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# A Framework for Assessment of Micro Level Vulnerability to Climate Variability of Farmers: A Case Study in Kerala, India

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

The vulnerability of farmers to climate variability is an important topic of discussion. It varies depending upon diverse factors that disturbing it, likewise, the extent of vulnerability varies according to different levels, i.e.; from a whole country level to an individual level or in other words from macro to micro level. This study attempts to build a framework for the assessment of the microlevel vulnerability of farmers. A vulnerability index was made from normalized values of three major component indices (sensitivity, exposure, and adaptive capacity), which is made up of a selected number of sub components. The study was conducted by selecting respondents from two districts of Kerala, and it was found that this method can be used as an empirical method to interpret the vulnerability to climate variability, keeping the fact that it is only a constrained measure of risk.

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## 1. INTRODUCTION

Vulnerability, which can be defined as the extent to which climate change can damage or harm a system, not only depends on the sensitivity and exposure of the system but also on the ability to adapt to new climatic conditions (IPCC). Frequent extreme weather events and displaced seasons are causing worry to the farmers and above all, threatens food security**.** It is clear that both at the macro level and at the micro level, vulnerability to climate change is different. So, it is important to take up vulnerability studies in all the possible levels and to take up corrective policy decisions.

Blaike et al [1]. stated that vulnerability is the characteristics of a person or a group in terms of their ability to anticipate, face, resist and recover from the impact of natural hazards and, furthermore, stated that the vulnerability can be seen in a range of resilience to susceptibility. Adger [2] recognized vulnerability as the extent to which a social or natural system are likely to damage from climate change. It is generally perceived as the function of two components; the effect that an event can have on humans, referred to as capacity or social vulnerability; and the risk of such an event, called an exposure. Karthick [3]. Used the integrated assessment approach on the vulnerability of agricultural households to climate variability by developing agricultural vulnerability index using primary data. The vulnerability index was created by developing indices for three main components; adaptability, sensitivity and exposure, each of which comprises of several sub-components.

## 2. MATERIALS AND METHODS

In this study, vulnerability of farmers to climate variability in the Palakkad and Wayanad district were analysed by constructing a vulnerability index using the selected sub components under three causative major components (Adaptive capacity, Sensitivity and Exposure).

This assessment approach emphasises mainly on the economic and bio physical status of farmers. Sensitivity and exposure are considered as a positive influence to vulnerability and adaptive capacity as a negative factor. A vulnerability index was made as a merged index of three major component indices to measure the vulnerability of farmers to climate variability. The process of constructing the component indices involves the normalization of all the sub component values and then taking the mean of the normalized value. For each sub components, the assumed relationship (Direct or Inverse) of sub component with the corresponding major component was considered for the normalization. The following formulas have been used to normalize the sub components based on the relationship between the sub component and the corresponding major component:

When the sub component was directly related with the corresponding major component,

$$z_i = \frac{x_i - x_{min}}{x_{max} - x_{min}}$$

When the sub component was inversely related with the corresponding major component [4],[5]

$$z_i = \frac{x_{max} - x_i}{x_{max} - x_{min}}$$

Where,

$z_i$ is normalized value of i$^{th}$ sub component in the area., $x_i$ is the value of the i$^{th}$ sub component in the study area., $x_{min}$ is the possible minimum value of the sub component and $x_{max}$ is the possible maximum value of the sub component.

The model specification is given as:
Vulnerability Index = Adaptive capacity Index+ Sensitivity Index + Exposure Index [4]

Three indices of sensitivity, exposure and adaptive capacity have been constructed by taking the mean of normalized values of the identified sub components. Higher the value of sensitivity index and exposure index, more will be the sensitivity and exposure to climate change and *vice versa*. The higher value of adaptive capacity index shows less adaptability to climate change and *vice versa*. The weighted mean of the three component indices will give rise to the vulnerability index, whose higher values indicate greater vulnerability and lower values a lower vulnerability to climate change.

**Table 1. Major and sub components used for vulnerability index**

| Major components | Sub-Components | Explanation of sub-components | Relationship |
|---|---|---|---|
| Adaptive capacity | Adoption of integrated farming | Percentage of respondents with the adoption of combination of farming practices | Inverse |
| | Farm income | Percentage share of average gross income earned from crop cultivation to the total average income | Direct |
| | Savings in financial institutions | Percentage of respondents which have institutional savings | Inverse |
| | Usage of own irrigation structure | Percentage of respondents which uses well irrigation for cultivation purpose | Inverse |
| | Dependence solely on agriculture as a source of income | Percentage of respondents which reported only agriculture as a source of income | Direct |
| | Cultivation in owned land | Percentage of respondents which cultivating crops only in owned land | Inverse |
| | Deviation in cultivation practice | Percentage of respondents reported variation in cultivation practice against climate variability | Inverse |
| Sensitivity | Average crop diversification index* | Number of crops cultivated by the sample respondents | Inverse |
| | Lack of risk mitigation practices | Percentages of households that do not have any risk mitigation practices | Direct |
| | Usage of common irrigation sources | Percentage of respondents that reported a river, lake, pond and tank as their irrigation source. | Direct |
| | Share of leased in land | Percentage share of leased in land to the total area cultivated by respondents | Direct |
| Exposure | Temperature | Total number of years with large variation in temperature that were reported by respondents in the past 5 years. | Direct |
| | Rainfall | Total number of years with variation in rainfall that were reported by respondents in the past 5 years | Direct |
| | Variation in wind pattern | Percentage of respondents reported high variability in wind pattern in the past 5 years | direct |

*Note: * Simpson's diversification index (SID) was used to assess the extent of crop diversification, which is given by the formula: SID = 1 - $(a_j / A)^2$; where, $a_j$ is the area under the $j^{th}$ crop and A- is the gross cropped area*

Primary data were collected from both the Palakkad and Wayanad districts of Kerala. Two districts were selected for fair comparison of vulnerability levels and there by authenticating the reliability of the index. Based on the criteria of maximum geographical area, the Chittoor block from Palakkad and Mananthavady from Wayanad districts were selected for the study and 60 respondents each was selected in random from both districts. Data was collected from farmers through personal interviews using a pre-tested and well-structured schedule. The survey was conducted between March and April of 2019.

## 3. RESULTS AND DISCUSSION

Total of 14 sub components were selected under the three components for the estimation of vulnerability index. There were four sub components under sensitivity, three under exposure and seven to explain the adaptive capacity. The values of each sub components, which was obtained during the primary data collection are presented in Table 3. Separate indices for sensitivity, exposure and adaptive capacity were constructed using the normalised values of the sub components and are presented in Table 4, 5. From the weighted mean of three

component indices, vulnerability index for each district were obtained (Table 7.). Higher the value of vulnerability index, higher will be vulnerability of farmers to climate change and vice versa.

**Table 2. Criteria for indices**

| Index range | Level of index |
|---|---|
| 0.0 - 0.2 | Very Low |
| 0.2 - 0.4 | Low |
| 0.4 - 0.6 | Medium |
| 0.6 - 0.8 | High |
| 0.8 - 1 | Very High |

*(Rao et al., Sugiarto et al.) [4], [5]*

Sensitivity can be described as the degree to which a system is affected, it can be either negatively or positively (IPCC, 2010). In this study sensitivity was described using four selected sub components: average crop diversification index, percentage share of leased in land in the total cultivated area by the farmers, percentage of farmers who do not have any risk mitigation measures and farmers using common irrigation structures. The sensitivity index obtained for Palakkad district were 0.425 and for Wayanad district it was 0.458. Both districts had medium level of sensitivity index.

Exposure was represented based on the perception of farmers about variation in the temperature, rainfall and wind pattern in the last five years. All the sub component had direct relationship with exposure, so higher values will increase the exposure index. The exposure index obtained were 0.566 and 0.609 for Palakkad and Wayanad districts respectively. Palakkad district had medium level in exposure index whereas Wayanad district had high level in exposure index.

**Table 3. Sub component values of vulnerability of farmers to climate variability**

| Major components | Sub components | Unit | Palakkad | Wayanad |
|---|---|---|---|---|
| Sensitivity | Simpson's crop diversification index | - | 0.78 | 0.74 |
| | Lack of any risk mitigation practices | Per cent | 28.33 | 35.00 |
| | Use of common irrigation sources | Per cent | 71.67 | 78.33 |
| | Share of leased in land | Per cent | 48.07 | 43.7 |
| Exposure | Temperature | Count | 2.33 | 2.45 |
| | Rainfall | Count | 2.07 | 2.43 |
| | Variation in wind pattern | Per cent | 81.67 | 85.00 |
| Adaptive capacity | Adoption of integrated farming | Per cent | 46.67 | 43.33 |
| | Proportion of farm income | Per cent | 69.31 | 68.41 |
| | Savings in financial institutions | Per cent | 35.00 | 31.67 |
| | Use of own irrigation structure | Per cent | 28.33 | 25.00 |
| | Dependence solely on agriculture as a source of income | Per cent | 51.67 | 50.00 |
| | Cultivation in owned land | Per cent | 23.33 | 40.00 |
| | Deviation in cultivation practice | Per cent | 55.00 | 43.33 |

**Table 4. Normalised sub component values of sensitivity of farmers to climate variability**

| S No. | Major component & Sub components | Value | | Relation | $X_{min}$ | $X_{max}$ | Normalised value | |
|---|---|---|---|---|---|---|---|---|
| | | Palakkad | Wayanad | | | | Palakkad | Wayanad |
| | Sensitivity | | | | | | | |
| 1 | Simpson's crop diversification index | 0.78 | 0.74 | Inverse | 0 | 1 | 0.220 | 0.260 |
| 2 | Share of leased in land | 28.33 | 35.00 | Direct | 0 | 100 | 0.2833 | 0.35 |
| 3 | Usage of common irrigation sources | 71.67 | 78.33 | Direct | 0 | 100 | 0.7167 | 0.7833 |
| 4 | Lack of risk mitigation practices | 48.07 | 43.7 | Direct | 0 | 100 | 0.4807 | 0.437 |

**Table 5. Normalised sub component values of exposure of farmers to climate variability**

| S No. | Major component & Sub components | Value | | Relation | X min | X max | Normalised value | |
|---|---|---|---|---|---|---|---|---|
| | | Palakkad | Wayanad | | | | Palakkad | Wayanad |
| | **Adaptive Capacity** | | | | | | | |
| 1 | Adoption of integrated farming | 46.67 | 43.33 | Direct | 0 | 100 | 0.533 | 0.567 |
| 2 | Proportion of farm income | 69.31 | 68.41 | Inverse | 0 | 100 | 0.693 | 0.684 |
| 3 | Savings in financial institutions | 35.00 | 31.67 | Direct | 0 | 100 | 0.450 | 0.567 |
| 4 | Use of own irrigation structure | 28.33 | 25.00 | Direct | 0 | 100 | 0.717 | 0.750 |
| 5 | Dependence solely on agriculture income | 51.67 | 50.00 | Inverse | 0 | 100 | 0.517 | 0.500 |
| 6 | Cultivation in owned land | 23.33 | 40.00 | Direct | 0 | 100 | 0.767 | 0.600 |
| 7 | Deviation in cultivation practice | 55.00 | 43.33 | Direct | 0 | 100 | 0.650 | 0.683 |

**Table 6. Index of the major components and vulnerability index**

| S No. | Indicator | Palakkad | Wayanad |
|---|---|---|---|
| 1 | Adaptive capacity index | 0.618 | 0.622 |
| 2 | Sensitivity index | 0.425 | 0.458 |
| 3 | Exposure index | 0.566 | 0.609 |
| | Vulnerability Index | 0.552 | 0.572 |

The sub components of adaptive capacity were represented by wealth or financial capital, technological change, livelihood strategy. Farmers with higher income, better livelihood strategy, financial support, good technical knowledge will be better prepared to climate change impacts. This represents good adaptive capacity of the farmers. Adaptive capacity index for Palakkad district were 0.618 and for Wayanad it was 0.622. Both districts had high level of index for adaptive capacity. But the adaptability to climate change of Wayanad district was found lower than that of Palakkad district.

## 4. CONCLUSION

The vulnerability index obtained for Palakkad district were 0.552 and 0.572 for Wayanad district, both were having medium vulnerability level. Farmers in Palakkad district was found more vulnerable to climate change than Wayanad district. Also understood that the component indices differ depending upon the situations of the study area. The sensitivity index, exposure index and adaptive capacity index obtained for Palakkad district were 0.618, 0.425, 0.566 and 0.618 for Wayanad district were 0.458, 0.609 and 0.622 respectively. Using the numerical values of the index, it can be concluded that farmers in Wayanad district was 3.6 per cent more vulnerable to climate change than in Palakkad district. From the study, it has been understood that vulnerability assessment can be done in micro levels in order to have further understanding of the effects climate variability and to have improved policy adaptations and to know the need and vital changes in risk mitigation. It should be noted that this index is not an absolute measure of damage or risk due to climate change and is only a constrained measure of risk.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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