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Assessing absorptive capacity of peri-urban agriculture in Kuttanad: A farming system based assessment

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Abstract
Rapid urbanization is one of the main reasons which worsened the effects of climate change, especially in the context of Kerala agriculture. It also led to the creation of peri-urban areas which is the transition zone between urban and rural areas. Hence, peri-urban agriculture is gaining importance in Kerala. Peri-urban agriculture is characterized by dynamic and synergistic interactions between urbanization and agricultural activities, making them pivotal for both food production and the related industries. However, one of the major concerns affecting the sustainability of peri-urban agriculture is climate change. One way to cope with the climate change is to build resilience among the communities. Identifying key areas that are most at risk is important in assessing the resilience of communities allowing for targeted interventions. With this objective, a study was conducted to assess the absorptive capacity of peri-urban agriculture in of Kerala. Data were collected through farmer interviews, focus group discussions, key informant interviews and discussion with extension personnel. Absorptive capacity was measured on the basis of five components, using 31 indicators. Sensitivity was the most significantly contributing factor to absorptive capacity of farming communities of *Kuttanad*. Absorptive capacity was found to be antagonistic with age of building and illness, while, food sufficiency, health check-up, better condition of roads, safety nets along with efficient interventions from local communities is pivotal in improving the absorptive capacity and thereby, climate resilience of farming communities. Sustained efforts and coordination between the local and scientific communities along with policy support is required for enhancing the climate resilience of *Kuttanad*.

Keywords: Climate resilience, Peri-urban agriculture, *Kuttanad*, Absorptive capacity, Exposure, Sensitivity, Stability, Safety nets

Introduction

Peri-urban agriculture is defined as the agriculture practices within and around cities which compete for resources (land, water, energy, labour) that could also serve other purposes to satisfy the requirements of the urban population (FAO, 2015) [4]. It involves communities, methods, policies, institutions, systems, ecologies and economies, largely mobilizing local resources to meet changing needs of local populations. It plays a vital role in ensuring food and nutritional security, as well as growth and sustenance of related industries of peri-urban areas. However due to expansion of villages and urbanization, peri-urban areas face the challenges of climate fluctuations. Climate change impact the agricultural sector in multitudinous manner. Erratic rainfall causes flood and drought situations which adversely affect crop yield. Extreme variation in temperature creates stress in crops and livestock, affecting their health, leading to deterioration in yield and quality. Climate change also results in outbreak of pests and diseases in peri-urban areas. Natural disasters and improper land management activities affect the soil fertility, making it unsuitable for cultivation. Since peri-urban areas play paramount role in agricultural production, one way to cope with the challenges of climate change is to build resilience in such areas.

Climate resilience is the capacity of systems to cope with a hazardous event, by responding in ways that maintain their essential function, identity and structure through adaptation, learning and transformation (FAO, 2015) [4]. The prime focus of improving climate resilience is to reduce the climate vulnerability among communities. Building climate resilience encompasses social, technological, economic, and political strategies (Folke, 2006) [6]. Resilience of a community is hugely depended on the measures that the community exercises during and after a disturbance has occurred so as to reduce the immediate impact on people's livelihoods and basic needs. Agriculture depends on the resilience of both social and ecological systems. In a social system, resilience varies among households, communities and regions, depending on the knowledge and resources farmers can mobilize and the services provided by government and other institutions.

On the other hand, the resilience of agriculture-related ecosystems depends largely on climate, land use, nutrient availability, and the size of the farming system. Hence, assessing absorptive capacity of communities is important to identify key areas that are most at risk and implement targeted interventions through capacity building within the communities.

Aims and Objectives

The study aims to assess the climate resilience of peri-urban agriculture in *Kuttanad* in terms of absorptive capacity, through development of Absorptive capacity Index (ABI). This approach is a triangulation which integrates information from multiple sources, including active participation of various stakeholders.

Materials and Methods

Description of the study area

Alappuzha was one of the three districts identified as climate change hotspots and vulnerable by Kerala State Action Plan for Climate Change (2014). Moreover, the district also showed high rate of urbanization (Economic Review, 2016). *Kuttanad* is a special agro-ecological unit in Kerala, spread over 61 panchayats and six municipal corporations of Alappuzha, Kottayam and Pathanamthitta districts. Large parts of these lands are below, at or just above sea level. Sea water inundation is controlled through bunds/barrages. The lowlands have soils formed in mixed alluvial and marine deposits. The poorly drained soils of the lowlands have copious amount of organic matter, are strongly acid in reaction and have clayey texture. One or two rice crops are taken in a year. Inland fisheries are another major activity. Even though *Kuttanad* is known as the 'rice granary of Kerala', due to rapid expansion of rural areas and urbanization, peri-urban areas of *Kuttanad* face the challenges of climate fluctuations. Flooding is one of the major constraints faced by the farming communities of *Kuttanad* every year. Climate induced sea level rise is also a serious issue. These hazards have led to coastal erosion, inundation, persistent storm events, and shifts in wetlands. Converse to the flood, for the past few years, *Kuttanad* is facing another grave danger- drought. Scarcity of rain and poor irrigation facilities have forced many farmers to abandon the crop half way through. According to Drought - Situation Assessment Report (2016), *Mavelikkara*, *Cherthala*, *Chengannur*, *Ambalappuzha* and *Karthikappalli* taluks had 'severe drought' vulnerability. Hence, the study area covered *Ambalappuzha, Aryad, Champakulam, Veliyanad* and *Thycattussery* blocks of *Kuttanad*.

Selection of sample

From peri- urban areas of each block, farmers affected by climatic hazards such as flood, drought, saline water intrusion were identified and listed in consultation with officials. From the prepared list, 30 farmers were selected at random. Thus, a total of 150 respondents were selected for the study.

Data collection

The required data were collected using structured interview schedule consisting of objective and descriptive questions. The interviews were conducted in local language. To bring about simplicity in questions and to improve understanding, the interview schedule was pilot tested among 50 non-sample respondents, who were not part of the survey and necessary changes were brought about. In addition, secondary data were collected from Krishi bhavans, Krishi Vigyan Kendras etc.

Description of the index

Absorptive capacity is operationally defined as the ability of a social system to absorb and cope with the impacts of climate variability and extremes using available skills and resources. Thus, it is a set of measures exercised during and after a disturbance has occurred to reduce the immediate impact on people's livelihoods and basic needs. The proposed ABI included five components: exposure, sensitivity, stability, safety nets, and demographic status and each component had relevant indicators. The dimensions and corresponding indicators were developed based on literature review and expert opinion. They were then pre-tested and checked within key informant interviews. The major components and the indicators are depicted in Table 1.

For calculating ABI, each component was calculated based on weighted average approach. The functional relationship of each of the 31 indicators under the five components to absorptive capacity was considered i.e., whether it increased or decreased the overall absorptive capacity. The indicators were measured on different scales, and therefore, each of the 31 indicators were transformed linearly to have an identical range [0,1] using min-max normalisation formula. Indicators that are expected to have a direct relationship with resilience were standardized using equation as:

$$I_a = \frac{S_r - S_{min}}{S_{max} - S_{min}}$$

Whereas indicators expected to have inversely related to resilience were standardized using

$$I_a = \frac{S_{max} - S_r}{S_{max} - S_{min}}$$

Where, I_a is the standardized value for the indicator *a*, S_r is the observed (average) value of the indicator, *min* and *max* are the minimum and maximum values of the indicator respectively. After standardisation, each of the six components/dimensions of absorptive capacity were calculated as the weighted sum of their respective indicators.

$$M_{Exposure} = \frac{W_{e1} + W_{e2} + W_{e3}}{3}$$

$$M_{Sensitivity} = \frac{W_{sens1} + W_{sens2} + W_{sens3} + W_{sens4} + W_{sens5}}{5}$$

$$M_{Stability} = \frac{W_{st1} + W_{st2} + W_{st3} + W_{st4} + W_{st5} + W_{st6} + W_{st7} + W_{st8} + W_{st9} + W_{st10} + W_{st11} + W_{st12} + W_{st13}}{13}$$

$$M_{Safety\ nets} = \frac{W_{sn1} + W_{sn2} + W_{sn3} + W_{sn4} + W_{sn5} + W_{sn6} + W_{sn7}}{7}$$

$$M_{Demographic\ status} = \frac{W_{d1} + W_{d2} + W_{d3}}{3}$$

where, W_{e1}, W_{e2} and W_{e3} are the averages of each indicator under dimension exposure; W_{sens1}, W_{sens2}, W_{sens3}, W_{sens4} *and* W_{sens5} are the averages of each indicator under dimension sensitivity; W_{st1}, W_{st2}, W_{st3}, W_{st4}, W_{st5}, W_{st6}, W_{st7}, W_{st8}, W_{st9}, W_{st10},W_{st11}, W_{st12} and W_{st13} are the averages of each indicator under dimension stability; W_{sn1}, W_{sn2}, W_{sn3}, W_{sn4}, W_{sn5}, W_{sn6} and W_{sn7} are the averages of each indicator under dimension safety nets; and W_{d1}, W_{d2} and W_{d3} are the averages of each indicator under dimension demographic status.

For calculating the ABI, each major component/ dimension contributed equally to the index:

$$ABI = \frac{M_{Exposure} + M_{Sensitivity} + M_{Stability} + M_{Safety\ nets} + M_{Demographic\ status}}{5}$$

Based on formulated index, the absorptive capacity of *Kuttanad* was assessed. The final index value varies between 0 and 1, where a higher value closer to 1 indicated absorptive capacity.

Results and Discussion

The ABI for *Kuttanad* (AEU-4) was 0.509 which indicated low to moderate absorptive capacity and resilience. The absorptive capacity contributed by sensitivity (0.729), demographic status (0.583), exposure (0.499), stability (0.475), and safety nets (0.388) plotted in Fig. 1 clearly illustrate the dimensional/ component contribution. Sensitivity contributed the highest to the overall absorptive capacity index while safety nets held the least value.

Table 1: Major components, indicators and hypothesised relationships.

Components	Indicators	Explanation	Source	Relation
Exposure	Occurrence of climatic hazards	Frequency of occurrence of climatic hazards (flood, drought, landslide, snowfall, strong winds, sea water intrusion) for the past ten years.	Asmamaw *et al.*, 2019 [1]	-ve
	Duration of hazards	% farm households who reported the duration of climatic hazards less than a week.	Balakrishnan, 2022 [2]	-ve
	Crop loss	% farmers who reported less yield loss (<50%) due to climatic hazards	New	-ve
Sensitivity	Age of building	% farm households who reside in houses less than 20 years of age	Fatemi *et al.*, 2020 [5]	-ve
	Water sufficiency	% farm households who reported no or very short period of water shortage.	Asmamaw *et al.*, 2019 [1]	+ve
	Food sufficiency	% households who reported very short period of food shortage during and after a disaster.	Asmamaw *et al.*, 2019 [1]	+ve
	Health check-up	% farmers who get regular health check up	New	+ve
	Illness	% respondents who or whose family members are suffering from chronic illness	Asmamaw *et al.*, 2019 [1]	-ve
Stability	Type of ownership of land	% farmers who own their farmland	New	+ve
	Disaster protection measures	% farmers who have adopted disaster protection measures in their farms and household premises.	Sengupta *et al.*, 2015 [18]	+ve
	Early warning systems	% respondents who get timely early warnings regarding climatic hazards.	Asmamaw *et al.*, 2019 [1]	+ve
	Relief camps	% farm households who reported relief camps within 5km premises.	Balakrishnan, 2022 [2]	+ve
	Condition of roads	% farm households who opined that the main roads in their locality are good conditioned.	New	+ve
	Repair of roads	% farmers who opined as damaged roads and bridges in their locality are repaired in less than 3 months	Balakrishnan, 2022 [2]	+ve
	Institutional support	% farm households who opined that they received support from govt, NGOs and other institutions during the crisis	Asmamaw *et al.*, 2019 [1]	+ve
	Social cohesion	% farmers who are socially cohesive.	Smith *et al*, 2012 [19]	+ve
	Soil fertility	% farm households who opined their soil in their farmland as fertile	Asmamaw *et al.*, 2019 [1]	+ve
	Recovery time	Time (days) needed by the households to recover to a functional operation after climatic hazard	Balica *et al*, 2012 [3]	-ve
	Risk orientation	% farmers who are oriented towards encountering risks and uncertainties	Patel and Chauhan, 2009 [15]	+ve
	Environmental concern	% farmers who have concern towards the environment.	Nath, 2018 [14]	+ve
	Self confidence	% farmers who have confidence to bear and recover from the difficult situations.	TANGO International, 2018 [20]	+ve
Safety nets	Crop diversity	% of households who grow at least one additional crop to reduce risk	Madhuri *et al.*, 2014	+ve
	Migration after the disaster hits	% farm households who migrated after the disaster hit	Sathyan *et al*, 2018	-ve/ +ve
	Insurance	% farmers who avail any kind insurance for crops, life and health	TANGO International, 2018 [20]	+ve
	Credit	% farmers who have no loan/ credit to be repaid.	New	-ve
	Savings	% farmers who maintain any kind of savings in form of cash, gold and the like.	TANGO International, 2018 [20]	+ve
	Compensation from government	% farmers who had received compensation from government on account of any disaster/ crop loss.	Narayan and Patnaik, 2009 [13]	+ve
	Allowances	% farmers who avail any allowances/grant from any agency	New	+ve

Demographic status	Gender of the household	% households where men are the head of the household purposively	Asmamaw *et al.*, 2019 [1]	+ve
	Dependency ratio	% farm households with lower dependency ratio	Asmamaw *et al.*, 2019 [1]	-ve
	Poverty status	% farm households who are above poverty level	New	+ve

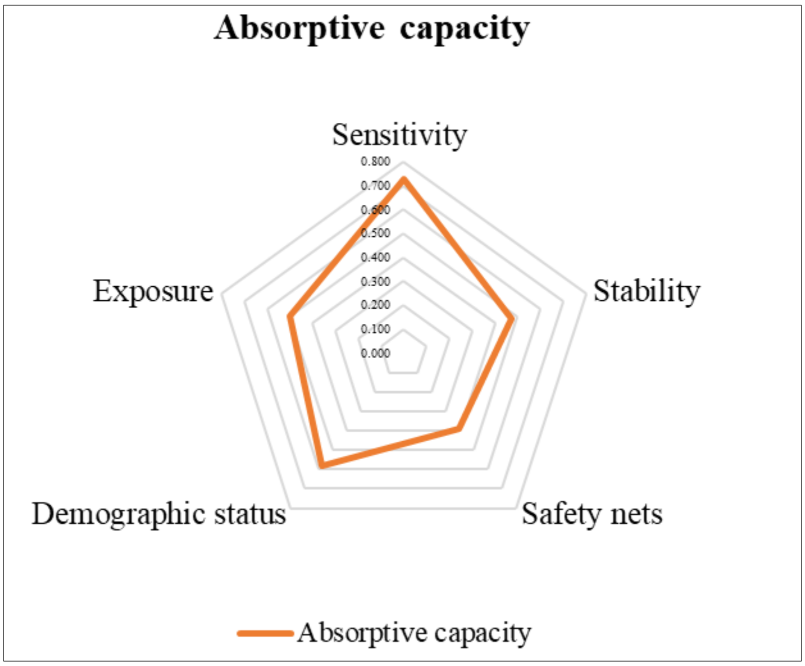

Fig 1: Distribution of the dimensions of Absorptive Capacity Index (ABI)

Due to efficient public distribution system and active disaster response activities, food sufficiency (1.000) was one of the major contributors to resilience of the farm households. Age of building and illness score were antagonistic to resilience. Almost half of the houses (49.8%) were above 20 years of age. More the age of the house, more ISS the chance of getting collapsed or damaged due to flood or landslide. However, apart from age of building, other factors such as location and the local climate conditions all interact to impact a building's ability to withstand climate-related challenges. Though a very important factor, health management in *Kuttanad*, especially during and after the recession of a disaster was found to be very poor. Incidence of contagious and infectious diseases such as *leptospirosis* was very common in *Kuttanad* in the post-flood situation. Only 6.67 percent of the farm households did regular health check-up. This throws light on the need for efficient interventions to strengthen the health sector. Though *Kuttanad* is enriched with so many lakes and rivers, quality drinking water was still a great concern for most of the households. Due to the intrusion of saline water into freshwater aquifers, households relied on water purifiers or canned water for daily use.

In the case of demographic status, the gender of the household had a significant role towards the ability of households to endure the risks associated with the climatic hazards. Ninety percent of the households were male-headed. It was found that male-headed households were comparatively much able to bear the ill-effects of disasters and take measures to recover from such effects in short time. In contrary, female-headed households found it difficult to cope with the disasters and bounce back as they had the double burden of looking after the family as well as earning for survival. Poverty status also influenced the absorptive capacity and resilience of communities. Those households who were above the poverty line (26.67%) were able to recover from the adverse effects of disasters due to better economic status. Important, yet antagonistic to absorptive capacity of the farming communities, was the dependency ratio. Only about 27 percent of the households had lower dependency ratio (>0.50). More the number of children and elderly population in a household, greater were their vulnerability to diseases and difficulty to migrate to safer places.

Under the dimension of exposure, there were three indicators and among these, duration of hazards held the highest value, because 63.33 percent of the farm households opined that the climatic disasters such as flood, drought etc prolonged less than a week. Only 13.33 percent of farmers responded that climatic hazards occurred only once a year. The major climatic hazards in lowlands of *Kuttanad* included, floods, saline water intrusion, heavy winds and drought. Even though flooding was a concern since ages for *Kuttanad*, drought had also become a grave issue in recent times, especially during the critical stages of crop growth. The rivers are getting dried up and a dip in the ground water level is also observed. A drought after the devastating flood is almost like a double catastrophe for the local community, which is fighting to mobilise resources to recover from the havoc. More the frequency and duration of disasters, lesser was the ability of the system to endure the impacts of the climatic extremes. Crop loss due to these climatic disasters was more than 50 percent. Only 30 percent of the farm households suffered crop loss less than 50 percent. Lesser crop loss reduced the burden on the farming communities in the post-disaster phase.

Stability of farming communities were determined by type of ownership of land, disaster protection measures taken by them, early warning systems, relief camp facilities, condition and repair of roads, social cohesion, institutional support, soil fertility, recovery time, risk orientation, environmental concern and self-confidence. Timely setting up relief camps was effective in rehabilitating people to safer place. Relief camps were safe places for the people as well as their assets, and such camps also provided them with clean drinking water and food which was otherwise would have been a major concern for people during the phase of a hazard. Good conditioned roads always aid in safe transport of people, goods, livestock, and agricultural products to safer destinations. About 73 percent farmers opined that they had access to good conditioned roads. However, timely repair of roads was a major concern. In the post-flood situations especially, ill-conditioned roads and bridges were not bring timely repaired which was a concern for considerate proportion of the households (40%). Those farmers who owned their farm land (63.33%) were able to bear the after effects and recover from hazards. Farmers who did not own or took land on lease had the burden of paying the lease and also covering the crop loss occurred. Early warning systems augments the absorptive capacity of the farming communities by providing timely early warnings about the likely occurrence of climatic hazards and help the households to take pro-active as well as reactive measures to tackle the crises. Well-functioning early warning systems through radio, tv, newspapers, sirens and announcements by the panchayats, and social media enhanced farmers' preparedness for climate-related disasters like floods and landslides. Only 26.67 percent of the farmers opined that they took less than one month to recover from the shocks. Only 53.33 percent of the farm households took disaster protection measures such as increasing the plinth height, installing barriers before doorways to stop entry of flood water, elevated shelves inside homes to keep utensils, construction of makeshift high platforms at home and placing of sandbags around the house at the onset of monsoons. Social cohesion played a significant role in enhancing the absorptive capacity of farmers of *Kuttanad* by encouraging collaboration and collective action among the farming communities. Institutional support, though very weak in enhancing bearing capacity, also contributed farmers' ability to absorb and recover from climatic hazards. Since, major share of the lands in *Kuttanad* is *kari* soils, forcing the households to rely mostly on monocropping. One of the most critical, yet obvious determinants of resilience of farmers are psychological factors such as risk orientation, environmental concern and self-confidence. Willingness of the farmers to take risks, their risk perception, and their approaches to risk management influenced their potential to endure uncertainties and climate risks. A highly risk-oriented farmer was aware of potential risks in his farming activities (Sarkar and Padaria, 2010) [16]. Farmers with higher environmental concern were more likely to adopt sustainable farming practices, erosion control measures, water conservation and efficient water management practices. Farmers with higher self-confidence were willing to make decisions and take risks under changing circumstances. Confident decision-making contributed to a farmer's ability to adapt to and respond effectively to challenges.

Safety nets that buffer the risks related to unprecedented climatic hazards included crop diversity, migration after the disaster hits, insurance, credit, savings, compensation from government and allowances. Diversifying crops cultivated helped farmers mitigate the impacts of climate variability. Even if one crop is affected by sudden unfavourable conditions or climatic hazards of any kind, other crops with different growth requirements may still survive, narrowing the overall risk of crop failure. Sixty percent of the households in *Kuttanad* cultivated vegetables and coconut, along with paddy. Majority of the households (86.67%) migrate to safer places after the incidence of a disaster, rather than moving pro-actively.

Credit, saving propensity, and insurance played paramount roles in contributing to the absorptive capacity and climate resilience of farmers. Credit is a double-edged sword for farmers. Credit aid in meeting any kind of unexpected circumstances, but at the same time, if not repaid timely, became a burden for the households. Half of the respondents had outstanding loan to be repaid, which diverts a considerate proportion of their earnings to repaying such debts. Savings can be used to cope with unexpected shocks such as crop failure, sudden health expenses, or market fluctuations. Sixty percent of the farmers, maintained savings in the form of cash, gold, post office or bank deposits. Majority of the farmers (93.33%) availed insurance in the form of crop and livestock insurance. Insurance transfers the financial burden of certain risks, like crop failure or livestock loss, to an insurance provider, reducing the direct impact of shocks on the farmer (Mohapatra *et al.*, 2012) [12]. Life insurance and health insurance also impart ability to the households to meet any kind of emergencies. However, the proportion of the households who got compensation or any kind of allowances was very less.

Table 2: Shows the normalised value of indicators, average value of components and absorptive capacity index.

Components	Indicators	Normalised value	Value	Average value of components	ABI
Exposure	Occurrence of climatic hazards	-0.413	-	0.499	0.509
	Duration of hazards	-0.783	63.33%		
	Crop loss	0.300	30.00%		
Sensitivity	Age of building	-0.850	49.8%	0.729	
	Water sufficiency	0.567	56.67%		
	Food sufficiency	1.000	100.00%		
	Health check-up	0.367	6.67%		
	Illness	-0.863	83.33%		
Stability	Type of ownership of land	0.650	63.33%	0.475	
	Disaster protection measures	0.278	53.33%		
	Early warning systems	0.500	30.00%		
	Relief camps	1.000	100.00%		
	Condition of roads	0.733	73.33%		
	Repair of roads	0.400	60.00%		
	Institutional support	0.267	100.00%		
	Social cohesion	0.650	86.67%		
	Soil fertility	0.167	16.67%		
	Recovery time	0.400	26.67%		
	Risk orientation	0.105	36.67%		

	Environmental concern	0.693	100.00%		
	Self confidence	0.338	10.00%		
Safety nets	Crop diversity	0.600	60.00%	0.388	
	Migration after the disaster hits	0.133	86.67%		
	Insurance	0.350	93.33%		
	Credit	0.500	50.00%		
	Savings	0.600	60.00%		
	Compensation from government	0.233	23.33%		
	Allowances	0.300	30.00%		
Demographic status	Gender of the household	0.900	90.00%	0.583	
	Dependency ratio	-0.306	26.67%		
	Poverty status	0.544	26.67%		

Conclusion
Climate resilience of a system relies on its ability to absorb, and recover from the adverse effects of climatic hazards. Exposure to climatic hazards, sensitivity, stability, safety nets, and demographic status are interconnected factors that collectively shape a farmer's absorptive capacity in the face of climate change challenges. Building resilience and enhancing absorptive capacity require a holistic approach that considers these factors and tailored interventions to specific contexts and communities. By understanding the intricacies of peri-urban agricultural systems and adopting climate-resilient practices, we can foster a sustainable and productive agricultural sector capable of withstanding the impacts of a changing climate and ensuring food security for urban and rural populations alike.

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