

**ASSESSING SOCIO-ECONOMIC VULNERABILITY OF
FARM HOUSEHOLDS TO CLIMATE CHANGE AND ITS
COPING MECHANISM IN MAHARASHTRA**



**THESIS SUBMITTED TO THE
ICAR-NATIONAL DAIRY RESEARCH INSTITUTE,
KARNAL (DEEMED UNIVERSITY)
IN PARTIAL FULFILLMENT OF THE
REQUIREMENT FOR THE AWARD OF THE
DEGREE OF**

**MASTER OF SCIENCE
IN
AGRICULTURAL ECONOMICS**

BY

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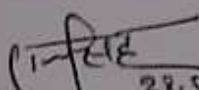
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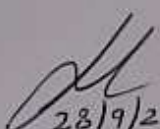
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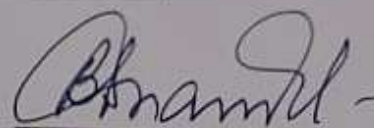
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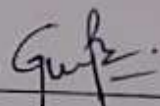

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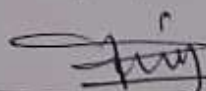
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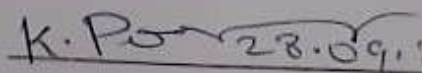
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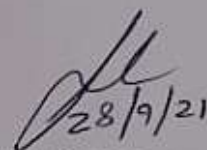
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This is to certify that the thesis entitled, “**ASSESSING SOCIO-ECONOMIC VULNERABILITY OF FARM HOUSEHOLDS TO CLIMATE CHANGE AND ITS COPING MECHANISM IN MAHARASHTRA**” submitted by **Mr. ADHAV CHAITANYA ASHOK** towards the partial fulfilment of the award of the degree of **MASTER OF SCIENCE in AGRICULTURAL ECONOMICS** of the **ICAR- NATIONAL DAIRY RESEARCH INSTITUTE (DEEMED UNIVERSITY)**, Karnal, Haryana, India, is a bonafide research work carried out by him under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

Date: 28/09/2021



28/9/21

**(SENDHIL R)
MAJOR ADVISOR & CHAIRMAN**

*Dedicated to
My family, Dr. Sendhil R.,
Prof.H.J. Wagh and the farming
spirit of India.*



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CONTENTS

Chapter No.	Title	Page No.
1	INTRODUCTION	1-6
2	REVIEW OF LITERATURE	7-15
	2.1 The degree of regional socio-economic vulnerability assessment	7
	2.2 The extent of vulnerability in farm households	10
	2.3 The extent of adoption and determinants of coping strategies practiced across vulnerable regions	12
	2.3.1 The extent of adoption (intensity of adoption)	12
	2.3.2 Determinants of management strategies	14
3	RESEARCH METHODOLOGY	16-35
	3.1 The degree of regional socio-economic vulnerability assessment	16
	3.1.1 Study area	16
	3.1.2 Data sources	17
	3.1.3 Vulnerability estimation	17
	3.1.4 Steps in vulnerability assessment	18
	3.1.4.1 Identification of suitable indicators	18
	3.1.4.1.1 Indicators on exposure and functional relationship	18
	3.1.4.1.2 Indicators on sensitivity and functional relationship	20
	3.1.4.1.3 Indicators adaptive capacity and functional Relationship	22
	3.1.4.2 Normalization	23
	3.1.4.3 Assignment of weights to indicators	23
	3.1.4.4. Socio-economic vulnerability index	24
	3.1.4.5 Categorization of districts	24
	3.1.4.6 Socio-economic vulnerability mapping of districts	25
	3.2 The extent of vulnerability in farm households	25
	3.2.1 Study area	25
	3.2.2 Data sources	25
	3.2.3 Steps in farm household vulnerability assessment	28
	3.2.3.1 Identification of farm level socio-economic vulnerability indicators	28
	3.2.3.1.1 Exposure indicators and their functional relationship	28
	3.2.3.1.2 Sensitivity indicators and their functional relationship	29
	3.2.3.1.3 Adaptive capacity indicators and their functional Relationship	31

	3.2.4	Regression tree analysis of district level and farm household level SeVI	32
	3.3	The level of adoption and determinants of coping strategies practiced across vulnerable regions to climate change	32
	3.3.1	Data sources	32
	3.3.2	Extent of adoption or intensity of adoption	33
	3.3.3	Determinants of coping strategies to climate change	34
4	RESULTS AND DISCUSSION		36-94
	4.1	The degree of regional socio-economic vulnerability	36
	4.1.1	Exposure	36
	4.1.2	Sensitivity	42
	4.1.3	Adaptive capacity	43
	4.1.4	Inter-index comparison of exposure, sensitivity and adaptive capacity values	43
	4.1.5	Socio-economic vulnerability index (SeVI)	44
	4.1.6	Mapping of districts	45
	4.1.7	Regression tree analysis of district-level socio-economic vulnerability index	48
	4.2	The extent of vulnerability in farm households	50
	4.2.1	Exposure	50
	4.2.2	Sensitivity	54
	4.2.3	Adaptive capacity	57
	4.2.4	Inter-index comparison of exposure, sensitivity and adaptive capacity	59
	4.2.5	Socio-economic vulnerability index for households in Maharashtra	60
	4.2.6	Regression tree analysis of farm household-level socio-economic vulnerability index	61
	4.3	Adoption and determinants of coping strategies practiced across vulnerable regions	63
	4.3.1	The extent of adoption of coping strategies	63
	4.3.1.1	Identification of coping strategies in crop farming, livestock farming and other component for different vulnerable districts	63
	4.3.1.2	Coping strategies identified in crop farming	63
	4.3.1.3	Coping strategies identified in livestock farming	67
	4.3.1.4	Coping strategies identified in other added component in farming	71
	4.3.1.5	Adoptions of coping strategies to climate change by households in different districts of Maharashtra	73
	4.3.1.5.1	Adoptions of coping strategies to climate change by households in Parbhani	73
	4.3.1.5.2	Adoptions of coping strategies to climate change by	74

		households in Sindhudurg	
	4.3.1.5.3	Adoption of coping strategies to climate change by households in Ahmednagar	74
	4.3.1.6	Intensity of adoption for different vulnerable districts	79
	4.3.2	Determinants of climate change coping strategies	83
	4.3.2.1	Mean difference between high level and low level adopters in different vulnerable districts	83
	4.3.2.2	Determinants of coping strategies for Parbhani	84
	4.3.2.2.1	Factors determining probability of adoption for Parbhani	84
	4.3.2.2.2	Factors determining intensity of adoption by high level and low level adopters for Parbhani	85
	4.3.2.3	Determinants of coping strategies for Sindhudurg	87
	4.3.2.3.1	Factors determining probability of adoption for Sindhudurg	87
	4.3.2.3.2	Factors determining intensity of adoption by high level and low level adopters for Sindhudurg	88
	4.3.2.4	Determinants of coping strategies for Ahmednagar	89
	4.3.2.4.1	Factors determining probability of adoption for Ahmednagar	89
	4.3.2.4.2	Factors determining intensity of adoption by high level and low level adopters for Ahmednagar	90
	4.3.2.5.1	Determinants of probability of adoption of coping strategies (overall)	91
	4.3.2.5.2	Determinants of intensity of adoption of coping strategies by high level and low level adopters	92
5	SUMMARY AND CONCLUSIONS		95-102
	REFERENCES		i-xv
	APPENDICES		I-XI

LIST OF TABLES

Table No.	Title	Page No.
3.1	Classification of drought based on the percentage departure of rainfall from mean	19
3.2	Exposure indicators and their functional relationship	20
3.3	Sensitivity indicators and their functional relationship	21
3.4	Adaptive capacity indicators and their functional relationship	22
3.5	Exposure indicators and their functional relationship	29
3.6	Sensitivity indicators and their functional relationship	30
3.7	Adaptive capacity indicators and their functional relationship	31
4.1a	Estimates of indicators used in the construction of exposure index in different districts of Maharashtra	37
4.1b	Estimates of indicators used in the construction of exposure index in different districts of Maharashtra	38
4.2	Estimates of indicators used in the construction of sensitivity index in different districts of Maharashtra	39
4.3	Estimates of indicators used in the construction of adaptive capacity index in different districts of Maharashtra	40
4.4	Exposure, sensitivity, adaptive capacity and composite socio-economic vulnerability indices for the districts of Maharashtra	41
4.5	Distribution of socio-economic parameters across vulnerability categories	42
4.6	Agro-climatic zone wise classification of socio-economic vulnerability	47
4.7	Gain summary for notes	48
4.8	District wise summary statistics of exposure, sensitivity, adaptive capacity and household vulnerability indices of Maharashtra	51
4.9	Category wise number of households in exposure, sensitivity, adaptive capacity and household vulnerability indices in selected districts	52
4.10	Average values of different exposure indicators in selected Districts	53
4.11	Estimates of different sensitivity indicators in selected Districts	56

4.12	Estimates of different adaptive capacity indicators in selected districts	58
4.13	Gain summary for notes	63
4.14	Percentage of households adopted coping strategies in Parbhani (n= 60)	76
4.15	Percentage of households adopted coping strategies in Sindhudurg (n= 60)	77
4.16	Percentage of households adopted coping strategies in Ahmednagar (n= 60)	78
4.17	Mean differences between high level and low level adopters in Parbhani	80
4.18	Mean differences between high level and low level adopters in Sindhudurg	81
4.19	Mean differences between high level and low level adopters in Ahmednagar	82
4.20	Explanatory variables and its measurement	83
4.21	Determinants of probability of adoption of coping strategies for Parbhani	85
4.22	Determinants of intensity of adoption of coping Strategies by high level and low level adopters for Parbhani	86
4.23	Determinants of probability of adoption of coping strategies for Sindhudurg	87
4.24	Determinants of intensity of adoption of coping strategies by high level and low level adopters for Sindhudurg	88
4.25	Determinants of probability of adoption of coping strategies for Ahmednagar	90
4.26	Determinants of intensity of adoption of coping strategies by high level and low level adopters for Ahmednagar	91
4.27	Determinants of probability of adoption of coping Strategies (n=180)	92
4.28	Determinants of intensity of adoption of coping strategies by high level and low level adopters	93

LIST OF FIGURES

Figure No.	Title	Page No.
3.1	Sampling plan	27
4.1	Radar pictorial of exposure, sensitivity and adaptive capacity Indices	44
4.2	Mapping of socio-economic vulnerability in Maharashtra	46
4.3	Agro-climatic zones in Maharashtra	46
4.4	Determinants of socio-economic vulnerability index	49
4.5 a	Radar pictorial of mean values of exposure, sensitivity and adaptive capacity indices	59
4.5 b	Scatter plot diagram of exposure, sensitivity and adaptive capacity indices for farm household	60
4.6	Determinants of farm household level SeVI	62

LIST OF PLATES

Plate No.	Title	After Page No.
1	Glimpses of Data Collection- Parbhani	
2	Glimpses of Data Collection- Sindhudurg	
3	Glimpses of Data Collection- Ahmednagar	

LIST OF APPENDICES

Appendix No.	Title
1	Interview schedule

Abbreviations

IPCC	=	Intergovernmental Panel on Climate Change
UNFCCC	=	United Nations Framework Convention on Climate Change
IMD	=	Indian Meteorological Department
GVA	=	Gross Value Added
GDDP	=	Gross District Domestic Product
PCA	=	Principal Component Analysis
AI	=	Artificial Insemination
SeVI	=	Socio-economic vulnerability index
SD	=	Standard Deviation
SAU	=	Standard Animal Unit
SID	=	Simpson Index of Diversification
SRI	=	System of Rice Intensification
NICRA	=	National Innovations in Climate Resilient Agriculture
ha	=	Hectare
mha	=	Million hectare
t/ha	=	Tonnes per hectare
mt	=	Million tonnes
mn	=	Million
Sq. km	=	Square kilometer
kg	=	Kilogram
₹	=	Rupee
NASA	=	National Aeronautics and Space Administration, USA

ABSTRACT

Extreme climate conditions such as heavy rain, flood, and drought over the years has affected the livelihoods of people taking a toll on the Maharashtra's agrarian economy. In such situation, even distress sale of livestock has been reported that led to irrecoverable losses. Large-scale migration too happened from Marathwada to cities such as Pune and other parts of the country. There is a big challenge at the forefront on unemployment, especially in the case of poor and socio-economically vulnerable farmers. Hence it is necessary to develop a long-term, holistic and comprehensive approach to adapt situations like socio-economic issues due to climate change. *In lieu* of the above issues, "Assessing socio-economic vulnerability of farm households to climate change and its coping mechanism in Maharashtra" has been attempted with the specific objectives on assessing the socio-economic vulnerability to climate change in the districts of Maharashtra, studying the climate change induced socio-economic vulnerability in the farm households of the study region and analysing the adoption level and determinants of coping strategies practiced across vulnerable regions. To develop a new socio-economic vulnerability index (SeVI) comprising crop, dairy as well as socio-economic indicators for 34 districts of Maharashtra, the Intergovernmental Panel on Climate Change (IPCC) approach comprising exposure, sensitivity and adaptive capacity. Using secondary data, the 34 districts were classified as high, moderate and low vulnerable to climate change, based on the magnitude of SeVI. Findings indicated that not even a single district had higher adaptive capacity than exposure and sensitivity combined together. The SeVI was highest in Nandurbar (0.91) and lowest in Pune (0.41). Out of 34 districts, 11 districts (with 39.94% cropped area) were highly vulnerable, 14 (with 36.85% cropped area) were moderately vulnerable, and nine (with 23.21% cropped area) were low vulnerable to climate change. Most of the highly vulnerable districts fall under the Central Maharashtra Plateau Zone with 22.22 per cent share of total cropped area. To construct the farm household-level SeVI using exposure, sensitivity and adaptive capacity, 180 farm households (60 from each class of vulnerability *i.e.*, high, moderate and low) were selected randomly. Out of 60 households from each district, 20 were engaged in crop farming, 20 in crop and livestock farming and remaining in crop farming, livestock farming and other component. Both primary data (agricultural year 2020-21) and secondary data were used in the analysis. Results show that from 180 households, 52 (28.88 %) were grouped under high SeVI, 75 (41.66 %) in moderate and 53 (29.44 %) in low category. Households in Ahmednagar district were quite good in adaptive capacity to climate change than Sindhudurg and Parbhani. Households in Sindhudurg were more exposed to climate change. Households of Parbhani were more sensitive to climate change. Access to water resources, source of credit, and incidence of droughts in selected districts influenced the SeVI. Important lacunae identified were limited access to climate resilient agriculture technologies, climate information services, *etc.* To analyse the adoption level and determinants of coping strategies practiced across vulnerable regions, 14 coping strategies were identified in crop farming, 14 in livestock farming and 16 in 'other' category. The mean value of adoption intensity was found highest in Ahmednagar (0.12), followed by Parbhani (0.10) and Sindhudurg (0.10). Education level, family members in farming and access to credit exhibited positive and significant influence on probability of adoption of coping strategies for Parbhani. In the case of high-level adopters, family members engaged in farming and education level had positive and significant influence on the intensity of adoption. In Sindhudurg, average farm size, access to credit and social participation had positive and significant influence on the probability of adoption. Age, education level, number of droughts in the past ten years exhibited positive and significant influence on the intensity of being a high level adopter in Sindhudurg district. In the case of Ahmednagar, average herd size had positive and significant relationship with the probability of adoption of coping strategies. Monthly gross income had positive and significant influence on the intensity of being a high level adopter of coping strategies to climate change. Grassroots assessments, followed by implementation of region-specific adaptation and mitigation strategies like water harvesting and conservation, enabling farm credit, early warning disaster system, climate-proof shelter for farm animals, vaccination and farm diversification can be adopted in vulnerable districts to cope up with the adverse effects of climate change.

सारांश

पिछले कुछ वर्षों में भारी बारिश, बाढ़, सूखा जैसी चरम जलवायु परिस्थितियों ने लोगों की आजीविका को प्रभावित किया है, जिससे महाराष्ट्र की कृषि अर्थव्यवस्था पर असर पड़ा है। जलवायु परिवर्तन के दौरान पशुधन की मजबूरन बिक्री हुई जिससे अपूरणीय क्षति हुई। मराठवाड़ा से पुणे और देश के अन्य हिस्सों में बड़े पैमाने पर प्रवास, यह पिछले पांच वर्षों में अचानक जलवायु परिवर्तन के कारण हुआ है। रोजगार तलाशने वालों के बजाय नौकरी देने वालों को प्रोत्साहित करना और ग्रामीण कृषि आबादी, विशेष रूप से गरीब और सामाजिक-आर्थिक रूप से कमजोर लोगों के लिए गुणवत्तापूर्ण स्वास्थ्य देखभाल को प्रोत्साहित करना बेरोजगारी की एक बड़ी चुनौती है। इसलिए जलवायु परिवर्तन के कारण विकसित हुए सामाजिक-आर्थिक मुद्दों जैसी स्थितियों के अनुकूल होने के लिए एक दीर्घकालिक, समग्र और व्यापक उपचार विकसित करना आवश्यक है। उपरोक्त मुद्दों के कारण, "महाराष्ट्र में जलवायु परिवर्तन और इसके मुकाबला तंत्र के लिए कृषि परिवारों की सामाजिक-आर्थिक भेद्यता का आकलन" विशिष्ट उद्देश्यों के साथ करने का प्रयास किया गया है। महाराष्ट्र के जिलों में जलवायु परिवर्तन के प्रति सामाजिक-आर्थिक भेद्यता का आकलन, अध्ययन क्षेत्र के किसान परिवारों में जलवायु परिवर्तन से प्रेरित सामाजिक-आर्थिक भेद्यता का अध्ययन करना, अपनाने के स्तर और कमजोर क्षेत्रों में प्रचलित रणनीतियों का मुकाबला करने के निर्धारकों का विश्लेषण करना, इन विशिष्ट उद्देश्यों का अध्ययन किया गया। पहला उद्देश्य एक नया सामाजिक-आर्थिक भेद्यता सूचकांक (SeVI) विकसित करना था जिसमें महाराष्ट्र के 34 जिलों के लिए फसल, डेयरी के साथ-साथ सामाजिक-आर्थिक संकेतक शामिल थे, जो जलवायु परिवर्तन पर अंतर-सरकारी पैनाल (आईपीसीसी) दृष्टिकोण के आधार पर जोखिम, संवेदनशीलता और अनुकूली क्षमता का उपयोग करते थे। यहाँ द्वितीयक आँकड़ों का प्रयोग किया गया है। सूचकांक के परिमाण के आधार पर जिलों को उच्च, मध्यम और कम संवेदनशील के रूप में वर्गीकृत किया गया था। हमारे विश्लेषण से पता चला कि एक भी जिले में एक साथ जोखिम और संवेदनशीलता की तुलना में अधिक अनुकूली क्षमता नहीं थी। SeVI नंदुरबार (0.91) में सबसे ज्यादा और पुणे में सबसे कम (0.41) था। 34 जिलों में से 11 (39.94% फसल क्षेत्र के साथ) अत्यधिक संवेदनशील थे, 14 (36.85% फसल क्षेत्र के साथ) मध्यम रूप से कमजोर थे, और नौ (23.21% फसली क्षेत्र के साथ) जलवायु परिवर्तन के प्रति कम संवेदनशील थे। अधिकांश अति संवेदनशील जिले मध्य महाराष्ट्र पठारी क्षेत्र के अंतर्गत आते हैं, जिनका कुल फसल क्षेत्र का 22.22 प्रतिशत हिस्सा है। दूसरे उद्देश्य में महाराष्ट्र के 180 कृषि परिवारों के लिए फसल, डेयरी के साथ-साथ सामाजिक-आर्थिक संकेतकों वाले जोखिम, संवेदनशीलता और अनुकूली क्षमता सूचकांकों का उपयोग करके नए कृषि घरेलू स्तर के सामाजिक-आर्थिक भेद्यता सूचकांक (SeVI) के निर्माण का प्रयास किया गया था। विश्लेषण में प्राथमिक डेटा (कृषि वर्ष 2020-21) और द्वितीयक डेटा दोनों का उपयोग किया गया था। अध्ययन क्षेत्र के किसान परिवारों में जलवायु परिवर्तन प्रेरित सामाजिक-आर्थिक भेद्यता का अध्ययन करने के लिए, 3 जिलों को उनकी भेद्यता स्थिति (उच्च, मध्यम और निम्न) के आधार पर यादृच्छिक रूप से चुना गया था। प्रत्येक जिले से, 2 ब्लॉक (3 जिलों के कुल 6 ब्लॉक) और प्रत्येक ब्लॉक से, गांवों के एक समूह (6 ब्लॉक से कुल 6 क्लस्टर) को यादृच्छिक रूप से चुना गया था। गांवों के प्रत्येक समूह से, 30 घरों (फसल की खेती में लगे = 10, फसल की खेती + पशुधन = 10 और फसल खेती + पशुधन + अन्य घटक = 10) को यादृच्छिक रूप से चुना गया (n = 180)। परिणाम बताते हैं कि 180 घरों से: 52 (28.88%) परिवार उच्च SeVI, 75 (41.66%) मध्यम SeVI श्रेणी में और 53 (29.44%) निम्न SeVI में थे। सिंधुदुर्ग और परभणी की तुलना में अहमदनगर जिले के परिवार जलवायु परिवर्तन के लिए काफी अनुकूल हैं। सिंधुदुर्ग में परिवार जलवायु परिवर्तन के प्रति अधिक संवेदनशील हैं। परभणी के परिवार जलवायु परिवर्तन के प्रति अधिक संवेदनशील हैं। जल संसाधनों तक पहुंच, ऋण के स्रोत और चयनित जिलों में सूखे की घटनाओं ने SeVI को प्रभावित किया। जलवायु अनुकूल कृषि प्रौद्योगिकियों, जलवायु सूचना सेवाओं आदि तक सीमित पहुंच की पहचान की गई महत्वपूर्ण कमियां हैं। तीसरे उद्देश्य ने अपनाने के स्तर और कमजोर क्षेत्रों में प्रचलित रणनीतियों का मुकाबला करने के निर्धारकों का विश्लेषण किया है। फसल खेती में (14) रणनीतियों की पहचान की गई, (14) पशुधन खेती में और (16) खेती में अन्य घटकों में (यदि जोड़ा गया)। गोद लेने की तीव्रता का औसत मूल्य अहमदनगर (0.12) में सबसे अधिक पाया गया, इसके बाद परभणी (0.10) और सिंधुदुर्ग (0.10) का स्थान रहा। शिक्षा स्तर, खेती में परिवार के सदस्यों और ऋण तक पहुंच ने परभणी के लिए मुकाबला करने की रणनीतियों को अपनाने की संभावना पर सकारात्मक और महत्वपूर्ण प्रभाव दिखाया। उच्च स्तर के दत्तक ग्रहण करने वालों के मामले में, खेती और शिक्षा स्तर में लगे परिवार के सदस्यों का अपनाने की तीव्रता के साथ सकारात्मक और महत्वपूर्ण प्रभाव पड़ता है। सिंधुदुर्ग में, औसत कृषि आकार, ऋण तक पहुंच और सामाजिक भागीदारी का गोद लेने की संभावना पर सकारात्मक और महत्वपूर्ण प्रभाव पड़ता है। पिछले दस वर्षों में आयु, शिक्षा स्तर, सूखे की संख्या का सिंधुदुर्ग जिले में उच्च स्तर के अपनाने लेने की तीव्रता के साथ सकारात्मक और महत्वपूर्ण प्रभाव है। अहमदनगर के मामले में, औसत झुंड के आकार का मुकाबला रणनीतियों को अपनाने की संभावना के साथ सकारात्मक और महत्वपूर्ण संबंध है। मासिक सकल आय का जलवायु परिवर्तन से मुकाबला करने की रणनीतियों के उच्च स्तर को अपनाने की तीव्रता के साथ सकारात्मक और महत्वपूर्ण प्रभाव पड़ता है। जमीनी स्तर पर आकलन, इसके बाद जल संचयन और संरक्षण जैसे क्षेत्र-विशिष्ट अनुकूलन और शमन रणनीतियों के कार्यान्वयन के बाद, कृषि ऋण को सक्षम करना, प्रारंभिक चेतावनी आपदा प्रणाली, खेत जानवरों के लिए जलवायु-सबूत आश्रय, टीकाकरण और कृषि विविधीकरण को कमजोर जिलों में अपनाया जा सकता है।



Chapter-1



Introduction

INTRODUCTION

A change in the long-term weather pattern that characterize the world's regions is referred to as global climate change. The word 'weather' refers to a region's frequent (short-term) changes in temperature, wind, and precipitation (Merritts *et al.*, 1998). Several studies confirm that climate models are predicting the future warming projections precisely (Alan, 2020). By the end of this century, the global mean sea level is expected to rise by 0.18 to 0.59 m (Mahato, 2014). With less rain in the south and south-east Asia, the precipitation trend has shifted. Since the 1970s, droughts have become more severe and long lasting. The perpetual snow cover has decreased in terms of both area and depth. Reports alarm that the Asia-Pacific region is home to six of the top ten countries most vulnerable to climate change. Bangladesh is at the top of the list, with India, Nepal, the Philippines, Afghanistan, and Myanmar following closely behind. In Bangladesh, for example, a 1.5 m sea-level rise will result in the displacement of around one-fifth of the country's population due to farmland loss (Mahato, 2014). Human impacts dominate modern climate change, which have now grown to a size that exceeds natural variability (Karl and Trenberth, 2003). Changes in atmospheric chemistry caused by humans are the primary cause of global climate change. These disturbances are largely caused by pollution related to energy usage, but urbanization and land use changes play a big role at the local and regional levels. Despite progress in tracking and understanding climate change, there are still many scientific, technological, and structural barriers to precisely preparing for, responding to, and mitigating the impact of climate change. While the rates of change that can be anticipated are still unpredictable, these changes will gradually manifest themselves in significant and observable ways, such as changes in temperature and rainfall extremes, declines in seasonal and perennial snow and ice extent, and sea level rise. Anthropogenic climate change is now very likely to continue for several decades.

India's average temperature rose by 0.7°C between 1901 and 2018, and it is projected to rise further by 4.4°C by the end of this century (Ministry of Earth Sciences, GOI, 2020). Indian regions are characterized with a high populace mainly dependent on livelihoods sensitive to climate variations and witness to frequent fluctuations in agricultural production affecting the income levels (Brown *et al.*, 2007; Bizikova *et al.*, 2013). High dependence on climate-sensitive sectors, limited infrastructure, volatile markets, poor socio-economic and low biophysical status of the habitat makes the rural poor most vulnerable to climate change

(Banerjee, 2014; Safriel *et al.*, 2005; Singh *et al.*, 2017a). In India, vulnerability studies have focused mainly on how adaptation practices to climate change in agriculture were influenced by a wide range of social factors (Dhanya and Ramachandran, 2016). The developing countries like India, are highly vulnerable to drought than the developed countries (Magalhães, 1996) because of their high reliance on climate-related livelihood activities and limited adaptive ability. Rural households in developing countries are particularly vulnerable to climatic risks such as drought (UNFCCC, 2009a).

According to the Indian Meteorological Department (IMD), drought is caused by a natural decrease in rainfall over a long period of time, usually a season or more, and is often accompanied by other climatic factors such as high temperature, high wind, and low relative humidity, all of which can exacerbate the severity of the drought. Drought can also be categorized as meteorological (due to lack of rainfall), hydrological (because of surface water storage dryness), agricultural (due to deficiency of root zone soil moisture), and socio-economic drought (due to water supply deficiency for socio-economic purposes) (Hollins and Dodson, 2013). Environmental indicators make up the first three groups, while water management indicators make up the fourth (Wilhite *et al.*, 2000).

In Maharashtra, maximum employment of 56 per cent was observed in agriculture and allied activities (Misra, 2012). Except for sugarcane, little has been accomplished in the sector in comparison to other regions of the country over the last six decades (Sawant *et al.*, 2010). The growth in the rainfall is 113.4 per cent of usual rainfall and the crop sector is projected to rise by 16.2 per cent, livestock by 4.4 per cent, and forestry and logging by 5.7 per cent (Economic Survey of Maharashtra, 2019-20). Cereals, pulses, oilseeds, cotton, and sugarcane production are expected to increase by 60, 14, 28, 33, and 40 per cent, respectively (Economic Survey of Maharashtra, 2019-20). The state had the highest agricultural growth rate of 21 per cent in 2016-17, and the second highest in the last ten years was 15.6 per cent in 2010-11, followed by 12.3 per cent in 2013-14 (Ministry of Agriculture & Farmers Welfare, GOI, 2017). The average size of operational holding as per the Agriculture Census 2015-16 is 1.34 ha whereas in Agriculture Census 2010-11 it was 1.44 ha. The total area of small & marginal operational holdings (upto 2.0 ha) was 92.20 lakh ha constituting 45 per cent of the total area of operational holdings whereas number of small and marginal operational holdings were 121.55 lakh which were 79.5 per cent of the total number of operational holdings (Economic Survey of Maharashtra, 2020-21). The state ranks seventh at all-India level with total livestock population of about 3.31 crore (Department of Animal Husbandry and Dairying, GOI, 2019).

Also, ranks fifth at all-India level with poultry birds population of about 7.43 crore (Department of Animal Husbandry and Dairying, GOI, 2019). During 2019-20, the average daily collection of milk by the government and co-operative dairies was 0.96 lakh litre and 39.76 lakh litre respectively whereas the corresponding figures during 2018-19 were 1.79 lakh litre and 49.14 lakh litre respectively (Economic Survey of Maharashtra, 2020-21). During 2019-20, marine and inland fish production was 4.44 and 1.18 lakh metric tonne, respectively (Economic Survey of Maharashtra, 2020-21). The forest area of the state at the end of the year 2019-20 was about 20 per cent of geographical area of the State, as against the target of 33 per cent set under the National Forest Policy, 1988 (Economic Survey of Maharashtra, 2020-21).

Based on socio-political and other geographical considerations, the state is divided into five main regions: Vidarbha (north-eastern region), Marathwada (south-central region), Khandesh (north-western region), Northern Maharashtra and Western Maharashtra (Konkan). The state has been divided into 9 agro-climatic zones based on rainfall, soil type and the vegetation as Central Maharashtra Plateau Zone, Central Vidarbha, Eastern Vidarbha Zone, North Konkan Coastal Zone, South Konkan Coastal Zone, Scarcity Zone, Sub Montane Zone, Western Ghat Zone, Western Maharashtra Plain Zone (NDDDB, 2015). Maharashtra occupies the western and central part of the country and has a long coastline stretching nearly 720 km along the Arabian Sea. The Western Ghats is not only the prominent biodiversity resource for the region and an important climatic divide (average elevation of 1200 meters), but also forms one of the three watersheds of the state from which, several important rivers, including Godavari and Krishna originate. Climate shocks and stressors such as cyclones, floods, droughts, changing rainfall patterns and extreme temperatures are some examples of uncertainties faced by Maharashtra. Climate-related uncertainty refers to the inability to predict the scale, intensity and impact of climate change on human and natural environments (Curry and Webster, 2011). Uncertainties in climate change projections are high and combined with the economic and political drivers of change makes local level effects difficult to predict (IPCC, 2014). State's 70 per cent of geographical area falls under the semi-arid region. The state has "prominently observed" droughts from 2011-12 onwards (Economic Survey of Maharashtra, 2018-19). During monsoon 2020, the state received 113.4 per cent of its daily rainfall (Economic Survey of Maharashtra, 2020-21). State's 139 talukas received excessive rainfall, 173 received average rainfall, and 43 received insufficient rainfall (excluding talukas in Mumbai City and Mumbai suburban districts) (Economic Survey of Maharashtra, 2020-21). The predominance of rainfed regions, fluctuating climatic conditions like extreme rainfall,

persistent droughts and acute underdevelopment in regions like Vidarbha, Marathwada, and Konkan were the state's major development challenges. Because of all these reasons Maharashtra was purposively selected for the present study.

Problem Statement

Extreme climate conditions such as heavy rain, flood and drought over the years, has affected the livelihoods of people, taking a toll on the state's economy. There was a distress sale of livestock during climate change that lead to irrecoverable losses. Large-scale migration to happened from Marathwada to cities such as Pune and other parts of the country. This happened due to sudden climatic variations in the past five years. (Department of Agriculture, GOI, 2017). There is a big challenge of unemployment, especially poor and socio-economically vulnerable (Economic Survey of Maharashtra, 2019-20). There have been multiple research endeavours aimed at assessing the relative vulnerability or adaptive potential of entities across various indices in the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC) (Balasubramanian *et al.*, 2007; Gbetibouo *et al.*, 2010; Hahn *et al.*, 2009; Malone and Brenkert, 2008; Iglesias *et al.*, 2011). There is no empirical data on what influences farmers' individual adaptation decisions (Vincent, 2007) or how adaptation can be quantified (Yohe and Tol, 2002). The current literature does not adequately discuss the complex, forward-thinking, and site-specific features and processes of adaptation (Hinkel, 2011). According to the IPCC Fourth Assessment Report 2007, vulnerability is the degree to which a system is vulnerable to, or unable to cope with, adverse effects of climate change, including climate instability and extremes. Socio-economic vulnerability comprises of various social and economic variables of farm households contributing uncertainty to cope up with the climate change. Vulnerability comprises of three basic components *viz.*, exposure, sensitivity and adaptive capacity. Exposure is the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, economic, social, cultural assets in places and settings that could be adversely affected (IPCC, 2011). Climate sensitivity is the degree to which a system or species is affected, either negatively or positively, by climate variability or change (IPCC, 2014). Adaptive capacity is described as the ability of structures, organizations, humans, and other organisms to adjust to potential harm, to take advantage of opportunities, or to react to consequences (IPCC, 2014). Despite the extensive research on vulnerability on a global scale, a very few studies have been conducted in Maharashtra state of India. Present research is focused to address the following climate change issues in Maharashtra.

- What is the present status of socio-economic vulnerability to climate change in the districts of Maharashtra?
- Is there any difference in the socio-economic vulnerability of farm households in the study region?
- What is the probability and intensity of adoption and what are the determinants of the coping strategies practiced across vulnerable regions?

Objectives

To seek answers to the above questions, the present research entitled “**Assessing socio-economic vulnerability of farm households to climate change and its coping mechanism in Maharashtra**” has been conducted with the following specified objectives:

1. To assess the socio-economic vulnerability to climate change in the districts of Maharashtra.
2. To study the climate change induced socio-economic vulnerability in the farm households of the study region.
3. To analyse the adoption level and determinants of coping strategies practiced across vulnerable regions.

Research hypothesis

Research hypothesis of the study are as follows:

1. Socio-economic variables highly influence the vulnerability status of the farm households in Maharashtra.
2. Adoption level of management strategies depends on awareness of the farm household and social participation
3. Climate change adaptation and mitigation strategies results in enhanced gross income and ultimately empower the farm households.

Scope of the study

This study was conducted in Maharashtra to determine the vulnerability of farm households to climate change and adoption of coping strategies. The research intends to create a new socio-economic vulnerability index that includes possible relevant social and economic variables related to farm households. The index aids in the classification of districts in Maharashtra into low, medium and high category. Post classification, the study intends to capture the extent of

climate change induced vulnerability in rural households. The research investigates the level of adoption of coping strategies and the socio-economic factors that influence in the study region. Overall, the study's aim was to see how climate change coping strategies affects crop, dairy and other component's production potential and farm income.

Limitations of the study

- The study is largely based on primary data collected from the respondents by personal interview method. Reliability of the collected data solely depends on the memory recall of the households as there is no proper record maintained by them.
- Though, concerned efforts were made to get the accurate information from the respondents, but the probability of error and biasedness in the data provided by some of the respondents could not be avoided completely.
- The study in second objective is limited to only three districts of Maharashtra *i.e.* Parbhani, Sindhudurg and Ahmednagar owing to both time and resource constraints. Therefore, the results obtained from the study cannot be generalized for the other regions.

Organization of the study

The research is divided into five parts, with each chapter focusing on a different aspect of the main theme. The first chapter introduces the concepts of climate change, vulnerability, drought, global scenario, Indian scenario, Maharashtra scenario, researchable problems, goals, research hypothesis, study scope, and limitations. The second chapter discusses the review of literature, which covers a variety of publications relevant to the research. The third chapter discusses research methodology, including the research subject, data sources, materials, and methods. The study's findings and discussion are explained in the fourth chapter. The fifth chapter concludes the study with policy recommendations, followed by list of references and appendices.



Chapter-2



Review of Literature

REVIEW OF LITERATURE

In this chapter various previous literature were reviewed and discussed based on the general subject areas of the objectives.

2.1. The degree of regional socio-economic vulnerability assessment

2.2. The extent of vulnerability in farm households

2.3. The extent of adoption and determinants of coping strategies

2.1. THE DEGREE OF REGIONAL SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

Abundant literature are available on assessment of climate change induced socio-economic vulnerability. A majority of the studies have used the Intergovernmental Panel on Climate Change (IPCC) methodology for regional level climate change assessment. Brenkert and Malone (2005) in their study on modelling vulnerability and resilience to climate change used the Vulnerability-Resilience Indicator Prototype (VRIP). The model was adapted from the global/country version to account for Indian dietary practices and data availability regarding freshwater resources. Results (scaled to world values) showed that, nine Indian states were moderately resilient to climate change, principally because of low sulfur emissions and a relatively large per centage of unmanaged land. Szlafsztein and Sterr (2007) have documented numerous natural impacts of flood and erosion processes over the last 25 years in the NE coastal zone of the State of Pará (Brazil). A composite coastal vulnerability index based on Geographical Information Systems (GIS) was used to determine the socioeconomic vulnerabilities of this coastal region (CVI). A reliable measure of differences (5 classes) among regions and communities that were exposed to similar ranges of hazards was created by combining 16 separate natural and socioeconomic variables into a single indicator. Fekete *et al.* (2010) in their combined assessment on scales as a challenge for vulnerability assessment, two case studies were conducted, one on a subnational level and the other on a local level, to demonstrate challenges and benefits arising from scale implications. Both assessments looked at vulnerability in the form of German river floods. Vulnerability evaluations must be mindful of scale consequences in order to develop a spatial comparison and incorporate topics such as the environment and community. The findings show that vulnerability assessments and scale are inextricably linked, not only in terms of technological implementation but also in terms of

conceptualization, which requires further scientific progress. Das (2013) studied regional variation in potential vulnerability in Indian agriculture to climate change. The Socio-Economic Vulnerability Index (SeVI) was calculated using indicators like irrigation strength, per centage of people living in poverty, per centage of agricultural workers among total workers, and literacy rate. Modified UNDP method has been used in constructing both biophysical vulnerability index and socio-economic vulnerability index. Results showed that most of the states with high vulnerability are located in India's central and north-central regions, according to research. Malakar and Mishra (2017) in their study on assessing socio-economic vulnerability to climate change focused on a city-level index-based approach. Various indicators of socio-economic vulnerability have been compiled and segregated into major components like infrastructure, technology, finance, social and space. Senapati and Gupta (2017) in their study on socio-economic vulnerability due to climate change on fishing communities in Mumbai, Maharashtra surveyed 200 fishermen from five fishing villages in Mumbai. The findings show that weakness persists in the fishing community due to physical and financial resource constraints. Due to their inability to use powerful mechanized boats and advanced technology, fishermen from *Madh* and *Worli* villages have been found to be more vulnerable and less adaptable. Binita *et al.* (2015) in their study on climate change vulnerability assessment in Georgia, for the 1980s, 1990s, 2000s, and 2010s, climate change vulnerability indices were calculated. Climate change exposure was calculated as the difference between decadal mean temperature and precipitation (1971–2000) and baseline temperature and precipitation (1971–2000) using the United States Historical Climatology Network version 2.5, as well as extreme hydroclimatic hazards such as floods, heat waves, and droughts. Temperature and precipitation anomalies were observed, with an overall trend toward drying and warming. A clearly defined rise in extreme hydroclimatic events in recent decades has captured the anomalous cooling cycle in Georgia between 1970 and 1980, as well as the post-1980 warm-up. Some metro Atlanta and coastal counties were the most vulnerable to climate change. Ayanlade *et al.* (2018) studied rainfall variability and drought characteristics in two agro-climatic zones in Africa. In their study, inter-station and seasonality statistics reveals that there were less variable and wetter early growing seasons and late growing seasons in the rainforest zone, also more variable and drier growing seasons in other stations. The results show high spatial and temporal rainfall variability for the stations. Consequently, there are several anomalies in rainfall in recent years but much more in the locations around the Guinea Savanna. Rao *et al.* (2019) worked on assessing differential vulnerability of communities in the agrarian context in two districts of Maharashtra. A community engaging vulnerability

assessment tool was used to explore the climate risks and vulnerabilities of different social groups. Insights indicate that vulnerability is socially differentiated across farmer categories and social groups. Krishnan *et al.* (2019) in their study on vulnerability and spatial decision making for climate-change adaptation, formulated SeVI as a function of sensitivity and adaptive capacity for planning grassroot-level interventions and adaptation strategies. The indicators were identified through a literature review, expert consultations, and an opinion survey. Also, statistical tests were used to validate them. Results showed that 92 villages (30%) in Sindhudurg were classified as highly vulnerable based on CVI values. Carpena (2019) studied impact of drought on household food consumption and nutritional intake. They found that dry shock has a statistically significant and negative effect on household nutrition. Singh (2020) worked on farmers' perception of climate change and adaptation decisions in Bundelkhand region of India. In their study, multi-stage sampling technique was adopted to select study sites and respondents. Study findings revealed that variability in temperature and rainfall has affected adversely to the livelihoods of farmers. Balaganesh *et al.* (2020) worked on development of composite vulnerability index and district level mapping of climate change induced drought in Tamil Nadu, India. In their study Composite Drought Vulnerability Index (CDVI) was developed. Vulnerability mapping showed that most of the districts fall under northeastern and southern agro-climatic zones; a few districts in Cauvery delta and western zones which were prone to high vulnerability. Most of the districts in northwestern, western, and high rainfall zones were less vulnerable, whereas the remaining districts of Tamil Nadu were identified under moderate vulnerable to drought category. Swami and Parthasarathy (2020) studied dynamics of exposure, sensitivity, adaptive capacity and agricultural vulnerability at district scale for Maharashtra, India their findings show that a few districts are vulnerable despite being least exposed to climate variability signifying the contribution of sensitivity and adaptive capacity parameters towards their vulnerability. The results also highlight the intra-regional district level variability in resource distribution, exposure and sensitivity parameters indicating the significance of having a district-wise policy for Maharashtra, India.

Summary of the studies

The socio-economic vulnerability index was calculated using a variety of indicators (exposure, sensitivity, adaptive capability, social, economic, climatic, *etc.*). The IPCC form of vulnerability assessment was used in most of the studies. The importance of vulnerability mapping in assessing the varying degrees of vulnerability of different localities is critical.

Results of the most studies showed that the central part of India highlighting Maharashtra and other neighboring states are highly socio-economically vulnerable to climate change. Climate variables were found to have significant and negative effect on farm level gross margin. Notwithstanding studies have been conducted on vulnerability but still there is a scope for developing composite socio-economic vulnerability index, comprising different socio-economic variables related to farm households in highly climate affected states like Maharashtra. Present study strives to fulfill the research gap at farm household level and regional level differences in socio-economic vulnerability.

2.2. THE EXTENT OF VULNERABILITY IN FARM HOUSEHOLDS

In various literature, the level of socio-economic vulnerability in farm households has been evaluated using various approaches. Bantilan and Anupama (2002) performed an in-depth study of farm household behaviour under risk has been facilitated by ICRISAT's Village-Level Studies (VLS) panel data and other household surveys. Crop management techniques, the most common of which are crop diversification and intercropping, have shown to partially smooth out crop income variability during drought years. The impact of public sector assistance in helping households adapt to sources of vulnerability, such as drought, is also demonstrated by the VLS data. Crop insurance is defined as a direct policy response to reduce the severity of vulnerability. Vincent (2004) developed SeVI using IPCC vulnerability framework for assessing vulnerability at household level. Study reveals that there is an urgent need for local-level planning and prioritization of adaptation strategies. Fekete (2009) worked on development of Social Vulnerability Index (SVI). For this study, remote sensing data were used. The focus of the study was on development and validation of a social vulnerability map of population characteristics towards river-floods. Deressa *et al.* (2009) assessed the farmers' vulnerability to climate disasters such as floods, droughts, and hailstorms using the "Vulnerability as Predicted Poverty (VEP)" approach. According to the findings, farmers' vulnerability to climate extremes can be minimized by increasing their income and requiring them to meet regular minimum requirements. Hahn *et al.* (2009) used a pragmatic approach focused on the Livelihood Vulnerability Index (LVI) and the LVI-IPCC approach to evaluate livelihood vulnerability to climate variability and change in Mozambique. According to their findings, water availability and socio-demographic structure are the two most significant factors that affect vulnerability. Kale (2013) studied socio-economic, psychological and situational causes of suicides of farmers in *Vidarbha* region of Maharashtra. This study was undertaken for identification of various causes of suicides of farmers in highly suicide prone

six districts of *Vidarbha* with exploratory design of social research. In this study total 200 victims were selected by proportionate method of random sampling. It covered 178 villages and 34 tehsils of six districts of *Vidarbha* region. Results showed that low education level, large to medium family size with nuclear type of families, small and marginal rainfed holding with no source to access the irrigation, low productivity due to monsoon vagaries and low annual income were the causes of farmers suicides in the *Vidarbha* region of Maharashtra. Tesso *et al.* (2012) used the IPCC methodology, which included bio-physical and socio-economic indicators, to assess the vulnerability of farm households in Ethiopia to climate change-induced shocks. Outcome of the study reveal that farmers in highland areas were more vulnerable to natural shocks than farmers in lowland areas. Also, vulnerability to natural shocks can be reduced by improving adaptive capacity across various indicators. Radhakrishnan *et al.* (2017) worked on vulnerability of dairy based livelihoods to climate variability and change in the Western Ghat region of Ratnagiri, Maharashtra, India. In this study, vulnerability was assessed for dairy based livelihoods to climate change by applying index-based approach (IPCC), total of 28 indicators were used to construct an overall Livelihood Vulnerability Index (LVI). Data were collected through participatory rural appraisal (PRA). The analysis revealed that the dairy farmers of *Lanja* taluka were most vulnerable among those of Ratnagiri district. The index score of dairy based livelihoods of *Lanja* taluka was negative with overall value - 4.17 with 48 per cent farmers having high level of vulnerability. In a study on inherent vulnerability assessment, Rajesh *et al.* (2018) focused on local level vulnerability assessment to improve the household adaptive capacity. In order to identify vulnerable households, Inherent Vulnerability Index (IVI) was used, a non-linear principal analysis technique to assess a mixed scale data set. In the villages of *Kimsar*, *Ramjeeewala*, and *Malla Banas*, a large number of households were listed as extremely vulnerable. A majority of the households in *Talla Banas* is moderately vulnerable. In the villages of *Dharkot*, *Kandakhal*, and *Bhumiyakisar*, a higher proportion of households were vulnerable. Swami and Parthasarathy (2018) briefed the challenges and approaches to vulnerability and adaptation to climate change in Maharashtra, India. In this study, household level survey (HHS) of 185 farmers along with focused group discussion in eight villages of Akola district was carried out to know the implementation and awareness of various government plans, schemes, role of formal institutions and the deriving factors for their adaptation. The study necessitates separate policy formulation related to climate variability and agriculture for each district to bring out the solution for regional issues (socio-political, farmers, agriculturalists, and economical). Thorat and Sirohi (2018) worked on income risk and management strategies of rural households in the distressed regions of

Maharashtra. In this study, an analysis of various strategies that rural households adopt, to avoid consumption shortfalls due to income shocks has been carried out empirically using the logit model. The results based on a primary survey of 200 rural households in the region indicate that irregular rainfall along with pest and disease outbreaks before crop harvest are the main sources of environmental risks.

Summary of the studies

Exposure, sensitivity and adaptive capacity (IPCC approach) are usually recognized as constituent parts of socio-economic vulnerability, studies at the household level. IPCC methodology can be effectively used for household level index development of socio-economic vulnerability. Assessing socio-economic vulnerability at household level is urgent for local-level planning and prioritization of adaptation strategies. Quantitative and qualitative variables have been used as indicators in the literature. For assessing the vulnerability, IPCC approach and the VEP method were mostly used.

2.3. THE EXTENT OF ADOPTION AND DETERMINANTS OF COPING STRATEGIES

2.3.1. The extent of adoption (intensity of adoption)

The extent of adoption, also known as the intensity of adoption, has been measured using a variety of methods. In northern Tanzania, Nkonya *et al.* (1997) assessed adoption intensity as the area planted with improved maize seed or the amount of fertilizer applied per unit area. In Cameroon, Nchinda *et al.* (2010) calculated the adoption intensity for improved yam seed technology. It was measured as a percentage of the total area covered by improved seed technology. Milder *et al.* (2011) studied performance and potential of conservation agriculture for climate change adaptation and mitigation in Sub-Saharan Africa. In this study, the findings suggest that the most promising opportunity for climate adaptation is to generate significant climate change mitigation benefits supported by the reduction of deforestation and forest degradation (REDD). Double hurdle model was used in this study. Other studies, such as Mal *et al.* (2012), Tambo and Abdoulaye (2012), and Ghimire *et al.* (2015), have assessed the adoption strength (extent) as a proportion of area under better technologies or varieties, such as *Bt* cotton in northern India, drought tolerant maize (DTM) technology in rural Nigeria, and improved maize varieties in Nepal. Udmale *et al.* (2014) worked on farmers' perception of drought impacts, local adaptation and administrative mitigation measures in the Maharashtra State of India. This study reveals that, decrease in yield of cereals, horticultural crops, livestock

production and loss of employment, all associated with decreased income of farmers, which were the most immediate economic impacts of drought. Roco *et al.* (2014) focused on farm level adaptation decisions to face climatic change and variability in Central Chile. In this study, two-part hurdle model explains the decision and intensity of adaptation. Findings state that, access to weather information has a strong positive influence on the adaptation decision. Darko (2015) used a ranking scale approach to measure the intensity of acceptance of different cultural practices of cocoa research developments in Ghana and found that the rate of adoption had a positive impact on productivity. Singh (2020) worked on farmers' perception of climate change and adaptation decisions at microlevel in the Bundelkhand region of India. This study reveals that, farmers are highly aware of climate change and its adverse effect on agriculture and livelihoods. Hence, farmers firstly identified the main barriers and then they started to adjust resources, communicated, and shared their indigenous expertise to cope up with changing climate. Most farmers believed that the lower livelihood status (least basic amenities) and a fewer employment opportunity in the non-farm sectors are the major barriers. Balaganesh *et al.* (2020) developed a composite vulnerability index and district level mapping of climate change induced drought in Tamil Nadu, India. Double hurdle model was used for the analysis. This study revealed that, to mitigate the ill-effects due to drought, focus should be given for developing regional level adaptation strategies and coping mechanisms like water conserving techniques and farm ponds. Bandyopadhyay *et al.* (2020) worked on drought mitigation proposal for a new drought policy with a special reference to Gujarat (India). Certain drought mitigation measures prescribed and practiced in the state of Gujarat are found to be inadequate, ineffective, and wrong. The government needs to frame strategies involving the community and ensuring stakeholders' participation in drought management.

Summary of the studies

Most farmers believed that the lower livelihood status (least basic amenities) and a fewer employment opportunity in the non-farm sectors are the major barriers for adoption of adaptation and mitigation strategies. To mitigate the ill-effects due to socio-economic vulnerability, focus should be given for developing regional level adoption strategies and coping mechanisms. Double hurdle model is widely used for studying the adoption (adaptation and mitigation) strategies across vulnerable regions.

2.3.2. Determinants of coping strategies

In various literature, the determinants of management strategies have been tested using diverse approaches. The double hurdle model was used by Teklewold *et al.* (2006) to determine the factors influencing the pace and extent of poultry technology in Ethiopia. Various socio-economic variables were identified as the determinants. Gbetibouo and Ringlar (2009) used the Heckman's probit and Multinomial Logit (MNL) model to identify the determinants of climate adaptation in the Limpopo Basin of South Africa. Household size, farming experience, wealth, water access, credit, extension, tenure rights, and off-farm activities are identified as the important factors that influence the adaptive capacity. In Nigeria, Tambo and Abdoulaye (2012) used the double hurdle model to investigate the factors that influence climate change adaptation technologies like drought tolerant maize (DTM). The first hurdle in the model decided whether or not to implement a technology, and the second hurdle determined the intensity of adoption (extent of adoption), which was dependent on the first decision. Education, credit, farm size, and association membership were found to be some of the factors that influenced adaptation strategies. Mal *et al.* (2012) used a double hurdle model to figure out the factors influencing *Bt* cotton adoption and its widespread in North India. The findings revealed that knowledge is critical for adoption and its scope. Experience is a barrier to technology adoption, while access to credit motivates farmers to adopt. Using a double hurdle model, Saxena (2016) investigated the factors influencing cooperative membership activity in Uttarakhand. In this analysis, the first hurdle was addressed using a logit model for cooperative membership, and the second hurdle was analysed through a multivariate linear regression model for evaluating the factors affecting the level of participation. Priscilla *et al.* (2017) used a double hurdle model to investigate the factors influencing the participation behaviour in Manipur. Tobit model was used for the first hurdle, while the truncated regression model was used for the second hurdle. The level of participation was positively influenced by age and technical efficiency, while farming experience and total milk production had negative relationship. Thorat and Sirohi (2018) in their study on income risk and management strategies of rural households in the distressed regions of Maharashtra found that successful social risk management policies are critical in deprived areas to boost the socio-economic status of rural households. Ahmed (2019) studied the adoption of climate smart agricultural (CSA) technologies and determinants choice of adaptation strategies to climate variability in Midhega Tola district of Eastern Ethiopia. The multinomial logistic model (MNL) model results revealed that livestock ownership, income, access to weather information, and the education

level of the household head have a positive impact on CSA adoption, while gender and age of the household head have a significant and negative impact on CSA adoption. Ghosh and Ghosal (2020) studied the determinants of household livelihood vulnerabilities to climate change in the Himalayan foothills of West Bengal, India. Owing to climate change, four major domains of vulnerabilities have been considered *viz.*, income loss, crop loss, housing loss, and overall livelihood loss. To identify the deciding factors, ordinal logistic regression and focus group discussion were used. Relevant variables such as the size of agricultural property, the occupation of the household's heads, caste, participation in self-help organisations, and perception of precipitation patterns are the key determinants of income loss in a maximum number of households. Furthermore, the form of housing, mostly non-concrete and semi-concrete homes, is an important factor in deciding the household vulnerability to climate change.

Summary of the studies

The adaptation and mitigation strategies were determined by the education level, age, experience, access to extension and credit, climate change knowledge, and other socio-economic variables related to the head of the household. Quantitative and qualitative socio-economic factors make up these variables. Various tools like double hurdle model, endogenous regression model and multinomial logistic (MNL) model were used to evaluate the determinants.



Chapter-3



Research Methodology

RESEARCH METHODOLOGY

The present investigation is based on the extent of vulnerability within region as well as farm households to climate change and the possible means to cope the associated adverse impact(s). In order to draw significant implications from any study, it is critical to use an appropriate technique. As a result, this chapter focuses on the study's data, analytical tools and techniques. For the aforementioned purpose, this chapter is organised under the following sections:

3.1. The degree of regional socio-economic vulnerability assessment

3.2. The extent of vulnerability in farm households

3.3. The level of adoption and determinants of coping strategies practiced across vulnerable regions to climate change

3.1. THE DEGREE OF REGIONAL SOCIO-ECONOMIC VULNERABILITY ASSESSMENT

3.1.1. Study area

Maharashtra has been selected purposively for this study as the state is severely facing rainfall and temperature anomalies along with the persistent droughts and many climatic factors impacting agriculture and allied activities. At present there are 36 districts in the state out of which two districts namely, Mumbai Central and Mumbai Suburban have been omitted in this study because of data unavailability related to farming and dairying. Therefore, the remaining 34 districts of Maharashtra have been selected for the present study. Agriculture is the prime livelihood source for 51 per cent of the state population (NABARD, 2019). Most of the rural population with a considerable share of small and marginal farmers and economically backward communities of the state rely on agriculture and allied activities for their livelihoods. Climate change is considered one of the most important challenges for Maharashtra. Maharashtra is an agrarian economy despite being one of the most industrialised states in India. (India Brand Equity Foundation, 2020). Water scarcity during the *kharif* season (June to October) of 2018-19 in 26 districts affected 151 talukas (Economic Survey of Maharashtra, 2018-19). The area under *rabi* crops (November to February) was 50 per cent less in 2018-19 compared to the previous year, mainly due to the deficient rainfall in September and October 2018 (Economic Survey of Maharashtra, 2018-19). This signifies a key threat to communities that depend on agriculture for food and livelihoods. To combat this, climate induced socio-

economic vulnerability assessment has been prioritized at regional level which helps to develop effective adaptation and mitigation strategies.

3.1.2. Data sources

For the development of district level SeVI, secondary data were collected on various climatic as well as socio-economic variables for the 34 districts of Maharashtra. All the variables were selected based on extensive literature enquiry and data availability (Brenkert and Malone, 2005; Malakar and Mishra, 2017; Balaganesh *et al.*, 2020). District level daily average rainfall, temperature and relative humidity data were collected for a period of 30 years (1991 to 2020) from the online web services of ‘Solar Radiation Data (SoDa)¹ - Solar energy services for professionals’ (web services, databases, algorithms, end-user applications). District level crop production statistics data, area under cultivation and operational holdings of small and marginal farmers were collected across Maharashtra, per cent sown area, per cent cropped area, total irrigated area and other farming related data for the past three agricultural years (2017-18 to 2018–19) were collected from various state government reports and Economic Survey of Maharashtra (2018-19, 2019-20). District level data on total bovine population, total milk production, per capita milk availability for the same period were obtained from the advanced estimates and livestock census data published by the Department of Animal Husbandry, Government of Maharashtra, Livestock Census and other official reports.

3.1.3. Vulnerability estimation

Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system. Exposure is the nature and degree to which a system is exposed to climate change. Sensitivity is the degree to which a system is adversely affected by climate change. Adaptive capacity is the capability of a production system or region to better adjust to climate change (IPCC, 2007).

$$\mathbf{Vulnerability = (Exposure + Sensitivity) - Adaptive Capacity} \quad (1)$$

In Eq. (1), the combined effect of exposure and sensitivity is called as ‘potential impact’, which is very much destructive, if the region or production system has a high magnitude of index.

¹ <http://www.soda-pro.com/web-services/meteo-data/merra>

Hence, vulnerability level of a region is the extent of potential impact over adaptive capacity of that region or production system (Sendhil *et al.*, 2018).

$$\mathbf{Vulnerability = Potential Impact - Adaptive Capacity} \quad (2)$$

where,

$$\mathbf{Potential Impact = Exposure + Sensitivity} \quad (3)$$

3.1.4. Steps in vulnerability assessment

The following steps have been used to construct the district level socio-economic vulnerability index to climate change.

3.1.4.1. Identification of suitable indicators

Selection of indicators is of utmost importance for any study on vulnerability assessment. Hence, much care has been taken into consideration to finalize the variables under each indicator by thorough review of published literature and discussion with experts to give the *apriori* functional relationship (see Tables 3.2-3.4).

3.1.4.1.1. Indicators on exposure and functional relationship

Table 3.2 depicts the exposure indicator variables and their functional relationship. The explanation for selected indicator variables is given in the following section.

a) Trend analysis for climatic variables

For the trend analysis, non-parametric Mann-Kendall's test (Mann, 1945; Kendall, 1976) has been performed for climate variables. This test, as a robust statistical method, has been mostly used for studying the spatial variation and temporal trends of climatic time series (Yue and Wang, 2004; Tabari *et al.*, 2011; Mondal *et al.*, 2012; Yadav *et al.*, 2014; Vijayasarithy, 2015). Coefficient of trend in daily average temperature, relative humidity and rainfall of *kharif* (July to October), *rabi* (November to February) and summer (March to June) seasons have been calculated for the 30 years period ranging from 1991 to 2020. Apparently, the climate indicators show a positive functional relationship with the exposure (Sendhil *et al.*, 2018). If the coefficients of selected variables increase, the exposure of the region to vulnerability increases, and *vice-versa*.

b) Drought return periods for a certain precipitation deficit (compared to a normal situation)

Drought is the reduction of natural water resources due to deficiency of rainfall for prolonged period (Zhang *et al.*, 2012). The IMD defines drought as a period of year or season when the deficiency of rainfall is more than 25 per cent of the corresponding mean. Based on per centage departure from the mean, the seasonal drought can be classified as moderate, severe and extreme.

Table 3.1 Classification of drought based on the per centage departure of rainfall from mean.

Rainfall departure from mean (%)	Category of drought
< - 25 to – 45	Moderate
< - 45 to – 60	Severe
< - 60 or less	Extreme

Source: Pandey *et al.* (2008)

The average return period of drought is calculated by the following equation (Amrit *et al.*, 2018),

$$R = \frac{N}{n} \tag{4}$$

Where,

R is the average return period of drought.

N is the total number of years used for data analysis.

n is the total number of years with rainfall deficit of more than 25 per cent.

Mathematically, the return period (R) is the reciprocal of frequency (F),

$$i.e., F = \frac{1}{R} \tag{5}$$

Similarly, the return period of severe and extreme drought events has been calculated as the total number of years of rainfall record analysed divided by number of severe and extreme drought events respectively in each district (Amrit *et al.*, 2018). For example, if the return period is of 5 years for a precipitation deficit of 20 per cent, it means that there is a precipitation deficit (expected) of 20 per cent for every five years.

Table 3.2 Exposure indicators and their functional relationship.

S.No.	Exposure	Relationship with component
1	Trend in <i>kharif</i> rainfall (Coefficient of trend)	+
2	Trend in <i>rabi</i> rainfall (Coefficient of trend)	+
3	Trend in <i>summer</i> rainfall (Coefficient of trend)	+
4	Trend in <i>kharif</i> temperature (Coefficient of trend)	+
5	Trend in <i>rabi</i> temperature (Coefficient of trend)	+
6	Trend in <i>summer</i> temperature (Coefficient of trend)	+
7	Trend in <i>kharif</i> relative humidity (Coefficient of trend)	+
8	Trend in <i>rabi</i> relative humidity (Coefficient of trend)	+
9	Trend in <i>summer</i> relative humidity (Coefficient of trend)	+
10	Return period of moderate meteorological drought (No. of years)	-
11	Return period of severe meteorological drought (No. of years)	-
12	Return period of extreme meteorological drought (No. of years)	-
13	No. of consecutive two or more drought years (No. of years)	+
14	Return period of two years or more persistent droughts (No. of years)	-
15	No. of consecutive three or more drought years (No. of years)	+
16	Return period of three years or more persistent drought (No. of years)	-

Note: Selection of climatic variables (1-9): Ahsan and Warner (2014); Sendhil *et al.* (2015); Sendhil *et al.* (2016); Sendhil *et al.* (2018); Ayanlade (2018); Balaganesh *et al.* (2020), Selection of drought related variables (10-16): Amrit *et al.* (2018)

3.1.4.1.2. Indicators on sensitivity and functional relationship

Sensitivity indicator variables and their functional relationship have been explained in Table 3.3. Indicators like average size of operational holdings for small and marginal farmers; density of population; per centage of workers to the total population; per cent cropped area to the total area; per cent sown area to the total area; per cent area under non-agricultural use (Ahsan *et al.*, 2014; Malakar and Mishra, 2017; Balaganesh *et al.*, 2020; Singh, 2020) have a positive functional relationship with the sensitivity. If the value of these variables increases, then sensitivity increases and ultimately the socio-economic vulnerability increases. Also, indicators like per cent barren and uncultivable area; total irrigated area; total bovine population; ground water availability; farmers suicides (Brenkert and Malone, 2005;

Balaganesh *et al.*, 2020; Singh, 2020) show a negative functional relationship with the sensitivity. If the value of the aforementioned variables increases, sensitivity declines and finally decreases the vulnerability level. For district wise farmers suicide, value of two years data for the period 2018 and 2019 have been considered. If the number of farmers suicide increases in a district, it is expected to increase the overall sensitivity in the region.

a) Cropping intensity

Cropping intensity shows the number of crops being cultivated from the same part of land in an agricultural year. It is calculated by computing the ratio between gross cropped area and net sown area, expressed in per centage. This indicator has a negative functional relationship with the sensitivity. If the cropping intensity increases, sensitivity declines and finally vulnerability decreases. The formula for cropping intensity is as follows:

$$\text{Cropping intenisty} = \frac{\text{Gross cropped area}}{\text{Net sown area}} \times 100 \tag{6}$$

Table 3.3 Sensitivity indicators and their functional relationship.

S.No.	Sensitivity	Relationship with component
1	Average size of operational holdings for marginal farmers (%)	+
2	Average size of operational holdings for small farmers (%)	+
3	Density of population (Number of people per square mile)	+
4	Share of workers to the total population (%)	+
5	Share of cropped area to the total area (%)	+
6	Share of sown area to the total area (%)	+
7	Share of area under non-agricultural use (%)	+
8	Share of barren and uncultivable area in total cropped area (%)	-
9	Total irrigated area (Per ‘000 ha.)	-
10	Total bovine population (Per ‘000 ha.)	-
11	Ground water availability (max. mbgl)	-
12	Cropping intensity (%)	+
13	Farmers suicides (2018, 2019) (Number)	+

Note: Selection of variables, 1-2: Ahsan and Warner (2014), 3: Malakar and Mishra (2017), 5-9: Balaganesh *et al.* (2020); Singh (2020), 12: Balaganesh *et al.* (2020), 13: Brenkert and Malone (2005), and 4,10,11: Authors inclusion base on expert opinion.

3.1.4.1.3. Indicators on adaptive capacity and functional relationship

Indicator variables on adaptive capacity and their functional relationship have been explained in Table 3.4.

a) Simpson index of crop diversification

Simpson index of diversification (SID) has been used for calculating the district level crop diversification in Maharashtra (Shinde *et al.*, 2013; Vardan and Kumar, 2015; Mittal and Hariharan, 2016). Principal crops grown in the state like rice, jowar, bajra, wheat, tur, mung, urad, gram and other pulses, oilseeds, groundnut, sunflower, soybean, cotton, sugarcane, turmeric and vegetables have been considered to calculate the index.

Table 3.4 Adaptive capacity indicators and their functional relationship.

S.No.	Adaptive Capacity	Relationship with component
1	Share of area under forest (%)	+
2	Share of pasture and grazing land (%)	+
3	Literacy rate (%)	+
4	Total breedable bovine (Number per ha.)	+
5	Human development index (Index value)	+
6	Total milk production ('000 MT)	+
7	Per capita milk availability (grams/day)	+
8	Annual credit plan (crore)	+
9	<i>Antyodaya Anna Yojana</i> (AAY) food grain distribution (MT)	+
10	Number of fair price shops (Number per '000 KM)	+
11	Real gross domestic value added at constant prices (2011-12) (crore)	+
12	Proportion of households electrified per square km. (%)	+
13	District artificial insemination center (Number)	+
14	<i>Krishi Vigyan Kendra</i> (Number)	+
15	Simpson index of crop diversification (0 – 1)	+

Note: Selection of variables, 3: Brenkert and Malone (2005), 12: Ahsan. (2010), 15: Shinde *et al.* (2013); Vardan and Kumar (2015); Mittal and Hariharan (2016) and 1,2,4-11,14: Authors inclusion base on expert opinion.

If SID increases, adaptive capacity increases, hence the socio-economic vulnerability decreases.

$$SID = 1 - \sum_j \left(\frac{a_j}{GCA}\right)^2 \tag{7}$$

where,

- a_j represents the area under the j^{th} crop

- GCA represents the gross cropped area

b) Other indicators

Other indicators like per cent area under forest; per cent pasture and grazing land; literacy rate (Brenkert and Malone, 2005; Balaganesh *et al.*, 2020); total breedable bovine; human development index; total milk production; per capita milk availability; Annual credit plan; *Antyodaya Anna Yojana* (AAY) food grain distribution; number of fair price shops; real gross domestic value added (RGDVA) at constant prices (2011-12); per centage of households electrified per square km (Ahsan, 2010); number of district artificial insemination centers (Maiti *et al.*, 2015); number of *Krishi Vigyan Kendra* have positive functional relationship with the adaptive capacity. If coefficient of the variables increases, adaptive capacity increases. Hence, vulnerability declines.

3.1.4.2. Normalization

Normalization of the indicators is an important step while computation of the index in order to confirm that all the indicators are comparable owing to measurement on different scales (Anand and Sen, 1994; Vincent, 2004; Varadan and Kumar, 2015; Kale *et al.*, 2016; Mahida and Sendhil, 2017; Sendhil *et al.*, 2018; Mamrutha *et al.*, 2020; Balaganesh *et al.*, 2020; Mohan *et al.*, 2021).

Normalization of data was carried out following the procedure outlined by Mahida and Sendhil (2017). If the indicators having positive functional relationship with their respective index, then the normalization has been done with the following formula,

$$\text{Normalization} = \frac{(\text{Actual value} - \text{Minimum value})}{(\text{Maximum value} - \text{Minimum value})} \quad (8)$$

If negative functional relationship expected with the vulnerability, we used the following formula for normalization,

$$\text{Normalization} = \frac{(\text{Maximum value} - \text{Actual value})}{(\text{Maximum value} - \text{Minimum value})} \quad (9)$$

3.1.4.3. Assigning weights to the indicators

After performing normalization of the indicators, respective weights were assigned based on their level of contribution to the vulnerability. Mostly assigning equal weights, inverse of variance, expert opinion and principal component analysis (PCA) (Acharya *et al.*, 2021) are the commonly used methods. Each method has its own benefits and drawbacks (Varadan and

Kumar, 2015; Sendhil *et al.*, 2018; Balaganesh *et al.*, 2020). PCA is the most widely used technique for assigning the weights assuming the existence of linear relationship among variables (Ayyoob *et al.*, 2013; Kale *et al.*, 2016; Sendhil *et al.*, 2018; Balaganesh *et al.*, 2020; Mamrutha *et al.*, 2020). On that account, PCA tool has been used in the present study. The functional equation for the PCA is given as follows:

$$X_t = \Lambda_t F_t + e_t \quad (10)$$

where,

- X_t indicates the N -dimensional vector of variables influencing the vulnerability.
- Λ_t represents the $r \times 1$ common factor.
- F_t represents the factor loading.
- e_t represents the associated idiosyncratic error-term of order $N \times 1$.

The weights from the PCA were calculated from the following equation.

$$W_i = \sum |L_{ij}| E_j \quad (11)$$

where, W_i represents the weight of the i^{th} variable, E_j represents the Eigen value of the j^{th} factor, and L_{ij} represents the loading value of the i^{th} variable on j^{th} factor.

3.1.4.4. Socio-economic vulnerability index

Exposure, sensitivity and adaptive capacity indices were calculated separately by using their respective indicators along with their respective calculated weights in the following equation (Sendhil *et al.*, 2018; Balaganesh *et al.*, 2020).

$$Index_{District} = \frac{\sum_{i=1}^n X_i W_i}{\sum_{i=1}^n W_i} \quad (12)$$

where, X_i represents the normalized value of the i^{th} variable, and W_i is the weight of the i^{th} variable.

Finally, the SeVI was calculated as per the IPCC approach, using Eq. (1).

$$SeVI = (Exposure + Sensitivity) - Adaptive Capacity \quad (13)$$

3.1.4.5. Categorization of districts

After computation of the SeVI, 34 districts of Maharashtra were categorized as high, moderate and low using the 'mean \pm standard deviation' norm (Ayyoob *et al.*, 2013; Kale *et al.*, 2016; Sendhil *et al.*, 2018; Balaganesh *et al.*, 2020). The categorization is as follows:

- High = $SeVI > (Mean + 0.5 SD)$
- Moderate = $(Mean - 0.5 SD) < SeVI < (Mean + 0.5 SD)$
- Low = $SeVI < (Mean - 0.5 SD)$

3.1.4.6. Socio-economic vulnerability mapping of districts

Based on the aforementioned categorization, mapping was done for different districts in Maharashtra. The idea of mapping is to visually capture the regional socio-economic vulnerability as a cluster in the study region to draw relevant policy implications.

The techniques outlined above were used to determine the socio-economic vulnerability at the district level.

3.2. THE EXTENT OF VULNERABILITY IN FARM HOUSEHOLDS

3.2.1 Study area

According to the first objective, 34 districts of Maharashtra have been grouped into three categories: highly vulnerable, moderately vulnerable, and less vulnerable. One district was chosen at random from each vulnerable group of districts, accordingly three districts were selected out of 34 (Fig. 1.). Two blocks were chosen at random from each district, and a cluster of villages was chosen from each block. Cluster of villages in Parbhani block (Digras, Govindpur, Indevadi), in Gangakhed block (Anandwadi, Akoli, Belwadi), in Kudal (Mulde, Ambadpal, Tulsuli), in Vengurle (Bhogave, Vetore, Adeli) in Ahmednagar (Mathani, Ranjani, Dehere) and in Pathardi (Tisgaon, Nivdunge, Manikdaundi) were selected randomly.

3.2.2. Data sources

Considering the purpose, data availability, and previous studies, both primary and secondary data were collected for this investigation (Vincent, 2007; Fekete, 2009; Deressa *et al.*, 2009; Hahn *et al.*, 2009; Kale, 2013; Tesso *et al.*, 2012; Radhakrishnan *et al.*, 2017; Swami and Parthasarathy, 2020; Thorat and Sirohi 2018; Sendhil *et al.*, 2018; Kumar *et al.*, 2020). Primary data on farm households' socio-economic and demographic characteristics, including general information on land holding, irrigated area, area under cultivation, herd size, crop yield,

livestock production, drought losses, farm, dairy and revenue generated from other component (if added), crop insurance, credit facility, memberships in institutions, extension contact (agriculture and veterinary), and so on, were collected for the agricultural year 2020-21 using a well-structured interview schedule (Appendix I-XI). Secondary data on climatic variables like daily average rainfall, temperature, and relative humidity were obtained from the online web services of 'Solar Radiation Data (SoDa²) - Solar energy services for professionals' for a period of 30 years (1991 to 2020). For computing the farm household level socio-economic vulnerability, this study examined both primary and secondary data available on exposure, sensitivity, and adaptive capacity.

² <http://www.soda-pro.com/web-services/meteo-data/merra>

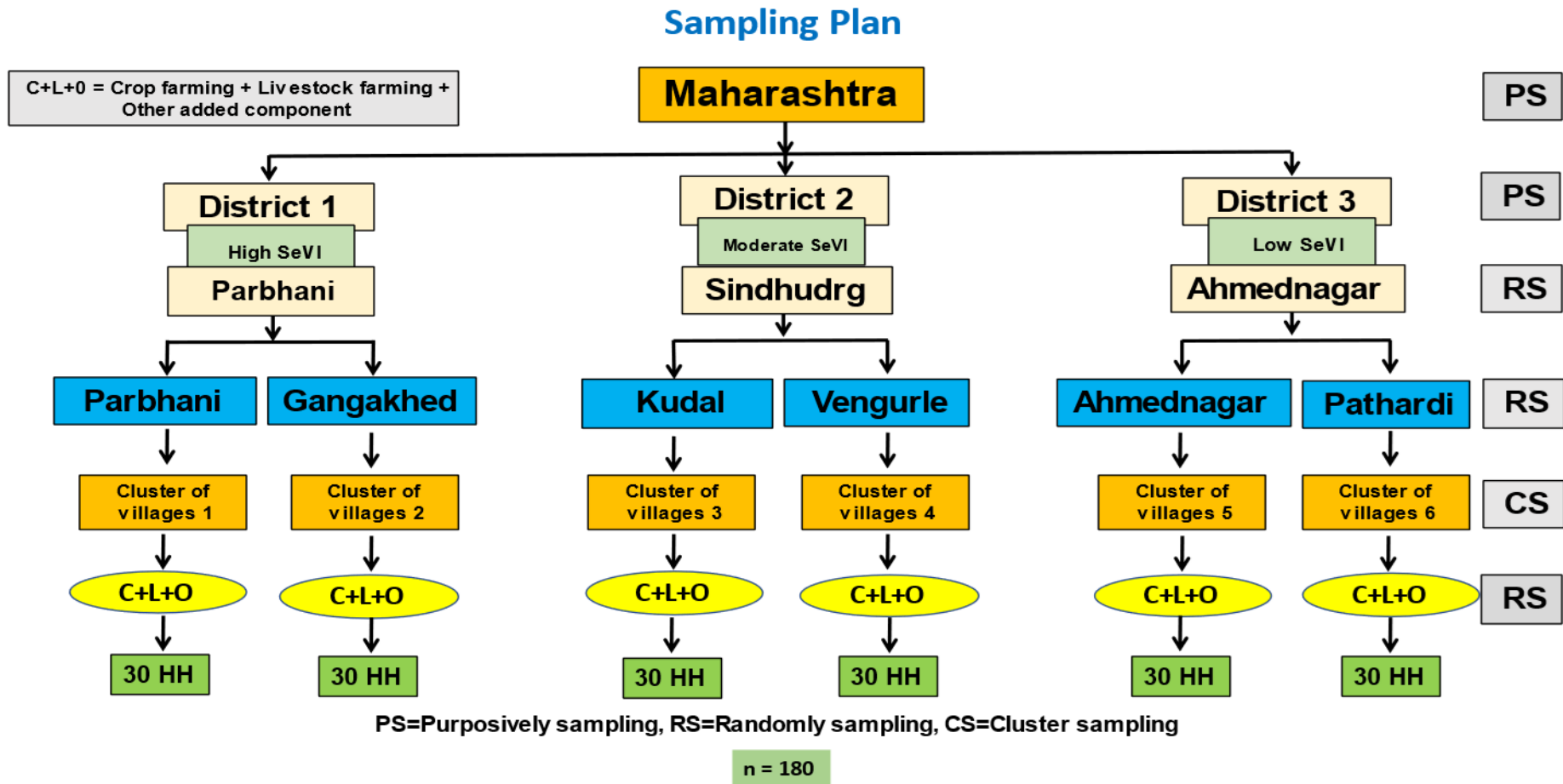


Fig. 3.1. Sampling Plan

3.2.3. Steps in farm household vulnerability assessment

The following steps were used to determine the socio-economic vulnerability index of farm households to climate change.

3.2.3.1. Identification of farm level socio-economic vulnerability indicators

The appropriate indicators for the assumed functional relationship, which is necessary for vulnerability assessment, were chosen after an in-depth review of relevant literature and expert opinion.

3.2.3.1.1. Exposure indicators and their functional relationship

For the farm households, 16 exposure indicator variables and their functional relationship were finalised (refer Table 3.5). These investigations were carried out with the help of block level meteorological data (30 years spanning from 1991 to 2020) for daily average rainfall, temperature and relative humidity. As a result, the indicators based on rainfall data varied from block to block within a district but were consistent across all farm households within a block; whereas the indicators on temperature were consistent throughout both blocks of a district, and even across all farm households within a block. Non-parametric Mann-Kendall's test (Mann, 1945; Kendall, 1976) was performed to estimate the trend values of climate factors such as daily average rainfall, relative humidity, and temperature. The analysis was done for the three seasons namely *khariif* (July to October), *rabi* (November to February) and summer (March to June). Primary data were collected for other variables such as nearest possible water resource in kilometres, inclusion of village in drought declared areas, number of droughts faced in the past ten years, number of hailstorms in the past 10 years, number of cold spells in the past 10 years, and number of cyclones in the past 10 years. The aforementioned indicators contributed positively to the exposure (Ahsan, 2010; Sendhil *et al.*, 2015; Sendhil *et al.*, 2016; Sendhil *et al.*, 2018; Ayanlade *et al.*, 2018; Balaganesh *et al.*, 2020). Indicator such as number of forests, reserves and grazing land within 10 km² area contributed negatively to the exposure. If the area under forests, reserves and grazing land increased in a specified area, it is expected that it would diminish the exposure to climate change.

Table 3.5 Exposure indicators and their functional relationship.

S.No.	Exposure	Relationship with component
1	Trend in <i>kharif</i> rainfall (Coefficient of trend)	+
2	Trend in <i>rabi</i> rainfall (Coefficient of trend)	+
3	Trend in <i>summer</i> rainfall (Coefficient of trend)	+
4	Trend in <i>kharif</i> temperature (Coefficient of trend)	+
5	Trend in <i>rabi</i> temperature (Coefficient of trend)	+
6	Trend in <i>summer</i> temperature (Coefficient of trend)	+
7	Trend in <i>kharif</i> relative humidity (Coefficient of trend)	+
8	Trend in <i>rabi</i> relative humidity (Coefficient of trend)	+
9	Trend in <i>summer</i> relative humidity (Coefficient of trend)	+
10	Nearest possible water resource (km)	+
11	Inclusion of village in drought declared areas (1-Yes / 0-No)	+
12	No. of droughts in the past 10 years (Number)	+
13	No. of forests, reserves and grazing land within 10 km^2 area (Number)	-
14	No. of hailstorms in the past 10 years (Number)	+
15	No. of cold spells in the past 10 years (Number)	+
16	No. of cyclones in the past 10 years (Number)	+

Note: Selection of the variables: 1-9: Ahsan (2010); Sendhil *et al.* (2015); Sendhil *et al.* (2016); Sendhil *et al.* (2018); Ayanlade (2018); Balaganesh *et al.* (2020), 10-12: Authors inclusion based on expert opinion, 13: Pandey and Jha (2012); Gerlitz *et al.* (2017), 14-16: Ahsan and Warner (2014)

3.2.3.1.2. Sensitivity indicators and their functional relationship

Fifteen sensitivity indicator variables and their functional relationship to sensitivity are shown in Table 3.6. Primary data on family details, physical assets, natural assets, losses due to drought and natural calamities, land holdings, livestock details were obtained from 180 families across three districts (60 in each district). Indicators like type of house - calculated from ordinal value of 0-5, where 0 indicating kutcha house, while 5 depicting Bungalow - (Ahsan and Warner, 2014; Sherly *et al.*, 2015), easy access to electricity, nature of roads (paved/not paved) (Sherly *et al.*, 2015), and easy access to the drinking water resources (Sherly *et al.*, 2015) contributes negatively to the sensitivity. As values of above variables increased it reduced the

level of sensitivity. Variables like dependence on natural resources, consumption expenditure on food, family members with chronic illness (Malakar and Mishra, 2017), loss of family members and livestock due to drought, loss of land due to natural calamities, total operational holdings (Pandey and Jha, 2012), households under below poverty line, family size (Sherly *et al.*, 2015), and unemployed households (Ahsan and Warner, 2014) positively affected the sensitivity. As the value of above variables increased, sensitivity is expected to increase and *vice-versa*.

Table 3.6 Sensitivity indicators and their functional relationship.

S.No.	Sensitivity	Relationship with component
1	Household type (Kutch=0; Pucca=1; Semi pucca=2; Roof-tiled=3; Thatched=4; Bungalow=5)	-
2	Depending on natural resources (1-Yes / 0-No)	+
3	Total consumption expenditure on food (₹/month)	+
4	Easy access to electricity (1-Yes / 0-No)	-
5	Family members with chronic illness (Number)	+
6	Nature of roads (Paved=1/Not paved=0)	-
7	Loss of family member due to drought (Number)	+
8	Loss of livestock due to drought (Number)	+
9	Loss of land due to natural calamities (acre)	+
10	Total operational holdings (acre)	+
11	BPL Households (Number)	+
12	Family size (Number)	+
13	Unemployed household (Number)	+
14	Per cent irrigated area (acre)	-
15	Easy access to the drinking water resources (1-Yes / 0-No)	-

Note: Selection of the variables: 1- Ahsan and Warner (2014); Sherly *et al.* (2015), 2-4,7-9,11,14: Authors inclusion based on expert opinion, 5- Malakar and Mishra (2017), 6- Sherly *et al.* (2015), 10- Pandey and Jha, (2012), 12- Sherly *et al.* (2015), 13- Ahsan and Warner (2014), 15- Sherly *et al.* (2015).

3.2.3.1.3. Adaptive capacity indicators and their functional relationship

Table 3.7 presents the indicators on adaptive capacity and their functional relationship. For sources of climate variability related information, 11 different sources were identified and the frequency was calculated for each household. Other variables included in the adaptive capacity were easy access to credit, group credit facility (Malakar and Mishra, 2017), inclusion in government crop insurance scheme, number of animals insured, number of animals registered for feed camp, number of visits by the veterinary doctor, average farm size, average herd size, area under crop insurance (Malakar and Mishra, 2017), total milk production (Ayanlade *et al.*, 2018; Balaganesh *et al.*, 2020), monthly gross income, number of employed persons in a household (Malakar and Mishra, 2017), farming experience in years, number of trainings attended, and social participation. Also, education level of the household head was considered using a scale from 0 to 6 (Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6).

Table 3.7 Adaptive capacity indicators and their functional relationship.

S.No.	Adaptive Capacity	Relationship with component
1	Sources of climate variability related information (Frequency)	+
2	Easy access to credit (1-Yes / 0-No)	+
3	Enjoying group credit facility (1-Yes / 0-No)	+
4	Applied for any gov. crop insurance scheme (1-Yes / 0-No)	+
5	Animals insured (Number)	+
6	Animals registered for feed camp (Number)	+
7	No. of visits of veterinary doctor (within 15 days)	+
8	Average farm size (acre)	+
9	Average herd size (acre)	+
10	Total area under crop insurance (acre)	+
11	Total milk production in (lit/month)	+
12	Monthly gross income (Rupees/month)	+
13	Employed household (Number)	+
14	Farming experience (No. of years)	+
15	Trainings attended (Number)	+
16	Social participation (1-Yes / 0-No)	+
17	Education level of the household head (Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6)	+

Note: Selection of the variables:1,4-7,12,14: Authors inclusion based on expert opinion,2,3,8,9,10,17: Malakar and Mishra (2017), 11- Ayanlade *et al.* (2018); Balaganesh *et al.* (2020)

If the values of the above listed variable increases, the adaptive capacity increases, as it has a positive functional relationship with the adaptive capacity (Malakar and Mishra, 2017; Sendhil *et al.*, 2018; Ayanlade *et al.*, 2018; Balaganesh *et al.*, 2020).

For the computation of farm household level SeVI, the procedure outlined in section 3.1.4, 3.1.4.2, 3.1.4.3 and 3.1.4.4. was performed.

3.2.4. Regression tree analysis of district level and farm household-level SeVI

Morgan and Sonquist (1963) proposed the regression tree analysis as a method for analysing the survey data that does not impose any restrictions on interactive effects and is independent of the order in which explanatory variables appear in the model. In order to classify the socio-economic variables that influence the SeVI, regression tree analysis – a non-parametric approach – was used. The strategy, which uses a variance-minimizing algorithm, makes it easier to identify the underlying characteristics that are more closely linked to the SeVI. Based on the stated partition criteria, *i.e.*, the dependent variable (SeVI in our case), the regression tree model gradually partitions the data into sub-groups in order to find the increasing homogeneity. By constructing the most homogeneous nodes feasible, the dependent data is separated into a series of descending left and right child nodes produced from the parent nodes (Larsen and Spekman, 2004). When the independent variables supply no further information, the procedure comes to a halt. Terminal nodes indicates the end of the tree construction and it may be justified statistically (Cak *et al.*, 2013; Riar *et al.*, 2020; Sendhil *et al.*, 2020). The following is the functional framework:

$$Y_i = f(X_1, X_2, \dots, X_n)$$

Y_i refers to the SeVI in this study, and X_i variables are socio-economic variables that were used to create the composite SeVI at the district or household level.

3.3. THE LEVEL OF ADOPTION AND DETERMINANTS OF COPING STRATEGIES PRACTICED ACROSS VULNERABLE REGIONS

3.3.1. Data source

To estimate the probability and intensity of adoption, primary data were collected regarding the adaptation and mitigation techniques pre-listed from literature review and discussion with the local experts used in crop farming, livestock farming, as well as ‘other’ category, to seek an understanding on the decision of the farm households’ adaptation strategies towards climate

change (Tewksbury, 2009). Data were collected through face-to-face interview of the farm households to probe their choice of the climate change adaptation strategies (Thinda *et al.*, 2020).

3.3.2. Extent of adoption or intensity of adoption

The intensity of adoption for different categories (crop, livestock and others) is given as:

For crop farming,

$$A = \frac{\sum_{i=1}^n \frac{Ci}{N1}}{n} \dots\dots\dots (14)$$

Where,

- A is the intensity of adoption of coping strategies by a farmer in crop farming
- Ci is the area under *ith* coping strategy (i =1,2,...,n)
- n is total number of coping strategies selected in crop farming
- N1 is the total operational holdings

For livestock,

$$B = \frac{\sum_{j=1}^m \frac{Dj}{N2}}{m} \dots\dots\dots (15)$$

Where,

- B is the intensity of adoption of coping strategies by a farmer in livestock farming
- Dj is the number of animals under *jth* coping strategy (i =1,2,...,m)
- m is the total number of coping strategies selected in livestock farming
- N2 is the herd size

For ‘other’ category,

$$C = \frac{\sum_{k=1}^p \frac{Ek}{N3}}{p} \dots\dots\dots (16)$$

Where,

- C is the intensity of adoption of coping strategies by a farmer in ‘other’ component
- Ek is the number of units under *kth* coping strategy (i =1,2,...,p)
- p is the total number of coping strategies selected in ‘other’ component
- N3 is the size of other component (if available)

Overall intensity,

$$G = \left(\frac{A+B+C}{3} \right) * 100 \dots\dots\dots (17)$$

Where, G is the overall intensity of adoption (%) for a particular farmer. If the intensity of adoption (G) is greater than its mean value, the particular farmer will be designated as a high-level adopter, otherwise low-level adopter.

3.3.3. Determinants of coping strategies to climate change

The decision to adopt a climate change adaptation strategy is a discrete outcome: either a farmer adopts a strategy or not. Farm households make decisions to cope with the climate change, while their preferences are influenced by various factors (Thinda *et al.*, 2020). Adoption of coping strategies to climate change generally entails a two-part decision-making process: whether to adopt? and then how much to adopt?. These two choices can be made together or separately (Gebremedhin and Swinton, 2003). The double-hurdle model, introduced by Cragg (1971), embodies the idea of the farm households’ decision on the extent of participation in an activity is the result of two processes: the first hurdle (decision to adopt) and the second hurdle (intensity of adoption) (Engel and Moffatt, 2014).

The double hurdle model is expressed as:

$$d_i^* = z_i' \alpha + \sum i \dots\dots\dots (18)$$

$$d_i = 1 \text{ if } d_i^* > 0 \text{ and if } d_i^* \leq 0 \dots \text{ First hurdle (decision to adopt)}$$

$$y_i = x_i \beta + \mu_i$$

$$y_i = y_i^* > 0 \text{ and if } d_i^* > 0$$

$$y_i = 0 \text{ otherwise} \dots \text{ Second hurdle (intensity of adoption)}$$

Where,

- d_i^* is the latent variable that defines the household decision to adopt.
- d_i is the observed household decision to adopt and takes a value of 1 if the farmer adopts the coping strategy and 0 otherwise.
- y_i^* is the latent variable describing the intensity of adoption
- y_i is the observed response on intensity of adoption
- z and x are the vectors of variables explaining the decision to adopt and intensity of use respectively, which are permitted to overlap.
- Variables like age, education of household head, farm size, herd size, monthly

gross income, number of family members employed in farming, access to credit, number of sources of climate variability related information, number of droughts in the past 10 years, social participation and trend in annual rainfall have been considered for analysis.

- α and β are the vectors of the parameters
- e_i and μ_i are the error-terms with mean '0' and variance '1'.



Chapter-4



Results and Discussion

RESULTS AND DISCUSSION

The discussion of the analysis as per the proposed objectives of the research and the findings are presented in this chapter under various headings.

4.1. The degree of regional socio-economic vulnerability

4.2. The extent of vulnerability in farm households

4.3. Adoption and determinants of coping strategies practiced across vulnerable regions

4.1. THE DEGREE OF REGIONAL SOCIO-ECONOMIC VULNERABILITY

In pursuit of this objective, a new socio-economic vulnerability index (SeVI) was developed, which included climate, crop, livestock, social and economic indicators for 34 districts in Maharashtra, India, followed by district-level mapping of climate change-induced socio-economic vulnerability in the study area.

4.1.1. Exposure

Exposure index for 34 districts of Maharashtra was computed using climatic variables like average daily temperature, rainfall, relative humidity and drought return period (Table 4.4). Sangali experienced the highest exposure (0.62) to climate change and lowest by Wardha (0.38) with a mean index score of 0.50 and SD of 0.06. A less divergence (difference between the maximum and minimum index value) of 0.24 has been observed in exposure among districts. Twelve districts namely Pune, Beed, Gadchiroli, Nashik, Palghar, Satara, Ahmednagar, Kolhapur, Sindhudurg, Nandurbar, Ratnagiri and Sangali were categorized under high exposure; thirteen districts such as Amaravati, Parbhani, Nagpur, Nanded, Jalna, Solapur, Raigad, Chandrapur, Gondia, Bhandara, Buldhana, Aurangabad and Thane were categorized in moderate exposure; nine districts such as Wardha, Washim, Osmanabad, Akola, Yavatmal, Latur, Hingoli, Jalgaon and Dhule were found under low exposure to climate change. Eight districts under high exposure are from the Central Maharashtra Plateau Zone, only one district (Nandurbar) is under Western Maharashtra Plain Zone. This may be due to high consistent temperature and rainfall changes (Balaganesh *et al.*, 2020) and lower number of drought return periods (Amrit *et al.*, 2018) in the given zone. The highest weightage was observed for the coefficient of trend in *kharif* temperature (5.75), which is an important indicator for the socio-economic vulnerability. The lowest weight was found in return period of two years or more persistent droughts (2.85), suggesting a very less possibility of frequent drought occurrence and hence reduces the socio-economic vulnerability.

Table 4.1a: Estimates of indicators used in the construction of exposure index in different districts of Maharashtra.

District	Coefficient of Trend [Units: Rainfall: Millimetres (mm), Temperature: Kelvin (K), Relative Humidity: Per centage (%)]								
	<i>Kharif</i> rainfall	<i>Kharif</i> temperature	<i>Kharif</i> RH	<i>Rabi</i> rainfall	<i>Rabi</i> temperature	<i>Rabi</i> RH	<i>Summer</i> rainfall	<i>Summer</i> temperature	<i>Summer</i> RH
Ahmednagar	105.88	-0.01	-0.12	1.06	0.02	-0.14	275.39	-0.02	0.32
Akola	60.24	-0.02	-0.09	1.07	0.03	-0.14	204.86	-0.01	0.27
Amravati	57.89	-0.03	-0.09	3.68	0.03	-0.13	188.28	-0.01	0.27
Aurangabad	81.93	-0.02	-0.07	1.30	0.02	-0.14	18.64	-0.02	0.29
Beed	89.61	-0.02	-0.04	1.98	0.03	-0.15	233.83	-0.02	0.29
Bhandara	63.82	-0.03	-0.08	8.31	0.03	-0.14	194.20	-0.01	0.26
Buldhana	67.68	-0.02	-0.09	1.71	0.02	-0.14	223.73	-0.01	0.28
Chandrapur	65.43	-0.03	-0.06	7.33	0.03	-0.15	189.27	-0.02	0.25
Dhule	67.09	-0.02	-0.07	1.07	0.02	-0.12	221.86	-0.01	0.19
Gadchiroli	101.10	-0.02	-0.07	8.39	0.03	-0.14	261.41	-0.02	0.25
Gondia	59.80	-0.03	-0.09	9.09	0.03	-0.12	203.20	-0.01	0.26
Hingoli	80.42	-0.03	-0.06	3.75	0.03	-0.15	229.79	-0.02	0.27
Jalgaon	49.57	-0.02	-0.11	1.28	0.02	-0.13	194.53	-0.01	0.28
Jalna	77.66	-0.02	-0.07	1.65	0.03	-0.15	254.41	-0.02	0.28
Kolhapur	189.00	0.00	-0.07	1.33	0.02	-0.14	565.95	-0.03	0.29
Latur	103.41	-0.02	-0.02	3.39	-2.23	-0.16	219.28	-0.02	0.28
Nagpur	62.50	-0.03	-0.08	7.39	0.03	-0.14	175.98	-0.01	0.25
Nanded	91.75	-0.03	-0.04	4.09	0.03	-0.15	215.89	-0.02	0.27
Nandurbar	55.35	-0.01	-0.10	1.08	0.01	-0.10	219.79	-0.01	0.27
Nashik	112.42	-0.01	-0.14	1.62	0.02	-0.12	499.72	-0.02	0.28
Osmanabad	102.85	-0.02	-0.03	2.70	0.03	-0.16	230.10	-0.03	0.28
Palghar	68.08	0.00	-0.10	1.07	0.00	-0.03	460.48	0.00	0.21
Parbhani	95.47	-0.02	-0.04	2.95	0.03	-0.16	229.23	-0.02	0.28
Pune	149.42	-0.01	-0.08	1.42	0.02	-0.14	560.16	-0.02	0.29
Raigad	104.44	0.00	-0.10	0.86	0.01	-0.12	536.13	-0.01	0.16
Ratnagiri	180.88	0.00	-0.09	0.84	0.01	-0.05	569.42	-0.01	0.24
Sangli	174.27	0.00	-0.08	1.66	0.02	-0.14	448.93	-0.03	0.31
Satara	188.47	-0.01	-0.08	1.20	0.02	-0.15	572.15	-0.02	0.29
Sindhudurg	176.57	0.00	-0.07	0.78	0.01	-0.07	594.38	-0.01	0.15
Solhapur	114.15	-0.01	-0.08	2.20	0.03	-0.15	236.53	-0.03	0.31
Thane	82.93	0.00	-0.10	0.99	0.01	-0.08	492.85	-0.01	0.21
Wardha	56.77	-0.03	-0.07	7.12	0.03	-0.15	170.53	-0.01	0.24
Washim	70.23	-0.03	-0.07	3.49	0.03	-0.15	224.63	-0.01	0.27
Yavatmal	52.19	-0.03	-0.07	6.76	0.03	-0.15	181.60	-0.01	0.26

*Note** Daily average values of all the climate variables were considered for trend analysis. RH: Relative Humidity.

Table 4.1b: Estimates of indicators used in the construction of exposure index in different districts of Maharashtra.

District	Return period					No. of times consecutive drought years	
	Moderate meteorological drought (number of years)	Sever meteorological drought (number of years)	Extreme mete. drought (number of years)	2 years or more persistent droughts (number of years)	Three years or more persistent drought (number of years)	Two or more drought (number of years)	Three or more drought (number of years)
Ahmednagar	5	23	57	19	0	6	0
Akola	6	38	113	113	0	1	0
Amravati	6	57	0	38	0	3	0
Aurangabad	5	23	57	19	57	6	2
Beed	5	16	38	23	0	5	0
Bhandara	8	57	0	0	0	0	0
Buldhana	7	57	0	38	0	3	0
Chandrapur	7	0	0	0	0	0	0
Dhule	7	23	57	38	0	3	0
Gadchiroli	7	0	0	57	0	2	0
Gondia	8	57	0	57	0	2	0
Hingoli	6	38	113	38	0	3	0
Jalgaon	7	57	0	38	0	3	0
Jalna	6	19	0	57	0	2	0
Kolhapur	9	28	113	0	0	0	0
Latur	5	38	57	28	113	4	1
Nagpur	9	0	0	0	0	0	0
Nanded	6	38	0	28	113	4	1
Nandurbar	6	38	0	23	57	5	2
Nashik	8	57	0	57	0	2	0
Osmanabad	6	38	113	57	113	2	1
Palghar	8	28	113	28	0	3	0
Parbhani	6	38	113	38	0	3	0
Pune	7	38	113	57	57	2	2
Raigad	9	38	57	57	0	2	0
Ratnagiri	9	38	57	113	0	1	0
Sangli	6	38	113	28	57	4	2
Satara	16	57	0	0	0	0	0
Sindhudurg	13	28	0	13	0	1	0
Solhapur	6	19	57	28	113	4	1
Thane	8	28	113	38	0	3	0
Wardha	8	57	113	113	0	1	0
Washim	8	28	113	113	0	1	0
Yavatmal	7	38	0	113	0	1	0

Source: Amrit et al. (2018)

Table 4.2: Estimates of indicators used in the construction of sensitivity index in different districts of Maharashtra.

District	Average size of operational holdings for marginal farmers (hectare)	Average size of operational holdings for small farmers (hectare)	Density of population (%)	Per centage of workers to the total population (%)	Per cent cropped area (hectare)	Per cent sown area (hectare)	Per cent area under non-agricultural use (hectare)	Per cent barren and uncultivable area (hectare)	Total irrigated area (hectare)	Total bovine population (number)	Ground water availability (max.mbgI)	Cropping intensity (%)	Farmers suicides 2018,2019 (number)
Ahmednagar	0.53	1.42	266	46	70.29	64.36	1.48	5.83	363600	1599658	18.9	91.57	25
Akola	0.7	1.44	320	39.8	96.51	81.65	2.58	1.50	28800	283050	30.9	84.60	0
Amravati	0.72	1.49	237	42	68.97	53.12	3.23	1.58	86500	594594	29	77.02	265
Aurangabad	0.58	1.45	366	40.6	77.37	63.84	9.75	0.98	132700	633002	18.3	82.52	129
Beed	0.51	1.36	242	44.3	72.72	63.83	3.13	4.39	222000	754808	16.5	87.77	226
Bhandara	0.49	1.37	294	47.3	66.45	46.09	9.28	2.13	116500	319897	11.6	69.35	0
Buldhana	0.62	1.44	268	45.5	77.55	58.95	4.28	4.29	51900	595677	25.1	76.01	271
Chandrapur	0.57	1.44	193	44.9	45.19	35.88	8.58	2.22	106500	459952	18.8	79.39	0
Dhule	0.61	1.43	285	53.6	55.70	44.54	1.96	6.31	58800	452203	21.7	79.96	23
Gadchiroli	0.56	1.42	74	51.2	13.20	9.88	4.43	1.24	60000	525730	15	74.83	0
Gondia	0.5	1.41	253	48.3	43.36	33.20	10.26	4.54	100900	385154	10.1	76.57	0
Hingoli	0.59	1.43	244	46.6	101.33	81.20	2.21	2.21	77400	306328	20.5	80.14	0
Jalgaon	0.62	1.45	360	42.5	83.72	68.47	2.53	4.68	152000	846407	55	81.79	22
Jalna	0.55	1.41	254	44.4	96.10	80.27	7.34	2.04	103200	504048	15.2	83.53	0
Kolhapur	0.36	1.39	504	46.9	74.89	59.21	4.67	5.49	152400	852521	10.7	79.06	0
Latur	0.62	1.41	343	40.4	92.69	79.19	2.55	1.40	68800	414695	38.4	85.44	0
Nagpur	0.66	1.45	470	37.8	59.31	47.61	8.85	3.41	128700	491030	20.9	80.27	25
Nanded	0.59	1.4	319	41.8	78.83	67.78	3.23	2.40	97000	738814	21.5	85.98	0
Nandurbar	0.68	1.34	277	73	59.36	50.94	2.09	7.31	41500	378271	31	85.81	0
Nashik	0.53	1.44	393	43.8	56.96	47.87	2.78	8.97	245300	1116284	21.5	84.04	83
Osmanabad	0.57	1.33	219	44	110.38	85.24	2.06	0.83	124900	550868	17.9	77.22	22
Palghar	0.37	1.35	1150	41.4	73.48	66.67	16.90	7.30	21800	308637	6.3	90.73	0
Parbhani	0.6	1.45	295	42.2	128.51	82.27	5.15	1.52	86400	398356	34.5	64.02	0
Pune	0.49	1.47	603	40.8	76.40	64.79	4.18	6.66	344800	1144893	14.3	84.80	15
Raigad	0.38	1.37	368	41.4	32.39	28.18	7.27	14.59	19700	239131	6.3	87.00	0
Ratnagiri	0.39	1.4	197	45	41.23	36.96	2.58	24.11	11400	276172	41	89.66	0
Sangli	0.43	1.37	329	47.2	79.73	60.59	4.64	4.45	177600	818754	11.5	75.99	0
Satara	0.42	1.34	287	46.6	66.37	50.96	2.72	8.88	223700	679332	16.5	76.79	0
Sindhudurg	0.32	1.32	163	46.6	32.00	31.23	4.11	23.41	21300	157254	15.8	97.60	0
Solhapur	0.57	1.49	290	45.3	70.64	67.80	1.06	4.27	261900	1241858	24.9	95.99	0
Thane	0.41	1.42	1157	39.1	41.09	37.28	9.45	4.08	21800	172043	36	90.73	0
Wardha	0.74	1.44	206	44.5	72.90	59.40	6.58	2.76	38100	322529	10.3	81.48	0
Washim	0.69	1.44	244	44.6	91.11	64.00	2.54	1.59	22800	221917	14	70.25	0
Yavatmal	0.7	1.47	204	45.5	67.88	56.04	4.62	3.58	106500	684497	14.7	82.55	286

Table 4.3: Estimates of indicators used in the construction of adaptive capacity index in different districts of Maharashtra.

District	Per cent area under forest (hectare)	Per cent pasture and grazing land (hectare)	Literacy rate (%)	Total Breedable Bovine (number)	HDI (0-1)	Total milk production ('000 MT)	Per capita milk availability (grams/day)	Annual credit plan (crores)	AAY Food grain distribution (2019-20) (million tonnes)	No. of Fair Price shops (number)	RGDVA at constant prices (2011-12) (crores)	Per centage of households electrified (per square km.)	District Artificial insemination centre (AIC) (number)	KVK (number)	Simpson index of crop diversification (SICD) (0-1)
Ahmednagar	9.63	2.57	79.05	934468	0.72	1480.7	874	11313	25757	1883	57439	55.26	0	2	0.53
Akola	4.73	3.21	88.05	110051	0.72	84.9	874	3438	12685	965	20765	73.13	0	1	0.7
Amravati	25.11	2.28	87.38	234618	0.72	132.4	123	4480	27109	1914	31417	50.50	5	2	0.77
Aurangabad	8.06	4.31	79.02	252876	0.73	184.3	130	7811	17252	1801	48873	70.14	4	2	0.63
Beed	2.01	2.86	76.99	303240	0.68	407.7	417	3463	7172	1964	21225	44.03	0	2	0.62
Bhandara	17.38	7.88	83.76	136543	0.72	109.6	248	1427	20149	893	12088	80.88	0	1	0.42
Buldhana	7.91	3.74	83.4	236749	0.68	176.9	182	3876	13460	1710	18985	57.41	0	2	0.74
Chandrapur	32.90	4.04	80.01	128960	0.72	84.1	104	2535	33772	1526	26842	56.49	0	1	0.71
Dhule	25.91	0.52	72.8	163741	0.67	156.7	202	2631	20695	981	21867	54.91	0	1	0.68
Gadchiroli	78.62	3.82	74.36	141263	0.61	42.9	107	618	23163	1195	7867	16.99	0	1	0.32
Gondia	44.41	17.16	84.95	130064	0.70	75	152	948	23916	998	12924	63.59	0	1	0.28
Hingoli	1.39	2.67	78.18	106172	0.65	63.6	143	2201	7614	796	8744	50.99	0	1	0.76
Jalgaon	13.23	4.15	78.2	358250	0.72	277.5	175	6455	39050	1933	43675	76.23	0	2	0.72
Jalna	0.85	2.55	71.52	163238	0.66	125.3	169	2853	11814	1279	17100	52.31	0	1	0.69
Kolhapur	18.23	4.09	81.51	547840	0.77	672.7	467	12869	16401	1572	62639	117.71	0	1	0.79
Latur	0.47	2.16	77.26	229469	0.66	176.9	191	5480	11576	1347	25205	54.46	4	1	0.71
Nagpur	16.06	5.57	88.39	195104	0.79	160.1	92	3447	35046	1961	90934	117.28	6	1	0.77
Nanded	8.80	3.66	75.45	294213	0.66	292.9	232	4319	21628	1720	32364	55.35	0	2	0.75
Nandurbar	65.32	1.39	64.38	116660	0.60	111.3	177	1434	20784	1061	11820	41.07	0	1	0.69
Nashik	20.05	2.67	82.31	486757	0.75	383.6	165	18000	48947	20609	88931	87.14	5	2	0.62
Osmanabad	0.55	2.25	78.44	271556	0.65	316.2	509	3122	8902	1074	14755	46.16	0	1	0.66
Palghar	61.81	8.61	83.44	102197	0.80	181.6	40	2919	28512	1082	266168	311.68	0	1	0.62
Parbhani	4.45	1.44	73.34	136135	0.68	157.1	225	3652	11185	1451	17268	55.17	0	1	0.75
Pune	10.98	4.19	86.15	694983	0.81	1110.4	306	60631	13931	2906	209808	160.83	5	2	0.59
Raigad	20.80	5.25	83.14	94329	0.76	65.6	66	4960	24861	1396	48030	94.25	0	1	0.55
Ratnagiri	0.72	3.41	82.18	94452	0.73	58.7	101	2939	11039	956	21519	63.50	0	1	0.68
Sangli	5.55	2.35	81.48	496766	0.74	526.8	503	7000	7319	1357	38811	70.40	0	1	0.68
Satara	13.12	7.06	82.87	401010	0.74	564.1	507	7800	8937	1656	39556	63.72	0	1	0.64
Sindhudurg	7.41	0.19	85.56	52931	0.75	45.8	148	2056	6414	430	11846	56.08	0	1	0.63
Solhapur	2.15	2.55	77.02	715810	0.73	527.8	328	9289	16861	1872	60140	59.13	0	2	0.44
Thane	34.56	4.81	84.53	84461	0.80	181.6	42	11500	14418	591	266168	348.53	0	1	0.62
Wardha	12.19	7.27	86.99	122395	0.72	95.6	200	2167	13960	848	16213	51.07	0	1	0.74
Washim	5.81	6.25	83.25	99227	0.65	89.1	217	1990	13164	871	9317	48.10	0	1	0.73
Yavatmal	16.70	4.59	82.82	250183	0.70	119.2	115	4064	35467	1881	24390	52.25	0	1	0.71

Note*HDI = Human Development Index, AAY= Antoyoday Anna Yojana (December 2000), RGDVA= Real gross domestic value added, KVK = Krishi Vigyan Kendra .

Table 4.4: Exposure, sensitivity, adaptive capacity and composite socio-economic vulnerability indices for the districts of Maharashtra.

S. No.	District	Exposure	Sensitivity	Adaptive Capacity	Composite SeVI
1	Ahmednagar	0.56 ^H	0.40 ^L	0.42 ^H	0.54 ^L
2	Akola	0.41 ^L	0.68 ^H	0.33 ^M	0.76 ^H
3	Amravati	0.47 ^M	0.61 ^H	0.31 ^L	0.76 ^H
4	Aurangabad	0.52 ^M	0.56 ^H	0.26 ^M	0.81 ^H
5	Beed	0.53 ^H	0.50 ^M	0.19 ^L	0.83 ^H
6	Bhandara	0.51 ^M	0.44 ^M	0.28 ^M	0.66 ^M
7	Buldhana	0.51 ^M	0.57 ^H	0.21 ^L	0.87 ^H
8	Chandrapur	0.50 ^M	0.45 ^M	0.30 ^M	0.65 ^M
9	Dhule	0.45 ^L	0.49 ^M	0.23 ^L	0.71 ^M
10	Gadchiroli	0.54 ^H	0.39 ^L	0.21 ^L	0.72 ^M
11	Gondia	0.51 ^M	0.43 ^L	0.31 ^M	0.62 ^M
12	Hingoli	0.44 ^L	0.57 ^H	0.20 ^L	0.81 ^H
13	Jalgaon	0.45 ^L	0.47 ^M	0.28 ^M	0.64 ^M
14	Jalna	0.48 ^M	0.54 ^H	0.20 ^L	0.83 ^H
15	Kolhapur	0.57 ^H	0.42 ^L	0.43 ^H	0.56 ^L
16	Latur	0.43 ^L	0.54 ^H	0.27 ^M	0.69 ^M
17	Nagpur	0.47 ^M	0.51 ^M	0.46 ^H	0.52 ^L
18	Nanded	0.47 ^M	0.50 ^M	0.20 ^L	0.77 ^H
19	Nandurbar	0.59 ^H	0.52 ^M	0.20 ^L	0.91 ^H
20	Nashik	0.55 ^H	0.41 ^L	0.45 ^H	0.50 ^L
21	Osmanabad	0.41 ^L	0.50 ^M	0.25 ^L	0.66 ^M
22	Palghar	0.55 ^H	0.52 ^M	0.50 ^H	0.57 ^L
23	Parbhani	0.47 ^M	0.55 ^H	0.22 ^L	0.80 ^H
24	Pune	0.53 ^H	0.44 ^M	0.56 ^H	0.41 ^L
25	Raigad	0.50 ^M	0.37 ^L	0.31 ^M	0.56 ^L
26	Ratnagiri	0.60 ^H	0.34 ^L	0.25 ^L	0.70 ^M
27	Sangali	0.62 ^H	0.41 ^L	0.35 ^H	0.68 ^M
28	Satara	0.56 ^H	0.35 ^L	0.37 ^H	0.54 ^L
29	Sindhudurg	0.58 ^H	0.33 ^L	0.24 ^L	0.66 ^M
30	Solapur	0.49 ^M	0.48 ^M	0.27 ^M	0.70 ^M
31	Thane	0.52 ^M	0.48 ^M	0.47 ^H	0.54 ^L
32	Wardha	0.38 ^L	0.59 ^H	0.29 ^M	0.68 ^M
33	Washim	0.40 ^L	0.57 ^H	0.24 ^L	0.73 ^H
34	Yavatmal	0.42 ^L	0.61 ^H	0.31 ^M	0.72 ^M
Mean		0.50	0.49	0.31	0.68
SD		0.06	0.08	0.10	0.11

Note: H = High, M = Moderate and L = Low; SD = Standard Deviation

4.1.2. Sensitivity

Sensitivity index for the 34 districts of Maharashtra (Table 4.4) showed that the highest sensitivity was registered in Akola (0.68) and lowest in Sindhudurg (0.33) with a mean index of 0.49 and SD of 0.08. A high divergence of 0.35 has been observed in sensitivity due to its varying range amongst the districts. About eleven districts were categorized as highly sensitive, thirteen districts as moderately sensitive and ten districts as low sensitive. Sensitivity was observed high in eleven districts such as Latur, Jalna, Parbhani, Aurangabad, Buldhana, Hingoli, Washim, Wardha, Yavatmal, Amaravati, Akola (Central Maharashtra Plateau Zone), Eastern and Western Vidarbha. A moderate level of vulnerability experienced in thirteen districts like Bhandara, Pune, Chandrapur, Jalgaon, Thane, Solapur, Dhule, Nanded, Beed, Osmanabad, Nagpur, Nandurbar and Palghar (Scarcity Zone, South and North Konkan Coastal Zone). It was lowest in ten districts such as Sindhudurg, Ratnagiri, Satara, Raigad, Gadchiroli, Ahmednagar, Nashik, Sangali, Kolhapur and Gondia (Scarcity Zone, Sub montane Zone). Higher sown area, higher share of small and marginal land holders to the total farmers, high sown area, and low groundwater level (Ahsan and Warner, 2014; Malakar and Mishra, 2017; Balaganesh *et al.*, 2020; Singh, 2020) have a positive relationship with the sensitivity. Despite having high irrigated area with high bovine population, some districts have not escaped from the sensitivity.

Table 4.5: Distribution of socio-economic parameters across vulnerability categories.

Category	Total cropped area ('000 hectare)	Total irrigated area (hectare)	Total bovine population (No.)	Average size of operational holdings for marginal farmers (acre)	Average size of operational holdings for small farmers (acre)	Farmers suicides (No.)
High	948.36 (39.94)	950200 (24.51)	5408865 (27.78)	6.83 (36.58)	15.46 (32.17)	891.00 (64.01)
Moderate	875.07 (36.85)	1405200 (36.24)	7455970 (38.30)	7.69 (41.19)	19.67 (40.94)	353.00 (25.36)
Low	551.17 (23.21)	1521800 (39.25)	6603529 (33.92)	4.15 (22.23)	12.92 (26.89)	148.00 (10.63)

Note: * Mumbai City and Mumbai Suburban districts are omitted from the analysis.

**For bovine population analysis, 20th Livestock Census-2019 data have been used.

Figures within parentheses indicate the per centage to respective total.

Districts like Beed, Nagpur and Aurangabad were having higher number of suicides (Brenkert and Malone, 2005) which is the main reason for higher sensitivity. Hence, a comprehensive measure is needed to mitigate the socio-economic vulnerability. The highest sensitivity

weightage (contribution to the index) was found in the case of per cent sown area (4.46) whereas, the lowest was observed in groundwater availability (2.69).

4.1.3. Adaptive capacity

Adaptive capacity index for the 34 districts of Maharashtra is presented in Table 4.4. The highest adaptive capacity was found in Pune (0.56), while the lowest was observed in Beed (0.19) with a mean index of 0.31 and SD of 0.10. Among the dimensions of SeVI, the highest divergence value (0.37) was observed in adaptive capacity. About nine districts were classified as highly adaptive to climate change, eleven districts as moderately adaptive and fourteen districts show low adaptive capacity. Highly adaptive districts are from the Western Ghat Zone, Western Maharashtra Plain Zone, and North Konkan Coastal Zone. The main reason for this may be high literacy rate, high rate of crop diversification, higher breedable population, higher milk yield, and high number of district artificial insemination centres (Shinde *et al.*, 2013; Maiti *et al.*, 2015; Vardan and Kumar, 2015; Mittal and Hariharan, 2016). Moderately and low adaptive districts are from the Central Maharashtra Plateau Zone, Eastern and Western Vidarbha Zones because of low rate of crop diversification, low per centage of electrified households, low literacy rate and low milk production (Brenkert and Malone, 2005; Balaganesh *et al.*, 2020). Total milk production registered the highest weightage (5.47) among the indicator variables, which increased the adaptive capacity of the farmers as it is an important risk reducing component in farming, while the lowest weightage was found in the case of SID (2.53).

4.1.4. Inter-index comparison of exposure, sensitivity and adaptive capacity

Adaptive capacity index was lower for all the districts than exposure and sensitivity index, with the exception of Pune (adaptive capacity = 0.58). Districts like Sangali has highest exposure, low sensitivity and high adaptive capacity. Hence categorized in moderate SeVI group. This implies that low sensitivity and high adaptive capacity play an important role in reducing the socio-economic vulnerability to climate change. Hingoli and Washim have low exposure, high sensitivity and low adaptive capacity indices. Hence both the districts represent high SeVI. Buldhana and Parbhani have moderate exposure but with high sensitivity and low adaptive capacity. Hence, these two districts represent high SeVI category. None of the districts show higher value of exposure and sensitivity than adaptive capacity. Critical evaluation of inter-index comparison showed that all the districts have low adaptive capacity comprising more

sensitivity and exposure implying that the study region is significantly vulnerable to climate change.

For instance, combining the information from SeVI mapping and Table 4.5, it is explicit that out of 34 districts, 11 were categorized as highly vulnerable (having 39.94% cropped area), 14 as moderately vulnerable (36.85% cropped area), and nine as low vulnerable to climate change (23.21% cropped area). Further, farmers' suicide, a crucial indicator for SeVI, is more in the highly vulnerable region of Maharashtra registering 64.01 per cent.

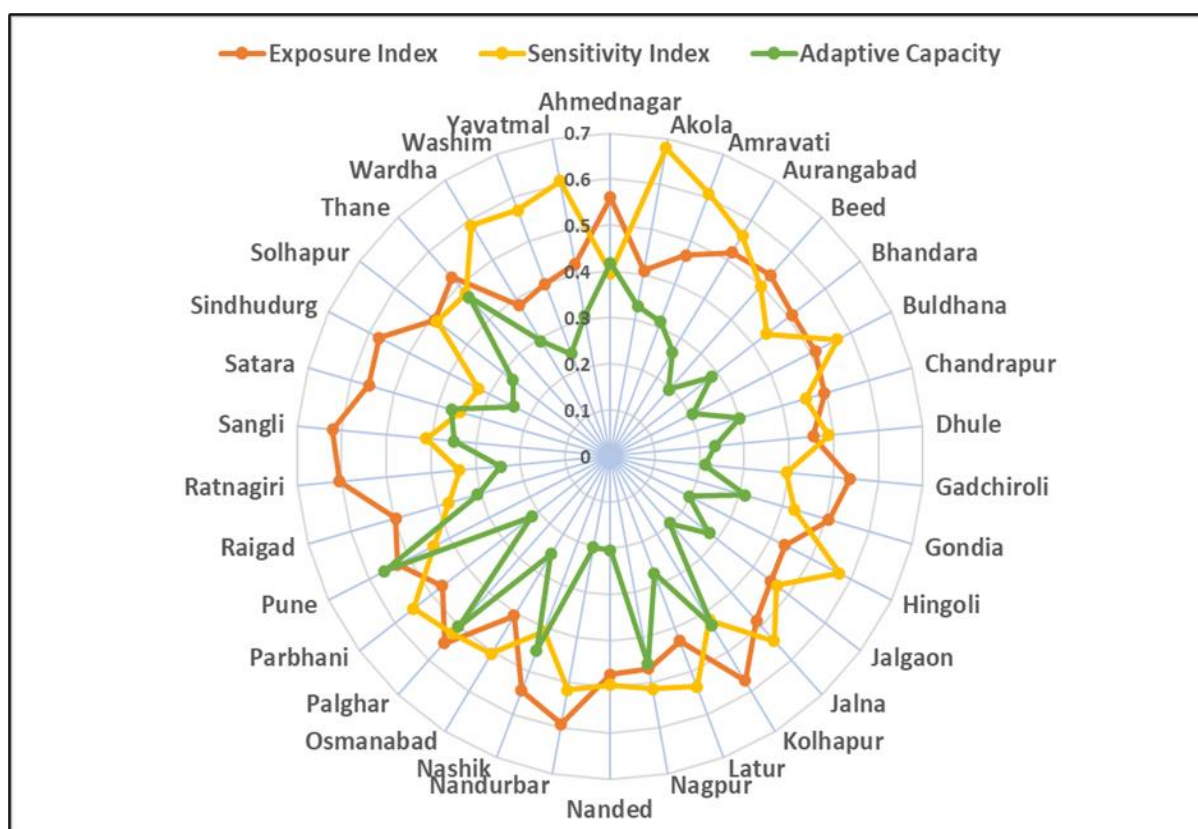


Fig. 4.1 Radar pictorial of exposure, sensitivity and adaptive capacity indices

4.1.5. Socio-economic vulnerability index (SeVI)

The SeVI was computed using exposure, sensitivity and adaptive capacity indices (Table 4.4). SeVI shows a wide divergence of 0.50 with a mean index of 0.68 and SD of 0.12. The composite index was highest in Nandurbar (0.91) and lowest in Pune (0.41). Results of district level vulnerability showed that out of thirty-four districts, eleven districts were categorized as highly vulnerable, fourteen as moderately vulnerable and 9 as low vulnerable to climate change. Most of the highly vulnerable districts are from the Central Maharashtra Plateau Zone. Moderately vulnerable districts are from the Central and Eastern Vidarbha Zone. Low vulnerable districts are from the North Konkan Coastal, Scarcity Zone and Western

Maharashtra Zone. Potential impact for each district was calculated using the sum of exposure and sensitivity (Eq.3.) that shows a mean score of 0.98, SD of 0.06 and low divergence value of 0.24. The highest potential impact was observed in Nandurbar ($0.59 + 0.52 = 1.11$), followed by Buldhana (1.08), Palghar (1.07), Sangali, Jalna, Beed (1.03), Parbhani (1.02) and Hingoli (1.01). Possible reason behind this may be the high values of trend coefficients for climatic variables (For e.g., coefficient of trend in *kharif* daily average temperature and rainfall is 3.07 K and 0.23 mm for Nandurbar) and persistent droughts prevailing in these districts. Lowest potential impact was found in Raigad ($0.53 + 0.44 = 0.87$). Reason behind this may be the high drought return period causing low potential impact that reduced the overall socio-economic vulnerability to climate change.

4.1.6. Mapping of districts

Based on categorization of districts (Table 4.6), the socio-economic vulnerability mapping was done for different districts (Figure 2). Maharashtra has been divided into nine agro-climatic zones based on rainfall, soil type and the vegetation as Central Maharashtra Plateau Zone, Central Vidarbha, Eastern Vidarbha Zone, North Konkan Coastal Zone, South Konkan Coastal Zone, Scarcity Zone, Sub Montane Zone, Western Ghat Zone, Western Maharashtra Plain Zone (NDDDB, 2015). Fig. 4.2. and Table 4.6 gives a clear picture of vulnerability across the state comprising agro-climatic zones. Table 4.6 presents the agro-climatic zone wise categorization of socio-economic vulnerability. Central Vidarbha Zone shares 6.78 per cent cropped area as highly vulnerable, 3.52 per cent area as moderately and 1.48 per cent as low vulnerable. Eastern Vidarbha Zone shares 4.39 per cent total cropped area under moderately vulnerable category. North Konkan Coastal Zone is having 2.85 per cent area as low vulnerable. South Konkan Coastal Zone covers 1.83 per cent area under moderately vulnerable category. Scarcity Zone shares 4.80 per cent of the total cropped area as highly vulnerable, 5.18 per cent area as moderately vulnerable and 3.42 per cent as low vulnerable. Sub Montane Zone shares 3.53 per cent of the total cropped area as moderately vulnerable and 3.34 per cent area as low vulnerable. In the Western Ghat Zone, moderately vulnerable districts share 3.29 per cent of the total cropped area, less vulnerable districts in this zone shares are 7.86 per cent area. Western Maharashtra Plain Zone, which is a great source of biodiversity in Maharashtra, shares 1.48 of the total cropped area as highly vulnerable, 5.73 and 3.34 per cent as moderate and low vulnerable to climate change.

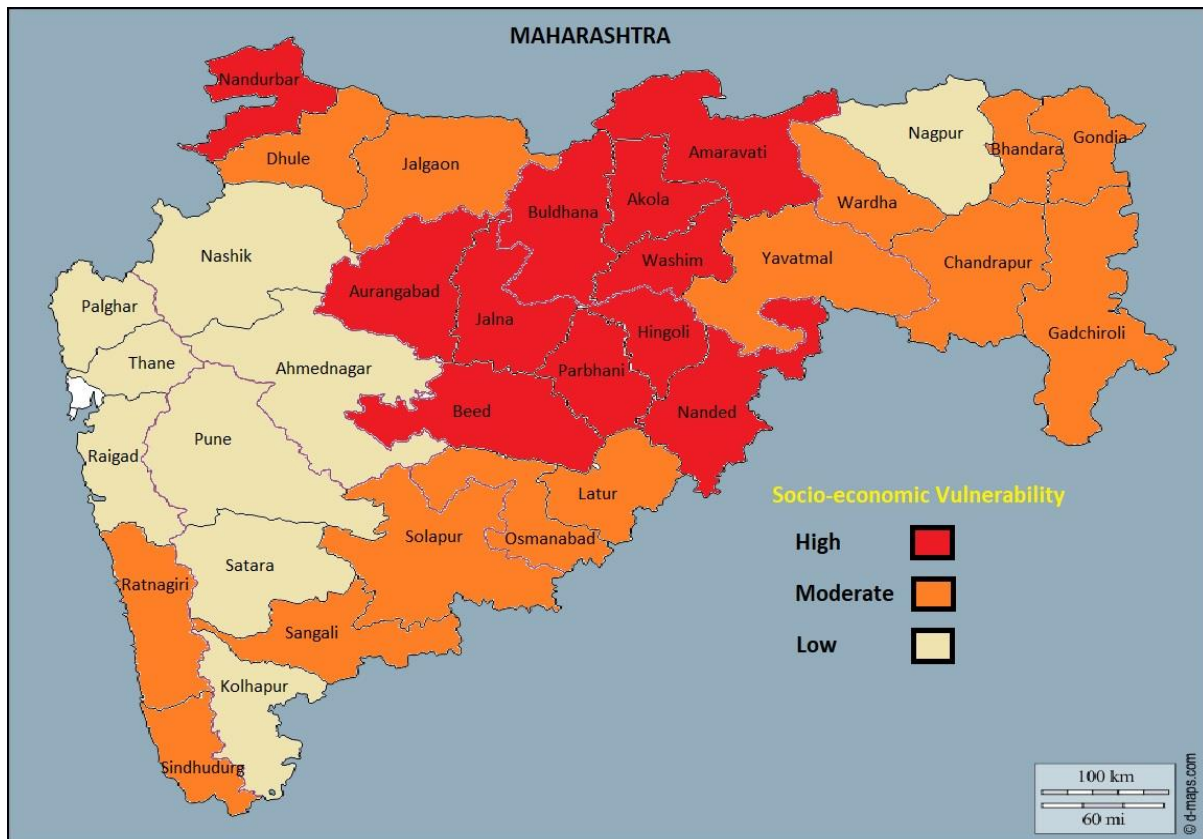


Fig. 4.2 Mapping of socio-economic vulnerability in Maharashtra.

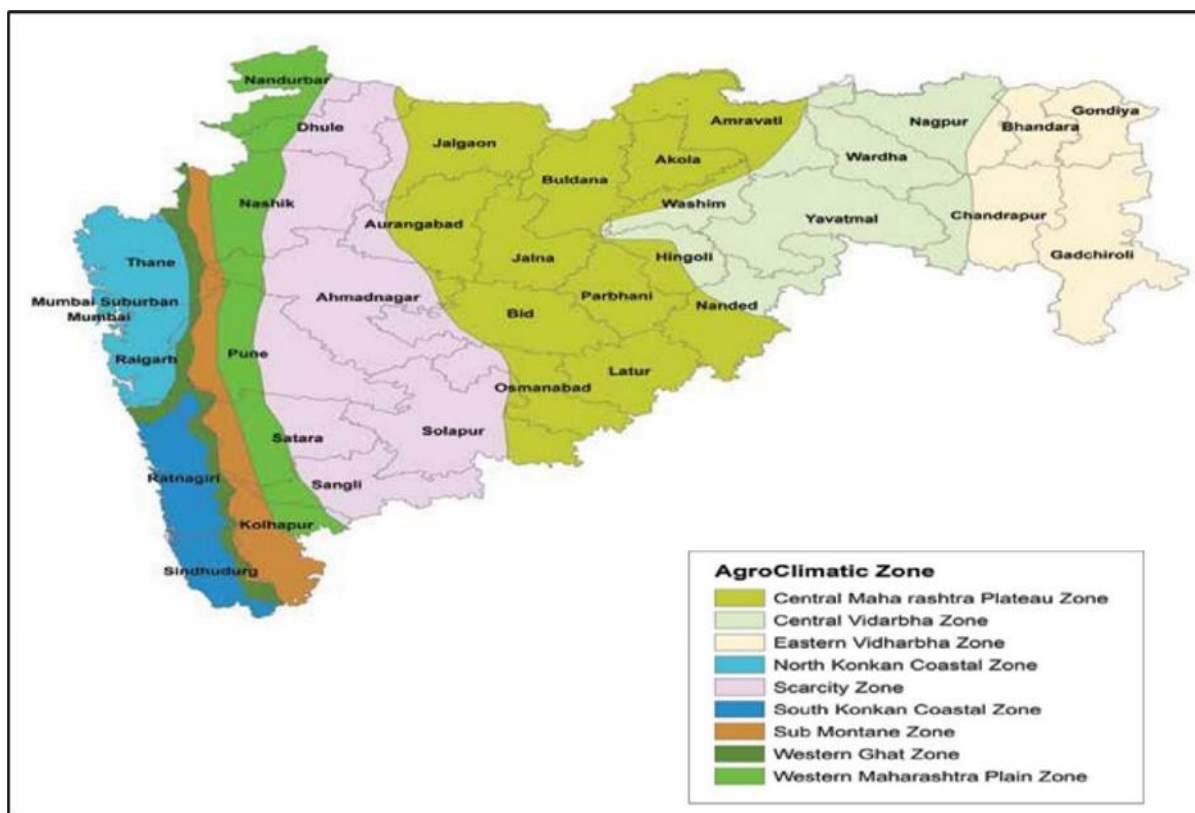


Fig.4.3 Agro-climatic zones in Maharashtra.

Source: Dairying in Maharashtra, A Statistical Profile, NDDB, 2015

Table 4.6: Agro-climatic zone wise classification of socio-economic vulnerability.

Agro-climatic zone	Categories of socio-economic vulnerability					
	High	% share of total cropped area	Moderate	% share of total cropped area	Low	% share of total cropped area
Central Maharashtra Plateau Zone	Aurangabad, Buldhana, Jalna, Beed, Parbhani, Nanded, Hingoli, Washim, Akola, Amaravati	22.22	Jalgaon, Osmanabad and Latur	7.17	-	-
Central Vidarbha	Part of Washim, Hingoli, Nanded	6.78	Wardha, Yavatmal	3.52	Nagpur	1.48
Eastern Vidarbha Zone	-	-	Bhandara, Gondia, Chandrapur, Gadchiroli	4.39	-	-
North Konkan Coastal Zone	-	-	-	-	Palghar, Thane, Raigad	2.85
South Konkan Coastal Zone	-	-	Ratnagiri, Sindhudurg	1.83	-	-
Scarcity Zone	Dhule, Part of Nandurbar and Aurangabad	4.80	Solapur, Part of Nashik, Sangali	5.18	Ahmednagar, Satara	3.42
Sub Montane Zone	-	-	Part of Satara and Kolhapur	3.53	Part of Nashik and Pune	3.34
Western Ghat Zone	-	-	Part of Kolhapur, Nashik	3.29	Part of Palghar, Thane, Raigad, Pune, Satara, Nashik	7.86
Western Maharashtra Plain Zone	Part of Nandurbar	1.48	Part of Satara, Sangali, Kolhapur	5.73	Part of Nashik, Pune	3.34

Note: *Mumbai and Mumbai Suburban, two districts from North Konkan Coastal Zone are omitted due to unavailability of farming data.

Most of the highly vulnerable districts are located in the Central Maharashtra Plateau, Central Vidarbha and Scarcity Zone. This is because these zones have high exposure and sensitivity compared to others and also low drought return periods causing threat to farming. Moderately vulnerable districts are found in every agro-climatic zone, with the exception of North Konkan Coastal Zone. This is because North Konkan Zone have high sensitivity but low adaptive capacity implying the scope for diversified farming in this area. There is not a single district found in Central Maharashtra and Eastern Vidarbha Zone under low vulnerable category. Mapping of districts showed that there is an instant need for focused policy efforts in the Central Maharashtra Plateau Zone, Scarcity Zone and Eastern Vidarbha Zone.

4.1.7. Regression tree analysis of district-level socio-economic vulnerability index

The regression tree (Morgan and Sonquist, 1963) was constructed (Fig.4.4) using SPSS (ver. 21) with the classification and regression tree (CRT) option, as its parent and child nodes fixed at 5 and 2 observations, respectively (minimum level). Total number of nodes observed were 15 and number of terminal nodes were eight. District level SeVI was selected as a dependant variable (Coirolo, 2013) and all other variables used to construct the SeVI were included as dependant variables for the analysis. Results revealed that the human development index (HDI) (McLaughlin and Cooper, 2010), return period from moderate meteorological drought, trend in *kharif* rainfall, per centage of workers to the total population, trend in summer rainfall were closely associated variables affecting the degree of socio-economic vulnerability (Kar and Das, 2015).

Table 4.7: Gain summary for nodes

Node	N	Per cent	Mean
13	2	5.9%	0.8880
14	4	11.8%	0.8178
9	3	8.8%	0.7779
11	3	8.8%	0.7357
8	3	8.8%	0.6914
5	2	5.9%	0.6723
10	9	26.5%	0.6560
6	8	23.5%	0.5242
Growing Method: CRT Dependent Variable: District-level SEVI			

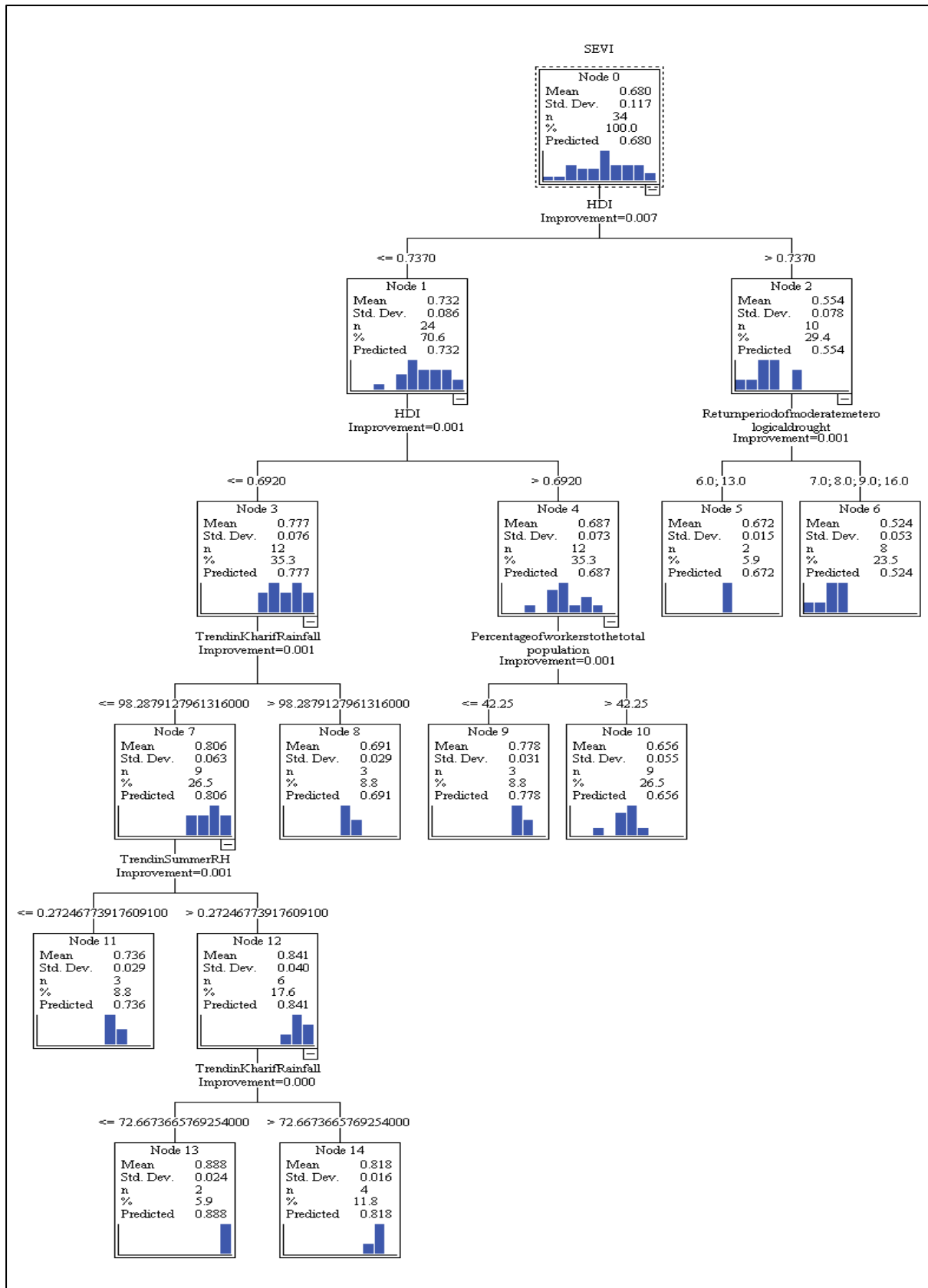


Fig. 4.4 Determinants of socio-economic vulnerability

4.2. THE EXTENT OF VULNERABILITY IN FARM HOUSEHOLDS

In order to address this research objective, a new composite farm household level socio-economic vulnerability index (SeVI) was constructed comprising climate, crop, livestock, and socio-economic indicators for rural farm households in the selected districts across vulnerability category.

4.2.1. Exposure of rural households to climate change

Exposure index is presented from Table 4.8 to 4.10. District wise summary statistics of exposure index for 180 households of Maharashtra is presented in Table 4.8. Sindhudurg registered the highest mean value of exposure index (0.51), followed by Parbhani (0.42), while lowest value was found in Ahmednagar (0.33). The overall mean value and SD were 0.42 and 0.08, respectively. The maximum exposure to climate change among the sample households was from Sindhudurg (0.51), whereas minimum exposure was observed in the households of Ahmednagar (0.33). A least divergence of 0.20 (subtracting the minimum index from the maximum) has been found in the exposure. From three exposure categories, high category has mean index value of 0.51, whereas moderate category has 0.42, while low exposure category has 0.33.

Every exposure category has a particular number of households, which is presented in Table 4.9. Out of 60 households of Parbhani, 11 households (18.33 %) were found in high exposure category, 29 households (48.33 %) in moderate exposure and 20 households (33.33 %) in low exposure category. From 60 households of Sindhudurg, 12 households (20.00 %) were found in high exposure category, 15 households (25.00 %) in moderate exposure and 33 households (55.00 %) in low exposure category. Out of 60 households of Ahmednagar, 15 households (25.00 %) were found in high exposure category, 34 households (56.67 %) in moderate exposure and 11 households (18.33 %) in low exposure category. In the pooled sample of 180 households, about 38 households (21.11 % of overall) were from high exposure category, while 78 households (43.33 % of overall) belong to moderate category, whereas the remaining 64 households (35.56 % of overall) came under low exposure category. It is explicit that, two-thirds (116) of the 180 households (64.44 %) in the Maharashtra study region were exposed to high to moderate levels of climate change, which is a major concern.

The probable reasons could be obtained from Table 4.10, which shows the contribution of different exposure indicators in selected districts. The highest weightage (under exposure indicators) was observed for the trend in *rabi* rainfall (3.38 mm), while the lowest was found

for the trend in number of cold spells in the past 10 years (1.10). The district wise mean values of trend in *kharif* rainfall (176.57 mm), trend in *summer* rainfall (594.38 mm), number of forests, reserves and grazing land within 10 km area (4.32), and number of cold spells in the past 10 years (1.58) for the Sindhudurg district were highest, followed by Parbhani and Ahmednagar. Also, trend in *rabi* relative humidity (-0.7 %) and trend in *summer* temperature (-0.01 K) were highest (negative trend) in Sindhudurg as compared to Parbhani and Ahmednagar. Highest positive increasing trend in daily average rainfall for *kharif* season was found in Sindhudurg (176.57 mm), followed by Ahmednagar (105.88 mm) and Parbhani (95.47 mm). This signifies that households in Sindhudurg are highly exposed to climate change as compared to other two districts. Surprisingly, trend in daily average rainfall for *rabi* season was highest in Parbhani (2.95 mm), followed by Ahmednagar (1.06 mm) and Sindhudurg (0.78 mm). Trend in daily average temperature for *rabi* season was highest in Parbhani (0.03 K), followed by Ahmednagar (0.02 K) and Sindhudurg (0.01 K). None of the villages in Sindhudurg were included in drought declared areas but in Parbhani and Ahmednagar, the average values of village inclusion were (1.00) and (0.92) respectively, as all households of Parbhani (60) and 55 households of Ahmednagar said that their village is included in drought-declared area list. The proximity to the nearest possible water resource is estimated to be 1.44 kilometres in Ahmednagar, followed by Sindhudurg (1.78 kilometres) and Parbhani (4.43 kilometres). Surprisingly, the number of droughts in the past 10 years was highest in Ahmednagar with total value of 214, followed by Parbhani (205) and Sindhudurg (89).

Table 4.8: District wise summary statistics of exposure, sensitivity, adaptive capacity and household vulnerability indices of Maharashtra.

District	Exposure		Sensitivity		Adaptive capacity		Farm household vulnerability	
	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Parbhani (SeVI: High) (n = 60)	0.42 (0.04)	0.37- 0.57	0.47 (0.06)	0.34- 0.62	0.17 (0.04)	0.10- 0.34	0.72 (0.08)	0.49- 0.90
Sindhudurg (SeVI: Moderate) (n = 60)	0.51 (0.01)	0.48- 0.53	0.27 (0.05)	0.08- 0.39	0.31 (0.04)	0.19- 0.40	0.46 (0.07)	0.31- 0.59
Ahmednagar (SeVI: Low) (n = 60)	0.33 (0.03)	0.24- 0.39	0.23 (0.05)	0.12- 0.31	0.44 (0.09)	0.33- 0.89	0.12 (0.12)	-0.42- 0.30
Overall (n = 180)	0.42 (0.08)	0.24- 0.57	0.42 (0.08)	0.24- 0.57	0.31 (0.21)	0.10- 0.89	0.43 (0.26)	-0.42- 0.90

Note: Figures within parentheses indicate standard deviation.

Table 4.9: Category wise number of households in exposure, sensitivity, adaptive capacity and household vulnerability indices in selected districts.

Particulars	Category	Districts			Overall (n 180)
		Parbhani (SeVI:High) (n = 60)	Sindhudurg (SeVI:Moderate) (n = 60)	Ahmednagar (SeVI:Low) (n = 60)	
Exposure	High	11 (18.33)	12 (20.00)	15 (25.00)	38 (21.11)
	Moderate	29 (48.33)	15 (25.00)	34 (56.67)	78 (43.33)
	Low	20 (33.33)	33 (55.00)	11 (18.33)	64 (35.56)
Sensitivity	High	15 (25.00)	17 (28.33)	17 (28.33)	49 (27.22)
	Moderate	20 (33.33)	23 (38.33)	21 (35.00)	64 (35.55)
	Low	25 (41.67)	20 (33.33)	22 (36.67)	67 (37.22)
Adaptive capacity	High	13 (21.67)	15 (25.00)	8 (13.33)	36 (20.00)
	Moderate	27 (45.00)	27 (45.00)	35 (58.33)	89 (49.44)
	Low	20 (33.33)	18 (30.00)	17 (28.33)	55 (30.56)
Farm Household vulnerability	High	15 (25.00)	18 (30.00)	19 (31.67)	52 (28.89)
	Moderate	25 (41.67)	23 (38.33)	27 (45.00)	75 (41.67)
	Low	20 (33.33)	19 (31.67)	14 (23.33)	53 (29.44)

Note: Figures within parentheses indicate the per centage to the sample size.

Table 4.10: Estimates of different exposure indicators in selected districts

Variables	Districts		
	Parbhani (SeVI: High) (n = 60)	Sindhudurg (SeVI: Moderate) (n = 60)	Ahmednagar (SeVI: Low) (n = 60)
Trend in <i>kharif</i> rainfall (Mann Kendall Trend)	95.47 (0.00)	176.57 (0.00)	105.88 (0.00)
Trend in <i>kharif</i> temperature (Mann Kendall Trend)	-0.02 (0.00)	0.00 (0.00)	-0.01 (0.00)
Trend in <i>kharif</i> RH (Mann Kendall Trend)	-0.04 (0.00)	-0.07 (0.00)	-0.12 (0.00)
Trend in <i>rabi</i> rainfall (Mann Kendall Trend)	2.95 (0.00)	0.78 (0.00)	1.06 (0.00)
Trend in <i>rabi</i> temperature (Mann Kendall Trend)	0.03 (0.00)	0.01 (0.00)	0.02 (0.00)
Trend in <i>rabi</i> RH (Mann Kendall Trend)	-0.16 (0.00)	-0.07 (0.00)	-0.14 (0.00)
Trend in <i>summer</i> rainfall (Mann Kendall Trend)	229.23 (0.00)	594.38 (0.00)	275.39 (0.00)
Trend in <i>summer</i> temperature (Mann Kendall Trend)	-0.02 (0.00)	-0.01 (0.00)	-0.02 (0.00)
Trend in <i>summer</i> RH (Mann Kendall Trend)	0.28 (0.00)	0.15 (0.00)	0.32 (0.00)
Nearest possible water resource (KM.)	4.43 (1.95)	1.78 (0.78)	1.44 (0.90)
Village included in drought declared areas (Yes=1/No=0)	1.00 (0.00)	0.00 (0.00)	0.92 (0.28)
Number of droughts in last 10 years (Number)	3.42 (1.26)	1.48 (0.70)	3.57 (1.02)
Number of forests, reserves and grazing land within 10 km area (Number)	3.63 (1.14)	4.32 (0.65)	4.03 (0.98)
Number of hailstorms in the past 10 years (Number)	2.28 (1.28)	0.00 (0.00)	0.67 (0.99)
Number of cold spells in the past 10 years (Number)	0.68 (1.06)	1.58 (1.23)	0.95 (1.16)
Number of cyclones in the past 10 years (Number)	0.15 (0.36)	1.00 (0.00)	0.00 (0.00)

Note: Figures in parentheses indicate standard deviation.

4.2.2. Sensitivity

Estimates of sensitivity indices are presented in Table 4.8, 4.9 and 4.11. District wise summary statistics of sensitivity index for 180 households of Maharashtra is presented in Table 4.11. Parbhani has the highest mean value of sensitivity index (0.47), followed by Sindhudurg (0.27), while the lowest value was found in Ahmednagar (0.23). The overall mean and SD were 0.42 and 0.08, respectively. The maximum sensitivity index in the overall sample were from the households of Parbhani (0.47), whereas minimum index was observed in the households of Ahmednagar (0.23). A high divergence of 0.62 (subtracting the minimum index from the maximum) has been found in the sensitivity indicating a wide variation in the index. From the three sensitivity groups, high category has a mean index of 0.47, whereas moderate category has 0.27, while low sensitivity category has 0.23.

Every sensitivity category has a particular number of households, which is presented in Table 4.9. Out of 60 households from Parbhani, 15 (25.00 %) belonged to high sensitivity category, 20 (33.33 %) in moderate and 25 (41.67 %) in low sensitivity category. From 60 households of Sindhudurg, 17 (28.33 %) were found in high sensitivity category, 23 (38.33 %) in moderate sensitivity and 20 (33.33 %) in low sensitivity category. Out of 60 households of Ahmednagar, 17 (28.33 %) were found in high sensitivity category, 21 (35.00 %) in moderate sensitivity and 22 (36.67 %) in low sensitivity category. Taking an overview of 180 households into consideration, about 49 households (27.22 % of overall) belonged to high sensitivity category, while 64 households (35.55 % of overall) were from moderate category, whereas the remaining 67 households (37.22 % of overall) came under low sensitivity category. Almost two-third (113) of the 180 households (62.77 %) in the Maharashtra study region were sensitive for high to moderate levels of climate change.

The possible reasons could be obtained from Table 4.11, which shows the estimates of different sensitivity indicators in the selected districts. Among the sensitivity indicators, the weightage was highest for the variable on nature of roads (paved=1/not paved=0) (3.64), followed by family size (3.52) and unemployed households (3.48), while the lowest was found in loss of land due to natural calamities (1.10). Estimates were higher for the indicators (having positive functional relationship with sensitivity) like 100 per cent dependence on natural resources, total consumption expenditure on food (₹/household) (₹ 3361.17/ household), loss of family members due to drought (0.05), loss of livestock due to drought (3.12), loss of land due to natural calamities (0.08 acre), no of family members below poverty line (3.23), family size

(5.33) and unemployed households (5.03). Estimates of different sensitivity indicators (having negative functional relationship with sensitivity) like household type (5: Bungalow), easy access to the electricity (100 %), easy access to the drinking water resources (100 %) were higher in Ahmednagar as compared with Parbhani and Sindhudurg. Probable cause of 100 per cent dependence of households on natural resources in the Parbhani may be, lack of proper infrastructure facilities and low exposure to urban areas. Out of 60 households of Parbhani, 50 households were having access to the electricity which is very low as compared to Sindhudurg (57) and Ahmednagar (60). Due to all these reasons Parbhani faces higher sensitivity than Ahmednagar and Sindhudurg. The probable reasons for higher share of operational holdings in Ahmednagar may be due to positive on farm net returns and adequate farming practices followed. In contrast, the farm households in Parbhani and Sindhudurg were having low share of operational holdings than Ahmednagar. Besides, in comparison to other districts, Parbhani has higher mean index value (0.47) than overall mean value of sensitivity (0.42) in most of the sensitivity variables. Hence, the households in Parbhani were more sensitive to SeVI induced by climate change than other districts.

Table 4.11: Estimates of different sensitivity indicators in selected districts

Variables	Districts			Overall (n = 180)
	Parbhani (SeVI: High) (n = 60)	Sindhudurg (SeVI: Moderate) (n = 60)	Ahmednagar (SeVI: Low) (n = 60)	
Household type (Kutch=0; Pucca=1; Semi pucca=2; Roof- tiled=3; Thatched=4; Bungalow=5)	2.00 (0.91)	4.00 (1.07)	5.00 (1.64)	3.00 (1.48)
*Depending on natural resources (Yes=1/No=0)	60 (100.00)	56 (93.33)	6 (10.00)	122 (0.47)
Total consumption expenditure on food (₹/month)	3361.17 (875.10)	2665.97 (843.51)	3102.17 (1136.27)	3043.10 (1002.55)
*Easy access to electricity (Yes=1/No=0)	50 (83.33)	57 (95.00)	60 (100.00)	167 (92.78)
*Family members with chronic illness (Number)	6 (10.00)	6 (10.00)	12 (20.00)	24 (13.33)
*Nature of roads (Paved=1/Not paved=0)	0.00 (0.00)	56 (93.33)	60 (100.00)	116 (64.44)
*Loss of family member due to drought (Number)	3 (5.00)	0 (0.00)	3 (5.00)	6 (3.33)
Loss of livestock due to drought (Number)	3.12 (1.94)	0.07 (0.36)	0.70 (1.24)	1.29 (1.88)
Loss of land due to natural calamities (Acre)	0.08 (0.28)	0.07 (0.25)	0.03 (0.18)	0.06 (0.24)
Total operational holding (acre)	4.23 (2.13)	2.00 (1.16)	4.43 (2.15)	3.56 (2.17)
BPL family members (Number)	3.23 (1.20)	3.22 (1.14)	3.22 (0.86)	3.22 (1.08)
Family size (Number)	5.33 (1.26)	4.62 (1.13)	5.02 (1.12)	4.99 (1.21)
Unemployed household (Number)	5.03 (1.22)	4.30 (0.97)	4.73 (1.06)	4.69 (1.13)
Per cent irrigated area (acre)	55.07 (17.09)	69.08 (16.38)	65.58 (21.74)	63.24 (19.49)
*Easy access to the drinking water resources (Yes/No)	58 (96.67)	60 (100.00)	60 (100.00)	178 (98.89)

Note: * Figures within parentheses indicate the per cent to sample size.

**Figures within parentheses indicate standard deviation.

4.2.3. Adaptive capacity

Tables 4.8, 4.9, and 4.12 show the estimates of adaptive capacity. Table 4.12 shows the district-level summary statistics for the adaptive capacity index for 180 households in Maharashtra. Ahmednagar has the highest mean value of adaptive capacity index (0.44), followed by Sindhudurg (0.31), and Parbhani (0.17). The overall mean and standard deviation were 0.42 and 0.08, respectively. The households in Parbhani had the lowest adaptive capacity index (0.017), while the households of Ahmednagar had the highest (0.44). The adaptive capacity has the highest divergence of 0.79 (subtracting the minimum index value from the maximum). The high adaptive capacity category has a mean index value of 0.44, the moderate adaptive capacity category has a value of 0.31, and the low adaptive capacity category has a value of 0.17. Each adaptive capacity category has a specific number of households, as shown in Table 4.9. From a total of 60 households in Parbhani, 13 (21.67 %) were found in high adaptive capacity category, 27 (45.00 %) in moderate adaptive capacity and 20 (33.33 %) in low adaptive capacity category. From 60 households of Sindhudurg, 15 (25 %) were found in high adaptive capacity category, 27 (45 %) in moderate adaptive capacity and 18 (30 %) in low adaptive capacity category. Out of 60 households in Ahmednagar, 8 (13.33 %) were found in high adaptive capacity category, 35 (58.33 %) in moderate adaptive capacity and 17 (28.33 %) in low adaptive capacity category. In the pooled sample, about 36 households (20.00 % of overall) belonged to high adaptive capacity category, while 89 households (49.44 % of overall) were from moderate category, whereas the remaining 55 households (30.56 % of overall) came under low adaptive capacity category. Overall, two-third (125) of the 180 households (69.44 %) in the study region were adaptive to high and moderate levels of climate change which is a good indication. The mean adaptive capacity index was low (0.17) in Parbhani due to lower values of estimates of education level (3: middle), farming experience (13.08 years), climate variability related information (1.95), access to the credit (81.67 %), group credit facility (6.66 %), interest in government crop insurance (91.67 %), animal insurance (0.27), animals registered for feed camp (0.10), number of visits of veterinary doctors (0.92), farm size (4.23 acres) and herd size (4.63), area under crop insurance (1.98 acre), milk production (587.10 lit./month) and monthly gross income (₹62404.10). On contrary, the mean value of adaptive capacity was higher (0.44) in Ahmednagar due to higher mean values of education level (5: higher secondary), farming experience (18.95 years), adequate climate variability related information (4.58), access to the credit (95 %), group credit facility (78.33), government crop insurance (1.00), animal insurance (1.00), animals registered for feed camp (6.48), frequent

visits of veterinary doctors (2.88), farm size (4.93 acres) and herd size (6.48), area under crop insurance (4.48 acres), milk production (1937.50 lit./month) and lastly sufficient monthly gross income (₹112393.26). Due to all these reasons, Ahmednagar district is highly adaptive to climate change as compared to Parbhani and Sindhudurg.

Table 4.12: Estimates of different adaptive capacity indicators in selected districts

Variables	Districts			Overall (n = 180)
	Parbhani (SeVI: High) (n = 60)	Sindhudurg (SeVI: Moderate) (n = 60)	Ahmednagar (SeVI: Low) (n = 60)	
Sources of climate variability related information (Frequency)	1.95 (1.15)	3.88 (0.78)	4.58 (1.44)	3.47 (1.60)
*Easy access to credit (Yes=1/No=0)	49 (81.67)	54 (90.00)	57 (95.00)	160 (88.89)
*Enjoying group credit facility (Yes=1/No=0)	4 (6.66)	47 (78.33)	58 (96.66)	109 (60.56)
*Applied for any gov. crop insurance (Yes=1/No=0)	55 (91.67)	54 (90.00)	60 (100.00)	169 (93.89)
Number of animals insured	0.27 (0.83)	0.87 (1.33)	3.52 (14.82)	1.55 (8.72)
Number of animals registered for feed camp	0.10 (0.40)	2.58 (1.17)	6.48 (4.48)	3.06 (3.75)
Number of visits of veterinary doctor (within 15 days)	0.92 (0.71)	1.82 (0.87)	2.88 (1.00)	1.87 (1.18)
Average farm size (acre)	4.23 (2.13)	2.00 (1.16)	4.93 (2.15)	3.72 (92.25)
Average herd size (acre)	4.63 (2.07)	4.80 (1.51)	6.48 (4.48)	5.31 (3.09)
Total area under crop insurance (acre.)	1.98 (1.28)	0.97 (0.84)	4.48 (4.48)	2.48 (3.11)
Total milk production in (lit/month)	587.10 (396.93)	578.83 (269.18)	1937.50 (1344.73)	1034.48 (1042.68)
Monthly gross income (₹/month)	62404.10 (28859.71)	48751.70 (20312.60)	112393.26 (63794.67)	74516.35 (50201.03)
Employed households (Number)	0.30 (0.56)	0.35 (0.51)	0.28 (0.49)	0.31 (0.52)
Farming experience (Years)	13.08 (4.59)	17.92 (7.19)	18.95 (8.47)	16.65 (7.4)
Trainings attended (Number)	0.18 (0.59)	1.37 (0.86)	2.82 (1.37)	1.46 (1.47)
*Social participation (Yes=1/No=0)	10 (16.67)	52 (86.67)	60 (100.00)	122 (67.78)
Education level (Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6)	3 (1.45)	3 (1.24)	5 (1.48)	3 (1.51)

Note: * Figures in parentheses indicate per centage

**Figures in parentheses indicate standard deviation.

4.2.4. Inter-index comparison of exposure, sensitivity and adaptive capacity

The inter-index mean values of exposure, sensitivity and adaptive capacity were presented in Fig. 4.5a and 4.5b. The overall vulnerability is higher in Parbhani (0.72) in comparison to Sindhudurg (0.46) and Ahmednagar (0.12). Among the vulnerability components, the exposure to climate change was higher in Sindhudurg (0.51) as compared to Parbhani (0.42) and Ahmednagar (0.33). The mean sensitivity index value was higher in Parbhani (0.47) relative to Sindhudurg (0.27) and Ahmednagar (0.23). On contrary, the adaptive capacity index was found higher in Ahmednagar (0.44) as compared to Parbhani (0.17) and Sindhudurg (0.31). This reveals that the households in Ahmednagar district are equipped with good adaptive capacity to climate change induced socio-economic vulnerability than Sindhudurg and Parbhani. Alternatively, the households in Sindhudurg are more exposed to climate change. The households in Parbhani are more sensitive to climate change.

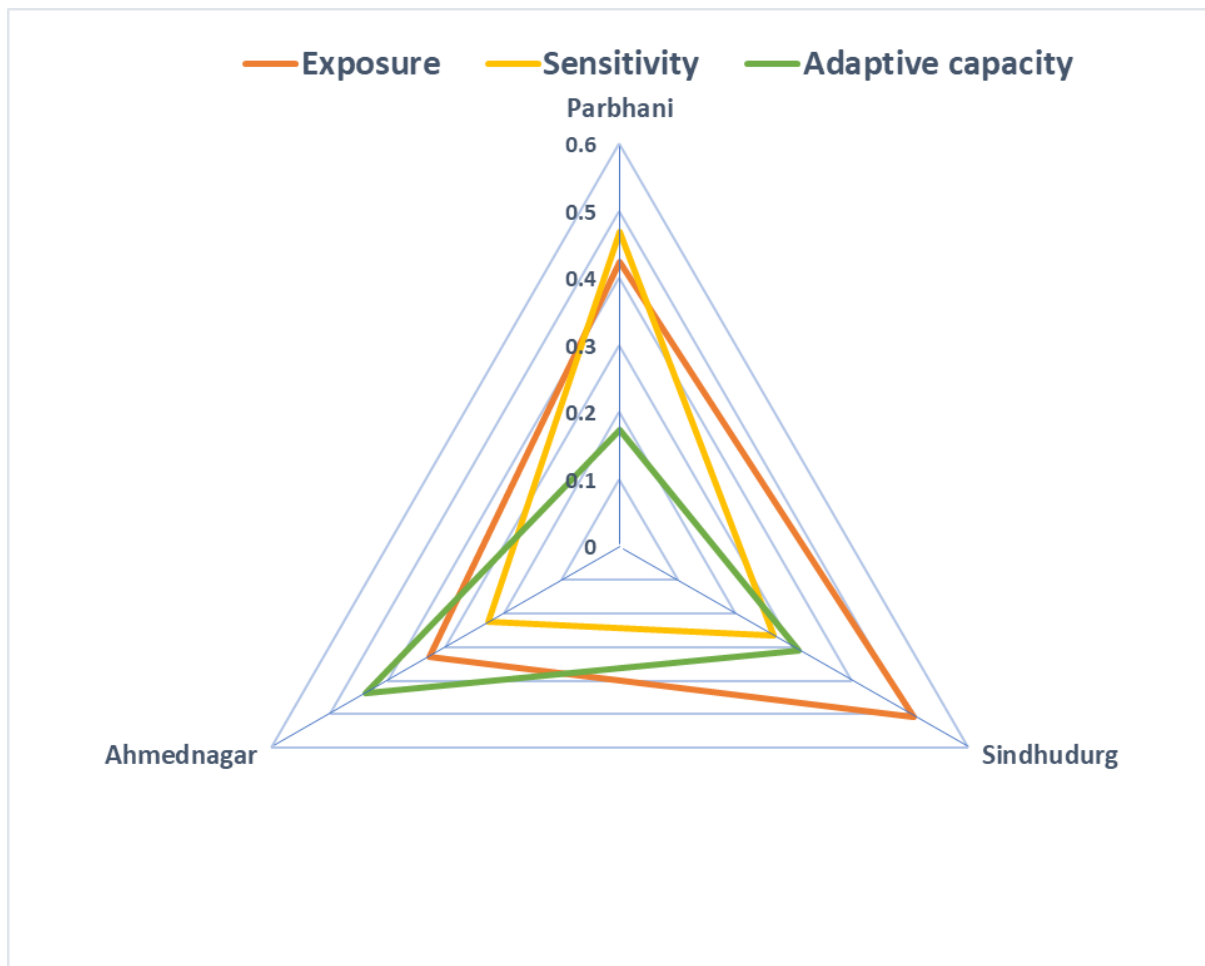


Fig. 4.5a Radar pictorial of mean value of exposure, sensitivity and adaptive capacity indices

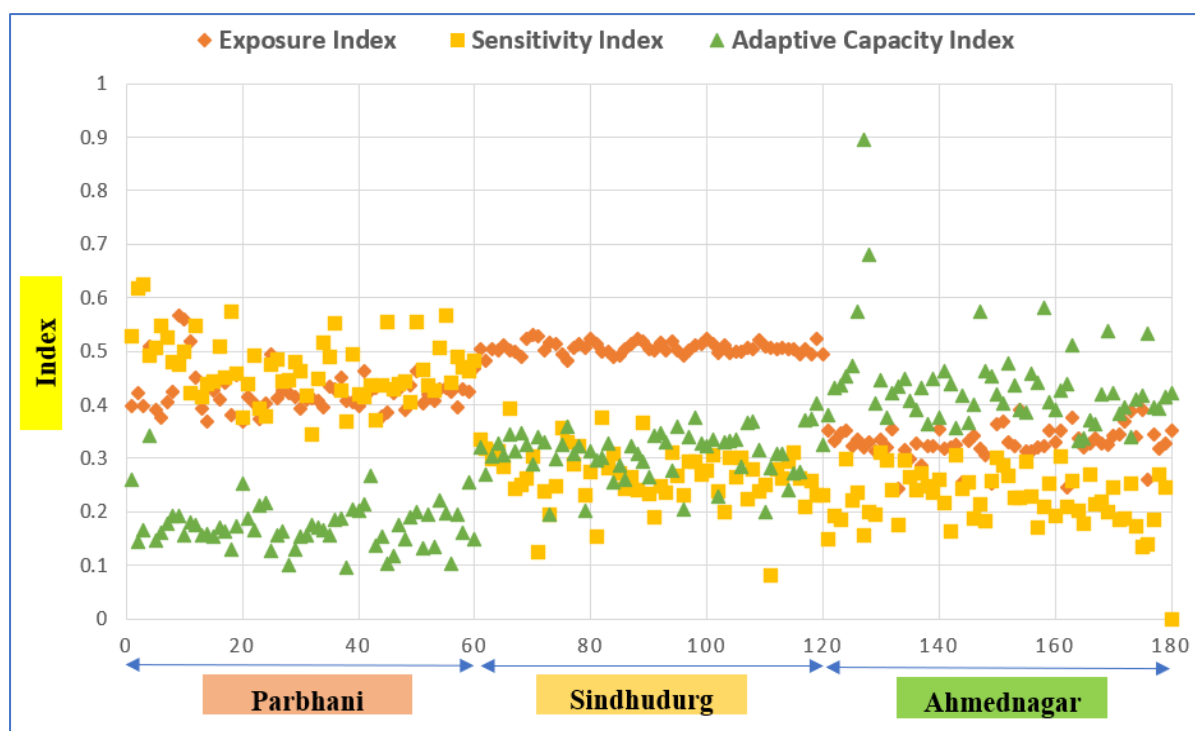


Fig. 4.5b Scatter plot of exposure, sensitivity and adaptive capacity indices for farm households

4.2.5. Socio-economic vulnerability index for households in Maharashtra

The composite SeVI was calculated considering the exposure, sensitivity and adaptive capacity of the households in the study region (Table 4.8 and 4.9). Table 4.8 depicts the district wise summary statistics of socio-economic vulnerability index for the randomly selected 180 farm households in Maharashtra. Parbhani has the highest mean value of SeVI (0.72) due to its high exposure to climate change (0.42) and highest sensitivity (0.47), which led to the highest potential impact ($0.42+0.47=0.89$) coupled with the lowest adaptive capacity (0.17). Sindhudurg registered a moderate level socio-economic vulnerability with a mean SeVI estimated at 0.46 owing to its second highest exposure (0.51) and second highest sensitivity (0.27), which resulted in the second highest potential impact (0.78) along with a moderate adaptive capacity (0.31). The lowest mean value of SeVI among selected households was observed in Ahmednagar district (0.12) owing to its lowest exposure (0.33) and lowest sensitivity (0.23), which resulted in the least potential impact (0.56) against the highest adaptive capacity (0.44) among the districts. The overall mean value of SeVI (0.43) across districts is a resultant of moderate exposure (0.42) and sensitivity (0.42) to climate change, which aggregated and resulted in high potential impact (0.84) with the estimated adaptive capacity of 0.31.

The overall standard deviation of SeVI was calculated as 0.26 indicating the extent of dispersion in the series. The SeVI in the overall sample was maximum for a household in Parbhani (0.72), whereas the minimum was observed in Ahmednagar district (0.12). The socio-economic vulnerability has a very high divergence of 1.32 because of its wider range among the households. The mean index value of high, moderate and low categories were estimated at 0.72, 0.46 and 0.12, respectively for the household level. Category wise number of households across vulnerability level is presented in Table 4.9 and Fig. 6. Out of 60 households in Parbhani, 15 (25.00 %) were found in high SeVI category, 25 (41.67 %) in moderate SeVI and 20 (33.33 %) in low SeVI category. From the 60 households in Sindhudurg, 18 (30 %) were found in high SeVI category, 23 (38.33 %) in moderate and 19 (31.67 %) in low SeVI category. In the case of Ahmednagar, 19 households (31.67 %) were found in high vulnerability category, 27 (45 %) in moderate and 14 (23.33 %) in low category. Overall, in the pooled sample, 52 households (28.88 %) belonged to high SeVI category, while 75 households (41.66 %) categorised under moderate, whereas the remaining 53 households (29.44 %) found to be in low category.

4.2.6. Regression tree analysis of farm household-level socio-economic vulnerability index

To capture the sequence of factors that determine the farm household level SeVI, a regression tree analysis was performed (Ji *et al.*, 2013). The regression tree was constructed (Fig.4.6) using the SPSS (ver. 21) with the classification and regression tree (CRT) option, as its parent and child nodes fixed at 10 and 5 observations, respectively (minimum level to appear in the classification). The total number of nodes observed were 21 and number of terminal nodes are 11. In this analysis, the farm level SeVI was selected as a dependant variable (Feleke *et al.*, 2016) and all other variables which are used in the construction of the composite index were selected as independent variables. It was found from the analysis that number of animals registered for feed camp, unemployed households, loss of livestock due to drought, trend in *kharif* rainfall, easy access to electricity, total consumption expenditure on food, social participation and number of droughts in the past ten years were most influencing the degree of farm household level vulnerability (Goel and Vasisht, 1992).

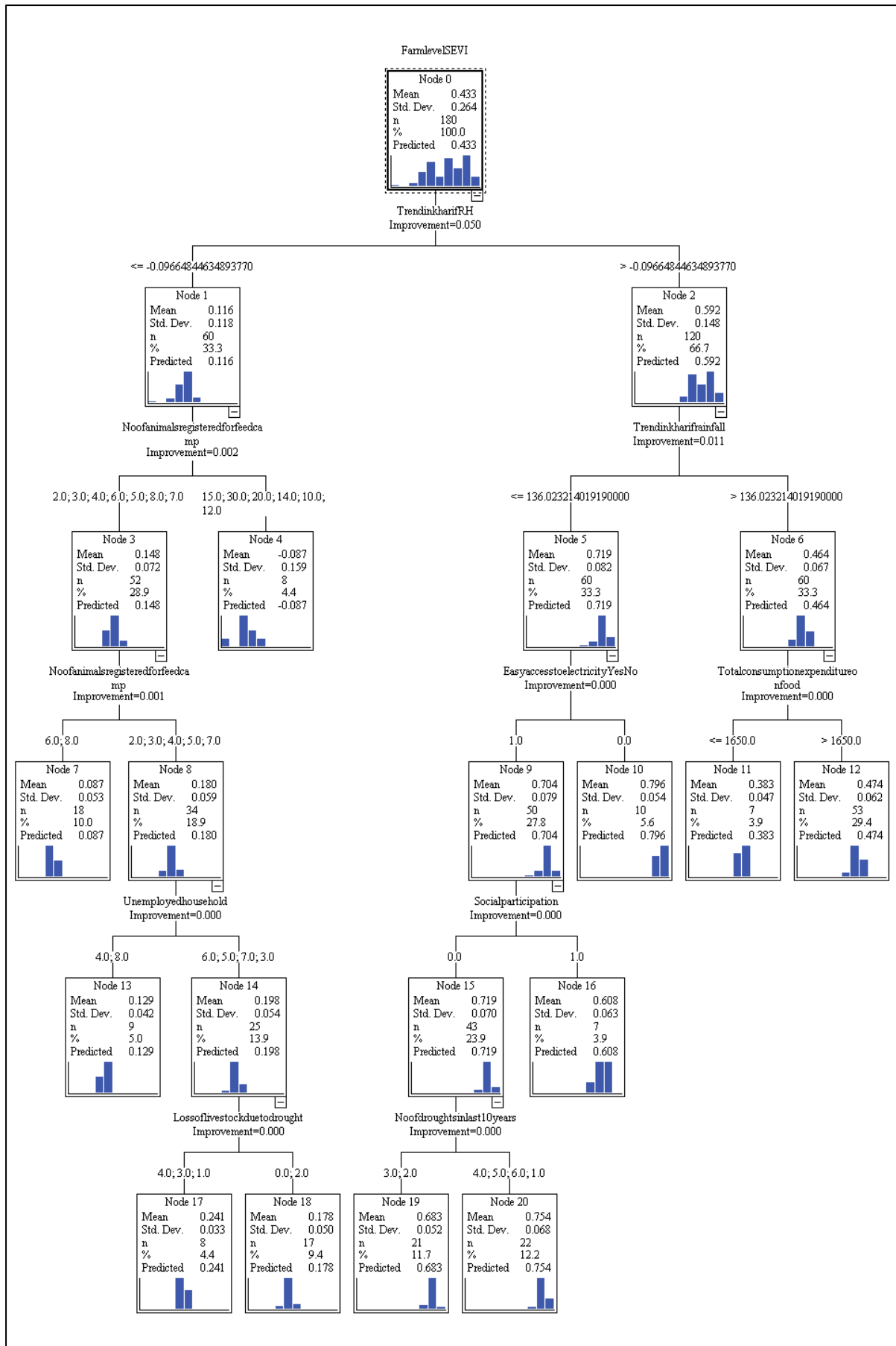


Fig. 4.6. Determinants of farm household-level SeVI

Table 4.13: Gain summary for nodes

Node	N	Per cent	Mean
10	10	5.6%	0.7961
20	22	12.2%	0.7541
19	21	11.7%	0.6832
16	7	3.9%	0.6083
12	53	29.4%	0.4743
11	7	3.9%	0.3833
17	8	4.4%	0.2407
18	17	9.4%	0.1775
13	9	5.0%	0.1294
7	18	10.0%	0.0870
4	8	4.4%	-0.0866
Growing Method: CRT			
Dependent Variable: Farm household-level SEVI			

4.3. ADOPTION AND DETERMINANTS OF COPING STRATEGIES PRACTICED ACROSS VULNERABLE REGIONS

4.3.1. EXTENT OF ADOPTION OF COPING STRATEGIES

4.3.1.1. Identification of coping strategies in crop farming, livestock farming and other component across vulnerable districts

4.3.1.2. Coping strategies identified in crop farming

4.3.1.2.1. The System of Rice Intensification (SRI)

Paddy is Maharashtra's second most important crop, grown on 14.99 lakh hectares with an annual production estimated at 32.37 lakh metric ton (MT). The state's average productivity is 2.01 t/ha, placing it 13th in the country in rice production (Bose, 2019). Paddy farming needs a lot of water. Due to the current water shortage and the crop's high-water consumption, an alternate technique is being considered. The SRI is looked upon as a potential solution to manage the water scarcity problem. This technique was initially used in Madagascar in the 1980s. It offers three significant advantages in combating climate change, particularly in drought situations *viz.*, 'reduced water demand,' 'reduced methane emissions,' and 'reduced nitrogen fertilisers' are among the advantages. Paddy fields require between 24 and 30 per cent of the world's freshwater resources for irrigation. The SRI approach reduces the need for irrigation for paddy farming by roughly 25-50 per cent. As a result, there is more water

available for other crops, human needs, and so on. As a result, groundwater exploitation is reduced (Vijayasathy, 2015).

4.3.1.2.2. Seed drill sowing

For seed drill sowing, simple seeding devices having 2 to 4 furrow openers and hand filled funnel with tubing are being used. The seeds are placed by plough man into the funnel which is distributed equally to tubes placing seed below furrow openers. Now-a-days many seed drills and seed-cum-fertilizer drills are available for different rainfed areas. These drills are pulled by bullocks. They have metering devices for seed and fertilizer to adjust the seed and fertilizer rate. These drills have flexibilities to adjust the depth of seed and fertilizer placement as well as spacing. The furrow openers of such seed drills are designed in such a way that adequate soil cover is maintained over drilled seed while deep seeding in dry condition, leaving open furrows. These drills can cover 2 to 5 times more area in a day depending on the number of furrow openers, as compared to single row seed drilling with a local plough. Tractor drawn seed-cum-fertilizer drills are also available for rainfed areas but their use is limited due to small holding and lack of tractor power in rainfed areas. Self-metering seed-cum-fertilizer drills having many furrow openers are not easily adopted by the rainfed farmers because of their high cost, complex mechanism, poor repair facilities in villages, poor bullock power, small and fragmented holdings, lack of cooperation and poor economic conditions of farmers. Rainfed seeding device should be cheap, simple, easily repairable and versatile (JNKKV, 2006).

4.3.1.2.3. Broadcasting

Broadcast seeding is particularly useful for dense plant spacing, such as in cover crops and lawns. Broadcast seeding would take 10–20 per cent more seed than conventional drill planting. Traditional row sowing is more complicated, time-consuming, and difficult. Broadcast seeding is better for plants that don't need precise spacing or can be thinned out later. Seed is often lightly buried after broadcasting with some form of raking operation, which is often done with vertical tillage equipment. By increasing seed-to-soil touch, these tools help to improve the success rate in germination.

4.3.1.2.4. Drought tolerant, early maturing, salt tolerant varieties

In Parbhani, 692 villages were declared as drought-prone (Government of Maharashtra, 2018¹). Sindhudurg is one of the Maharashtra's drought-prone districts, with a 121-kilometer coastline.

¹ <https://cdn.s3waas.gov.in/s39cf81d8026a9018052c429cc4e56739b/uploads/2018/11/2018111522.pdf>

Droughts and extensive floods are more prevalent, notably in talukas Malvan, Kudal, Sawant wadi, Vengurla, Dogad, and Kankavli (Government of Maharashtra, 2018²). Also, in Ahmednagar district, 408 villages were declared as drought-prone. To cope with such extreme climatic changes and frequent-persistent droughts, drought-tolerant or drought-resistant crop cultivars are important as they yield better under these stress conditions. Plant resilience to stressors caused by climate change is also improved by breeding new and improved crop types (Vijayasathy, 2015). Drought-resistant and short-duration crop cultivars allow farmers to increase agricultural production despite drought.

4.3.1.2.5. Mulching

Mulching has a significant impact as a water-saving technique in rainfed crop cultivation to alleviate water stress in agriculture. It is primarily important for maintaining soil moisture, regulating soil temperature, and limiting soil evaporation, all of which have an impact on crop yield. Mulching has several strategic implications for the soil environment, crop development, and climate. Mulch insulates the soil, assisting in the creation of beautiful and preserved habitats by providing a shelter from cold and hot temperatures (Kader *et al.*, 2019)

4.3.1.2.6. Summer ploughing

The first and most obvious benefit is that the infiltration capacity and permeability of the soil increase as a result of the breaking of the hard crusted upper layer of the soil and deep ploughing, which increases *in-situ* moisture conservation. As a result, plant roots will receive more moisture with less effort. Summer ploughing improves the soil structure due to alternate drying and cooling. Tillage improves soil aeration, which aids in the growth of microorganisms. Organic matter decomposition is accelerated, resulting in increased nutrient availability to plants. Increased aeration also aids in the breakdown of herbicide and pesticide residues, as well as harmful allelopathic chemicals exuded by the previous crop roots and weeds (such as couch grass), which inhibit the growth of other nearby plants.

4.3.1.2.7. Conservation agriculture practices

Conservation tillage, such as summer ploughing and crop residue mulching, boost crop yield while conserving the resources and protecting the environment (Vijayasathy, 2015). By improving the soil moisture retention, reducing the soil erosion, and reducing soil impact, these techniques mitigate climate-related risks like drought and floods (Smit and Wandel, 2006).

² <https://cdn.s3waas.gov.in/s3fae0b27c451c728867a567e8c1bb4e53/uploads/2018/07/2018071320.pdf>

Improved soil nutrient recycling may help to protect crops from pests and diseases (Holland, 2004).

4.3.1.2.8. Zero tillage

Though zero tillage is an integrated part of conservation agricultural practices, it was independently assessed as an important strategy to climate change. Cropping practices including ridge farming tillage (RFT), no tillage (NT), and stubble mulch farming tillage (SMFT) have shown to be superior to traditional tillage (CT) in terms of improving and stabilising crop yields, conserving moisture, and reversing land degradation (Udumale *et al.*, 2014).

4.3.1.2.9. Taking help of early warning and forecasting of climate change

Early alert, early response, an efficient intelligence system, timely maintenance of the irrigation system and adoption of a crop stabilisation strategy, and an effective programme of relief works by advance shelf of projects of the works by different departments are among the preparations for coping with such drought situations (Das, 2013).

4.3.1.2.10. Soil fertility and nutrient management

To improve soil fertility and for efficient nutrient uptake, residual sodium carbonate (RSC) rich waters is being encouraged to use for irrigation. This practice can be performed only after amending with gypsum or as soil amendment.

4.3.1.2.11. Crop insurance

In India, crop insurance has progressed from the Pilot Crop Insurance Scheme to the *Pradhan Mantri Fasal Bima Yojana*. It serves as an useful institutional instrument for coping the loss due to hazards in crop production. To benefit from this scheme, farmers must pay a uniform 2 per cent premium for all *kharif* crops and 1.5 per cent for all *Rabi* crops. For annual commercial and horticultural crops, 5 per cent premium will be required. Farmers pay relatively low premiums, and the government pays the rest to ensure that farmers receive the entire amount covered in the event of crop loss due to natural calamities. In this way this is a risk reducing mechanism for the standing crop to cope with the climate change. In Maharashtra for the *kharif* season of 2019, the area insured under the PMFBY was 67.920 lakh ha benefitting 85536 farmer (Ministry of Agriculture and Farmers Welfare, 2019-20³).

³ <https://pmfby.gov.in/stateWiseDataPage>

4.3.1.2.12. Improved water management

Artificial reservoir (farm pond), micro irrigation, use of sprinklers, water harvesting, judicious use of surface and groundwater for drinking and irrigation, and scheduled irrigation can be helpful strategies to cope with the climate change. In the case of rice, continuous standing of water is required only in the initial 15-20 days to suppress growth of weeds. However, later, irrigating one day after disappearance of water is the most economical and efficient way of scheduling irrigation. Sowing of cotton, soya bean, maize, etc. on the ridges and furrows and letting water in alternate furrows can save 20-30 per cent of water. Sprinklers for cereal crops like wheat and drip system for widely spaced crops sown in lines like sugarcane, cotton, maize *etc.* can increase the efficiency by 80-90 per cent. Harvested rainwater stored in unlined tanks and ponds should be used for pre-sowing or first irrigation to ensure uniform germination. Storing this water for later period will result into infiltration and evaporation losses.

4.3.1.2.13. Insect pest and disease management

Pesticides and nutritional shortages for the main crops (sorghum, pigeon pea, soya bean, cotton, gramme, safflower, and sweet lime) have been suggested as part of the Integrated Pest Management Approach (IPMP) to offset the negative effects of climate change. It is necessary to mainstream the biological control and the use of bio-pesticides, as well as provide guidance on trainings and presentations, safe handling, and implementation (WHO, 2010).

4.3.1.3. Coping strategies identified in livestock farming

4.3.1.3.1. Climate proof shelter

In the livestock industry, shelter management to cope with the climate change is critical. Dairy animals experience less heat stress when they are housed in summer-oriented housing. Summer productivity loss is reduced by proper housing and better health management (Pandey *et al.*, 2008; NICRA, 2018). Farmers in the selected study regions, may not have modern shelters like large dairy farms, but they do have adequate shelters that help to mitigate the heat stress and other climate-related difficulties.

4.3.1.3.2. Mineral mixture feeding

Now a days feeding practices has got much importance in climate affected areas of Maharashtra. Mineral deficiency and imbalances in cattle have been recorded in practically every part of the globe. Ca, P, Na, Co, Cu, I, Se, and Zn are the mineral elements most likely

to be deficient in ruminant grazing settings. Mg, K, Fe, and Mn may be insufficient in some areas under certain conditions, whereas excess of F, Mo, and Se can be exceedingly harmful. Factors influencing the consumption of mineral mixture include: (1) soil fertility and forage type, (2) season, (3) available energy and protein, (4) individual requirements, (5) salt content of water, (6) palatability of mineral mixture, (7) availability of fresh minerals and (8) physical form of minerals (McDowell, 1996). Productivity of dairy animals in Maharashtra can be improved by using the mineral mixture feeding technique. During drought, farmers witnessed an increase in the milk yield because of the mineral mixture (Williams *et al.*, 2018).

4.3.1.3.3. Feeding Vitamin E

Deficiency in nutrients is the cause of disease, and cure or prevention by correction of the deficiency will lead to increased productivity. Several deficiencies have been found in the arid zone animals of Maharashtra. Of them, Pica is caused by the lack of energy and protein. Copper, cobalt, selenium, zinc (Elshahawy and Aly, 2016), iron, and iodine are some of the trace minerals that cause anaemia, stunted growth, reproductive disorders, pica (Kishore, 1998), and other general and unique deficiency symptoms. Apart from these, deficiencies of vitamins A, D, E, B and C have also been identified (Gahlot, 2012).

4.3.1.3.4. Balanced feeding

Most of the farmers in Parbhani region, control dairy animal feeding in drought situations by altering the ratio of green fodder, dry fodder, and concentrates. Obtaining feed is extremely difficult during drought incidence and climate anomalies. As a result, a few farmers alter their feeding regimens in order to increase the milk supply and returns. This is a common practice followed in most of the climate affected regions of Maharashtra (Avadhutrao, 2020).

4.3.1.3.5. Regular vaccination

The field level vaccination programme for FMD (Foot and Mouth Disease), HS (Haemorrhagic Septicaemia) , , BQ (Black Quarter) and Tetanus, as well as the carcass disposal pattern, were found to be 68.17 per cent, 33.17 per cent, 46.83 per cent, 58.00 per cent, and 67 per cent, respectively in the four districts (Sangli, Satara, Solapur and Kolhapur) of the Western Maharashtra Zone (Madkar *et al.*, 2020). Kolhapur is one-of-a-kind district in Maharashtra, with fertile land and high potential for dairy development, as well as government hospitals and local assistance for treatment. But as we look into climate affected districts like Parbhani, Sindhudurg and Ahmednagar, the rate of vaccination is very low. Dairy animals that are

regularly vaccinated are less likely to contract the illness and other health problems as a result of the changing climate. One of the livestock adaptation solutions to climate unpredictability is preventive vaccination (NICRA, 2018). This improves animal health, resulting in increased milk supply and income for farmers.

4.3.1.3.6. Azolla cultivation

Azolla is an aquatic fern that has a symbiotic relationship with the bacteria *Anabena Azollae*. Dairy animals fed with Azolla result in lower feed cost coupled with higher milk quality and output. Minerals, proteins, vitamins, and other nutrients are abundant in Azolla (Joysowal, 2018). However, only a few farmers opt for azolla feeding, which boosts milk output during droughts.

4.3.1.3.7. Hydroponics

Indian agriculturalists are battling with a drastic reduction in the supply of locally produced food for India's huge population, due to drought and vagaries of global warming (Pina, 2016). A hydroponic system, also known as soilless farming, is considered to be a potential method of growing crops without the use of soil. Plant roots grow in a liquid nutrient solution or inside moist inert materials such as Rockwool and Vermiculite in a hydroponic system. The liquid nutrient solution is a water-based mixture of essential plant nutrients. This system has sparked increased interest in the states with arid climates, such as Maharashtra. As a best alternative, which involves producing fodder without soil in a confined environment (high-tech or low-cost device) and harvesting it after 7-8 days. It is gaining popularity because it is used to ensure a consistent supply of high-quality green forage for livestock throughout the year. The inclusion of 5-10kg of hydroponic fodders per cow per day increases the milk production by 8-13 per cent and meat quality based on nutrient digestibility (Shit, 2019). Furthermore, this activity of agriculture resolves many of the issues that threaten the year-around cultivation due to its economic viability and ability to serve as a potential solution to India's diminishing supply of fertile soil or clean and surplus water.

4.3.1.3.8. Seaweed utilization

In many Southeast Asian countries, seaweed is extensively farmed and traded. Seaweed production was reported to be 29.4 million wet tonnes (27.7% of total aquaculture produce) in 2015, with a market value of over 4.8 billion USD (Ye, 2017). Most of the seaweed is produced in Asian countries, primarily in China, Japan, Korea, Indonesia, the Philippines, Malaysia, and

Vietnam. Currently, seaweed farming is promoted in a number of developing countries with increasing economies in order to help rural coastal communities for achieving greater economic prosperity (Crawford, 2002). The practice is not that much popular in coastal districts of Maharashtra but can be inculcated with proper training and demonstrations.

4.3.1.3.9. Hay and silage making

In making silage, *propionibacteria* is used as starter culture. *Propionibacterium freudenreichii* or *Prop. Lactobacillus spp.* is usually added with *acidipropionici*, which is isolated from the fermented high-moisture maize. This addition increases the aerobic stability while lowering the number of moulds and yeasts in maize silage. Since propionic acid is also corrosive, it is not used as a single item. Silage's organic matter digestibility improves, allowing cattle to grow faster and healthier. In the case of milk production; the yield either rises or stays the same (Deborde *et al.*, 2012).

4.3.1.3.10. Augmented fodder supply through improved varieties

Improved fodder varieties produced by the Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (NH 615-Anusaya, NH 635, NH-452 (Renuka), NH 545, NHH-44, NHH 250, PH-316 (Ganga), PH-348 (Yamuna) offers a better solution to fodder scarcity during drought. It always boosts the availability of feed resulting in increased milk output.

4.3.1.3.11. Growth enhancing higher crude protein

To improve the higher crude proteins in fodder, application of foliar spray of urea is recommended. Protein enhanced fodder supply improves the milk quality assuring income safety to the farmers and ultimately reduces the socio-economic vulnerability.

4.3.1.3.12. Use of perennial and non-conventional fodder

Sugarcane tops and dry sugarcane leaves from sugarcane growing areas may be transported, enriched for crude protein content and fed in scarcity areas.

4.3.1.3.13. Periodic health check-up including deworming

Specific livestock-targeted interventions are needed in drought situations to assist the households in surviving the immediate crisis and to assist the communities in restoring their livelihoods (Gizachew, 2012). The need for a particular intervention like animal health services including periodic health check-up depends on the nature of the emergency, the local context and the phase of the emergency (*i.e.* ongoing, immediate aftermath, recovery or rehabilitation)

4.3.1.3.14. Dual purpose crops

Dual purpose crops like barley (varieties RD 2715, RD 2035, RD 2522 and BH 75) may be sown in October, as a coping strategy to fulfil the fodder demand. One cutting may be taken for fodder at 50-60 days after sowing.

4.3.1.4. Coping strategies identified in other added component in farming

4.3.1.4.1. Temperature control in poultry and fishery

4.3.1.4.1.a) Poultry: Taking into consideration of poultry population (354.60 crores) and the estimated annual production of eggs in Maharashtra state (33 eggs available per capita per year), temperature control facility has been suggested as a coping mechanism (RKVY, 2017). Heating is critical for maintaining the proper temperature in the brooder house. Temperatures that are too hot or too low delay the development and cause birds' death. The temperature should be 95°F (35°C) for the first week, then decreased by 5°F per week for the following weeks until it reaches 70°F (21°C).

4.3.1.4.1.b) Fishery: In Maharashtra, Sindhudurg is an important district with respect to fisheries production. A temperature control system adjusts the incoming water temperature to maintain the optimum required to promote maximum fish growth. The longer-term intention is for an innovative water heater and cooler fuelled by biogas generated from the tank's biomass waste (aquacultural faeces and food waste) (European Commission, 2011). Also, the temperature of the sea surface is thought to be a good predictor of both ocean variability and more complex ocean processes. Fishermen, like others who cannot notice the sea-level rise, are unable to detect a rise in the sea temperature as a result of climate change. In the states like Maharashtra and Andhra Pradesh, temperatures have reportedly risen at the surface and even far below, however this is linked to extensive drilling, industrial discharges (particularly from Maharashtra's atomic power plant), chemical effluents, and urban trash (Salagrama, 2012⁴).

4.3.1.4.2. Periodic health check-up

Periodic health check-up plays a vital role in farm animal health by reducing the risk of disease incidence and ultimately causing a decline in risk caused by the climate change. Signs of a sick, injured, or otherwise distressed chicken include:

- Hiding more often than they used to

⁴ http://aquaticcommons.org/11190/1/Climate_Change_Full.pdf

- Changing their daily schedule (such as reduced dust bathing)
- Labored breathing, gurgling sounds, or a constantly open mouth.
- Immobility, inactivity or unresponsiveness to your approach
- Sitting far more often than usual
- Avoiding the rest of the flock
- Being bullied more by the rest of the flock or a quick pecking order reduction
- A limp in their step or standing on one foot
- Unusual or abnormal droppings including all white stool, blood in stool, or worms.
- A pale or discoloured comb or wattle

4.3.1.4.3. Increasing daily fishing time

Fishing communities in Maharashtra and Tamil Nadu account for 20 per cent of India's marine fish production (Department of Fisheries, 2020). Due to climate change, the daily average fishing time varies according to weather conditions, so fishers must increase the daily fishing time as per their need and convenience.

4.3.1.4.4. Increasing fishing efforts

Around 90 per cent of fishermen in Maharashtra observed a decline in total catch, as a result of which they have changed their fishing methods. With respect to elements like experience and income an individual's socioeconomic characteristics are the driving factors to increase fishing efforts (Krishnadas *et al.*, 2013).

4.3.1.4.5. Changing fishing time

Changing fishing time to late night or early morning is also a contemporary mechanism to cope with the foreseen climatic variability.

4.3.1.4.6. Aquaculture production

Maharashtra ranks seventh in the country with respect to fish production, holding a 5 per cent share, is yet to fully realise its untapped potential. In Maharashtra, marine fisheries have a larger share (82%) than inland fisheries (18%) (Bhendarkar *et al.*, 2020). The cyclical vulnerability of marine catch and the ever-increasing demand provide opportunities to increase the share of inland fisheries in the food basket.

4.3.1.4.7. Migrating to another fishing area

Many fisherfolk in the poor world rely on migration as a primary source of income, owing to unpredictable fish supply due to changing climate and pricing (Fiona, 2010).

4.3.1.4.8. Fishing further away or deep inside the water

The threats to riverine human communities are especially dangerous for disadvantaged populations from remote locations that rely on subsistence agriculture and fisheries and are particularly prone to long-term heavy metal exposure. Due to these reasons increasing fishing efforts away or deep inside the water helps to stabilize the income and reduces the socio-economic vulnerability (Fernandes *et al.*, 2016).

4.3.1.4.9. Catching smaller fish

Catching smaller fish and rearing them for aquaculture in bulk quantity nowadays gives profitable returns in remote areas of Maharashtra.

4.3.1.5. Adoption of coping strategies to climate change by households in different districts of Maharashtra

4.3.1.5.1. Adoption of coping strategies to climate change by households in Parbhani

The coping strategies are presented in Table 4.14 for Parbhani district. There were 14 strategies identified in crop farming. None of the households adopted the SRI technique as there was limited area under rice cultivation in Parbhani, but other strategies were adopted like drought tolerant varieties (68.33%), insect pest and disease management (65.00%), crop insurance (58.33%), broadcasting (53.33%), subsidiary income and employment generating activities (51.6%), mulching (46.67%), improved water management (45.00%), seed drill sowing (43.33%), soil fertility and nutrient management (36.67%), zero tillage (30.00%), summer ploughing (25.00%), conservation agriculture practices (23.33%) and taking help of early warning and forecasting of drought (23.33%). There were 14 strategies identified in livestock farming such as farm households that adopted perennial and non-conventional fodder (80.00%), mineral mixture feeding (78.33%), dual purpose crops (71.67%), balanced feeding (61.66%), augmented fodder supply through improved varieties (56.67%), cereal fodders growth enhancing higher crude protein contents (55.00%), regular vaccination (53.33%), periodic health check-up including deworming (51.67%), climate proof shelter (48.33%), hay and silage making (40.00%), azolla cultivation (25.00%), feeding Vitamin E (18.33%) and hydroponics (11.67%). There were 16 strategies identified in other components in farming. Around 70 per cent of the households adopted balanced feeding in poultry, followed by climate

proof shelter in poultry (60%), temperature control in poultry (55%), short-term to long-term financing (45%), regular vaccination in broilers and layer breeders (40%), dual purpose crops (40%), periodic health check-up (35.00%), participation non-fishing livelihoods (35%), migrating to another fishing area (30%), changing fishing time (25%), testing approaches large-scale and small-scale fisheries (20.00%), increasing fishing efforts (20%), aquaculture production (15%), fishing further away or deep inside the water, catching smaller fish (15%) and increasing daily fishing time (10%).

4.3.1.5.2. Adoption of coping strategies to climate change by households in Sindhudurg

The coping strategies are presented in Table 4.15 for Sindhudurg district. Out of 14 strategies identified in crop farming like drought tolerant varieties (78.33%), crop insurance (68%), soil fertility and nutrient management (63%), insect pest and disease management (60%), subsidiary income and employment generating activities (58%), broadcasting (53.33%), taking help of early warning and forecasting of drought (53%), improved water management (45%), conservation agriculture practices (38.33%), mulching (35.00%), zero tillage (30%), summer ploughing (25%), 23.33 per cent households adopted the SRI and seed drill sowing (21.67%). In livestock farming, 65 per cent households adopted climate proof shelter. Other strategies adopted were as follows: use of perennial and nonconventional fodder (58.33%), balanced feeding (48.33%), augmented fodder supply through improved varieties (45%), mineral mixture feeding (45%), regular vaccination (43.33%), dual purpose crops (38.33%), periodic health check-up including deworming (35%), feeding Vitamin E (25%), seaweed utilization (23.33%), cereal fodders growth enhancing higher crude protein contents (23.33%), hay and silage making (18.33%), hydroponics (13.33%) and azolla cultivation (8.33%). For strategies in other components, 75 per cent households adopted climate proof shelter in poultry, followed by balanced feeding in poultry (65%), temperature control in poultry (60%), regular vaccination in broilers and layer breeders (55%), aquaculture production (55.00%), increasing daily fishing time (45%), changing fishing time (45%), periodic health check-up (35%), catching smaller fish (35%), participation non-fishing livelihoods (30%), testing approaches large-scale and small-scale fisheries (30%), short-term and long-term financing (15%) and migrating to another fishing area (10%).

4.3.1.5.3. Adoption of coping strategies to climate change by households in Ahmednagar

The coping strategies are presented in Table 4.16 for Ahmednagar district. Households adopted strategies like crop insurance (68.33%), insect pest and disease management (65.00%),

improved water management (63.33%), soil fertility and nutrient management (61.67%), drought tolerant varieties (53.33%), seed drill sowing (51.67%), broadcasting (46.67%), mulching (46.67%), zero tillage (43.33%), subsidiary income and employment generating activities (40.00%), conservation agriculture practices (36.67%), summer ploughing (25.00%) and taking help of early warning and forecasting of drought (23.33%). In livestock farming strategies adopted were like mineral mixture feeding (53.33%), use of perennial and nonconventional fodder (53.33%), balanced feeding (51.67%), dual purpose crops (51.67%), 50 per cent households adopted climate proof shelter, augmented fodder supply through improved varieties (48.00%), regular vaccination (46.67%), cereal fodders growth enhancing higher crude protein contents (36.67%), periodic health check-up including deworming (36.67%), feeding Vitamin E (28.33%), hay and silage making (25.00%), azolla cultivation (11.67%) and hydroponics (3.33%). In other components, 50 per cent households adopted climate proof shelter in poultry, balanced feeding in poultry (45%), temperature control in poultry (40%), regular vaccination in broilers and layer breeders (35%), short-term to long-term financing (30%), changing fishing time (25%), increasing daily fishing time (20%), periodic health check-up (15%), catching smaller fish (15%) dual purpose crops (10%), testing approaches large-scale and small-scale fisheries (10%), increasing fishing efforts (10%), aquaculture production(10%), no farm household migrated to another fishing area hence adoption per centage for this strategy was zero, fishing further away or deep inside the water and participation non-fishing livelihoods (10%).

Table 4.14: Per centage of households adopted coping strategies in Parbhani (n = 60)

Crop farming			Livestock farming			Others		
S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households
1	Drought Tolerant, early maturing, salt tolerant Varieties	68.33	1	Use of perennial and nonconventional fodder	80.00	1	Balanced feeding	70.00
2	Insect pest and disease management	65.00	2	Mineral mixture feeding	78.33	2	Climate proof shelter	60.00
3	Crop insurance	58.33	3	Dual purpose crops	71.66	3	Temperature management	55.00
4	Broadcasting	53.33	4	Balanced feeding	61.66	4	Short-term to long-term financing	45.00
5	Subsidiary income and employment generating activities	51.66	5	Augmented fodder supply through improved varieties	56.66	5	Regular vaccination	40.00
6	Mulching	46.66	6	Cereal fodders growth enhancing higher crude protein contents	55.00	6	Dual purpose crops	40.00
7	Improved water management	45.00	7	Regular vaccination	53.33	7	Periodic health check-up	35.00
8	Seed Drill sowing	43.33	8	Periodic health check-up including deworming	51.66	8	Participation non-fishing livelihoods	35.00
9	Soil fertility and nutrient management	36.66	9	Climate proof shelter	48.33	9	Migrating to another fishing area	30.00
10	Zero tillage	30.00	10	Hay and Silage making	40.00	10	Changing fishing time	25.00
11	Summer Ploughing	25.00	11	Azolla cultivation	25	11	Testing approaches large-scale and small-scale fisheries	20.00
12	Conservation agriculture practices	23.33	12	Feeding Vitamin E	18.33	12	Increasing fishing efforts	20.00
13	Taking help of Early Warning and Forecasting of Drought	23.33	13	Hydroponics	11.66	13	Aquaculture production	15.00
14	SRI	00.00	14	Seaweed utilization	00.00	14	Catching smaller fish	15.00
						15	Increasing daily fishing time	10.00
						16	Fishing further away or deep inside the water	10.00

Table 4.15: Per centage of households adopted coping strategies in Sindhudurg (n = 60)

Crop farming			Livestock farming			Others		
S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households
1	Drought Tolerant, early maturing, salt tolerant Varieties	78.33	1	Climate proof shelter	65.00	1	Climate proof shelter	75.00
2	Crop insurance	68.33	2	Use of perennial and nonconventional fodder	58.33	2	Balanced feeding	65.00
3	Soil fertility and nutrient management	63.33	3	Balanced feeding	48.33	3	Temperature management	60.00
4	Insect pest and disease management	60.00	4	Mineral mixture feeding	45.00	4	Regular vaccination	55.00
5	Subsidiary income and employment generating activities	58.33	5	Augmented fodder supply through improved varieties	45.00	5	Aquaculture production	55.00
6	Broadcasting	53.33	6	Regular vaccination	43.33	6	Increasing daily fishing time	45.00
7	Taking help of Early Warning and Forecasting of Drought	53.33	7	Dual purpose crops	38.33	7	Changing fishing time	45.00
8	Improved water management	45.00	8	Periodic health check-up including deworming	35.00	8	Periodic health check-up	35.00
9	Conservation agriculture practices	38.33	9	Feeding Vitamin E	25.00	9	Catching smaller fish	35.00
10	Mulching	35.00	10	Seaweed utilization	23.33	10	Testing approaches large-scale and small-scale fisheries	30.00
11	Zero tillage	30.00	11	Cereal fodders growth enhancing higher crude protein contents	23.33	11	Fishing further away or deep inside the water	30.00
12	Summer Ploughing	25.00	12	Hay and Silage making	18.33	12	Participation non-fishing livelihoods	30.00
13	SRI	23.33	13	Hydroponics	13.33	13	Short-term to long-term financing	15.00
14	Seed Drill sowing	21.66	14	Azolla cultivation	08.33	14	Migrating to another fishing area	10.00
						15	Dual purpose crops	00.00
						16	Increasing fishing efforts	00.00

Table 4.16: Per centage of households adopted coping strategies in Ahmednagar (n = 60)

Crop farming			Livestock farming			Others		
S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households	S.No.	Coping strategies	% of households
1	Crop insurance	68.33	1	Mineral mixture feeding	53.33	1	Climate proof shelter	50.00
2	Insect pest and disease management	65.00	2	Use of perennial and nonconventional fodder	53.33	2	Balanced feeding	45.00
3	Improved water management	63.33	3	Balanced feeding	51.66	3	Temperature management	40.00
4	Soil fertility and nutrient management	61.66	4	Dual purpose crops	51.66	4	Regular vaccination	35.00
5	Drought Tolerant, early maturing, salt tolerant Varieties	53.33	5	Climate proof shelter	50.00	5	Short-term to long-term financing	30.00
6	Seed Drill sowing	51.66	6	Augmented fodder supply through improved varieties	48.33	6	Changing fishing time	25.00
7	Broadcasting	46.66	7	Regular vaccination	46.66	7	Increasing daily fishing time	20.00
8	Mulching	46.66	8	Cereal fodders growth enhancing higher crude protein contents	36.66	8	Periodic health check-up	15.00
9	Zero tillage	43.33	9	Periodic health check-up including deworming	36.66	9	Catching smaller fish	15.00
10	Subsidiary income and employment generating activities	40.00	10	Feeding Vitamin E	28.33	10	Dual purpose crops	10.00
11	Conservation agriculture practices	36.66	11	Hay and Silage making	25.00	11	Testing approaches large-scale and small-scale fisheries	10.00
12	Summer Ploughing	25.00	12	Azolla cultivation	11.66	12	Increasing fishing efforts	10.00
13	Taking help of Early Warning and Forecasting of Drought	23.33	13	Hydroponics	03.33	13	Aquaculture production	10.00
14	SRI	00.00	14	Seaweed utilization	00.00	14	Fishing further away or deep inside the water	10.00
						15	Participation non-fishing livelihoods	10.00
						16	Migrating to another fishing area	00.00

4.3.1.6. Intensity of adoption for different vulnerable districts

The intensity of adoption across districts as per the extent of vulnerability is given in Table 4.17 to 4.19. The mean value of intensity of adoption in Parbhani is estimated at 0.10 and SD as 0.07 (Table 4.17). The households in Parbhani having the intensity of adoption more than the mean value are called as high level adopters and *vice-versa*. Out of 60 households in Parbhani, 26 were classified as high level adopters and the remaining (34 households) were low level adopters. The high and low level adopters have the mean value of intensity of adoption as 0.18 and 0.05, respectively. These values were significantly different at five per cent level of probability. Sindhudurg has the mean value of intensity of adoption as 0.10 and SD as 0.07 (Table 4.18). Out of 60 households in Sindhudurg, 30 were identified as high level adopters, while the remaining 30 households were categorized as low level adopters. The high and low level adopters have the mean value of intensity of adoption as 0.16 and 0.04, respectively. These values were significantly different at five per cent level of probability. Ahmednagar district has a mean value of 0.12 and a standard deviation of 0.08 (Table 4.19). In Ahmednagar, 29 of 60 households were high level adopters, with a mean intensity of adoption estimated at 0.19, and 31 were low level adopters, with 0.05 as the mean intensity of adoption. At the 5 per cent level of probability, these mean values were significantly different. Among district wise aggregate mean value of intensity of adoption, the highest value was observed in Ahmednagar (0.12), followed by Parbhani (0.10) and Sindhudurg (0.10). This shows that households in Ahmednagar were having more intensity to adopt the coping strategies in comparison to other two districts. Likewise, the intensity of adoption by high level adopters were also high in Ahmednagar (0.19) followed by Parbhani (0.18) and Sindhudurg (0.16). However, more number of high level adopters were observed in Sindhudurg (31), followed by Ahmednagar (29) and Parbhani (26). The results revealed that Ahmednagar is having the highest intensity of adoption (0.12) due to the increased awareness towards water management practices. Though more number of high level adopters were found in Sindhudurg (31), their intensity to adopt coping strategies were low (0.10) because Sindhudurg is a coastal district facing a frequent occurrence of cyclones along with a persistent drought situation. Also, in Parbhani, due to prevailing drought condition, the intensity of adoption by high level adopters was low (0.18), in comparison to Ahmednagar (0.19).

Table 4.17: Mean difference between high and low level adopters in Parbhani (SeVI: High)

Variables	Overall (n= 60)	High level adopters (n = 26)	Low level adopters (n = 34)	Mean differences between high and low level adopters
Dependant				
Adoption	0.83 (0.37)			
Intensity of adoption	0.10 (0.07)	0.18 (0.06)	0.05 (0.04)	0.13*
Explanatory				
Age	44.67 (9.29)	44.88 (9.02)	44.50 (9.49)	0.38
Education level	3.18 (1.45)	4.88 (1.25)	3.41 (1.56)	1.47
Monthly gross income	62404.10 (28859.71)	71638.93 (27152.98)	55342.18 (28122.96)	16296.76*
Average farm size	4.23 (2.13)	4.38 (2.45)	4.12 (1.84)	0.27
Average herd size	4.63 (2.07)	5.15 (1.54)	4.24 (2.33)	0.92
Sources of climate variability related information	1.95 (1.15)	3.81 (1.14)	2.06 (1.14)	1.75**
Easy access to credit	0.82 (0.39)	1.77 (0.42)	0.85 (0.35)	0.92*
Number of droughts in last 10 years	3.42 (1.26)	3.62 (1.27)	3.26 (1.22)	0.35*
Number of family members engaged in farming	5.03 (1.22)	5.12 (1.60)	4.97 (0.82)	0.14
Social participation	0.17 (0.37)	0.23 (0.42)	0.12 (0.32)	0.11
Trend in annual rainfall	94.38 (1.58)	95.06 (1.81)	94.63 (1.32)	0.43**

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend

Figures within parentheses indicate standard deviation.

**, * indicate the statistical significance at 1 and 5 per cent level of probability, respectively.

Table 4.18: Mean difference between high and low level adopters in Sindhudurg (SeVI: Moderate)

Variables	Overall (n= 60)	High level adopters (n = 30)	Low level adopters (n = 30)	Mean differences between high and low level adopters
Dependant				
Adoption	0.80 (0.40)			
Intensity of adoption	0.10 (0.07)	0.16 (0.04)	0.04 (0.03)	0.12*
Explanatory				
Age	42.90 (10.38)	44.70 (11.26)	43.10 (9.42)	1.60*
Education level	3.02 (1.24)	4.57 (1.33)	3.47 (0.96)	1.10*
Monthly gross income	48751.70 (20312.60)	56870.31 (21145.73)	40633.08 (15691.98)	16237.24*
Average farm size	2.00 (1.16)	2.90 (0.86)	2.10 (1.38)	0.80**
Average herd size	4.80 (1.51)	5.00 (1.44)	4.60 (1.56))	0.40
Sources of climate variability related information	3.88 (0.78)	4.83 (0.780)	3.93 (0.77)	0.90**
Easy access to credit	0.90 (0.30)	0.93 (0.25)	0.87 (0.34)	0.07
Number of droughts in last 10 years	1.48 (0.70)	1.53 (0.72)	1.43 (0.67)	0.10
Number of family members engaged in farming	4.30 (0.97)	5.17 (1.00)	4.43 (0.92)	0.73
Social participation	0.87 (0.34)	1.83 (0.37)	0.90 (0.30)	0.93**
Trend in annual rainfall	171.92 (11.03)	173.55 (11.65)	172.30 (10.35)	1.25*

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend

***Figures within parentheses indicate standard deviation.

**, * indicate the statistical significance at 1 and 5 per cent level of probability, respectively.

Table 4.19: Mean difference between high and low level adopters in Ahmednagar (SeVI: Low)

Variables	Overall (n= 60)	High level adopters (n = 29)	Low level adopters (n = 31)	Mean differences between high and low level adopters
Dependant				
Adoption	0.90 (0.30)			
Intensity of adoption	0.12 (0.08)	0.19 (0.05)	0.05 (0.04)	0.14*
Explanatory				
Age	44.55 (8.98)	44.90 (7.64)	44.23 (10.07)	0.67
Education level	4.30 (1.48)	4.45 (1.25)	4.16 (1.65)	0.29
Monthly gross income	112393.26 (63794.67)	127194.22 (37645.06)	117256.88 (80636.79)	9937.34**
Average farm size	4.93 (2.15)	7.79 (1.95)	5.06 (2.31)	2.73*
Average herd size	6.48 (4.48)	8.76 (2.53)	7.16 (5.65)	1.60
Sources of climate variability related information	4.58 (1.44)	5.38 (1.56)	4.77 (1.29)	0.61
Easy access to credit	0.95 (0.22)	1.93 (0.25)	0.97 (0.18)	0.96*
Number of droughts in last 10 years	3.57 (1.02)	3.59 (0.81)	3.55 (1.19)	0.04
Number of family members engaged in farming	4.73 (1.06)	5.72 (1.05)	4.74 (1.08)	0.98*
Social participation	0.93 (0.25)	0.97 (0.18)	0.90 (0.30)	0.06
Trend in annual rainfall	104.40 (3.54)	104.53 (3.60)	104.28 (3.47)	0.25

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend

Figures within parentheses indicate standard deviation.

** , * indicate the statistical significance at 1 and 5 per cent level of probability, respectively.

4.3.2. DETERMINANTS OF CLIMATE CHANGE COPING STRATEGIES

In this section, the factors that influence the adoption of climate change coping strategies were discussed. Adoption of coping strategies involves a two-step decision-making process: the first step is determining whether to adopt or not (probability of adoption), and the second step is determining how much to adopt (intensity of adoption). These steps can be captured by Cragg's original double hurdle model (1971). The first step is to determine whether the respondent is a high level adopter or not using the Probit model, and the second step is to determine the factors affecting the adoption level using the Tobit model. Table 4.20 shows the explanatory variables used in the analyses and their measurement. A total of 11 explanatory variables were selected for the analysis, including some climate explanatory variables like "trend in annual rainfall", and "number of droughts in the past 10 years" as the present study is related to climate change.

Table 4.20: Explanatory variables and its measurement

S.No.	Variables	Measurement
1	Age	Age of household head (years)
2	Education level	Educational level of the household head (Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6)
3	Monthly gross income	₹/month
4	Average farm size	Acre
5	Average herd size	Number of animals
6	Sources of climate variability related information	Frequency
7	Easy access to credit	Access to credit in formal and informal institutions (No=0; Yes=1)
8	Number of droughts in the past 10 years	Number
9	Number of family members engaged in farming	Number
10	Social participation	Participation in social activities (No=0; Yes=1)
11	Trend in annual rainfall	Mann Kendall trend

Note: References used to select the explanatory variables S.No.1: Arslan *et al.*, 2014, 2: Tambo and Abdoulaye, 2012; Awotide *et al.*, 2014, 3: Asfaw *et al.*, 2016, 4: Akudungu, 2012, 5: Husin *et al.*, 1999, 6: Ochieng *et al.*, 2017, 7: Mal *et al.*, 2012, 8: Cavatassi *et al.*, 2011, 9,10,11: Suvedi *et al.*, 2017.

4.3.2.1. Mean difference between high and low level adopters across vulnerable districts

Mean difference between high and low level adopters in high (Parbhani), moderate (Sindhudurg) and low (Ahmednagar) socio-economically vulnerable districts are presented in Table 4.17 to 4.19, respectively. In Parbhani, a significant difference at one per cent level was

observed between high and low level adopters in mean value of the variables like sources of climate variability related information and trend in annual rainfall. Also, significant difference at five per cent level of probability was observed in intensity of adoption, monthly gross income, number of droughts in the past ten years, and easy access to credit (Table 4.17). This shows that the dependent variable (intensity of adoption) and almost half of the explanatory variables were having statistically significant mean difference between high and low level adopters. The mean value for all the variables was more in high level adopters category than the low level adopters. This reveals that the high level adopters of Parbhani were relatively efficient in comparison to their counterpart. In the case of Sindhudurg, the variables such as intensity of adoption, age, education level, monthly gross income, and trend in annual rainfall have significant mean differences at five per cent level of probability, whereas average farm size, sources of climate variability related information and social participation were significantly different at one per cent level between high and low level adopters (Table 4.18). Also, the high level adopters have relatively higher mean values across variables. Ahmednagar has significant mean difference in monthly gross income at one per cent level of probability between high and low level adopters; whereas intensity of adoption, average farm size, easy access to credit and number of family members engaged in farming were significantly different at five per cent level between high and low level adopters (Table 4.19). In this district also, the high level adopters have a higher mean value across variables considered for the study.

4.3.2.2. Determinants of coping strategies in Parbhani

4.3.2.2.1. Factors determining the probability of adoption in Parbhani

Probit regression is used to determine whether (or not) a respondent is a high level adopter. In the double hurdle model, this is the first step. The factors determining the probability of adoption of coping strategies in Parbhani are presented in Table 4.21. The results show that education level, number of family members in farming and access to credit (Mal *et al.*, 2012) have positive and significant influence on probability of adoption. This shows that as these variables increase, the likelihood of being a high-level adopter increases as well. The marginal effect of education level coefficient shows that as the education level increases by 'one' level (*i.e.*, from primary to secondary), the probability of being a high level adopter increases by 0.007. Likewise, the marginal effect on access to credit and number of family members engaged in farming are also interpreted. Access to credit encourages the adoption of coping strategies, corroborating the findings of Vijayasathy (2015).

Table 4.21: Determinants of adoption of coping strategies in Parbhani (SeVI: High)

Variables	Coefficients	Standard Errors	Marginal Effects
Age	-0.2633	0.2601	-0.001
Education level	0.1984*	0.2726	0.007
Monthly gross income	0.5399	0.4136	0.005
Average farm size	-0.3897	0.3151	-0.010
Average herd size	-0.3853	0.3595	-0.010
Sources of climate variability related information	0.4416	0.3164	0.020
Easy access to credit	0.0845*	0.2877	0.011
Number of droughts in the past 10 years	0.4858	0.2758	0.020
Number of family members engaged in farming	0.0410*	0.2663	0.002
Social participation	2.0236	130.1929	0.283
Trend in annual rainfall	-0.4510	0.3097	-0.015
Constant	26.968	18.904	
Number of observations	60		
Chi square	16.743		
R ² (Nagelkerke)	0.410		

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * Indicates the statistical significance at 5 per cent level of probability.

4.3.2.2.2. Factors determining the intensity of adoption by high and low level adopters in Parbhani

Factors affecting the intensity of adoption are measured using the tobit regression. This is the second step in the double hurdle model. Out 60 households in Parbhani, 26 were high level adopters and 34 were low level adopters. Factors determining the intensity of adoption by high and low level adopters in Parbhani are presented in Table 4.22. The result, in the case of high level adopters, showed that the number of family members engaged in farming (Danso-Abbeam *et al.*, 2019) and education level have positive and significant relationship with the intensity of adoption of coping strategies. As education of the household increases, the intensity of adoption also increases (Tambo and Abdoulaye, 2012). Other variables like herd size (Husin *et al.*, 1999) and trend in annual rainfall have negative but significant relationship

Table 4.22: Determinants of intensity of adoption of coping strategies in Parbhani (SeVI: High)

Variables	High level adopters		Low level adopters	
	Coefficients	Standard Errors	Coefficients	Standard Errors
Age	0.0009	0.0015	-0.0008	0.0008
Education level	0.0003*	0.0160	-0.0086	0.0047
Monthly gross income	-0.0346	0.0340	-0.0011	0.0183
Average farm size	-0.0074	0.0115	-0.0051	0.0043
Average herd size	-0.0139*	0.0114	-0.0064	0.0041
Sources of climate variability related information	0.0102	0.0149	0.0194*	0.0072
Easy access to credit	0.0160	0.0325	-0.0041	0.0202
Number of droughts in last 10 years	0.0039	0.0134	0.0127*	0.0062
Number of family members engaged in farming	0.0234*	0.0104	0.0060	0.0086
Social participation	0.0126	0.0364	0.0367	0.0223
Trend in annual rainfall	-0.0088*	0.0098	-0.0056	0.0051
Constant	0.8803	0.9670	0.5059	0.4798
Number of observations	26		34	
Prob>Chi square	0.0408		0.0133	
R ²	0.4761		0.4537	
Adjusted R ²	0.0645		0.1806	

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability

with the intensity of adoption. Also, variables like age, sources of climate variability related information (Ochieng *et al.*, 2017), number of droughts faced by the farmer in the past 10 years (Cavatassi *et al.*, 2011), and access to credit (Mal *et al.*, 2012) are having positive relationship with intensity of adoption but not significant. These results suggest that as these variables increase, the likelihood of being a high level adopter increases but not significantly. Surprisingly in the case of low level adopters, sources of climate variability related information and number of droughts faced by the farmers in the past ten years have positive and significant relationship with the intensity of being a low level adopter of coping strategies. If these variables increase, the low intensity of adoption increases.

4.3.2.3. Determinants of coping strategies in Sindhudurg

4.3.2.3.1. Factors determining the probability of adoption in Sindhudurg

The factors determining the probability of adoption of coping strategies in Sindhudurg are presented in Table 4.23. The results show that average farm size, access to credit (Mal *et al.*, 2012) and social participation (Suvedi *et al.*, 2017) have positive and significant influence on

Table 4.23: Determinants of probability of adoption of coping strategies in Sindhudurg (SeVI: Moderate)

Variables	Coefficients	Standard Errors	Marginal Effects
Age	0.3267	0.2497	0.007
Education level	-0.3919	0.2258	-0.067
Monthly gross income	-0.1700	0.2292	0.002
Average farm size	0.4209*	0.2879	0.078
Average herd size	0.0052	0.2313	0.001
Sources of climate variability related information	-0.1866	0.2379	-0.051
Easy access to credit	0.0085*	0.2084	0.006
Number of droughts in last 10 years	0.2156	0.2545	0.066
Number of family members engaged in farming	-0.4288	0.2614	-0.094
Social participation	0.0056*	0.2632	0.004
Trend in annual rainfall	0.4491	0.2155	0.009
Constant	-4.291	3.888	
Number of observations	60		
Chi square	12.436		
R ² (Nagelkerke)	0.296		

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability

the probability of adoption. This shows that as these variables increase, the likelihood of being a high-level adopter increases as well. The marginal effect of average farm size coefficient shows that as the average farm size (Akudungu, 2012) increases by one acre, the probability of being a high level adopter increases by 0.078. Likewise marginal effect on access to credit and social participation are also interpreted. Access to credit encourages the adoption of coping strategies, which is comparable again with Akudungu (2012) and Vijayasathy (2015).

4.3.2.3.2. Factors determining the intensity of adoption in Sindhudurg

Out of 60 households in Sindhudurg, 30 were high level adopters and 30 were low level adopters. The factors determining the intensity of adoption by high and low level adopters in Sindhudurg are presented in Table 4.24. The result, in the case of high level adopters, showed that age

Table 4.24: Determinants of intensity of adoption of coping strategies in Sindhudurg (SeVI: Moderate)

Variables	High level adopters		Low level adopters	
	Coefficients	Standard Errors	Coefficients	Standard Errors
Age	0.0012*	0.0006	0.0011	0.0007
Education level	0.0096*	0.0048	0.0006	0.0063
Monthly gross income	-0.0004	0.0197	-0.0126	0.0138
Average farm size	-0.0051*	0.0090	0.0143*	0.0048
Average herd size	-0.0080	0.0047	-0.0041	0.0042
Sources of climate variability related information (Frequency)	-0.0022	0.0084	-0.0118	0.0076
Easy access to credit	-0.0408	0.0277	-0.0238	0.0187
Number of droughts in last 10 years	0.0065*	0.0106	0.0032	0.0095
Number of family members engaged in farming	-0.0019	0.0077	-0.0084	0.0077
Social participation	0.0357	0.0220	0.0242	0.0236
Trend in annual rainfall	-0.0002	0.0007	0.0008	0.0006
Constant	0.1664	0.1138	-0.0665	0.1416
Number of observations	30		30	
Prob>Chi square	0.580		0.0086	
R ²	0.4978		0.5407	
Adjusted R ²	0.1908		0.2601	

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability.

(Arslan *et al.*, 2014), education level (Tambo and Abdoulaye, 2012; Awotide *et al.*, 2014), number of droughts in the past ten years (Roco *et al.*, 2014) have a positive and significant relationship with the intensity of being a high level adopter of coping strategies. This shows that as these variables increase, the intensity of being a high-level adopter increases. Other variables like social participation have positive but not significant relationship with the intensity of adoption. In the case of low level adopters, average farm size is having a positive and significant relationship with being a low level adopter. The result showed that average farm size (-0.0051) has a negative and significant influence on the intensity of adoption by high level adopters, which is contradictory to the probability of adoption. This is because, when the farm size increases, households may not deviate too much from intensity of adoption, which leads to decrease in the intensity of adoption.

4.3.2.4. Determinants of coping strategies in Ahmednagar

4.3.2.4.1. Factors determining the probability of adoption in Ahmednagar

The factors determining the probability of adoption of coping strategies in Ahmednagar are presented in Table 4.25. The results show that the average herd size has a positive and significant relationship with the probability of adoption of coping strategies. These results are comparable with the results of Asfaw *et al.* (2019). The marginal effect coefficient on average herd size shows that as the average herd size (Husin *et al.*, 1999) increases by one animal, the probability of being a high level adopter increases by 0.003. Likewise, marginal effects on other variables can be interpreted. Also, the monthly gross income is having a significant but negative relationship with the probability of adoption of coping strategies. This means that as monthly gross income decreases, the probability of being a high level adopter increases (Marenya *et al.*, 2017). Variables like number of family members engaged in farming, social participation, trend in annual rainfall, average farm size, easy access to credit and education level have positive relationship with the probability of adoption but not significant.

Table 4.25: Determinants of probability of adoption of coping strategies in Ahmednagar (SeVI: Low)

Variables	Coefficients	Standard Errors	Marginal Effects
Age	-0.182	0.449	-0.0002
Education level	0.446	0.434	0.0027
Monthly gross income	-0.714*	2.629	0.0023
Average farm size	0.707	1.222	0.0030
Average herd size	0.154*	2.672	0.0003
Sources of climate variability related information	-0.404	0.588	-0.0025
Easy access to credit	0.709	0.432	0.0294
Number of droughts in last 10 years	-0.945	0.705	-0.0084
Number of family members engaged in farming	0.448	0.695	0.0038
Social participation	0.893	0.518	0.0324
Trend in annual rainfall	0.511	0.278	0.0013
Constant	-17.173	11.634	
Number of observations	60		
Chi square	19.910		
R ² (Nagelkerke)	0.591		

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability.

4.3.2.4.2. Factors determining the intensity of adoption in Ahmednagar

Out 60 households in Ahmednagar district, 29 were high level adopters and the rest 34 belonged to low level adopter category. Factors determining the intensity of adoption by high and low level adopters in Ahmednagar are presented in Table 4.26. For high level adopters, the monthly gross income has a positive and significant relationship with the intensity of being a high level adopter of coping strategies to the climate change (Asfaw *et al.*, 2016). Also, other variables like sources of climate variability related information, easy access to credit, number of family members engaged in farming, social participation and trend in annual rainfall have positive but not significant relationship with the intensity of being a high level adopter. As Ahmednagar district falls under the low socio-economically vulnerable category, these results are comparable and logical. In the case of low level adopters, number of droughts in the past

ten years, easy access to credit and sources of climate variability related information are having negative but significant relationship with the intensity of being a low level adopter. The possible reason is increase in these variables might leads a farmer to move on towards a high level of adoption of coping strategies. As values of these variables decrease, the intensity of being a low level adopter increase. The variable like age was negative but insignificantly related to both high (-0.0001) and low level adopters (-0.0003). This shows that more experienced farmers opt for high level adoption than low level adoption.

Table 4.26: Determinants of intensity of adoption of coping strategies in Ahmednagar (SeVI: Low)

Variables	High level adopters		Low level adopters	
	Coefficients	Standard Errors	Coefficients	Standard Errors
Age	-0.0001	0.0016	-0.0003	0.0009
Education level	-0.0004	0.0091	0.0044	0.0045
Monthly gross income	0.0101*	0.0640	-0.110	0.194
Average farm size	-0.0125*	0.0065	0.0062	0.0055
Average herd size	-0.0385*	0.0127	0.0230	0.0148
Sources of climate variability related information	0.0071	0.0058	-0.0033*	0.0073
Easy access to credit	0.0133	0.0406	-0.0750*	0.0355
Number of droughts in last 10 years	-0.0021	0.0134	-0.0057*	0.0077
Number of family members engaged in farming	0.0060	0.0105	-0.0009	0.0064
Social participation	0.0213	0.0605	0.0491*	0.0280
Trend in annual rainfall	0.0007	0.0028	0.0022	0.0021
Constant	0.0174	0.3374	-0.2913	0.2414
Number of observations	29		31	
Prob>Chi square	0.0077		0.0483	
R ²	0.4932		0.4926	
Adjusted R ²	0.1652		0.1989	

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability .

4.3.2.5.1. Determinants of probability of adoption of coping strategies (Overall)

The factors determining the probability of adoption of coping strategies for high and low level adopters (n=180) are presented in Table 4.27. Dummy (High=0, Moderate=1, Low=2) as an independent variable was introduced to capture the effect of degree of vulnerability on probability of adoption. Access to credit and social participation were having a positive and

significant relationship with the probability of adoption of coping strategies (Mengistu and Assefa, 2019). Dummy variable showed a negative and significant relationship with the probability of adoption at 5 per cent level. The results also implies that the degree of vulnerability decreases due to increased probability of adoption.

Table 4.27: Determinants of probability of adoption of coping strategies (n=180)

Variables	Coefficients	Standard Errors
Age	-0.0140	0.0127
Education level	0.0326	0.0873
Monthly gross income	2.22E-06	5.38e-06
Average farm size	0.0391	0.0727
Average herd size	-0.0739	0.0763
Sources of climate variability related information	-0.0022	0.1110
Easy access to credit	0.6430*	0.3344
Number of droughts in last 10 years	0.0264	0.1191
Number of family members engaged in farming	-0.0483	0.1098
Social participation	0.5561*	0.3551
Trend in annual rainfall	-0.0036	0.0058
Degree of vulnerability (Dummy variable)	-0.1087*	0.2927
Constant	1.4472	1.3615
Number of observations	180	
Wald Chi ²	9.91	
Prob>Chi square	0.6239	

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability.

4.3.2.5.2. Determinants of intensity of adoption of coping strategies by high and low level adopters

The factors determining the intensity of adoption of coping strategies for high and low level adopters (n=180) are presented in Table 4.28. A pooled regression analysis was performed to check whether the determinants of coping strategies are having a significant relationship with the intensity of adoption in the case of all 180 households in selected districts across vulnerability level (*i.e.*, High SeVI=Parbhani, Moderate SeVI: Sindhudurg, and Low SeVI=Ahmednagar). In the case of high level adopters, monthly gross income, average farm size, and

number of family members engaged in farming are having a positive and significant relationship with the intensity of adoption. Average herd size and degree of vulnerability (dummy variable) are having a negative and significant influence on being a high level adopter.

Table 4.28: Determinants of intensity of adoption of coping strategies by high and low level adopters.

Variables	High level adopters (n= 85)		Low level adopters (n=95)	
	Coefficients	Standard Errors	Coefficients	Standard Errors
Age	0.0006	0.0005	-0.0001	0.0003
Education level	0.0001	0.0040	0.0041*	0.0024
Monthly gross income	7.42E-07*	2.09e-07	-7.13e-09	1.70e-07
Average farm size	0.0002*	0.0029	0.0020	0.0018
Average herd size	-0.0128*	0.0031	-0.0011	0.0023
Sources of climate variability related information	0.0033	0.0038	0.0054	0.0035
Easy access to credit	-0.0063	0.0161	0.0205*	0.0111
Number of droughts in last 10 years	0.0030	0.0051	0.0008*	0.0034
Number of family members engaged in farming	0.0123*	0.0041	-0.0016	0.0036
Social participation	0.0204	0.0146	0.0173	0.0110
Trend in annual rainfall	0.0001	0.0002	-0.0009	0.0001
Degree of vulnerability (Dummy variable)	-0.0176*	0.0102	-0.0230*	0.0088
Constant	0.0699	0.0577	0.0245	0.0425
Number of observations	85		95	
Wald Chi ²	35.63		15.04	
Prob>Chi square	0.0004		0.2392	

Note: Units of the respective variables: Age: Age of household head in years, education level: Illiterate=0; Read and write=1; Primary=2; Middle=3; High School=4; Higher Secondary=5; Graduate and above=6, monthly gross income: ₹/month, average farm size: acre, average herd size: number of animals, sources of climate variability related information: frequency, access to credit in formal and informal institutions: No=0; Yes=1, no. of droughts in last 10 years: number, no. of family members engaged in farming: number, participation in social activities: No=0; Yes=1, trend in annual rainfall: Mann Kendall trend * indicates the statistical significance at 5 per cent level of probability.

As the probability of being a high level adopter increases, the degree of vulnerability decreases. In the case of low level adopters, education, easy access to credit, and number of droughts in the past ten years are having a positive and significant relationship with the probability of being

a low level adopter. As education level increases, the probability of being a low level adopter increases. This may be because of increased awareness due to higher education level of farm household. Increased access to credit increases the probability of being a low level adopter. Timely availability of credit makes the household to delay their farm operations of introducing coping strategies and divert the credit money flow to non-farm activities. Number of droughts in the past ten years also showed a negative and significant relationship with the probability of being a low level adopter. This may be due to the increasing distress of farmers and lack of motivation to introduce climate smart technologies in farming. The degree of vulnerability showed a negative and significant influence on the probability of being a low level adopter. As the socio-economic vulnerability decreases, the probability of being a low level adopter increases (Millock and Nauges, 2010).



Chapter-5



Summary and Conclusion

SUMMARY AND CONCLUSION

Climate change has become a serious threat to global community, especially vulnerable section like farmers. In Indian perspective Maharashtra is consistently facing major temperature and rainfall anomalies. This affects the agriculture production and sustainability of livelihoods negatively leading to socio-economic vulnerability. The extent of vulnerability plays an important role in determining the impact of climate change on rural households across regions so that suitable coping measures may be implemented. Such interventions bridge the gap between micro-level demands of farm households and macro-level policy initiatives.

In this context, the study on “**Assessing Socio-economic Vulnerability of Farm Households to Climate Change and its Coping Mechanism in Maharashtra**” was carried out, with the following specific objectives:

1. To assess the socio-economic vulnerability to climate change in the districts of Maharashtra.
2. To study the climate change induced socio-economic vulnerability in the farm households of the study region.
3. To analyse the adoption level and determinants of coping strategies practiced across vulnerable regions.

The first objective was aimed to develop a new socio-economic vulnerability index (SeVI) comprising crop, dairy as well as socio-economic indicators for 34 districts of Maharashtra based on the Intergovernmental Panel on Climate Change (IPCC) approach using exposure, sensitivity and adaptive capacity. Using secondary data, the districts were classified as high, moderate and low vulnerable based on magnitude of the index. To study the climate change induced socio-economic vulnerability in the farm households of the study region (Objective 2), 3 districts were selected randomly based on their vulnerability status (high, moderate and low). From each district, 2 blocks (total 6 blocks from 3 districts) and from each block, a cluster of villages (total 6 clusters from 6 blocks) were selected randomly. From each cluster of villages, 30 households were selected randomly (n = 180). Both primary data (agricultural year 2020-21) and secondary data were used in the analysis. For addressing the third objective, 14 coping strategies were identified in crop farming, 14 in livestock farming and 16 in ‘other’ category. The double hurdle model (DHM) was used to analyze probability and intensity of adoption of coping strategies practiced across vulnerable regions.

5.1 Salient Findings

5.1.1 Findings from Objective 1: Regional SeVI

- The regional level SeVI indicates that the highest exposure to climate change was observed in Sangali (0.62) and lowest in Wardha (0.38).
- Sensitivity was highest in Akola (0.68) and lowest in Sindhudurg (0.33).
- The highest adaptive capacity was found in Pune (0.56), while the lowest was observed in Beed (0.19).
- Overall, the constructed SeVI shows a wide divergence of 0.50 with a mean index of 0.68 and SD of 0.12. It was highest in Nandurbar (0.91) and lowest in Pune (0.41).
- A majority of the highly vulnerable districts fall under Central Maharashtra Plateau, Central Vidarbha and Scarcity Zone. Moderately vulnerable districts are found in every climatic zone barring North Konkan Coastal Zone.
- There is not a single district found in Central Maharashtra and Eastern Vidarbha Zone under low vulnerable category.
- Agro-climatic zone wise classification of socio-economic vulnerability shows that the Central Vidarbha Zone shares 6.78 per cent of the cropped area as highly vulnerable, 3.52 per cent area as moderately vulnerable and 1.48 per cent as low vulnerable. Eastern Vidarbha Zone shares 4.39 per cent total cropped area under moderately vulnerable category. North Konkan Coastal Zone is having 2.85 per cent area as low vulnerable. South Konkan Coastal Zone covers 1.83 per cent area under moderately vulnerable category.
- Scarcity Zone shares 4.80 per cent of the total cropped area as highly vulnerable, 5.18 per cent area as moderately vulnerable and 3.42 per cent as low vulnerable. Sub Montane Zone shares 3.53 per cent of the total cropped area as moderately vulnerable and 3.34 per cent area as low vulnerable. In the Western Ghat Zone, moderately vulnerable districts share 3.29 per cent of the total cropped area, low vulnerable districts in this zone shares are 7.86 per cent area. Western Maharashtra Plain Zone, which is a great source of biodiversity in Maharashtra, shares 1.48 of the total cropped area as highly vulnerable, 5.73 and 3.34 per cent as moderate and low vulnerable to climate change.

- The Central Maharashtra Plateau, Central Vidarbha and Scarcity Zones have a high exposure and sensitivity to climate change. Further, low drought return periods in those regions cause a potential threat to farming.
- North Konkan Zone have high sensitivity but low adaptive capacity implying the scope for diversified farming.
- Mapping of districts show that there is an instant need for focused policy efforts in Central Maharashtra Plateau Zone, Scarcity Zone and Eastern Vidarbha Zone.
- Results of regression tree analysis revealed that human development index (HDI), return period from moderate meteorological drought, trend in *kharif* rainfall, per centage of workers to the total population, and trend in summer rainfall were influencing the degree of socio-economic vulnerability.

5.1.2 Findings from Objective 2: Farm household level SeVI

- Household level (n=180) SeVI indicated that about 52 households (28.88 % of overall) were observed from high SeVI category, while 75 households (41.66 % of overall) were from moderate SeVI category, whereas remaining 53 households (29.44 % of overall) came under low SeVI category.
- Out of 60 households of Parbhani, 15 households (25.00 %) were found in high SeVI category, 25 households (41.67 %) in moderate SeVI and 20 households (33.33 %) in low SeVI category were observed. From 60 households of Sindhudurg, 18 households (30 %) were found in high SeVI category, 23 households (38.33 %) in moderate SeVI and 19 households (31.67 %) in low SeVI category were observed. Out of 60 households of Ahmednagar, 19 households (31.67 %) were found in high SeVI category, 27 households (45 %) in moderate SeVI and 14 households (23.33 %) in low SeVI category were observed.
- This reveals that households of Ahmednagar district were quite good adaptive to climate change induced socio-economic vulnerability than Sindhudurg and Parbhani. Households of Sindhudurg were more exposed to climate change. Households of Parbhani were more sensitive to climate change.
- Results of regression tree analysis revealed that number of animals registered for feed camp, unemployed households, loss of livestock due to drought, trend in *kharif* rainfall, easy access to electricity, total consumption expenditure on food, social participation

and number of droughts in last ten years were most closely associated variables which were affecting the degree of farm household level vulnerability.

5.1.3 Findings from Objective 3: Adoption and determinants of coping strategies

- In Parbhani, there were 14 strategies identified in crop farming. None of the households adopted the SRI technique as there was limited area under rice cultivation in Parbhani, but other strategies were adopted like drought tolerant varieties (68.33%), insect pest and disease management (65.00%), crop insurance (58.33%), broadcasting (53.33%), subsidiary income and employment generating activities (51.6%) and mulching (46.67%). There were 14 strategies identified in livestock farming such as farm households that adopted perennial and non-conventional fodder (80.00%), mineral mixture feeding (78.33%), dual purpose crops (71.67%), balanced feeding (61.66%) and augmented fodder supply through improved varieties (56.67%). There were 16 strategies identified in other components in farming. Around 70 per cent of the households adopted balanced feeding in poultry, followed by climate proof shelter in poultry (60%), temperature control in poultry (55%), short-term to long-term financing (45%), regular vaccination in broilers and layer breeders (40%), dual purpose crops (40%) and periodic health check-up (35.00%).
- In case of Sindhudurg, strategies identified in crop farming were like drought tolerant varieties (78.33%), crop insurance (68%), soil fertility and nutrient management (63%), insect pest and disease management (60%) and subsidiary income and employment generating activities (58%). In livestock farming, 65 per cent households adopted climate proof shelter. Other strategies adopted were as follows: use of perennial and nonconventional fodder (58.33%), balanced feeding (48.33%), augmented fodder supply through improved varieties (45%) and mineral mixture feeding (45%). For strategies in other components, 75 per cent households adopted climate proof shelter in poultry, followed by balanced feeding in poultry (65%), temperature control in poultry (60%), regular vaccination in broilers and layer breeders (55%) and aquaculture production (55.00%).
- In Ahmednagar, households adopted strategies like crop insurance (68.33%), insect pest and disease management (65.00%), improved water management (63.33%), soil fertility and nutrient management (61.67%) and drought tolerant varieties (53.33%) in crop farming component. In livestock farming strategies adopted were like mineral mixture feeding (53.33%), use of perennial and nonconventional fodder (53.33%),

balanced feeding (51.67%) and dual purpose crops (51.67%). In other components, 50 per cent households adopted climate proof shelter in poultry, balanced feeding in poultry (45%), temperature control in poultry (40%), regular vaccination in broilers and layer breeders (35%) and short-term to long-term financing (30%).

- The results of intensity of adoption show that, Parbhani has a mean value of 0.10 and a standard deviation of 0.07. In this district, 43.33 per cent (26) of the 60 households were high level adopters, while the remaining 56.66 per cent (34 households) were low level adopters. The high level and low level adopters have mean value of intensity of adoption as 0.18 and 0.13, respectively.
- Sindhudurg has a mean value of 0.10 and a standard deviation of 0.07. In Sindhudurg, 50 per cent (30) households were identified as high level adopters, while the remaining 50 per cent (30) were identified as low level adopters. The mean value of intensity of adoption for high and low level adopters is 0.16 and 0.04, respectively.
- Ahmednagar has a mean value of 0.12 and a standard deviation of 0.08. In Ahmednagar, 48.33 per cent (29) of 60 households were high level adopters, with a mean intensity of adoption of 0.19, and 51.66 per cent (31) were low level adopters, with a mean intensity of adoption of 0.05.
- In all districts, the mean values of high and low level adopters were significantly different at 5 per cent level of probability. Among district wise aggregate mean value of intensity of adoption, the highest value was observed in Ahmednagar (0.12), followed by Parbhani (0.10) and Sindhudurg (0.10). This shows that households in Ahmednagar were having more intensity to adopt the coping strategies in comparison to other two districts.
- The results of tobit analysis revealed that education level, number of family members in farming and access to credit have a positive and significant influence on probability of adoption of coping strategies for Parbhani. This shows that as these variables increase, the likelihood of being a high-level adopter increases as well. The marginal effect of education level coefficient shows that as the education level increases by 'one' level (Primary to secondary), the probability of being high level adopter increases by 0.007. The result in the case of high level adopters showed that number of family members engaged in farming and education level have positive and significant relationship with intensity of adoption of coping strategies by high level adopters. As education of the household increases, the intensity of adoption also increases. Other

variables like herd size and trend in annual rainfall have negative but significant relationship with intensity of adoption.

- Analysis of factors determining probability of adoption of coping strategies for Sindhudurg showed that average farm size, access to credit and social participation have positive and significant influence on probability of adoption. This shows that as these variables increase, the likelihood of being a high-level adopter increases as well. The marginal effect of average farm size coefficient shows that as the average farm size increases by one acre, the probability of being high level adopter increases by 0.078. The result in case of high level adopters showed that age, education level, number of droughts in the past ten years have positive and significant relationship with intensity of being high level adopter of coping strategies. This shows that as these variables increase, the intensity of being a high-level adopter increases.
- In the case of Ahmednagar, the results showed that average herd size has positive and significant relationship with probability of adoption of coping strategies. The marginal effect of average herd size coefficient shows that as the average herd size increases by one animal unit, the probability of being high level adopter increases by 0.003. Also, monthly gross income is having significant but negative relationship with probability of adoption of coping strategies. This means that as monthly gross income decreases the probability of being high level adopter increases. Factors determining intensity of adoption by high level and low level adopters for Ahmednagar were also analysed. For high level adopters, the monthly gross income has positive and significant relationship with intensity of being high level adopter of coping strategies to the climate change. In the case of low level adopters, the number of droughts in the previous ten years, easy access to credit, and sources of climate variability-related information have a negative but significant relationship with the intensity of being a low level adopter. This could be because an increase in these variables causes farmers to adopt coping strategies at a high level.
- Results of pooled regression analysis showed that access to credit and social participation were having positive and significant relationship with probability of adoption of coping strategies. Dummy variable showed negative and significant relationship with probability of adoption at 5 per cent level of significance. Degree of vulnerability decreases due to increased probability of adoption.

- In the case of high level adopters, monthly gross income, average farm size, no. of family members engaged in farming are having positive and significant relationship with intensity of adoption. Average herd size and degree of vulnerability (dummy variable) are having negative and significant influence on being high level adopter. As the probability of being high level adopter increase degree of vulnerability decreases.

5.2 Policy implications

Climate change has become a serious threat to Maharashtra's agrarian economy due to the persistent droughts, extreme floods, irregular rainfall, *etc.* Due to these sudden climatic variations, it is necessary to develop a holistic, comprehensive coping mechanism after assessing degree of climate change induced vulnerability.

5.2.1 High vulnerable districts

- To eliminate the ill-effects of climate change induced socio-economic vulnerability in highly vulnerable districts like Parbhani, regional level adaptation and mitigation strategies should be developed and diffused in farming. Social participation, access to credit, group credit facility should be improved in highly vulnerable districts. These factors will play a leading role towards risk averse economic growth in farming.

5.2.2 Moderate vulnerable districts

- In moderate vulnerable districts like Sindhudurg, strategies like water harvesting and conservation, proper credit disbursement, early warning and forecasting of climate change, climate proof shelter for farm animals, proper vaccination and periodic health check-up and diversified farming should be adopted. Grass root level evaluation and dissemination of sustainable coping strategies to climate change is important in vulnerable regions.

5.2.3 Low vulnerable districts

- Though the districts like Ahmednagar are low socio-economically vulnerable, still there is an acute need of developing immediate response force dealing with lacking coping strategies. Also, strategies like regular vaccination in broilers and layer breeders, temperature control in poultry, periodic health check-up, dual purpose crops, short-term to long-term financing were lacking in these districts. So, innovation and diffusion of

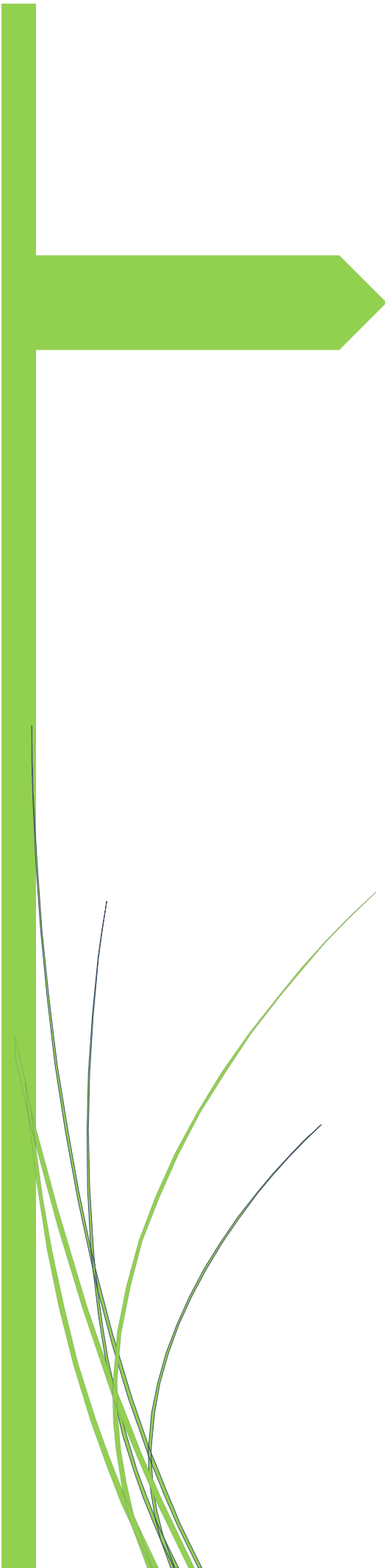
these strategies will benefit these districts to eliminate possible effects of climate change in future.

5.2.3 General recommendations

- Through strong communication channels, the policy-making process should include input from as many stakeholders as possible. Although policy will be highly diverse and frequently ambiguous due to the unique nature of each challenge posed by climate change, above mentioned fundamental principles will encourage strong policy formation.
- Adaptation efforts, particularly those aimed at mitigating the effects of a long-term climatic event, such as a drought or continuous flooding, necessitate government assistance, funding, and emergency measures.
- Adaptation and mitigation efforts must be flexible, as there is no such thing as a “single basket to all” policy. Finally, policy should be designed to encourage local household actions. Rural adaptation needs to reflect community priorities and, as such, should distribute upwards to strongly impact policies at the national level through popularising at the ground level actions in order to support these adaptation efforts.



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APPENDICES





M.Sc. Research

INTERVIEW SCHEDULE
on

“ASSESSING SOCIO-ECONOMIC VULNERABILITY OF FARM HOUSEHOLDS TO CLIMATE CHANGE AND ITS COPING MECHANISM IN MAHARASHTRA”

Vulnerability category: High / Moderate / Less

Serial No.: _____

SECTION-I

Village: _____ **Block:** _____ **District:** _____

1) General Information:

I.	Name of the Farmer:	
II.	Father's Name:	
III.	Caste:	
IV.	Family size:	
V.	House type:	Kachha / Pucca / Semi-pucca / Roof-tiled / Thatched / Bungalow (Break built house)

2) Family Composition:

Sl.No.	Relation with the respondent	Age	Sex M/F	Educational level* (0-6)	Occupation** (1-9)		Farming Experience (Yrs.)	Trainings attended (no.)	Monthly Income
					Main	Subsidiary			
I.	Self								
II.									
III.									
IV.									
V.									
VI.									
VII.									
VIII.									

M- Male F- Female

*0-Illiterate, 1- Read and write, 2- Primary, 3- Middle, 4- High School, 5- Higher Secondary, 6- Graduate & above

**1-Crop farming, 2-Dairy farming, 3-Sheep Farming, 4-Goat Farming, 5-Farm labour, 6-Business, 7-Rural artisans, 8-Service, 9-Others

3) Land Holding (ac): (Average Farm Size:)

Sl. No.	Particulars	Irrigated Area (ac)	Unirrigated Area (ac)	Total Area (ac)
I.	Owned			
II.	Leased-in			
III.	Leased-out			
IV.	Total cultivated land			
V.	Fallow land			
VI.	Total operational holding			

4) Source of irrigation (2019-20):

Sl. No.	Particulars	Total Area (ac)	Proportion to total area
I.	Canals		
II.	Open wells		
III.	Bore wells		
IV.	Tube wells		
V.	Tanks		
VI.	Other sources		

5) Crops cultivation (2019-20):

Sl. No.	Particulars	Irrigated Area (ac)	Rainfed Area (ac)	Total Area (ac)	Costs (₹ per ac)	Yield (Kg per acre)		Sale price (₹ per kg)		Returns (₹ per ac)	
						MP*	BP**	MP*	BP**	MP*	BP**
I.	Paddy										
II.	Jowar										
III.	Bajara										
IV.	Wheat										
V.	Redgram										
VI.	Blackgram										
VII.	Greengram										
VIII.	Horsegram										
IX.	Groundnut										
X.	Sunflower										
XI.	Soyabean										
XII.	Sugarcane										
XIII.	Turmeric										
XIV.	Cotton										
XV.	Onion										
XVI.	Fruits and vegetables										
XVII.	Protected cultivation										
XVIII.	Others (Specify)										

MP*= Main Product; BP**= By-Product

6) Inventory of Farm Infrastructure:

Sl. No.	Items	No.	Kaccha / pucca	Year of purchase / built	Purchase value (₹)	Present value (₹)
I.	Farmhouse					
II.	Cattle shed					
III.	Poultry shed					
IV.	Goat/ Sheep shed					
V.	Stores for grain					
VI.	Vermicompost unit					
VII.	Tubewell shed					
VIII.	Pumping set					
IX.	Fishpond					
X.	Others					

7) Inventory of Farm Machinery and Implements:

Sl. No.	Items	Nos.	Year of purchase	Purchase value (₹)	Present value (₹)	Expected remaining life (yrs.)	Annual Repairs (₹)
I.	Tractor						
II.	Disc harrow						
III.	Cultivator						
IV.	Combine harvester						
V.	Seed-drill						
VI.	Thresher						
VII.	Sprayer						
VIII.	Leveller						
IX.	Sickle						
X.	Hand hoe						
XI.	Spade						
XII.	Crow bar						
XIII.	Chaff cutter						
XIV.	Buckets						
XV.	Iron chain						
XVI.	Any Others (Specify)						

8) Livestock Inventory: (Average Herd Size:)

Sl. No.	Particulars		Crossbred cows		Indigenous cows		Buffaloes	
			Nos.	Value (₹)	Nos.	Value (₹)	Nos.	Value (₹)
I.	Milch animals:	In milk						
		Dry						
II.	Heifers:	Pregnant						
		Non-pregnant						
III.	Young stock: 1-2 Yrs.	Male						
		Female						
	>1 Yr.	Male						
		Female						
IV.	Draught animal (Bullock)							
V.	Bulls for mating							
	Grand total	Purchased						
		Farm born						

Sl. No.	Particulars		Goats		Sheep		Other	
			Nos.	Value (₹)	Nos.	Value (₹)	Nos.	Value (₹)
I.	Milch animals:	In milk						
		Dry						
II.	Doeling (goat):	Pregnant						
		Non-pregnant						
III.	Young stock: 1-2 Yrs.	Male						
		Female						
	>1 Yr. (lambs)	Male						
		Female						
	Grand total	Purchased						
		Farm born						

9) Livestock production (litres/ animal/ day): (2019-20)

Sl. No.	Animal type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I.	Crossbred cows												
II.	Indigenous cows												
III.	Buffaloes												
	Others												
	Price (₹ /lit)												

10) Production from other component: (2019-20)

Sl. No.	Type	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I.	Fishery												
II.	Poultry												
III.	Others												
	Price (₹ /lit)												

11) Social participation: Yes / No

Sl.	Extension agency	Member	Office bearer
I.	PACS		
II.	Cooperative Society		
III.	Self Help Group		
IV.	Farmer Producer Company		
V.	Farmers club		
VI.	Farmers Interest Group		
VII.	Farmer Organisation		
VIII.	Others		

12) Sources of climate variability related information:

Sl. No.	Sources	Frequency			Purpose			Rank
		Often	Occasionally	Never	Agricultural purpose	Non agricultural purpose	Both	
I.	Agricultural Officer							
II.	Assistant Agricultural Officer							
III.	Horticulture Officer							
IV.	Assistant Horticultural Officer							
V.	Livestock Inspector							
VI.	Veterinary Asst. Surgeon							
VII.	Mass Media							
VIII.	Print media							
IX.	Neighbour farmers							
X.	Friends and Relatives							
XI.	Others (Specify)							

12) Source of Earning of the Farmer (2019-20):

Sl. No.	Sources	Total Amount (₹)
I.	Crop farming	
	Livestock farming	
	Other farm enterprises	
II.	Other sources (Non agriculture) , if any:	

13) Do you have easy access to the credit? Yes / No **14) Do you enjoy group credit facility? Yes / No**

15) Details of loan taken:

Sl. No.	Source	Name of source	Total Amount (₹)	Purpose	Period of loan	Outstanding amount (₹)	Interest Rate
I.	PACS						
II.	Nationalised Bank						
III.	Money lender						
IV.	Others						

16) Have you applied for any government crop insurance scheme? Yes / No

17) Total area under crop insurance:

18) No. of animals insured:

19) No. of animals registered for 'Feed Camp':

20) No. of visits of Veterinary doctor to herd:

SECTION-II

- 1) **Total consumption expenditure on food:**
- 2) **No. of employed family members:**
- 3) **No. of unemployed family members:**
- 4) **Do you have 'Ration Card'? Yes / No**
If yes, then No. of BPL family members?
- 5) **Do you have easy access to the electricity? Yes / No**
- 6) **No. of family members with chronic illness:**
- 7) **Do you have easy access to drinking water resources? Yes / No**
If yes, nearest possible source? (km.)
- 8) **Nature of roads: Paved / Not paved**
- 9) **Damage to crop and dairy over the past 10 years due to climate change (drought, rainfall and temperature anomalies, floods, hailstorms, cyclones):**

Sl. No.	Resource	Nature of damage	Frequency of occurrence	Value of Damage		
				Quantity	Price (₹)	Amount (₹)
1.	Crop					
I.	Paddy					
II.	Jowar					
III.	Bajara					
IV.	Wheat					
V.	Redgram					
VI.	Blackgram					
VII.	Greengram					
VIII.	Horsegram					
IX.	Groundnut					
X.	Sunflower					
XI.	Soyabean					
XII.	Sugarcane					
XIII.	Turmeric					
XIV.	Cotton					
XV.	Onion					
XVI.	Fruits					
XVII.	Vegetables					
XVIII.	Others (Specify)					
2.	Livestock					
I.	Milch animals					
II.	Heifers					
III.	Young stock					
IV.	Bullocks					
V.	Bulls					
Others						
3.	Other component					

10) Effect of climate change (drought, rainfall and temperature anomalies, floods, hailstorms, cyclones in costal districts):

Parameters	Tick the relevant box			Parameters	Tick the relevant box		
	Yes		No		Yes		No
Left all land fallow	Yes		No	Scarcity of water for livestock	Yes		No
Left part of the land fallow	Yes		No	Sold livestock	Yes		No
Sold a part of land	Yes		No	Borrowed money from relatives/others	Yes		No
Leased out a part of land	Yes		No	Received support from government/NGOs	Yes		No
Shifted to other crops	Yes		No	Shifted to non-farm employment	Yes		No
Less feeding of livestock	Yes		No	Out migration to cities	Yes		No
Less milk yield	Yes		No	Discontinuance from farming	Yes		No
				Others	Yes		No

- 11) Whether any loss of family members due to drought over past 10 years? Yes / No. If yes, then how many?
- 12) Whether any loss of livestock due to drought over past 10 years? Yes / No. If yes, then how many?
- 13) Whether any loss of land due to natural calamities or climate change, government projects (dam, highway construction, etc.)? Yes / No. If yes, then how many acres?
- 14) Whether your village included in drought declared districts? Yes /No. If yes, No. of droughts in last 10 years?
- 15) No. of forests, reserves and grazing land within 10 km:
- 16) No. of hailstorms in last 10 years?
- 17) No. of cold spells in last 10 years?
- 18) No. of cyclones in last 10 years?

SECTION-III

1) Management strategies in crop, livestock and other component due to climate change:

Details of the strategies/practices	(0-No, 1-Yes)			Adopted Since	* Area adopted (ac)	** Constraints			
	Awareness	Access	Adopted			1	2	3	4
1) Crop:									
1. SRI									
2. Seed Drill sowing									
3. Broadcasting									
4. Drought Tolerant, early maturing, salt tolerant Varieties									
5. Mulching									
6. Summer Ploughing									
7. Conservation agriculture practices									
8. Zero tillage									
9. Taking help of Early Warning and Forecasting of Drought									
10. Soil fertility and nutrient management									
11. Crop insurance									
12. Improved water management									
• Supplemental irrigation through groundwater									
• Micro irrigation (drip/sprinkler)									
• Irrigation depth and frequency									
• Water harvesting and conservation									
13. Subsidiary income and employment generating activities									
14. Insect pest and disease management									
• No changes in technologies/ practices									
Any others (Specify)									

*Area adopted (ac) for crop

**Constraints 1: too costly; 2: too technical/ lack of skills; 3: not relevant to my farm; 4: no other alternate

Details of the strategies/practices	(0-No, 1-Yes)			Adopted Since	* Area adopted (ac) or *No. of animals adopted	** Constraints			
	Awareness	Access	Adopted			1	2	3	4
2) Livestock:									
1. Climate proof shelter									
2. Mineral mixture feeding									
3. Feeding Vitamin E									
4. Balanced feeding									
5. Regular vaccination									
6. Azolla cultivation									
7. Hydroponics									
8. Seaweed utilization									
9. Hay and Silage making									
10. Augmented fodder supply through improved varieties									
11. Cereal fodders growth enhancing higher crude protein contents application of urea as foliar spray									
12. Use of perennial and nonconventional fodder									
13. Periodic health check-up including deworming									
14. Special care of lactating animals									
15. Prioritizing number of unproductive male and female cattle for saving productive animals and all available resources will be deployed for their feeding.									
16. Dual purpose crops									
17. Use of perennial and nonconventional fodder									
18. Subsidiary Income and Employment Generating Activities									
• No changes in technologies/ practices									
• Any others (Specify)									

* Area adopted (ac) Or *No. of animals adopted for livestock.

****Constraints** 1: too costly; 2: too technical/ lack of skills; 3: not relevant to my farm; 4: no other alternate

Details of the strategies/practices	(0-No, 1-Yes)			Adopted Since	* Area adopted (ac) or *No. of animals adopted	** Constraints			
	Awareness	Access	Adopted			1	2	3	4
3) Other component:									
1. Climate proof shelter									
2. Balanced feeding									
3. Regular vaccination									
4. Temperature management									
5. Periodic health check-up									
6. Dual purpose crops									
7. Identification of resources and partners to ensure short-term to long-term financing through a range of donors from the private sector,									
8. Testing approaches (largescale and small-scale fisheries									
9. increasing daily fishing time									
10. increasing fishing efforts									
11. changing fishing time									
12. aquaculture production									
13. migrating to another fishing area									
14. fishing further away or deep inside the water									
15. catching smaller fish									
16. participation in alternative non-fishing livelihoods and taking a moratorium in fishing									
• No changes in technologies/ practices									
• Any others (Specify)									

* Area adopted (ac) Or *No. of animals adopted for other component.

**Constraints 1: too costly; 2: too technical/ lack of skills; 3: not relevant to my farm; 4: no other alternate

Signature of Investigator

Glimpses of Data Collection

1. Parbhani



2. Sindhudurg



3. Ahmednagar

