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Research and design of a Farmer Resilience Index in coastal farming communities of Tamil Nadu, India

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ABSTRACT

Climate disasters have a high impact on farming communities in terms of crop loss or reduced income. In the context of disasters, resilience is defined as the capacity to absorb its impacts, bounce back and even improve their previous status. The recent past two disasters namely Cyclone Thane (2011) and the South Indian floods (2015) had caused major crop loss in Cuddalore, India. A Farmer Resilience Index (FRI) has been assessed at the household level using primary data from 93 households (total) in Silambimangalam and Chinnakomatti villages in Cuddalore, with respect to the 2011 and 2015 disasters. The index has 18 parameters and 55 variables under four dimensions, namely, economic, social, technical, and physical. Farmers in both villages have average resilience to precipitation extremes, with FRI of 0.61 and 0.54, respectively. Seventy percent of the total samples are marginal farmers who have the lowest FRI of 0.47 and 4.3% are medium farmers having FRI of 0.83. Marginal farmers are poor and typically belong to lower castes with their farmlands located at lower elevations, which diminish their physical and economic resilience. The outcomes of the index reveal the current adaptive capacities of the farmers and have the potential to support future planning decisions.

Key words: climate resilience, current adaptive capacities, economic resilience, Farmer Resilience Index, marginal farmers, precipitation extremes

HIGHLIGHTS

- Resilience assessment is needed to improve adaptive capacities for future climate disasters.
- Farmer Resilience Index (FRI) has been used to assess resilience.
- Communities on the coast have better resilience and may be attributed to a reaction to a disaster experience.
- Large farmers have improved resilience and reduced risk of income loss from a climate disaster.
- The FRI has revealed the efforts taken by the farmers to address the impacts of a precipitation disaster.

GRAPHICAL ABSTRACT

1. INTRODUCTION

Climate changes can be identified by the increase in the occurrence of extreme climate events such as floods, droughts, landslides, and forest fires. Society is very sensitive, complex and is highly affected by these extreme events (Easterling 2000). Depending on the projections given by IPCC, weather events are likely to become more severe, intense, and less predictable in the future. Extreme weather events can become a disaster when the society or ecosystems are unable to cope with it effectively (IPCC 2007). Various impacts of climate disasters include unseasonal rainfall, degradation of soil resources, plant pest and disease outbreaks, economic and political crises, which along with exponential population growth are adding pressure to the global food system as (Rockström *et al.* 2009; Godfray *et al.* 2010; Pretty *et al.* 2010) agriculture is highly vulnerable to such impacts, thus leading to food and nutritional insecurity worldwide. In particular, precipitation disasters, which include cyclonic events, flash floods, and waterlogging in fields that are not normally submerged (Pachauri & Meyer 2014), lead to oxygen and nitrogen depletion for the crops. Even after the flood waters recede, crops face disease and pest attack, erosion problems, and competition from weeds.

The challenge here is to make farming systems and the farmers be able to fulfil their goal even in the presence of such random, unpredictable changes, or impacts. In recent years, the concept of resilience has been used increasingly to address such challenges faced by farmers in crop production systems (Tendall *et al.* 2015). This article highlights that the role resilience can play in addressing crop production challenges faced by farmers and sets a foundation for applying it for this rationale. Resilience with respect to precipitation extremes has been assessed in this study.

1.1. Resilience

According to Holling (1973), resilience is a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables. Community-level resilience in particular is the response of a community towards an event along with its ability to learn lessons and improve its adaptive capacity (Cutter *et al.* 2008). When adopting the concept of climate resilience for a community, it gives a better understanding as to what extent the individuals are equipped and capable to respond to climate disasters. According to Twigg (2009), community resilience is said to have three phases, namely: (1) capacity to absorb stress or destructive forces through resistance or adaptation, (2) capacity to manage, or maintain certain basic functions and structures, during disastrous events, and (3) capacity to recover or bounce back after an event. Such efforts taken by stakeholders within a community to address problems at a micro level are very effective rather than a large-scale approach.

Community-level resilience measurement is possible when the community is place-bound. Rural communities in India are known as a village in a rural setting and are largely agriculture based with farmers as the major stakeholders. The ability of farmers within a village to absorb, manage, and bounce back from a climate disaster is very important for crop production systems to function effectively. The resilience of farmers at a village level is all about equipping them to absorb and recover from shocks and stresses to their agricultural production and livelihoods. Communities can learn through reactions following a climate disaster in a pro-active way while expecting a disaster soon. Higher experience of climate disasters enhances the preparedness of people based on a learning effect that would follow after they experience such events (Mishra & Suar 2007).

1.2. Relationship between adaptation and resilience

Figure 1 is used to compare resilience and adaptation based on the link between resilience and vulnerability, in which vulnerability can be understood as measures of the characteristics of a system, namely its exposure and sensitivity to a possible hazard or disaster (Adger 2006). Resilience is the ability to resist and recover from such hazard or disaster in a short interval with minimum to no external support. It is a process that ensues during and post-disaster and helps to improve the abilities of the hazard-affected bodies to resist, to absorb the impacts of climate events, and to bounce back and even improve on their previous status. Adaptation is the process of reducing exposure and vulnerability to a hazard or disaster and to enhance

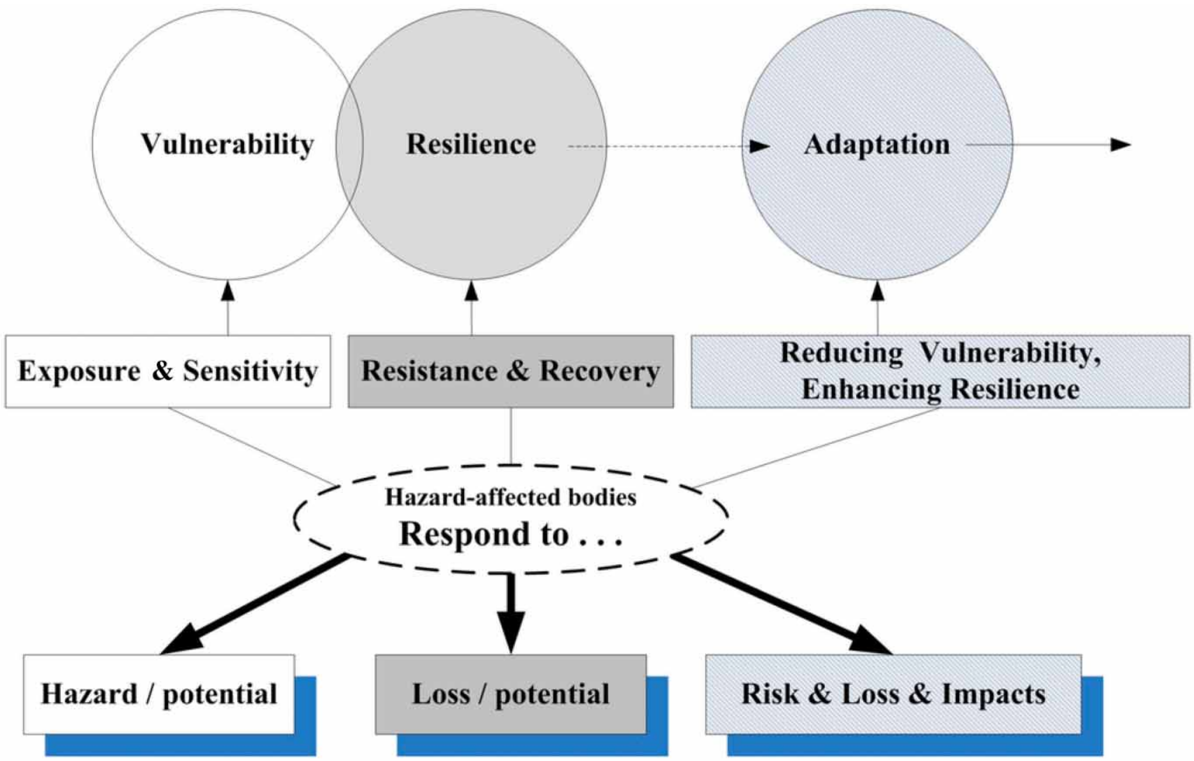

Figure 1 | The relationship between vulnerability, resilience, and adaptation. *Source*: Zhou *et al*. (2016).

resilience by responding to the disaster risk pre-disaster, and to its loss and impacts during and after the disaster occurrence (Zhou *et al.* 2010). Thus, reducing vulnerability and improving resilience are the two main objectives of adaptation and it varies with the structure, function, and surroundings of the hazard-affected bodies. Adaptation focuses on the condition of the hazard-affected bodies in the circle of disaster management and supports its sustainability and protection in the future (Zhou *et al.* 2016). Adaptation is higher than resilience as it could be improved based on social learning (White 1974) and experience and investment from various institutions (UNISDR 2015). Also, adaptation is place-oriented and is the understanding of disaster adaptation for a particular hazard-affected body or place (Zhou *et al.* 2016). However simultaneously, there has been a surge of critique on resilience and climate-resilient development, emerging mostly from the sectors of political ecology and human geography. Resilience is a term that has evolved considerably since its first coherent theorization by Holling (1973), but it still continues to include unfeasible rigid systems-thinking in its systematic search for local solutions. A great deal of effort has been made by researchers to humanize resilience, but the most realistic effort will be to include human-centred perspectives in resilience assessment and also in the implementation of adaptation measures. Adaptation should be understood as an uneven political process formed by highly differentiated levels of power and access to resources (Eriksen *et al.* 2015). Focus on people rather than the systems which they are a part of will help advance adaptation assistance (Mikulewicz 2019).

With this understanding of resilience, adaptation, vulnerability, and its downsides, a village-wise resilience index known as the Farmer Resilience Index (FRI) has been assessed using variables under four dimensions namely economic, social, technical, and physical for disclosing the resilience of farmers in two rural villages at the household level. The index has been assessed with respect to two disasters namely Cyclone Thane (2011) and the South Indian floods (2015) which caused crop damage and waterlogging in the Cuddalore district, Tamil Nadu, India. The index allows the integration of the theoretical aspects of how disasters need to be understood within a community (Joerin *et al.* 2012). Community-level assessment of resilience is necessary since stakeholders are heterogeneous (Antwi-Agyei *et al.* 2013), and it helps to understand the social dynamics to develop suitable location-specific adaptation strategies for better implementation.

2. METHODS

FRI is to be assessed and compared between farming households in two villages for a better understanding of farmer and community perspectives and response before, during, and after a precipitation-related disaster. The Eastern coast of India has experienced nearly 308 cyclones between 1891 and 2000 of which 103 cyclones were categorized as severe (Rao *et al.* 2007; Mohapatra 2015; Suchitra 2015). On review of trends of extreme precipitation indices for the Cuddalore district which is located on the South Eastern Coast of India, the indices have shown increasing trends during the North East (NE) monsoon season which is the main crop growing season in the district. In the past decade, two events namely Cyclone Thane of 2011 and the 2015 South Indian floods caused major crop loss in Cuddalore. During the 2015 floods, maximum 1-day rainfall was recorded as 144 mm on 23 November 2015, 134.8 mm on 2 December 2015, and 132.8 mm on 3 December 2015 in the Cuddalore rain gauge station which caused severe waterlogging in Cuddalore for over a month which caused huge crop damage to the farmers (Jayadas & Ambujam 2019). During Cyclone Thane of 2011, maximum wind of 76 knots (140 kmph) was recorded at the time of landfall in Cuddalore. Also, storm surge of about 1 m height inundated the low-lying coastal villages of Cuddalore (IMD 2011). More than 15,000 hectares of agricultural lands with standing crop were destroyed, and long-term tree crops such as coconuts, cashew nuts, and jackfruit were uprooted. The resilience index has been measured with respect to the 2011 and 2015 precipitation disasters mentioned above.

2.1. Sampling methodology

A cluster sampling methodology has been used to select samples from two villages (Bennett *et al.* 1991) in which a simple two-stage cluster sample was selected. First the different clusters were listed, from which one cluster was chosen by simple random sampling. From the chosen cluster, the sampling of households was carried out by simple random sampling. In the current study, the primary sampling units (PSUs) are the villages in the block. One village (PSU) is selected, from which secondary sampling units (SSUs) have been chosen. SSUs are farming households within each village. Parangipettai, a coastal block located in the Cuddalore district which is highly vulnerable to precipitation-related disasters (Jayadas & Ambujam 2019), was selected from which the PSUs were to be chosen. Forty-seven villages located within Parangipettai were first listed and then assigned numbers in order, and initially, five villages were chosen based on a random basis which is Chinnakomatti, Kothattai, Ariyakoshti, Silambimangalam, and Villiyanallur. Only two villages were to be selected for the resilience measurement and comparison, and hence, a face-to-face discussion was conducted with four experts to select two villages where the farmers were easy to approach and also highly vulnerable to extreme precipitation events. The experts were Non-Governmental Organization representative, two Government representatives from the Agriculture Extension Center, and one Government representative from the Irrigation Department who were all involved with the farmers in the study area.

Village 1 is Silambimangalam, which is on the coast, and village 2 is Chinnakomatti which is approximately at a maximum distance of 9 km away from the east coast (Silambimangalam and Chinnakomatti villages will be mentioned as village 1 and village 2, respectively, hereafter). Figure 2 shows the location of the Cuddalore district and Figure 3 shows the location where the two villages are located in Cuddalore. Both villages consist of a majority of farming households, thus making them highly suitable for measuring their resilience to precipitation extremes.

Village 1 and village 2 have 59.05 and 62.28% net sown area with respect to their total village area which was an important parameter used for the selection of the study area. Details about the villages chosen for study are given in Table 1.

SSUs have been chosen using the simple random sampling technique with 5% of SSUs from each village as the sample size which was fixed based on expert opinion. Field experiences and previous research by experts in Cuddalore indicate that farmer income and yield-related data from farming households are not highly skewed, and hence, the same can be assumed for the population. With a 5% margin of error, at a 95% confidence interval, the response distribution has been fixed as 5% based on expert opinion. Every alternate household within the village starting from the point where the community temple is located was considered as an SSU to achieve random sampling or near-random sampling with a non-farming household if encountered skipped and moved to the next farming household.

3. FRI FRAMEWORK

The FRI is based on the Climate Disaster Resilience Index framed by Joerin *et al.* (2014) and Joerin *et al.* (2012). The index has been designed to include all possible dimensions, indicators, and sub-indicators to address the complexity of a farmer and related farming systems in response to flood or cyclone or related disaster. The FRI has four dimensions namely economic, social, technical, and physical with each dimension having parameters with individual variables to determine the resilience of the farmers. Table 2 highlights the dimensions, parameters, and variables. The different dimensions, parameters, and variables of the FRI have been identified with the help of two experts along with an extensive literature reference. The

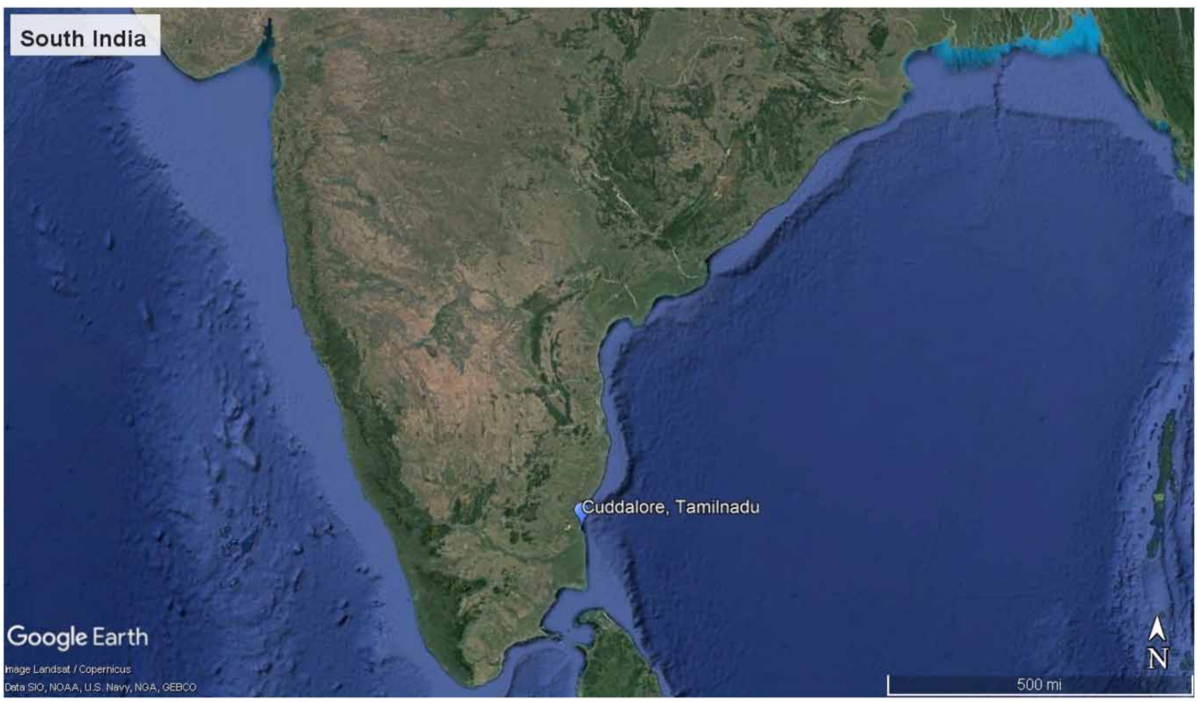

Figure 2 | Location of Cuddalore in Tamil Nadu, India. *Source*: Google Earth Pro.

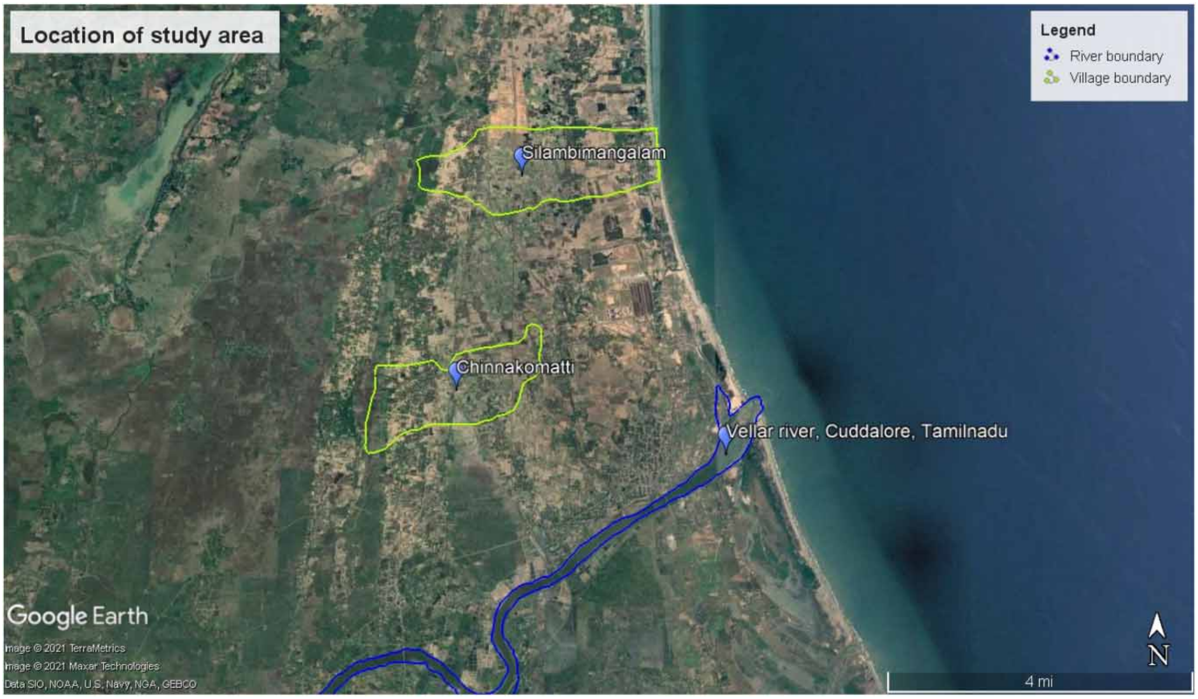

Figure 3 | Location of the study area. *Source*: Google Earth Pro, https://cuddalore.nic.in/map-of-district/ and Water Resources Department – Public Works Department, Government of Tamil Nadu.

Table 1 | Details of villages chosen for Farmer Resilience Index calculation (District Census Handbook, Cuddalore, Directorate of Census Operations, Tamil Nadu)

	Village 1	**Village 2**
Location	11°32′37″N, 79°44′32″E	11°30′11″N, 79°43′28″E
Area (km^2/ha)	7.54/754	5.31/531
Distance from the coast (km) approx.	max: 5 min: 0	max: 9 min: 5
Distance from the Vellar river (km) approx.	7.2	4.3
Net Area Sown (ha)	445.3	330.7
Total Irrigated Land Area (ha)	5.4	67.4
Total Un-irrigated Land Area (ha)	439.9	263.3
Total population (2011 census)	5,695	2,465
Number of households	1,455	593
Sample size (5% households)	70	23

variables considered for the assessment of farmer resilience towards precipitation extremes and related disasters such as floods, cyclones, or both have a direct or inverse relationship with resilience, also outlined in Table 2.

3.1. Calculation of the FRI

The methodology for calculating the FRI is explained in detail below. A questionnaire (Supplementary Material, Appendix 1) has been developed with the dimensions, parameters, and variables to be administered to the respondents of each farming household. The rationale of the questionnaire was the extreme precipitation events that had occurred between 1978 and 2015 which include Cyclone Thane of 2011 and the Deep Depression of the Bay of Bengal of 2015

Table 2 | Rationale for each variable with respect to extreme precipitation and related disasters

Core resilience factors (dimension)	Parameters	Nature of variable	Variables	Justification	Rationale (w.r.t precipitation-related disaster between 1978 and 2015)
1. Economic	1.1 Income	Continuous	1.1.1 Net annual income	Rose (2004)	A farmer with more financial resources at their disposal can use it for implementing measures to overcome the impacts of disaster before, during, or after.
		Continuous	1.1.2 Diversity of income	Armah *et al.* (2010), Defiesta & Rapera (2014)	
		Continuous	1.1.3 Income from any other jobs during the off-season		
		Continuous	1.1.4 Loss of income owing to a recent flood/cyclone (f/c) disaster	Joerin *et al.* (2014)	
		Continuous	1.1.5 Other amount received from family members and relatives	Defiesta & Rapera (2014)	
	1.2. Finance and savings	Ordinal	1.2.1 Access to credit facility for farming activities	Joerin *et al.* (2014)	
		Ordinal	1.2.2 Access to credit facility to prevent f/c disaster		
		Ordinal	1.2.3 Household saving practice		
		Nominal	1.2.4 Crop insurance		
	1.3. Budget and subsidies	Ordinal	1.3.1 Availability of subsidies for field drainage infrastructure	Defiesta & Rapera (2014)	
		Ordinal	1.3.2 Availability of subsidies for flood-resistant seeds varieties		
		Ordinal	1.3.3 Availability of subsidies/incentives for farmers to reclaim flood-affected lands		
	1.4. Household assets	Nominal	1.4.1 TV	Joerin *et al.* (2014)	A farmer with access to household and farm assets can easily use them to be more informed and prepared for an upcoming disaster, during the disaster and even during the disaster recovery process.
		Nominal	1.4.2 Radio		
		Nominal	1.4.3 Computer with internet		
		Nominal	1.4.4 Mobile phones with internet		
		Nominal	1.4.5 Mobile phones without internet		
		Nominal	1.4.6 Motorized vehicle		
	1.5. Farm assets	Nominal	1.5.1 Pump		
		Nominal	1.5.2 Farm tractor, farm tools and implements		
2. Social	2.1. Household/family labour	Ordinal	2.1.1 Household contribution to farm labour during f/c disaster?	Eakin *et al.* (2011)	A farmer with access to labour either from family utilize it before, during, and after a disaster
		Ordinal	2.1.2 Contribution of extended family members/relatives within the community towards farm labour during f/c disaster		
		Ordinal	2.1.3 Contribution of extended family members/relatives outside the community towards farm labour during f/c disaster		
	2.2. Social capital	Ordinal	2.2.1 Activeness in Farmer-Based Organizations (FBOs)	Egyir *et al.* (2015)	A farmer who is socially active has more access to labour from friends or neighbours which can be put to use before or during a disaster and also during the disaster recovery process.
		Continuous	2.2.2 Years of membership in FBOs		

(*Continued.*)

Table 2 | Continued

Core resilience factors (dimension)	Parameters	Nature of variable	Variables	Justification	Rationale (w.r.t precipitation-related disaster between 1978 and 2015)
		Ordinal	2.2.3 Social acceptance level of village head		A farmer who is in friendly terms with the village head can easily ask him for help before or during a disaster and also during the disaster recovery process.
	2.3. Level of literacy	Ordinal	2.3.1 Literacy rate	Deressa (2008)	Farmers who are literate and more educated can easily understand and accept the process of climate and its impacts, thus helping them to make informed decisions to overcome its impacts.
		Ordinal	2.3.2 Awareness of climate change	Joerin *et al.* (2014)	
		Nominal	2.3.3 Acceptance of climate change	Own formulation	
		Ordinal	2.3.4 Availability of public awareness programmes on f/c disaster	Joerin *et al.* (2014)	Farmers with access to public awareness programmes on disasters can take necessary measures before, during, or after a disaster.
		Nominal	2.3.5 Access to internet	Joerin *et al.* (2014)	Farmer with access to the internet can use it to keep them informed about disasters, its impacts and disaster management methods which will help them before, during, or after a disaster.
	2.4. Access to formal extension Service	Ordinal	2.4.1 Climate-related training	Frank & Buckley (2012)	Farmers with access to climate and disaster-related programmes are more informed about necessary measures to be taken before, during, or after a disaster.
		Ordinal	2.4.2 f/c disaster management training		
	2.5. Farming experience	Continuous	2.5.1 Years of farming	Defiesta & Rapera (2014)	A famer with more farming years have more experience and skills to adapt or recover from climate-related disasters.
3. Technical	3.1. Knowledge of seed varieties	Ordinal	3.1.1 Knowledge of flood-resistant varieties	Mabe *et al.* (2012)	A farmer with more knowledge on seed varieties has a better chance of adapting to climate change.
		Ordinal	3.1.2 Knowledge of early maturing varieties		
	3.2. Knowledge of crop diversification	Ordinal	3.2.1 Knowledge of intercropping	Own formulation	A farmer with more knowledge on different cropping practices has a better chance of adapting to climate change.
		Ordinal	3.2.2 Knowledge of relay cropping	Own formulation	
		Ordinal	3.2.3 Knowledge of multiple cropping	Own formulation	
	3.3. Knowledge of unconventional crop production practices	Ordinal	3.3.1 Knowledge of changed planting dates	Own formulation	
	3.4. Access to climate/weather information	Ordinal	3.4.1 Access to daily weather data	Lo & Tumusiime (2013)	Access to climate data through different means of media and communication helps the farmers to make informed decisions before, during, or after a disaster.
		Ordinal	3.4.2 Access to f/c disaster warnings		
		Ordinal	3.4.3 Access to climate predictions from reliable sources (scientifically based)		
		Ordinal	3.4.4 Knowledge of applications/ websites developed for sharing climate/weather information		
4. Physical	4.1. Farmland details	Nominal	4.1.1 Land tenure system	Jones (2010)	The length and nature of land tenure systems influences the farmer's preparedness to overcome a disaster or implement adaptation measures.
		Continuous	4.1.2 Elevation of farmland	Own formulation	Farmers with fields at higher elevation are more resilient towards disaster impacts rather than fields at lower elevation.
	4.2. Field drainage infrastructure	Nominal	4.2.1 Field surface drains	Own formulation	

(*Continued.*)

	Nominal	4.2.2 Field sub-surface drains	Own formulation	Farmers with good drainage infrastructure can easily adapt to disaster impacts when compared with fields without any drainage facilities
4.3. Access to good roads	Nominal	4.3.1 Access of farm to the nearby main road	Egyir *et al.* (2015)	Good road network/electricity supply is directly proportional to infrastructural capacities of a farmer to adapt to disasters and overcome its impacts.
	Nominal	4.3.2 Paved farm roads	Jones (2010)	
	Nominal	4.3.3 Access from house to farm roads during f/c events		
	Nominal	4.3.4 Status of interrupted roads after f/c events		
4.4. Access to electricity for agricultural purposes	Nominal	4.4.1 Access		
	Nominal	4.4.2 Availability of uninterrupted electricity		
	Nominal	4.4.3 Status of interrupted supply after f/c events	Own formulation	

(Jayadas & Ambujam 2019). Each variable is to be scored a value between 1 and 5 with 1 being the lowest score and 5 being the highest score (Joerin *et al.* 2012, 2014). The principal component analysis (PCA) has been done for the variables under each dimension for each village separately for fixing the weights. Dimension-wise PCA is more feasible since the number of variables under each dimension is comparatively less than the overall number of variables in all the dimensions together. The weightage for the respondent score has been fixed based on the component loadings of the first principal component with Eigenvalue >1 and a higher percentage of variance (Filmer & Pritchett 2001; McKenzie 2005).

After fixing weights for each variable, the weightage assigned has been multiplied with the respondent score to calculate the Resilience Index. Equation 1 is used to calculate the dimension-wise Resilience Index.

$$\text{Dimension-wise Resilience Index}_i = \frac{\sum_{j=1}^{n} (\text{Weightage} * \text{Variable score})_j}{n} \tag{1}$$

where i is the dimension (four dimensions) and j is the number of variables under the corresponding dimension.

The dimension-wise Resilience Index includes the Economic Resilience Index, the Social Resilience Index, the Technical Resilience Index, and the Physical Resilience Index. The overall FRI has been calculated using Equation 2.

$$\text{Farmer Resilience Index} = \frac{\sum_{i=1}^{n} \frac{\text{Dimension–wise Resilience Index}_i}{\text{Maximum Resilience Index}_i}}{n} \tag{2}$$

where i is the dimension (four dimensions).

For further analysis, the farmers in both the communities have been classified into different groups such as marginal, small, semi-medium, medium, and large operational holders based on their landholdings, and the overall dimension-wise Resilience Index and the overall FRI were calculated for each category. The classification of farmers is based on the classification provided by the Ministry of Agriculture and Farmers Welfare, Government of India. The classification standards have been downloaded from the following link: https://data.gov.in/resources/criteria-classification-marginal-small-medium-and-large-operational-holders-farmers. Table 3 shows the classification of farmers based on landholdings.

After calculating the different Resilient Indices, the indices have been grouped into quantiles. The classification of farmer resilience based on the quantile is given in Table 4.

Table 3 | Classification of farmers based on landholdings

S. No.	Category of operational holders	Criteria
1	Marginal	Below 1.0 hectare (ha)
2	Small	1.0 ha and above but less than 2.0
3	Semi-medium	2.0 ha and above but less than 4.0 ha
4	Medium	4.0 ha and above but less than 10.0 ha
5	Large	10.0 ha and above

Source: Ministry of Agriculture and Farmers Welfare, Government of India.

Table 4 | Classification of farmer resilience based on FRI values

FRI	Farmer resilience
0–0.3	Low
0.31–0.65	Medium/Average
0.66–1.0	High

Source: Own formulation.

4. RESULTS

4.1. Qualitative analysis

Qualitative data obtained from the questionnaire have been classified into three major categories, namely demographic characteristics, socio-cultural characteristics, and farming data, for further analysis. The key characteristics of the villages obtained from the questionnaire are given in Table 5.

The farmers in village 1 have more marginal and small farmers when compared with village 2. Also, the number of medium farmers is lesser for village 1 than village 2, clearly highlighting the statistic that the larger landholders are located in village 2. All the large landholders in village 2 belong to the most backward community where the people are educationally and socially superior to the scheduled castes which constitute people mostly below the poverty line. Village 1 has 19 families belonging to the scheduled castes, with the rest belonging to backward or most backward communities. The overall income of farmers in both the villages ranges between 25,000 and 35,000 Rupees per annum, with village 1 having a slightly higher average income than village 2, which is due to additional income from other jobs taken up by farmers in village 1. Farmers take up jobs as daily wage labourers in nearby construction sites, Neyveli Lignite Corporation, and are also a part of the rural employment opportunities provided by the Central Government.

Paddy and groundnut are the most commonly grown crops by farmers in both villages. Village 2 which has farmers with larger landholding also grows summer vegetables like watermelons and cucumbers. The qualitative data have been used while interpreting the FRI results, appropriately.

4.2. Quantitative analysis

4.2.1. Village-wise resilience index

The Resilience Index has been calculated for the four dimensions namely economic, social, technical, and physical followed by the FRI for both villages 1 and 2 separately and also for both the villages together. Statistical correlation has been used to determine whether there are connections between the 18 parameters under the various dimensions. The Pearson Product-Moment Correlation Coefficient *r*-values between the parameters under the four dimensions are poorly correlated with each other, exhibiting *r*-values less than 0.5. Therefore, the dimension-wise Resilience Index calculation will give a better picture of the resilience in the village (Joerin *et al.* 2014).

The Resilience Index for the four dimensions is given in Table 6. The Social Resilience Index for village 1 is less when compared with village 2 which can be rationalized with the qualitative data described in Section 4.1. Twenty-seven percent of farmers in village 1 belong to low caste groups/communities, whereas village 2 has no families from low caste groups.

Table 5 | Key characteristics of farmers in village 1 and village 2

Key characteristics of farmers			Village 1 (*n* = 70) Values in %	Village 2 (*n* = 23)
Demographic	Household size	(Average number of people, not in %)	4.5	4.4
	Farmer age	(Average number of years, not in %)	53	51.7
	Size of farm	Marginal	78.6	43.5
		Small	14.3	34.8
		Semi-medium	5.7	8.7
		Medium	1.4	13.0
		Large	0	0
Socio-cultural	Community	Backward community (BC)	73	0
		Scheduled caste (SC)	27	0
		Most Backward community (BC)	0	100
	Caste	Vanniyar	71	96
		Nadar	0	4
		Naikkar	1	0
		Low caste (SC)	27	0
Farming data	Income/year	(Average value in Indian Rupees/family, not in %)	30,500.00	29,000.00
	Crops cultivated	Paddy	71.4	91.3
		Sugarcane	0	4.3
		Groundnut	80.0	52.2
		Cashew	11.4	17.4
		Casuarina	5.7	0
		Flowers	5.7	8.7
		Summer vegetables (watermelon, cucumber)	2.9	47.8
		Vegetables (eggplant, lady's finger, chilli)	0	8.7
		Sesame	1.4	17.4
		Cotton	0	17.4
		Teak	0	4.3

Table 6 | Dimension-wise resilience index

	Economic Resilience Index	Social Resilience Index	Technical Resilience Index	Physical Resilience Index	Farmer Resilience Index	*Mean*	*95% confidence interval*	*Variance*
Village 1	0.64	0.44	0.73	0.63	0.61	*0.61*	*(0.47889, 0.74111)*	*0.01115*
Village 2	0.54	0.54	0.62	0.48	0.54	*0.544*	*(0.48217, 0.60583)*	*0.00248*
Mean	*0.58*	*0.38*	*0.43*	*0.47*	*0.46*			
Standard deviation	*0.0765*	*0.0647*	*0.0734*	*0.1071*	*0.0481*			

This social structure observed in the study area is a limitation to the observations and findings of this empirical study. The lack of involvement of farmers from village 1 in Farmer-Based Organizations may also be one of the reasons for their poor social resilience. On the contrary, in village 2, farmers are members of an NGO-based farmer group which is headed by a farmer from the same village. Many of the farmers in village 1 have not attended any climate-related training programmes when compared with farmers in village 2, thus making the farmers in village 1 less socially resilient. Farmers in village 1 have lesser farming experience with an average rating of 3.3 when compared with village 2 which has a rating of 3.9, thus making village 1 farmers less socially resilient than village 2 farmers.

Other than the social index, all other index values are high for village 1 when compared with village 2. Village 1 which is close to the coast is more vulnerable to flood or cyclone disasters but has better economic, technical, and physical resilience when compared with the interior village. Additional income from other jobs has also led to the improved economic resilience of farmers in village 1. Technical resilience of farmers in village 1 has the highest value of 0.73, with indicators of knowledge of seed varieties and crop diversification having a mean rating of 3.5, while indicators such as access to daily weather data, access to flood/cyclone (f/c) disaster warnings, access to climate predictions from reliable sources (scientifically based), and knowledge of applications/websites developed for sharing climate/weather information have mean ratings of 2.46, 2.84, 2.33, and 2.21, respectively.

Overall, for both the villages together, except for the economic dimension, all other dimensions have Resilience Index values below 0.5. The Economic Resilience Index has a value of 0.58, thus revealing the fact that the farmers in both villages are financially better when compared with social, technical, and physical resources. Farmers in both villages especially in village 1 have alternate sources of income other than agriculture which they used to cope with impacts of a precipitation-related disaster, thus making them more economically resilient to disasters. The process of the questionnaire survey brought to attention that the farmers were not able to understand the terms and conditions of use of their data which might have affected their attitude towards their willingness to share data (Wiseman *et al.* 2019). Probably, this could have also been one of the reasons for lower Economic Resilience values. The total FRI considering all the four dimensions for village 1 and village 2 were 0.61 and 0.54 which is greater than 0.5, thus making the farmers more than averagely resilient towards precipitation extremes and their impacts.

4.2.2. Resilience Index based on the landholdings

The number of farming households in each village and overall, falling under the different categories of landholding classification is given in Table 7.

One sample Wilcoxon signed-rank test has been carried out for the FRI (sample) based on landholdings to test the null hypothesis whether the sample median is equal to a median value provided by the user at a 5% significance level. The median value was provided as 0.8 which indicates high farmer resilience. *P*-values are >0.050 indicating that the null hypothesis cannot be rejected. Hence, the FRI sample medians are not significantly different from the hypothesized median.

The FRI for marginal farmers is the lowest with a value of 0.47 and for medium farmers; it is the highest with a value of 0.83. There is an increase in FRI as the farmers' landholdings increase. Farmers with large landholdings are said to be rich farmers when compared with farmers with small landholdings. Indicators under the economic dimension have a higher positive correlation with landholdings when compared with other dimension indicators. Indicators such as net annual income, diversity of income, and household saving practice have Pearson Product-Moment Correlation Coefficient *r*-values of 0.46,

Table 7 | FRI based on land classification

	Number of households			
Classification	**Village 1**	**Village 2**	**Total (*n*)**	**FRI[a]**
Marginal farmers	55	10	65	0.47
Small farmers	10	8	18	0.56
Semi-medium farmers	4	2	6	0.76
Medium farmers	1	3	4	0.83
Large farmers	Nil	Nil	Nil	Nil

[a]One sample Wilcoxon signed-rank test output.
Hypothesized median: 0.8.
Sample median: 0.66.
P (exact): 0.125.
Medians are not significantly different.

0.44, and 0.47, respectively, which implies that large/medium farmers have a better economic status in the village thus their higher economic resilience comparatively. Large/medium farmers have mobile phones with internet facilities unlike their counterparts (small/marginal farmers), thus increasing their ability to deal with climate-related disasters. Other indicators that have a positive correlation with landholdings include access to electricity, farming experience, reduced income due to a flood/cyclone disaster, and availability of farm assets. Large/medium farmers have lands spread throughout the village, thus reducing their income loss due to a precipitation extreme disaster. The village has been categorized into highland and lowland by the farmers and most of the large/medium farmers have lands in highlands, where there is not much water stagnation during flood events, good drainage facilities for the field, and better access to electricity. Highlands also have good access to road facilities, thus making the farmers more physically resilient towards climate change. The highlands have been mostly occupied by the upper caste people among villagers who are mostly medium or semi-medium farmers.

From the spider diagram in Figure 4, it is also evident that farmers with lesser landholdings have lower dimension-wise resilience when compared with medium farmers. Semi-medium farmers have better physical resilience than medium farmers but lesser economic, social, and physical resilience than medium farmers which is because of averaging the index values among the different classification groups.

The listing of Physical Resilience Index values from high to low, for ten households are given in Table 8, also confirm that farmers with larger landholdings have better physical resilience. Thus, the qualitative results obtained during the questionnaire survey corroborate the quantitative analysis results.

5. CONCLUSION

The assessment of farmer resilience to climate extremes integrates the different aspects of how resilience is understood by farmers as a community. Apart from the qualitative descriptive of the resilience of the farmers in the community, the strengths and weaknesses within the community are clearly explained as a quantitative descriptive for ease of comparison between communities. The outcomes of the index reveal the current adaptive capacities of the farmers in the community which will help initiate location-specific community-led planning and implementation of actions to enhance community resilience. This is very important considering the present situation of Indian villages wherein the local governing authority has the power to control processes within a village or community (Joerin *et al.* 2012). The findings show that farmers from both communities have below-average physical resilience which implies that farming households take few actions to improve their resilience since most of the extensions services and support are provided by governmental authorities.

Overall, village 1 which is highly vulnerable to precipitation disasters has better resilience than village 2 and one of the reasons may be attributed to the reaction of farming households to disaster experience. The experience of cyclones and subsequent floods must have enhanced the preparedness of the people in village 1 based on a learning effect that would take place among people after they experience such an event (Joerin *et al.* 2012). Farmers with lesser exposure to climate extremes have fewer disaster experiences and take a longer time to improve their resilience. Their ability to absorb and overcome shocks from disasters is gradual but certain when they constantly equip themselves with knowledge about climate extremes and their adaptation measures. The farmers in the village away from the coast have involved themselves in a non-

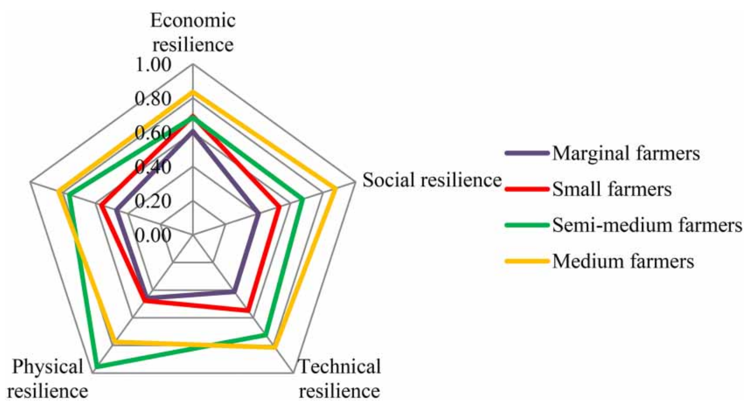

Figure 4 | Resilience Index of farmers based on their landholdings.

Table 8 | Maximum Physical Resilience Index for individual respondents

Farmer landholding (ha)	Classification of farmer	Physical Resilience Index
8	Medium	11.47
10	Medium	12.25
4.9	Medium	7.99
4.1	Medium	6.26
4	Semi-medium	7.14
4	Semi-medium	6.8
4	Semi-medium	7.06
4	Semi-medium	6.6
3.2	Semi-medium	7.06
2.8	Semi-medium	6.26

governmental-based farmer organization which has made them comparatively more aware of resilience improvement strategies attributing to their higher Social Resilience Index value than the village on the coast.

Both communities have several alternate sources of income other than agriculture and their economic condition is beneficial for them to cope with the impacts of a disturbance and also when stress or disaster is anticipated. Also, the findings bring out evidence that communities with the presence of households belonging to lower caste showcase low resilience, since lower caste farmers' fall below the poverty line and lack access to economic and physical resources. Lower caste farmers are also characterized by the location of farmlands at lower elevations when compared with other farmlands located at a higher elevation (Iversen *et al.* 2014), putting them at risk of income loss due to a disaster. Landholdings are also associated with the economic status of the farmers in a community. Large/medium farmers have mobile phones with internet facilities unlike their counterparts (small/marginal farmers), thus increasing their capacity to deal with climate-related disasters. They also have lands spread widely in the village, thus reducing their risk of income loss due to a disaster.

Agriculture itself is highly sensitive to any changes in climate, and hence, it is of utmost importance to improve the adaptive capacities of the farming communities of coastal blocks in the Lower Vellar River sub-basin, thereby reducing their vulnerability towards any extreme precipitation events in the future. Climate change is inevitable, so are extreme climatic events. The increasing trends of different rainfall extreme indices during the NE monsoon season which is the wet main crop growing season in Tamil Nadu and the early onset of the NE monsoon over the last few decades (Jayadas & Ambujam 2019) can be considered as a guiding tool for developing adaptation strategies.

Steps can be taken to improve and protect the livelihoods of the people, thereby increasing their resilience towards climate disasters. Adaptive capacity of the farming communities can be improved by increasing their literacy rate, by educating women and children, providing credits and insurances to farmers for protecting their livelihoods and for implementing modern methods to improve their resilience, and by developing Self-Help Groups managed by women for farmer extension services and credit borrowing. Access to good roads and electricity supply for farmlands can be improved in the coastal blocks by taking adequate steps to improve their adaptive capacities. Flood and drought-tolerant rice and other crop varieties can be propagated among the farmers and supplied to them at subsidized rates to sustain yield in the future. Organic farming can be coupled with the conventional method of rice and other crop cultivation, thus sustaining yields even during extreme climate events (Wani *et al.* 2013). Policymakers and the Government can work together along with the farmers to provide crop insurance, farm extension services, climate/weather information, and field drainage infrastructure for all farmers to increase their resilience by being able to cope with the impacts of precipitation extremes in the future.

To conclude, the FRI has revealed the efforts taken by the farmers to address problems related to a climate disaster at a community level. Further research on the problems identified is required to reinforce sound decisions to make communities more disaster-resilient in the future. The proposed index methodology can be used to assess farmer resilience associated with a precipitation disaster in most of the tropical farming communities with a proper understanding of the underlying patterns within the community along with the variables of interest. The index can easily be tailored to capture the responses of the stakeholders within a community to any type of climate disaster, thus making them more holistic and inclusive. The robust outcomes from the use of such tools to assess community resilience demonstrate the usefulness of the concept of resilience in order to overcome the impacts of a climate disaster.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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