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Vulnerability of agricultural systems to pollution: A farmer centred analysis

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Abstract
Agriculture is both a causative and victim of pollution. Therefore, farmers need to know about the exposure, sensitivity and adaptive capacity levels of their farms to pollution. In the study, perceived vulnerability levels of the farms of 180 farmers who cultivated rice, banana and vegetables from Thrissur and Palakkad districts of Kerala, India was assessed. The exposure, sensitivity and adaptive capacity indices were computed, and the overall vulnerability index of each panchayat was computed using these indices. The study notably concluded that, exposure was the most important factor that determined the vulnerability of the farming system to pollution. Farmers possessed only moderate levels of awareness about the adverse effects of environmental pollutants on their farming system.

Keywords: Environmental pollution, vulnerability, exposure, sensitivity, adaptive capacity, perception, quartiles, principal component analysis, vulnerability index, farmers

Introduction
Vulnerability is a function of exposure, sensitivity and adaptive capacity. Sanchez- Gonzalez, 2011 saw vulnerability as the inability of a system or a unit to withstand the effects of an environment that is hostile. This paper tries to explore what are the perceptions of farmers about vulnerability of their farms to extrinsic pollution.
Greater the exposure and sensitivity, the greater is the vulnerability. Adaptive capacity reduced vulnerability of a farming system to pollution. Therefore, reducing vulnerability would involve reducing exposure and sensitivity through specific measures or increasing adaptive capacity (Gbetibouo and Ringler, 2009) [10]. Understanding the farmers' perceptions can serve as a reality check in assessing the extent of vulnerability to environmental pollution of the farming systems and this paper intends to find the same.

Methodology
Study area and sampling
The study was done in the state of Kerala, India. Of the 14 districts the state, Thrissur and Palakkad were purposively selected since they have a large percentage of area under cultivation of rice (49.93%), banana (30.43%) and vegetables (19.74%) [Department of Economics and Statistics, 2018]. For rice-based systems, Puzhakkal which falls under the special rice production system of *Kole* lands of Thrissur district and Alathur, a major rice growing panchayat from Palakkad district were purposively selected. For vegetables and banana, two banana growing panchayats *viz*, Puthur and Pananchery and two vegetable cultivating panchayats *viz*., Nadathara and Madakkathara of Thrissur district were randomly selected. From each of these selected 6 panchayats, a random sample of 30 farmers were drawn for data collection. The total sample size was 180 farmers.

Data collection and analysis
For primary data collection, a pretested interview schedule was administered individually to the respondents. Profile of the farmers was analysed using descriptive statistics. The level of exposure, sensitivity and adaptive capacity of each agricultural system based on farmers' responses, were assessed using a pre-determined scale. The scale consisted of different number of statements under each dimension. Farmers' responses were recorded on a Likert scale (Raghuvanshi and Ansari, 2019) [18].
The total score as well as an index for all the statements were then calculated. To find the level of exposure, sensitivity and adaptive capacity of each agricultural system, the score of each statement was considered.

The level of exposure, sensitivity and adaptive capacity in all the six agricultural systems were categorized into three categories by taking the Mean and Standard Deviation.

Score of each statement = Sum of the farmers' score on the statement

The total score for each farmer respondent was computed by summing the scores of all the statements in each category and the index was found for each respondent, which was used to compare the different agricultural systems based on exposure, sensitivity, and adaptive capacity levels.

$$\text{Index of each farmer} = \frac{\text{Total score of the farmer X 100}}{\text{Maximum possible score of the farmer}}$$

Vulnerability status of the different agricultural systems

A vulnerability index was computed using exposure index, sensitivity index and adaptive capacity index of each farmer using the formula,

Vulnerability index = Exposure index + Sensitivity index – Adaptive capacity index (Gbetibou and Wringler, 2009) [10]

The statements of vulnerability based on the farmers' perception scores were then classified into three categories, 'High', 'Medium' and 'Low' based on the quartiles obtained.

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Table 1: Categorizing the statements of vulnerability using quartiles based on farmers' perception scores

Sl. No.	Category	Criteria
1	High	Scores>Q3
2	Moderate	Scores in between Q1 and Q3
3	Low	Scores<Q1

Results and Discussion

Socio demographic characteristics of the farmers

The socio demographic characteristics of the selected farmer respondents from all the selected six panchayats are shown in Table 2.

Table 2: Summary statistics of the socio demographic characteristics of farmers (N=180)

Sl. No	Variables	Mean	SD	Range of scores	
				Min.	Max.
1	Age	1.9111	0.89499	1	4
2	Education	3.1222	0.9341	1	4
3	Experience	2.1111	0.90497	0	5
4	Area of land holding	2.2333	0.88749	1	4
5	Proximity to industrial area	1.8	0.92651	0	3
6	Mass media contact	1.3667	0.6439	0	2
7	Water source	1.5444	1.19173	1	5
8	Occupation	2.8667	1.06944	1	4

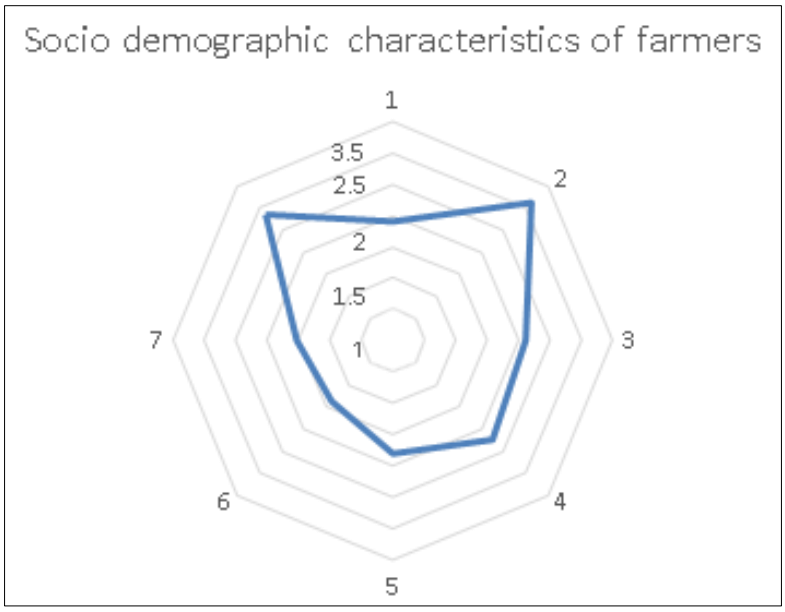

Fig 1: Summary statistics on socio demographic characteristics of the farmers Vulnerability of the systems as perceived by the farmers

Table 3: Vulnerability index of the six panchayats

Sl. No.	Panchayath	Exposure index	Sensitivity index	Adaptive capacity index	Vulnerability index
1	Puzhakkal	71.40	58.28	54.33	75.35
2	Alathur	55.40	53.142	59.67	48.88
3	Puthur	62.37	58.28	55.67	64.95
4	Pananchery	54.22	56.19	47.33	63.08
5	Nadathara	66.22	57.52	49.33	74.41
6	Madakkathara	47.40	54.47	49.33	52.55

Puzhakkal, which holds the fertile and remunerative rice production systems called *Kole* lands, had the highest Vulnerability Index. This area is also in the periphery of the large town, Thrissur, and in close proximity to high rise apartments, shopping malls and a teeming business area which is evident from the high vulnerability index. Predictably, the lowest perceived vulnerability went to Alathur, which is a predominantly rice producing area, but also mostly rural in nature. There can be other factors governing the pattern of perceived vulnerability, like presence of absence of awareness by farmers about sources and causes of pollution to their farms.

Table 4: Farmers' perception on exposure, sensitivity and adaptive capacity (N = 180)

Sl. No.	Statements	Total score	Quartiles
Exposure			
1	Agriculture sector has become more vulnerable to environmental pollution than other sectors	656	III
2	There is an occurrence of pollution caused by both natural changes in environment and human activities	622	III
3	Air, water and soil pollution negatively affect the farming practices	634	III
4	Pollution has emerged as a major problem	594	III
	affecting farming nowadays		
5	There is an occurrence climate change due to pollution	480	II
6	Pollution is largely leading to the fluctuations in the onset and patterns of rainfall	490	II
7	Extreme weather events in the last few years have affected the adaptation to pollution and mitigation practices	436	I
8	Biodiversity of species is threatened as a result of pollution	422	I
9	There are occurrences of dry spells associated with pollution	486	II
Sensitivity			
10	There is an increased incidence of weeds and insect pest attacks as a result of pollution than earlier times	584	II
11	There is a decrease in agricultural production due to pollution	542	II
12	There is increased deforestation as a consequence of pollution	488	II
13	There is an increase in soil erosion as a result of pollution	566	II
14	There is extinction of plant and animal species due to pollution	384	I
15	Livestockrearing has become vulnerable because of pollution	472	II
16	Productive capacity of livestock is adversely affected due to pollution	512	II
Adaptive Capacity			
17	Farmers resort to change in cropping pattern and cropping seasons due to pollution	484	II
18	Farmers change their livelihood pattern due to pollution	466	I
19	Farmers change their crop choice and crop cycle due to pollution	470	II
20	Farmers change their land use pattern due to pollution	474	II

The vulnerability statements with scores less than 469 belonged to the first quartile. These statements were perceived by the farmers to be low in their farming systems. The statements are, 'Extreme weather events in the last few years have affected the adaptation to pollution and mitigation practices', 'Biodiversity of species is threatened as a result of pollution',' There are occurrences of dry spells associated with pollution', 'There is extinction of plant and animal species due to pollution', and 'Farmers change their livelihood pattern due to pollution'.

The statements with scores in between 469 and 586.5 belonged to the second quartile and are, 'Pollution has emerged as a major problem affecting farming nowadays', 'There is an uncertainty in rainfall as a result of pollution', 'There is an increased incidence of weeds and insect pest attacks as a result of pollution than earlier times', 'There is a decrease in agricultural production due to pollution', 'There is increased deforestation as a consequence of pollution', 'There is an increase in soil erosion as a result of pollution', 'Livestock rearing has become vulnerable because of pollution',' Productive capacity of livestock is adversely affected due to pollution', 'Farmers resort to change in cropping pattern and cropping seasons, 'Farmers change their livelihood pattern', 'Farmers change their crop choice and crop cycle' and 'Farmers change their land use pattern'.

These statements were therefore perceived by the farmers to be the factors of vulnerability moderately affecting their respective farms.

The statements with scores more than 586.5 belonged to the third quartile, and consisted of the statements, 'Agriculture sector has become more vulnerable to environmental pollution than other sectors', 'There is an occurrence of pollution caused by both natural changes in environment and human activities', 'Air, water and soil pollution negatively affect the farming practices' and 'Pollution has emerged as a major problem affecting farming nowadays'. These statements were therefore perceived by the farmers to be the factors of vulnerability highly affecting their respective farms. The second quartile contained the most number of statements, 12/20. This indicates a medium level of perception by farmers about vulnerability. The farmers had only medium awareness about agricultural pollution from other parts of the country too. (Jayappa, 2020) [11]. The statements in the third quartile indicate an awareness level about the general pollution status only. The low perception about serious issues like effects on biodiversity (statement 8, 14), which complies with the results of the studies conducted by Dudley and Alexamder in 2017 [8], and livelihood threat (statement 18) indicate the need for urgent attention from extension and administrative systems to educate the farmers and address these issues.

Conclusion

Those parts of the study area which were perceived by the respondent farmers to have high vulnerability were also perceived to have higher exposure and sensitivity levels, with lower levels of adaptive capacity. The areas with perceived low vulnerability possessed higher adaptive capacity levels as perceived by the farmers. This finding is in agreement with that by Gbetibou and Wringler, 2009 [10] wherein exposure and sensitivity were positively related to vulnerability and adaptive capacity was negatively related.

Exposure was found to be the factor that mainly affects the vulnerability of a farming system to the ill effects of environmental pollution and a main reason for this could be the indiscriminate use of chemical fertilizers and pesticides by the farmers. This finding was found to be contradictory to that of the study conducted by Liu *et al*. in 2012 [13], where adaptive capacity was found to be the main cause for the differences in vulnerability of different areas to environmental pollution based hazards in middle inner Mongolia of China.

Switching over to organic farming and using bio-pesticides can, to a large extent reduce the exposure of the farms to environmental pollutants (Bhat *et al*, 2018) [4]. As majority of the farmers belong to the category of 'small farmers'

(Mahendra Dev, 2014) [14], implementation of adaptive measures in their farms also become an uphill task with limited area and resources to carry out the crop diversification activities or change in cropping pattern (Withers, 2007) [24]. A high majority of the farmers use mass media frequently (Abubakar *et al.*, 2009) [1]. Therefore, awareness programmes aimed at farmers about mitigating the ill effects environmental pollution must be propagated through mass media channels. Many of the environmental shows telecasted or broadcasted through mass media seem to lack in quality (Saikia in 2017) [16], hence, there is a need to train broadcasters and telecasters on proper ways of reporting environmental related issues. Provision of funding for media airing of environmental issues can be provided to increase TV environmental content A number of Government schemes and legislative measures have been implemented to safeguard the farmers against the ill effects of environmental pollution. But due to lack of awareness farmers often fail to make use of these programmes for their benefit. It is the duty of the farm advisors to educate the farmers in this regard so that they take up suitable pollution mitigation measures (Vrain and Lovett, 2016) [23].

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