



# Climate-Induced Livelihood Vulnerabilities and Adaptation in Contrasting Watersheds of Tamil Nadu, India

L. Muralikrishnan<sup>1\*</sup>; R. N. Padaria<sup>2</sup>; L. Ranjith<sup>3</sup>; Reshma Gills<sup>4</sup>

<sup>1,3,4</sup>Senior Scientist, ICAR-NAARM, Hyderabad

<sup>2</sup>Joint Director, ICAR-IARI, New Delhi

\*Corresponding Author

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**Abstract**— Climate change and land-use alterations are intensifying vulnerabilities in critical river basins, particularly within semi-arid agro-ecologies. This study assesses agro-ecology-specific climate risks, environmental degradation, and adaptation practices in the farming households of two contrasting watershed systems in Tamil Nadu: the Upper Vaigai (rainfed, drought-prone) and the Lower Palar (coastal, flood-prone). Primary data were collected from 200 farm households using a structured survey. The study found that the Upper Vaigai watershed is severely impacted by drought, leading to groundwater depletion, soil moisture deficits, and ecosystem degradation. In contrast, the Lower Palar watershed experiences intensive rainfall, cyclones, and floods, resulting in socioeconomic stresses such as migration and drinking water scarcity. While institutional mechanisms like MGNREGA, crop insurance, and extension services provided some adaptive support, implementation gaps persist. The findings underscore the need for location-specific strategies: enhancing soil and water conservation in Upper Vaigai and strengthening flood resilience and traditional water system management in Lower Palar. Integrating participatory GIS and ICT tools is recommended for building adaptive capacity across these climate-sensitive agro-ecologies.

**Keywords**— Climate vulnerability; watershed management; agro-ecology; adaptation strategies; Tamil Nadu.

## I. INTRODUCTION

Tamil Nadu, situated in the rain shadow region of the South-West Monsoon, depends heavily on the North-East Monsoon for its rainfall [1]. The region's topography fosters west-to-east flowing watersheds, which are increasingly stressed by changes in land-use patterns and climate variability [2, 3]. These changes manifest differently across agro-ecological zones, affecting the 'carrying capacity' of ecosystems and demanding 'environmental justice' in resource management [4].

This study focuses on two critical and contrasting watersheds: the Upper Vaigai and the Lower Palar. The Upper Vaigai watershed, a tropical wet to semi-arid transition zone, is crucial for originating the Vaigai River. Despite pockets of high rainfall (1500-2500 mm/year), most of this watershed receives only 500-1000 mm annually [5]. Environmental degradation in this upper catchment therefore threatens the entire river basin. Conversely, the Lower Palar watershed lies in a semi-arid to coastal zone. While its upper reaches are dry, its lower part receives higher rainfall (1000-1500 mm/year) and historically relied on tank-based water systems [6].

Climate vulnerabilities have intensified in both watersheds, but their manifestations differ, affecting agricultural livelihoods in distinct ways. Previous studies have often examined watersheds in isolation. A comparative analysis of contrasting agro-

ecologies is essential to develop nuanced, location-specific adaptation policies. Therefore, this study aims to: (1) assess and compare agro-ecology-specific climate risks and environmental vulnerabilities at the farm household level, and (2) identify and evaluate prevalent and potential climate-resilient adaptation practices in the Upper Vaigai and Lower Palar watersheds.

## II. METHODOLOGY

### 2.1 Study Area:

The study was conducted in two districts of Tamil Nadu: Theni District (representing the Upper Vaigai watershed) and Kancheepuram District (representing the Lower Palar watershed). These sites were purposively selected for their contrasting agro-climatic profiles and documented climate vulnerabilities.

### 2.2 Research Design and Sampling:

An ex-post facto research design was employed. A multi-stage sampling technique was used. First, the two districts were purposively selected. Second, one Community Development Block (CDB) with severe climate vulnerabilities was chosen from each district. Third, two villages were randomly selected from each CDB. Finally, from each village, 50 farmer households were randomly selected, yielding a total sample size of 200 (100 from each watershed).

### 2.3 Data Collection and Analysis:

Primary data were collected through face-to-face interviews using a pre-tested, structured schedule. The questionnaire captured data on:

- Socio-economic characteristics.
- Perceived climate risks and impacts (using a Likert-scale for severity).
- Observed agro-ecological changes.
- Adaptation practices and institutional support accessed.

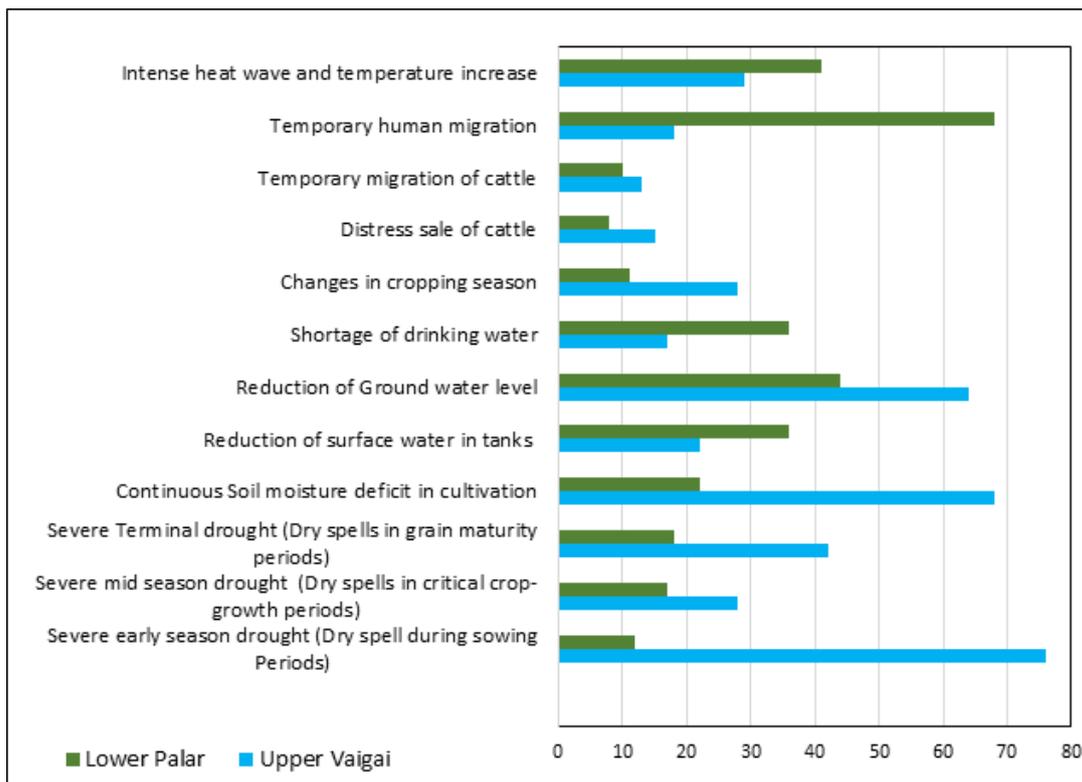
Data were analyzed using descriptive statistics (frequencies, percentages) to profile vulnerabilities and practices. Inferential statistics (Chi-square tests) were used to compare significant differences between the two watershed groups for key categorical variables.

## III. RESULTS AND DISCUSSION

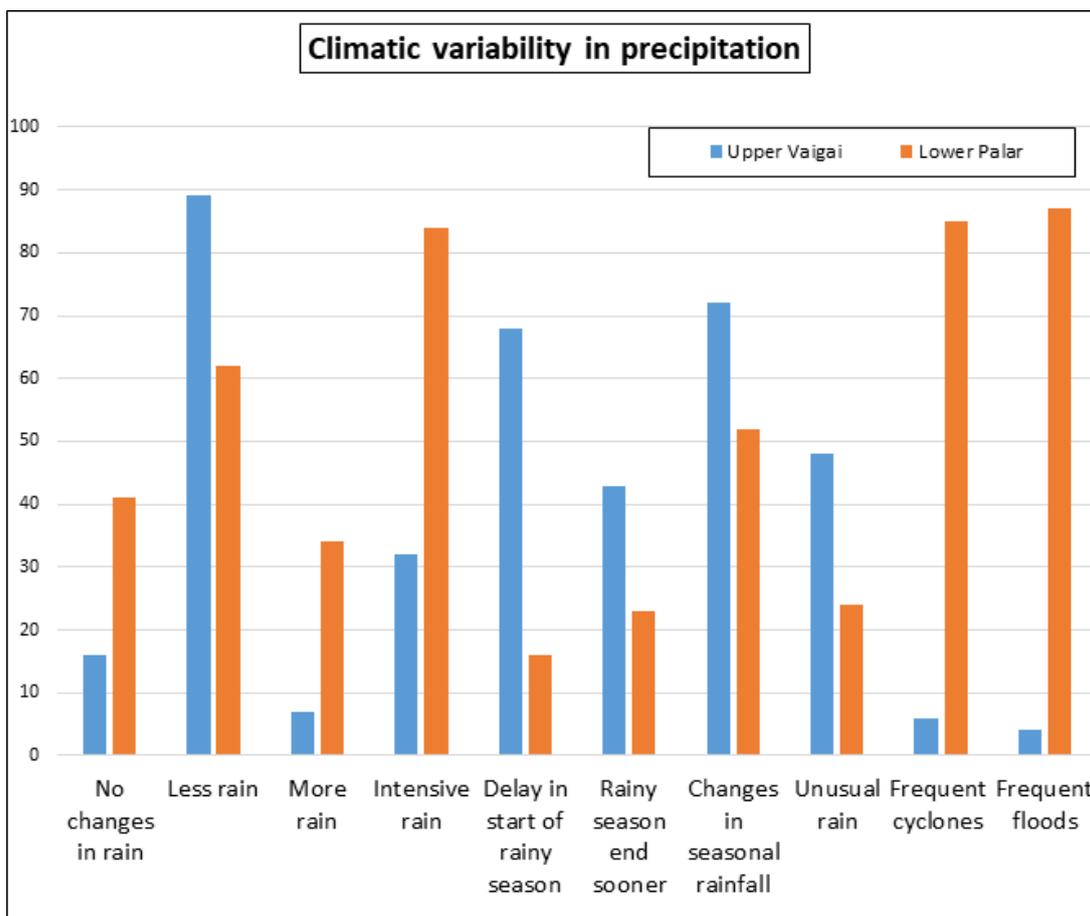
### 3.1 Characterizing Differential Climate Risks:

The climate risks perceived by farmers differed markedly between the two watersheds, underscoring their distinct agro-ecological contexts.

- **Drought-Related Vulnerabilities:** As presented in Figure 1, the Upper Vaigai watershed was more severely affected by drought parameters. Severe early-season drought (78% of respondents) and continuous soil moisture deficit (72%) were critical concerns. Consequently, groundwater level reduction was a high-impact issue for 65% of farmers. In contrast, while drought was present in Lower Palar, its socioeconomic impacts were more pronounced, with temporary human migration reported by 70% of farmers due to urban employment opportunities.
- **Rainfall and Extreme Event Vulnerabilities:** The pattern reversed for rainfall-related extremes (Figure 2). The Lower Palar watershed was highly vulnerable to frequent floods (88%), cyclones (85%), and intensive rainfall (84%). The Upper Vaigai watershed was predominantly affected by rainfall deficits, with less rainfall (89%) and delayed monsoon onset (68%) cited as major stresses.



**FIGURE 1: Severity of drought-related climate impacts in the study watersheds.**



**FIGURE 2: Severity of rainfall-related climate variability and extremes in the study watersheds.**

These results confirm that vulnerability is not monolithic but shaped by local geography. The Upper Vaigai, a rainfed upland system, is a drought-vulnerable hotspot, aligning with concerns about land-use change reducing infiltration [7]. The Lower Palar, a coastal lowland, is an extreme-weather hotspot, where urbanization compromises natural drainage [8].

### 3.2 Agro-Ecological Changes and Adaptive Practices:

Survey results on agro-ecological indicators revealed both common challenges and divergent trends (Table 1)

**TABLE 1**  
**COMPARATIVE PROFILE OF AGRO-ECOLOGICAL INDICATORS IN THE STUDY WATERSHEDS (N=200).**

S. No.	Agro-ecological Indicator	Upper Vaigai (% of HHs)	Lower Palar (% of HHs)
1	Increased climate-related problems	85	80
2	Changes in cropping pattern	70	75
3	Pests and diseases issues	30	40
4	Reduction in productivity	55	35
5	Degradation of grasslands	25	70
6	Reduced millets cultivation	75	65
7	Adoption of integrated farming	10	20
8	Area under agroforestry	8	10
9	Promotion of animal husbandry	12	15
10	Crop rotation practices	15	18

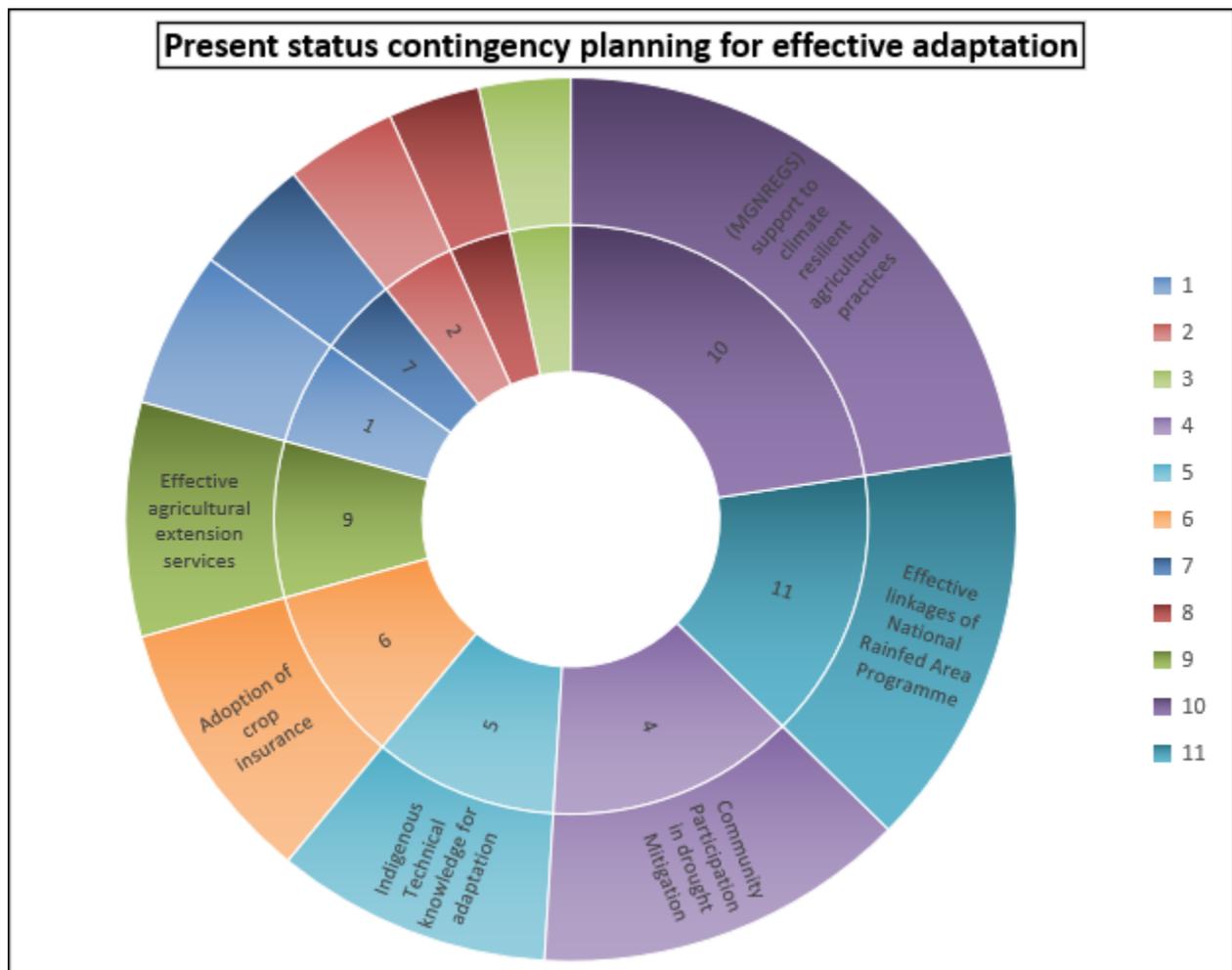
A high proportion of households in both watersheds reported increased climate problems and had altered cropping patterns. However, key differences emerged: **reduction in productivity** was a more acute concern in Upper Vaigai (55% vs. 35%), likely linked to severe moisture stress. Conversely, **degradation of grasslands** was far more widespread in Lower Palar (70% vs. 25%), possibly linked to flooding and salinity. The adoption of sustainable practices like integrated farming, agroforestry, and crop rotation remained low (<20%) in both regions, indicating a significant adaptation gap.

### 3.3 Institutional Support and Proposed Adaptation Framework:

Institutional mechanisms played a positive but incomplete role in adaptation. Programs like MGNREGA (for water conservation works), the National Rainfed Area Programme, crop insurance, and agricultural extension services were identified as crucial for livelihood security. However, their reach and farm-level implementation were reported as inconsistent.

Based on the findings, a two-pronged, location-specific adaptation approach is proposed (Figure 3):

- **For the Upper Vaigai Watershed:** The priority is enhancing **soil and water conservation (SWC)** and groundwater recharge. This requires strengthening MGNREGA-linked SWC works, promoting in-situ moisture conservation (e.g., mulching, contour bunding), and revitalizing community-based water management.
- **For the Lower Palar Watershed:** The focus must shift to **flood resilience and saline intrusion management**. This involves rehabilitating the traditional tank and lake system for drainage and storage, promoting saline-tolerant crop varieties, and developing climate-resilient coastal agroforestry models.



**FIGURE 3: Conceptual framework for location-specific climate adaptation in contrasting watersheds.**

Cross-cutting both regions is the need to **build social capital** through farmer collectives and to leverage **digital tools** (Participatory GIS, ICT-based advisories) for better natural resource management and dissemination of climate-smart practices.

#### IV. CONCLUSION

This comparative study reveals that climate vulnerabilities in Tamil Nadu's critical watersheds are profoundly shaped by local agro-ecology. The **Upper Vaigai watershed is a drought-vulnerable system** where agricultural stress and groundwater depletion are paramount. The **Lower Palar watershed is an extreme-weather vulnerable system** facing floods, ecological degradation, and associated socioeconomic disruptions.

A uniform climate adaptation policy is therefore inadequate. Resilience building must be location-specific:

- **Policy in Upper Vaigai** must prioritize investments in watershed-scale soil and water conservation and community-managed groundwater recharge.
- **Policy in Lower Palar** should focus on modernizing traditional water infrastructure for flood control, rehabilitating degraded lands, and promoting diversified, saline-resilient farming systems.
- **Across both regions**, there is a critical need to bridge the gap between institutional schemes and farm-level adoption by strengthening agricultural extension, fostering farmer institutions, and integrating geospatial and ICT technologies for targeted advisory services.

By adopting such a differentiated approach, stakeholders can enhance the adaptive capacity of farming communities, ensuring the ecological and socio-economic sustainability of these vital watersheds

### CONFLICT OF INTEREST

The authors declare no conflict of interest.

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