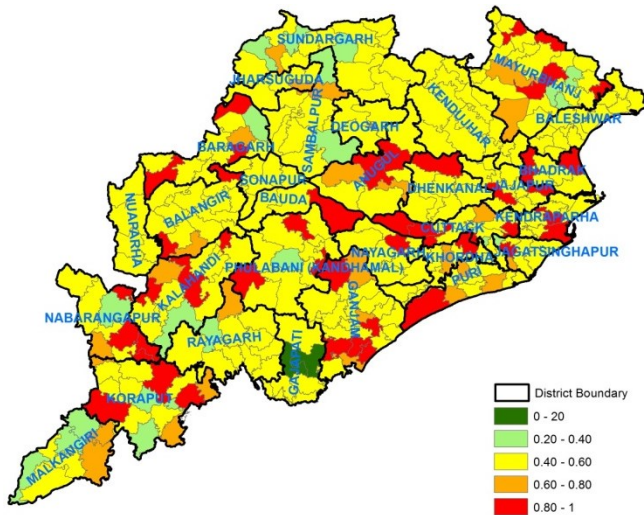
1. Less vulnerable if $0 < \bar{y}_i < z_1$
2. Moderately vulnerable if $z_1 < \bar{y}_i < z_2$
3. Vulnerable if $z_2 < \bar{y}_i < z_3$.
4. Highly vulnerable if $z_3 < \bar{y}_i < z_4$

5. Very highly vulnerable if $z_4 < \bar{y}_i < 1$

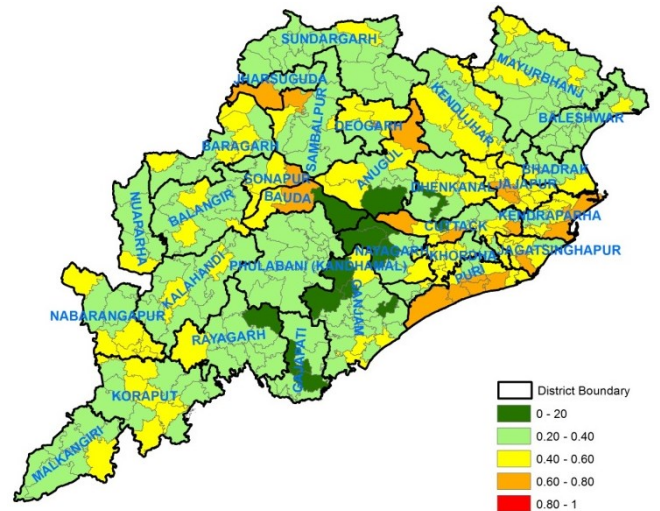
where, \bar{y}_i is the estimated ADVI value corresponding to a probability value.

Results of the vulnerability analysis over Odisha state are shown below;

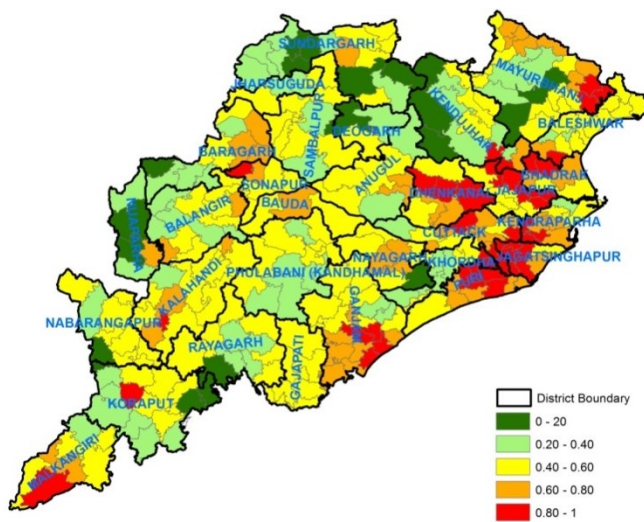
Exposure Index



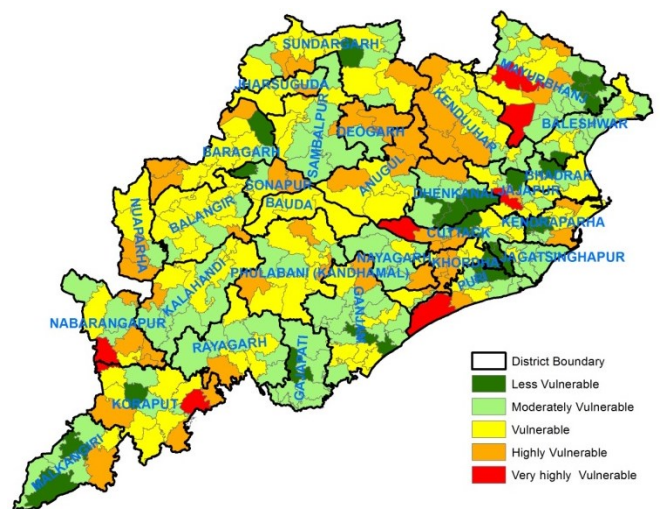
Sensitivity Index



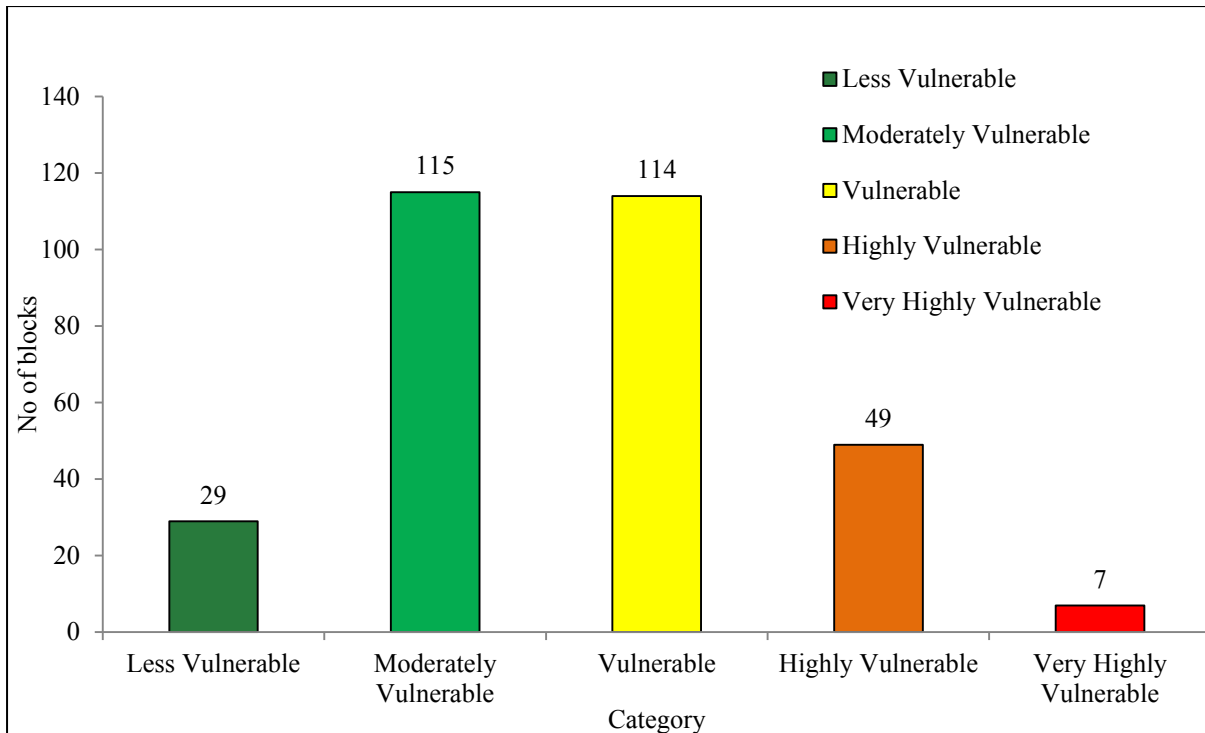
Adaptive capacity Index



Agriculture Drought Vulnerability Index



Blocks under different Agricultural drought vulnerability classes



Blocks under different Agricultural drought vulnerability classes in each district

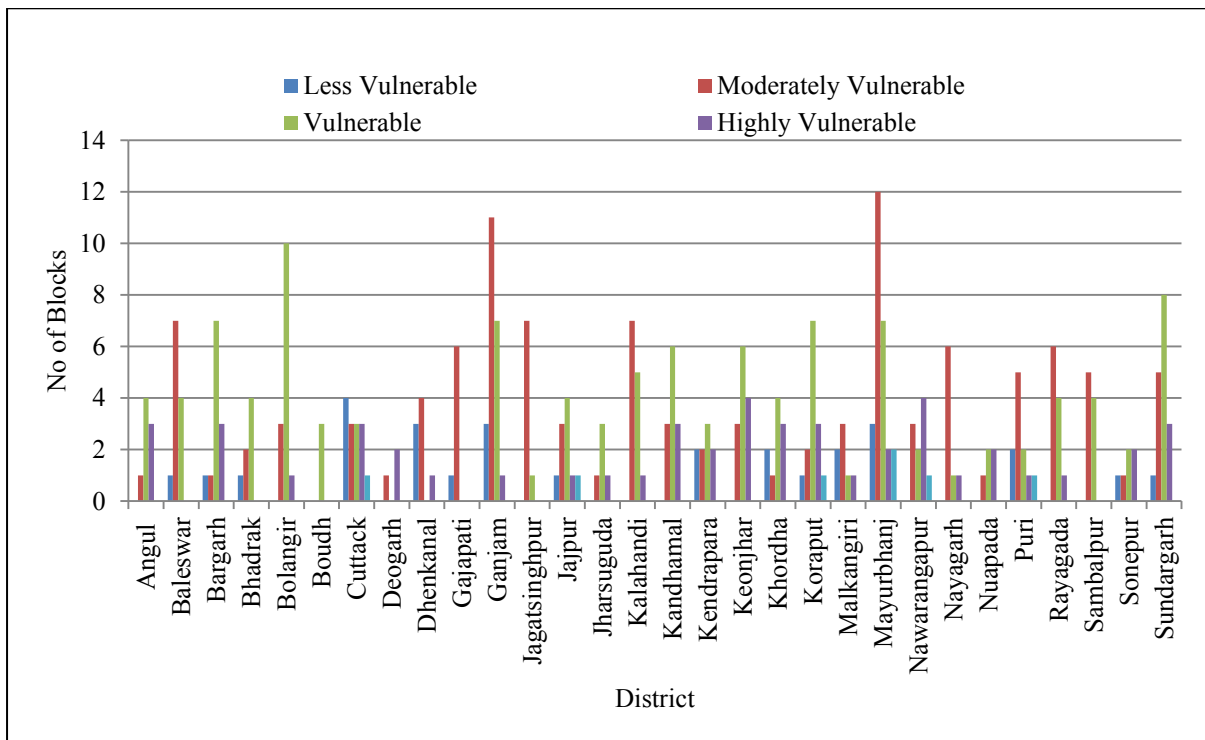


Table Agricultural drought vulnerability status of different blocks

District	Block	Agricultural drought vulnerability status
Angul	Angul	Vulnerable
Angul	Athmallik	Vulnerable
Angul	Banarpal	Vulnerable
Angul	Chhendipada	Vulnerable
Angul	Kaniha	Highly vulnerable
Angul	Kishorenagar	Highly vulnerable
Angul	Palalahada	Highly vulnerable
Angul	Talcher	Moderately vulnerable
Baleswar	Bahanaga	Moderately vulnerable
Baleswar	Baleswar	Moderately vulnerable
Baleswar	Baliapal	Vulnerable
Baleswar	Basta	Moderately vulnerable
Baleswar	Bhograi	Moderately vulnerable
Baleswar	Jaleswar	Vulnerable
Baleswar	Khaira	Moderately vulnerable
Baleswar	Nilagiri	Moderately vulnerable
Baleswar	Oupada	Vulnerable
Baleswar	Remuna	Moderately vulnerable
Baleswar	Simulia	Less vulnerable
Baleswar	Soro	Vulnerable
Bargarh	Ambabhona	Highly vulnerable
Bargarh	Attabira	Less vulnerable
Bargarh	Bargarh	Vulnerable
Bargarh	Barpali	Vulnerable
Bargarh	Bhatli	Vulnerable
Bargarh	Bheden	Moderately vulnerable
Bargarh	Bijepur	Vulnerable
Bargarh	Gaisilet	Vulnerable
Bargarh	Jharbandh	Highly vulnerable
Bargarh	Paikmal	Highly vulnerable
Bargarh	Rajborasambar	Vulnerable
Bargarh	Sohella	Vulnerable
Bhadrak	Bant	Moderately vulnerable
Bhadrak	Basudebpur	Vulnerable
Bhadrak	Bhadrak	Less vulnerable
Bhadrak	Bhandaripokhari	Vulnerable
Bhadrak	Chandabali	Vulnerable
Bhadrak	Dhamanagar	Vulnerable
Bhadrak	Tihidi	Moderately vulnerable
Bolangir	Agalpur	Vulnerable
Bolangir	Balangir	Vulnerable
Bolangir	Bangomunda	Moderately vulnerable

Bolangir	Belpara	Vulnerable
Bolangir	Deogaon	Vulnerable
Bolangir	Khaprakhol	Vulnerable
Bolangir	Loisinga	Vulnerable
Bolangir	Muribahal	Vulnerable
Bolangir	Patnagarh	Vulnerable
Bolangir	Puintala	Moderately vulnerable
Bolangir	Saintala	Moderately vulnerable
Bolangir	Tentulikhunti (Gudvella)	Highly vulnerable
Bolangir	Titilagarh	Vulnerable
Bolangir	Turekela	Vulnerable
Boudh	Boudh	Vulnerable
Boudh	Harbhanga	Vulnerable
Boudh	Kantamal	Vulnerable
Cuttack	Athagad	Less vulnerable
Cuttack	Badamba	Highly vulnerable
Cuttack	Banki	Highly vulnerable
Cuttack	Banki-Dampara	Highly vulnerable
Cuttack	Barang	Less vulnerable
Cuttack	Cuttack Sadar	Moderately vulnerable
Cuttack	Kantapada	Less vulnerable
Cuttack	Mahanga	Moderately vulnerable
Cuttack	Narasinghpur	Very highly vulnerable
Cuttack	Niali	Less vulnerable
Cuttack	Nischintakoili	Vulnerable
Cuttack	Salepur	Vulnerable
Cuttack	Tangi-Choudwar	Vulnerable
Cuttack	Tigiria	Moderately vulnerable
Deogarh	Barkot	Highly vulnerable
Deogarh	Reamal	Moderately vulnerable
Deogarh	Tileibani	Highly vulnerable
Dhenkanal	Bhuban	Moderately vulnerable
Dhenkanal	Dhenkanal	Less vulnerable
Dhenkanal	Gandia	Less vulnerable
Dhenkanal	Hindol	Moderately vulnerable
Dhenkanal	Kamakhyanagar	Moderately vulnerable
Dhenkanal	Kankadahad	Highly vulnerable
Dhenkanal	Odapada	Less vulnerable
Dhenkanal	Parajang	Moderately vulnerable
Gajapati	Gumma	Moderately vulnerable
Gajapati	Kasinagar	Moderately vulnerable
Gajapati	Mohana	Moderately vulnerable
Gajapati	Nuagada	Less vulnerable
Gajapati	Paralakhemundi	Moderately vulnerable
Gajapati	R. Udaygiri	Moderately vulnerable

Gajapati	Rayagada(Gaj)	Moderately vulnerable
Ganjam	Aska	Moderately vulnerable
Ganjam	Beguniapada	Vulnerable
Ganjam	Bellaguntha	Moderately vulnerable
Ganjam	Bhanjanagar	Vulnerable
Ganjam	Buguda	Moderately vulnerable
Ganjam	Chhatrapur	Less vulnerable
Ganjam	Chikiti	Vulnerable
Ganjam	Dharakote	Moderately vulnerable
Ganjam	Digapahandi	Vulnerable
Ganjam	Ganjam	Moderately vulnerable
Ganjam	Hinjilicut	Less vulnerable
Ganjam	Jagannathprasad	Highly vulnerable
Ganjam	Kabisuryanagar	Vulnerable
Ganjam	Khallikote	Moderately vulnerable
Ganjam	Kukudakhandi	Vulnerable
Ganjam	Patrapur	Moderately vulnerable
Ganjam	Polasara	Moderately vulnerable
Ganjam	Purusottampur	Moderately vulnerable
Ganjam	Rangeilunda	Vulnerable
Ganjam	Sanakhemundi	Moderately vulnerable
Ganjam	Seragad	Less vulnerable
Ganjam	Sorada	Moderately vulnerable
Jagatsinghpur	Balikuda	Moderately vulnerable
Jagatsinghpur	Biridi	Moderately vulnerable
Jagatsinghpur	Ersama	Moderately vulnerable
Jagatsinghpur	Jagatsinghapur (P)	Vulnerable
Jagatsinghpur	Kujang	Moderately vulnerable
Jagatsinghpur	Naugaon	Moderately vulnerable
Jagatsinghpur	Raghunathpur	Moderately vulnerable
Jagatsinghpur	Tirtol	Moderately vulnerable
Jajpur	Badachana	Vulnerable
Jajpur	Bari	Vulnerable
Jajpur	Binjharpur	Moderately vulnerable
Jajpur	Danagadi	Moderately vulnerable
Jajpur	Dasarathpur	Vulnerable
Jajpur	Dharmasala	Very highly vulnerable
Jajpur	Jajapur	Moderately vulnerable
Jajpur	Korei	Less vulnerable
Jajpur	Rasulpur	Highly vulnerable
Jajpur	Sukinda	Vulnerable
Jharsuguda	Jharsuguda	Vulnerable
Jharsuguda	Kirimira	Vulnerable
Jharsuguda	Kolabira	Highly vulnerable

Jharsuguda	Laikera	Moderately vulnerable
Jharsuguda	Lakhanpur	Vulnerable
Kalahandi	Bhawanipatna	Vulnerable
Kalahandi	Dharamgarh	Highly vulnerable
Kalahandi	Golamunda	Vulnerable
Kalahandi	Jayapatna	Moderately vulnerable
Kalahandi	Junagarh	Moderately vulnerable
Kalahandi	Kalampur	Moderately vulnerable
Kalahandi	Karlamunda	Vulnerable
Kalahandi	Kesinga	Moderately vulnerable
Kalahandi	Kokasara	Moderately vulnerable
Kalahandi	Lanjigarh	Moderately vulnerable
Kalahandi	Madanpur-Rampur	Vulnerable
Kalahandi	Narla	Vulnerable
Kalahandi	Thuamul-Rampur	Moderately vulnerable
Kandhamal	Baliguda	Moderately vulnerable
Kandhamal	Chakapad	Moderately vulnerable
Kandhamal	Daringbadi	Vulnerable
Kandhamal	G. Udayagiri	Highly vulnerable
Kandhamal	K.Nuagaon	Moderately vulnerable
Kandhamal	Khajuripada	Vulnerable
Kandhamal	Kotagarh	Vulnerable
Kandhamal	Phiringia	Vulnerable
Kandhamal	Phulbani	Highly vulnerable
Kandhamal	Raikia	Vulnerable
Kandhamal	Tikabali	Vulnerable
Kandhamal	Tumudibandha	Highly vulnerable
Kendrapara	Aul	Vulnerable
Kendrapara	Derabisi	Less vulnerable
Kendrapara	Garadpur	Moderately vulnerable
Kendrapara	Kendrapara	Less vulnerable
Kendrapara	Mahakalapada	Highly vulnerable
Kendrapara	Marsaghai	Moderately vulnerable
Kendrapara	Pattamundai	Vulnerable
Kendrapara	Rajkanika	Highly vulnerable
Kendrapara	Rajnagar	Vulnerable
Keonjhar	Anandapur	Vulnerable
Keonjhar	Banspal	Highly vulnerable
Keonjhar	Champua	Vulnerable
Keonjhar	Ghasipura	Moderately vulnerable
Keonjhar	Ghatgaon	Vulnerable
Keonjhar	Harichandanpur	Highly vulnerable
Keonjhar	Hatadihi	Moderately vulnerable
Keonjhar	Jhumpura	Vulnerable

Keonjhar	Joda	Highly vulnerable
Keonjhar	Kendujhar	Vulnerable
Keonjhar	Patana	Moderately vulnerable
Keonjhar	Saharapada	Vulnerable
Keonjhar	Telkoi	Highly vulnerable
Khordha	Balianta	Less vulnerable
Khordha	Balipatna	Less vulnerable
Khordha	Banapur	Vulnerable
Khordha	Begunia	Highly vulnerable
Khordha	Bhubaneswar	Vulnerable
Khordha	Bolagad	Vulnerable
Khordha	Chilika	Moderately vulnerable
Khordha	Jatani	Vulnerable
Khordha	Khordha	Highly vulnerable
Khordha	Tangi	Highly vulnerable
Koraput	Bandhugaon	Highly vulnerable
Koraput	Boipariguda	Highly vulnerable
Koraput	Borigumma	Moderately vulnerable
Koraput	Dasamantapur	Vulnerable
Koraput	Jeypore	Less vulnerable
Koraput	Koraput	Moderately vulnerable
Koraput	Kotpad	Vulnerable
Koraput	Kundra	Vulnerable
Koraput	Lakshmipur	Vulnerable
Koraput	Lamptaput	Vulnerable
Koraput	Nandapur	Vulnerable
Koraput	Narayanpatna	Very highly vulnerable
Koraput	Pottangi	Highly vulnerable
Koraput	Similiguda	Vulnerable
Malkangiri	Kalimela	Less vulnerable
Malkangiri	Khairput	Vulnerable
Malkangiri	Korkunda	Moderately vulnerable
Malkangiri	Kudumulguma	Highly vulnerable
Malkangiri	Malkangiri	Less vulnerable
Malkangiri	Mathili	Moderately vulnerable
Malkangiri	Podia	Moderately vulnerable
Mayurbhanj	Bahalda	Moderately vulnerable
Mayurbhanj	Bangiriposhi	Vulnerable
Mayurbhanj	Baripada	Less vulnerable
Mayurbhanj	Barsahi	Moderately vulnerable
Mayurbhanj	Betanati	Less vulnerable
Mayurbhanj	Bijatola	Moderately vulnerable
Mayurbhanj	Bisoi	Vulnerable
Mayurbhanj	Gopabandhunagar	Moderately vulnerable
Mayurbhanj	Jamda	Moderately vulnerable

Mayurbhanj	Jashipur	Very highly vulnerable
Mayurbhanj	Kaptipada	Moderately vulnerable
Mayurbhanj	Karanjia	Vulnerable
Mayurbhanj	Khunta	Moderately vulnerable
Mayurbhanj	Kuliana	Moderately vulnerable
Mayurbhanj	Kusumi	Moderately vulnerable
Mayurbhanj	Muruda	Less vulnerable
Mayurbhanj	Rairangpur	Vulnerable
Mayurbhanj	Raruan	Vulnerable
Mayurbhanj	Rasagovindpur	Moderately vulnerable
Mayurbhanj	Saraskana	Highly vulnerable
Mayurbhanj	Shamakhunta	Highly vulnerable
Mayurbhanj	Sukruli	Vulnerable
Mayurbhanj	Suliapada	Moderately vulnerable
Mayurbhanj	Thakurmunda	Very highly vulnerable
Mayurbhanj	Tiring	Vulnerable
Mayurbhanj	Udala	Moderately vulnerable
Nawarangapur	Chandahandi	Highly vulnerable
Nawarangapur	Dabugan	Moderately vulnerable
Nawarangapur	Jharigan	Moderately vulnerable
Nawarangapur	Kosagumuda	Very highly vulnerable
Nawarangapur	Nandahandi	Highly vulnerable
Nawarangapur	Nawarangpur	Vulnerable
Nawarangapur	Paparahandi	Highly vulnerable
Nawarangapur	Raighar	Moderately vulnerable
Nawarangapur	Tentulikhunti	Highly vulnerable
Nawarangapur	Umarkote	Vulnerable
Nayagarh	Bhapur	Moderately vulnerable
Nayagarh	Dasapalla	Moderately vulnerable
Nayagarh	Gania	Moderately vulnerable
Nayagarh	Khandapada	Vulnerable
Nayagarh	Nayagarh	Moderately vulnerable
Nayagarh	Odagaon	Moderately vulnerable
Nayagarh	Ranapur	Highly vulnerable
Nayagarh	Nuagaon	Moderately vulnerable
Nuapada	Boden	Highly vulnerable
Nuapada	Khariar	Moderately vulnerable
Nuapada	Komna	Vulnerable
Nuapada	Nuapada	Vulnerable
Nuapada	Sinapalli	Highly vulnerable
Puri	Astaranga	Moderately vulnerable
Puri	Bramhagiri	Highly vulnerable
Puri	Delanga	Moderately vulnerable
Puri	Gop	Moderately vulnerable

Puri	Kakatpur	Moderately vulnerable
Puri	Kanas	Vulnerable
Puri	Krushnaprasad	Very highly vulnerable
Puri	Nimapada	Less vulnerable
Puri	Pipili	Less vulnerable
Puri	Puri	Vulnerable
Puri	Satyabadi	Moderately vulnerable
Rayagada	Bissam Cuttack	Moderately vulnerable
Rayagada	Chandrapur	Moderately vulnerable
Rayagada	Gudari	Vulnerable
Rayagada	Gunupur	Moderately vulnerable
Rayagada	Kalyanasingpur	Moderately vulnerable
Rayagada	Kashipur	Moderately vulnerable
Rayagada	Kolnara	Vulnerable
Rayagada	Muniguda	Vulnerable
Rayagada	Padmapur	Moderately vulnerable
Rayagada	Ramanguda	Vulnerable
Rayagada	Rayagada	Highly vulnerable
Sambalpur	Bamra	Moderately vulnerable
Sambalpur	Dhankauda	Vulnerable
Sambalpur	Jamankira	Moderately vulnerable
Sambalpur	Jujomura	Moderately vulnerable
Sambalpur	Kuchinda	Vulnerable
Sambalpur	Maneswar	Vulnerable
Sambalpur	Naktideul	Moderately vulnerable
Sambalpur	Rairakhol	Moderately vulnerable
Sambalpur	Rengali	Vulnerable
Sonepur	Binika	Moderately vulnerable
Sonepur	Biramaharajpur	Highly vulnerable
Sonepur	Dunguripali	Less vulnerable
Sonepur	Sonepur	Vulnerable
Sonepur	Tarbha	Vulnerable
Sonepur	Ulunda	Highly vulnerable
Sundargarh	Balisankara	Vulnerable
Sundargarh	Baneigarh	Moderately vulnerable
Sundargarh	Baragaon	Vulnerable
Sundargarh	Bisra	Moderately vulnerable
Sundargarh	Gurundia	Vulnerable
Sundargarh	Hemgiri	Vulnerable
Sundargarh	Koida	Highly vulnerable
Sundargarh	Kuanrmunda	Vulnerable
Sundargarh	Kutra	Vulnerable
Sundargarh	Lahunipara	Vulnerable
Sundargarh	Lathikata	Moderately vulnerable
Sundargarh	Lephripara	Moderately vulnerable

Sundargarh	Rajagangapur	Less vulnerable
Sundargarh	Subdega	Vulnerable
Sundargarh	Sundargarh	Highly vulnerable
Sundargarh	Tangrapali	Highly vulnerable
Sundargarh	Nuagaon(Sun)	Moderately vulnerable