Strategies to Mitigate the Socio-Economic and Environmental Impacts of Climate Change: A Case of Northeastern India

(A Multi-Method Approach)

Dissertation

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Dedication

To My Grandmother

Publications planned from this dissertation

Five publications in the form of research articles are planned from this dissertation. The author of this dissertation is the first author in all five research articles, which are incorporated in this dissertation as individual chapters. For all research articles, the author of this dissertation has finished manuscripts, which are or will be submitted to peer-reviewed journals once the revision by all involved co-authors is completed. The following table summarizes the authorships for the planned publications from this dissertation.

Chapter Number	**Title of a manuscript/ research article**	**First author**	**Co-authors**
2.	How do tribal farmers of Northeastern India perceive and respond to climate change?	Amol Kamalakar Bhalerao	Livia Rasche, Jürgen Scheffran, María Máñez, Uwe A. Schneider
3.	Farmers' perception of climate change and its determinants	Amol Kamalakar Bhalerao	Livia Rasche, Jürgen Scheffran, María Máñez, Uwe A. Schneider
4.	A systematic SWOT analysis of Agricultural Research and Extension System of Northeastern India: a strategy formulation approach to deal with climate change impacts	Amol Kamalakar Bhalerao	Livia Rasche, Jürgen Scheffran, María Máñez, Uwe A. Schneider
5.	Climate change adaptation strategies for the Northeastern region of India: Insights from a Delphi experiment	Amol Kamalakar Bhalerao	Livia Rasche, Uwe A. Schneider
6.	Delphi forecasts on competency development to enhance climate-resilient farming in Northeastern India	Amol Kamalakar Bhalerao	Livia Rasche, Uwe A. Schneider

Declaration of Authorship

Amol Kamalakar Bhalerao,

Born in India, 2nd of May, 1987

I, hereby declare my share in the authorship of the dissertation chapters (research articles), which are either submitted or likely to be submitted to the peer-reviewed journals, as following:

Chapter number	**Title of a manuscript / research article**	**The contribution of the First author (Amol Kamalakar Bhalerao)**	**Contribution of co-authors**
2.	How to tribal farmers of Northeastern India perceive and respond to climate change?	Topic development (predominantly) Literature review (completely) Data collection (completely) Development of the methods and data analysis (completely) Review of results (completely) Manuscript writing (predominantly)	*Topic development:* Uwe A. Schneider *Manuscript editing:* Livia Rasche, Jürgen Scheffran, María Máñez, Uwe A. Schneider
3.	Farmers' perception of climate change and its determinants		
4.	A systematic SWOT analysis of Agricultural Research and Extension System of Northeastern India: a strategy formulation approach to deal with climate change impacts	Topic development (predominantly) Literature review (completely) Data collection (completely) Development of the methods and data analysis (completely) Review of results (completely) Manuscript writing (predominantly)	*Topic development:* Uwe A. Schneider *Manuscript editing:* Livia Rasche, Jürgen Scheffran, María Máñez, Uwe A. Schneider
5.	Climate change adaptation strategies for the Northeastern region of India: Insights from a Delphi experiment	Topic development (predominantly) Literature review (completely) Data collection (completely) Design of questionnaires (completely) Development of the methods and data analysis (completely) Review of results (completely) Manuscript writing (predominantly)	*Topic development:* Uwe A. Schneider *Manuscript editing:* Livia Rasche, Uwe A. Schneider
6.	Delphi forecasts on competency development to enhance climate-resilient farming in Northeastern India		

Zusammenfassung

Der Klimawandel ist wahrscheinlich die größte Herausforderung, mit der die Menschheit je konfrontiert war, da die Ernährungssicherheit von Milliarden Menschen bedroht ist. Extreme klimatische Ereignisse beeinflussen die Nahrungsmittelproduktion auf der ganzen Welt. Insbesondere kleine, auf marginalen Flächen in Südasien ansässige Landwirte sind vom Klimawandel betroffen und in ihrer empfindlichen Lebensgrundlage stark beeinträchtigt. Diese Dissertation entwickelt Strategien und Empfehlungen, um die sozioökonomischen und ökologischen Auswirkungen des Klimawandels zu mildern. Die Forschungsarbeit bietet politischen Entscheidungsträgern Erkenntnisse über Optionen, die Widerstandsfähigkeit der durch Klimawandel gefährdeten Bauerngemeinschaften in der nordöstlichen Region Indiens (NEI) zu fördern. Um die sozioökonomischen Dimensionen der betroffenen Interessengruppen im NEI Agrarsektor für die Bewältigung der Auswirkungen des Klimawandels zu untersuchen, werden mehrere sozialwissenschaftliche Methoden kombiniert. Diese Dissertation analysiert Wahrnehmungen, Prioritäten und Perspektiven (der zukünftigen Entwicklung) von Interessensgruppen aus dem Agrarsektor und präsentiert die gewonnenen Erkenntnisse in sieben Kapiteln.

Das erste Kapitel liefert Hintergrundinformationen zur Motivation dieser Doktorarbeit, zum Studiengebiet sowie zu den Forschungsfragen und den verwendeten Methoden um diese Fragen zu beantworten. Diese Dissertation konzentriert sich vor allem auf die nordöstliche Region Indiens, welche in acht Bundesstaaten gegliedert ist. Obwohl diese acht Bundesstaaten eine enorme kulturelle und topografische Vielfalt aufweisen, wird die gesamte Region in nur eine agroklimatische Zone eingestuft. Für diese Studie wurden 797 landwirtschaftliche Haushalte durch Leitfadeninterviews befragt. Darüber hinaus wurden 21 Brainstorming-Sitzungen durchgeführt, um Daten von Feldforschern und landwirtschaftlichen Beratern (aus Krishi-Vigyan-Kendra-Zentren) zu erfassen und damit die Stärken, Schwächen, Chancen und Risiken des Landwirtschaftlichen Forschungs- und Beratungssystems (*Agricultural Research and Extension System*, ARES) im Nordosten Indiens zu analysieren. Außerdem nahmen 21 Experten der Institute des *Indian Council of Agricultural Research* (ICAR) sowie die Leiter von 14 Krishi-Vigyan-Kendra-Zentren an drei Runden eines Delphi-Experiments teil, um mögliche Strategien

und Politikmaßnahmen zu bestimmen, welche die klimatische Widerstandsfähigkeit im NEI Agrarsektor verbessern.

Das zweite Kapitel analysiert die durch die Befragung von 797 landwirtschaftlichen Haushalten gesammelten Daten, um zu bewerten wie der Klimawandel, seine Auswirkungen und Anpassungsmaßnahmen durch die Landwirte wahrgenommen werden. Die Ergebnisse zeigen, dass die untersuchten Landwirte sich des Klimawandels durchaus bewusst sind und wissenschaftlich unterstützte Maßnahmen zur Sicherung ihrer Lebensgrundlage für notwendig halten. Die Landwirte verzeichneten wiederkehrende Ertragsverluste aufgrund von Niederschlagsschwankungen und Temperaturerhöhungen. Außerdem beobachteten die Landwirte einen Rückgang der Wasserressourcen für die Landwirtschaft und eine Verschlechterung der allgemeinen landwirtschaftlichen Produktivität aufgrund von klimatischen Veränderungen. Berichtete Anpassungen der Landwirte umfassen den Anbau von Mischkulturen, Sortenwechsel, Bodenschutz, Errichtung von Tierunterständen, Impfungen, Einführung moderner Tierfütterungssysteme sowie weitere Maßnahmen zur Aufrechterhaltung ihres Betriebseinkommens. Diese Maßnahmen sind allerdings nur bedingt geeignet, um die Landwirte nachhaltig gegen die Wirkungen des Klimawandels zu schützen. Mangelndes Bewusstsein für Änderungen, kostspielige Inputs, fehlende Kredite, schlechte Bodenfruchtbarkeit und Transportprobleme in hügeligen Gebieten beeinträchtigen eine wirksamere Anpassung der Landwirte.

Das dritte Kapitel der Dissertation untersucht Einflussgrößen der Wahrnehmung des Klimawandels durch Landwirte. Mit einem logistischen Regressionsmodell werden die Einflüsse von 36 sozioökonomischen und biophysikalischen Faktoren untersucht. Die Ergebnisse zeigen, dass insbesondere das Geschlecht des Hausherrn (männlich), Rinderbesitz, Wahrnehmung ungleichmäßiger Niederschläge, Realisierung von Veränderungen bei Waldprodukten und längere Entfernungen zu Märkten die Wahrnehmung des Klimawandels durch die Landwirte signifikant beeinflussen. Die Ergebnisse zeigen auch, dass die Landwirte den Klimawandel mit Entwaldung, Umweltverschmutzung und übermäßiger Fahrzeugnutzung in Verbindung bringen. Die Mehrheit der Landwirte sieht den Klimawandel durch eigene Beobachtungen bestätigt und ist empfänglich für Interventionen, um durch wissenschaftliche Beratung und Unterstützung (in Form von Technologien und Finanzierung) zukünftige Auswirkungen zu minimieren. Die Landwirte im NEI Agrarsektor empfinden im Rahmen des Klimawandels eine Mischung aus Ackerbau und Viehzucht als verhältnismäßig profitabel.

Das vierte Kapitel analysiert Stärken, Schwächen, Chancen und Bedrohungen von ARES (mittels einer *Strengths-Weaknesses-Opportunities-Threats*-Analyse) und stellt fest, dass externe Chancen nicht vollständig genutzt werden und interne, auf Organisationsmanagement beruhende Schwächen dominieren. Die Ergebnisse zeigen auch, dass viele Distrikte eine defensive Strategie wählen müssen, da die meisten von ihnen einen höheren Anteil an internen Schwächen und externen Bedrohungen aufweisen. Das System (ARES) sollte deshalb entschlossene Korrekturmaßnahmen ergreifen, um die Bürokratie zu minimieren und die Arbeitszufriedenheit der Mitarbeiter zu erhöhen, indem es gleiche Wachstumschancen, Anerkennung und Anreize für die Leistungsträger bietet und eine Unternehmenskultur schafft, die die Würde des Einzelnen respektiert.

Das fünfte und sechste Kapitel der Dissertation verwenden die Delphi-Technik, um mögliche Strategien zur Verbesserung der Widerstandsfähigkeit gegen Klimawandel zu bestimmen. Das fünfte Kapitel zeigt, dass (i) regenabhängige, wissenschaftsferne Landwirtschaft (ii) unzureichendes Angebot an Produktionsfaktoren (iii) geringe landwirtschaftliche Mechanisierung und Lebensmittelverarbeitung und (iv) geringe gesellschaftliche Widerstandsfähigkeit kritische Herausforderungen im NEI Agrarsektor sind. Experten empfehlen massive Investitionen in die Nachernteverarbeitung und den Einsatz von integrierten Agrarsystemen, um die Widerstandsfähigkeit gegen Klimaeinflüsse und die Nachhaltigkeit im NEI Agrarsektor zu fördern.

Das sechste Kapitel untersucht den Bedarf an notwendigen Kompetenzen sowohl für *Change Agents* als auch für indigene Bauern. Die Ergebnisse zeigen, dass *Change Agents* ihre Managementkompetenzen (d.h. die Verknüpfung der Landwirte mit dem Markt, Aufgeschlossenheit, Innovation bei der Problemlösung) verbessern sollten. Die Landwirte benötigen Kompetenzen in den Bereichen umweltfreundliche Landwirtschaft, Schutz der biologischen Vielfalt und Problemlösung auf Gemeindeebene. Experten empfehlen auch, dass Krishi-Vigyan-Kendra-Zentren bei der Umsetzung klimaschonender Strategien eine zentrale Rolle spielen sollten, da sie eine institutionelle Verbindung von Behörden zu landwirtschaftlichen Haushalten darstellen.

Schließlich fasst das letzte und siebte Kapitel die wichtigsten Ergebnisse der Dissertation zusammen und empfiehlt politische Maßnahmen, um den Bedürfnissen der indigenen

Landbevölkerung im Rahmen des Klimawandels gerecht zu werden und Politiken umzusetzen, welche die Klimabeständigkeit im Agrarsektor von NEI fördern.

Abstract

Climate change is probably the most alarming challenge ever faced by humankind as food security of billions is threatened. Extreme climatic events continue to affect food grain production across the world. Notably, the small, marginal and natural resource dependent farmers residing in South Asia are highly exposed to impacts of climate change as their fragile livelihood is severely affected. Therefore, this dissertation is designed to formulate and recommend strategies to mitigate the socio-economic and environmental impacts of climate change. This dissertation provides insights and options to policymakers that may foster the climate-resilience among vulnerable farming communities in the Northeastern region of India. This dissertation utilizes a multi-method approach to investigate the socio-economic dimensions of associated stakeholders to manage climate change impacts in the agricultural sector. This dissertation examines perceptions, priorities, and prospects (of future development) of stakeholders sampled from the agricultural sector of NER, which are presented across seven chapters.

The first chapter briefly provides background information on the motivation for this study, the study area, the objectives and research questions, and the employed methods to answer these questions. This dissertation is primarily focused on the Northeastern region of India (NER), which is a cluster of eight states. Though, eight Northeastern states of India exhibit enormous cultural and topographical diversity, this entire region is categorized as a single agro-climatic zone. In this study, 797 farm households participated through semi-structured interviews. Further, 21 brainstorming sessions were also conducted to collect data from field level researchers/extension professionals (from *Krishi Vigyan Kendras*), to analyze strengths, weaknesses, opportunities and threats of Agricultural Research and Extension System (ARES) of NER. Also, 21 experts from ICAR institutes and Heads of 14 *Krishi Vigyan Kendras*, participated in three rounds of Delphi experiment to forecast strategies/strategy options that would shape policies to foster climate-resilience in the agricultural sector of NER.

The second chapter analyses the data collected through the interviews of 797 farm households to assess farmers' perception of climate change, its impacts and adaptation actions. Results showed that sampled farmers were aware of climate change and expressed the need for

scientific interventions to support their livelihood. Farmers experienced recurring losses in agricultural yield due to rainfall variability and increased temperature. Farmers also reported a decline in water resource for farming and deterioration of farm fertility because of changes in climate pattern. Farmers have adopted basic adaptations like mixed cropping, change of crop varieties, soil conservation, shelters for livestock, vaccination and scientific feeding of livestock, and similar practices to maintain their farm income that may not provide climate-resilience for a longer time. However, farmers are unable to succeed due to prominent constraints like unawareness of adaptations, costly inputs, lack of credit, poor soil fertility and transportation issues in hilly areas.

The third chapter of the dissertation investigated determinants of farmers' perception of climate change using a logistic regression model by analyzing 36 socio-economic and biophysical attributes. Results showed that gender of head of farm household (male), cattle ownership, the perception of uneven rainfall, the realization of changes in forest produce and longer farm to market distance significantly shapes the farmers' perception of climate change. Results also revealed that farmers associate climate change to deforestation, pollution, and excessive vehicle use. Majority of farmers realized climate change through their experience and are potentially receptive to scientific interventions to minimize future impacts for which advisory services and assistance (in the form of technologies and funding) is recommended. Farmers of NER find a combination of crop farming with livestock relatively profitable in climate change scenario.

The fourth chapter analyzed strengths, weaknesses, opportunities, and threats of ARES of NER (using SWOT analysis) and found that external opportunities are not fully exploited due to the over dominance of internal weakness, which are arising from organizational management issues. Results also revealed that many districts would need to adapt to defensive strategy as the majority of them exhibit a higher proportion of internal weaknesses along with external threats. The system (ARES) must undertake firm corrective measures to minimize the bureaucracy and to enhance the job satisfaction among employees by providing equal growth opportunities, recognition, and incentives for performers, as well as by creating an organizational culture that respects individuals' dignity.

The fifth and sixth chapter of the dissertation utilized the Delphi technique to forecast the strategies/strategy options for enhancing climate-resilience. The fourth chapter revealed that

(i) rainfall dependent unscientific farming (ii) inadequate input supply (iii) low extent of farm mechanization and food processing and (iv) low societal resilience are critical challenges for the agricultural sector of NER. Experts recommended massive investment for post-harvest processing and integrated farming systems to foster climate-resilience as well as sustainability in the agricultural sector of NER.

The sixth chapter investigated the competency development needs for change agents as well as indigenous farmers. Results showed that upgradation of managerial competencies (i.e., linking farmers with the market, being open-minded, innovative in problem-solving) are required among change agents. Farmers need to be competent in the areas of eco-friendly farming, biodiversity conservation, and problem-solving at the community level. Experts also recommended that *Krishi Vigyan Kendras* have a pivotal role to play while implementing climate-smart strategies, as they are the institutional link to farm households.

Finally, the last chapter (i.e., seventh chapter) summarized the key findings of the dissertation and recommended policy measures to cater the needs of indigenous farming communities in climate change scenario by implementing policies that foster climate-resilience in the agricultural sector of NER.

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Abbreviations

AES	Agricultural Extension System
ARES	Agricultural Research and Extension System
ATARI	Agricultural Technology Application Research Institute
ATMA	Agricultural Technology Management Agency
CAU	Central Agricultural University
CI	Conservation International
CliSAP	Integrated Climate System Analysis and Prediction
DAC&FW	Department of Agriculture Cooperation & Farmers Welfare
DoE	Directorate of Extension
EFEM	External Factor Evaluation Matrix
FSC	Farm Science Center
GDP	Gross Domestic Product
HRD	Human Resource Development
ICAR	Indian Council of Agricultural Research
ICT	Information Communication Technology
IFEM	Internal Factor Evaluation Matrix
IFPRI	International Food Policy Research Institute
IFS	Integrated Farming System
INR	The Indian rupee
IPCC	Intergovernmental Panel on Climate Change
IQR	Inter Quartile Range

ITK	Indigenous Traditional Knowledge
KMO	Kaiser-Meyer-Olkin statistic
KVK	*Krishi Vigyan Kendra*
MINGS	Mathematics, Informatics and Natural Sciences Graduate School
NABARD	National Bank for Agriculture and Rural Development
NECS	North Eastern Council Secretariat, Government of India
NER	Northeastern Region of India
NGO	Non-Governmental Organization
PIB	Press Information Bureau
PPM	Potential Policy Makers
PTD	Participatory Technology Development
QD	Quartile Deviation
SAU	State Agricultural University
SHG	Self Help Group
SICSS	School of integrated Climate System Sciences
SPACE	Strategic Position and Action Evaluation Matrix
SWOT	Strength, Weakness, Opportunity and Threat
ToT	Transfer of Technology

Chapter 1: General Introduction

1.1 Background

Climate change severely affects all aspects of food security including food production, food access, food affordability, food consumption and stability of food prices, and threatens the livelihood of people living in poverty, especially those who are residing in developing countries (IPCC, 2014b). In recent decades, India, the second most populous nation in the world, has experienced more extreme climate events such as deadly heat waves (Bandyopadhyay, Bhuiyan, & Saha, 2016; Im, Pal, & Eltahir, 2017; Murari, Ghosh, Patwardhan, Daly, & Salvi, 2015), droughts (Ganguli & Reddy, 2014; K. N. Kumar, Rajeevan, Pai, Srivastava, & Preethi, 2013; Prasad et al., 2014), floods (Guhathakurta, Sreejith, & Menon, 2011; Thayyen, Dimri, Kumar, & Agnihotri, 2013; Wasson et al., 2013) and cyclones (Mendelsohn, Emanuel, Chonabayashi, & Bakkensen, 2012; Unnikrishnan, Kumar, & Sindhu, 2011). These types of extreme events are ultimately triggered by global warming (Dash, Jenamani, Kalsi, & Panda, 2007; Knutson et al., 2010; Rohini, Rajeevan, & Srivastava, 2016; Shah & Mishra, 2014). In the last 100 years, India experienced a temperature increase between 0.8°C to 1.0°C (Kothawale, Kumar, & Srinivasan, 2012). Recent climate model simulations project an increase in India's mean surface temperature between 2°C and 6°C by the end of this century (Basha et al., 2017). Consequently, the decline in the yields of major food crops (such as wheat, rice, maize) is forecasted (Bandara & Cai, 2014; Dawson, Perryman, & Osborne, 2016; Ray, Gerber, MacDonald, & West, 2015; Soora et al., 2013) which would, in absence of counter measures, increase hunger, poverty, malnutrition and severely slow-down India's economic growth (IPCC, 2014b). Similarly, the decline in freshwater resources will intensify competition and conflicts between users (IPCC, 2014b) and negatively affect irrigation-dependent crop production (Zaveri et al., 2016).

Indian agriculture is not only the integral part of India's socio-cultural and political fabric but also the backbone of the economy. The agricultural sector contributes about 18 percent to India's GDP and directly or indirectly employs almost 50 percent of the national workforce (MSPI, 2017). About 80 percent of Indian farmers classify as either small (i.e., landholding up to 1 Hectare) or marginal (i.e., landholding between 1 and 2 Hectares) and possess a proportionally small fraction of arable land to sustain their livelihood. Climate change is expected to harshly affect rural households with low endowments of cultivable land, inadequate use of agricultural inputs, limited access to infrastructure, and lack of education (IPCC, 2014b). In the last twenty

years (1998-2017), India suffered a total economic loss of USD 79.5 billion due to climate-related disasters according to a recent report published by UN Office for Disaster Risk Reduction (Wallemacq & House, 2018). Furthermore, the climate risk index of 2016, ranked India as the sixth most affected country due to climate change impacts. According to the climate risk index report, the highest number of deaths (2119 fatalities) due to climate-related disasters were reported from India. Low income, little adaptive capacity, and frequent exposure to climatic-disasters make billions of Indians (especially living in rural areas) highly vulnerable to climate change.

The vulnerability of a particular social system to climate change is a function of exposure, sensitivity and adaptive capacity (Adger, 2006; IPCC, 2001). Technical adaptations can considerably reduce adverse impacts by limiting the rate and magnitude of climate change (IPCC, 2014b). Hence, *place and context* specific adaptation strategies that reduce the vulnerability and exposure (of agriculture or any particular system) are highly advocated by the recent synthesis report of Intergovernmental Panel on Climate Change (IPCC, 2014a) to promote sustainable development and food security for continuously growing population. However successful adaptation requires (i) recognition of diverse interests of stakeholders and linking of societal objectives to the process of decision-making, and (ii) implementation of adaptation strategies that yield higher co-benefits. Thus, for the Indian agricultural sector, adaptation strategies that enhance climate-resilience and support the livelihoods of vulnerable households are urgently needed.

Considering the diversity and vulnerability of Indian farmers, technical strategies coupled with socio-economic and environmental concerns, would be much fitting to deal with climate change impacts. A recent study conducted by Carleton and Hsiang (2016) investigated the link between climatic factors and found their influence on socio-economic outcomes in various sectors (e.g., migration, labor supply, mortality, income, and other similar attributes). Carleton and Hsiang (2016) concluded that certain populations neutralize climate change impacts with the help of adaptations, and socio-economic benefits of successful adaptations can be even more beneficial to current and future generations. Further, Arora-Jonsson (2011) studied the *gender* dimension of climate change and generalized that gender plays a crucial role in managing the environment. Therefore, recommended contextualized debates and gender-sensitive decision-making to deal with climate change. Other socio-economic studies highlighted the need of aligning socio-economic structures for fostering adaptation processes

to limit potential damages under climate change (Adger, Barnett, Brown, Marshall, & O'brien, 2013; Alcamo, Flörke, & Märker, 2007; Fischer, Shah, Tubiello, & Van Velhuizen, 2005; Godfray et al., 2010).

Similarly, the involvement of all levels of governance and participation of all pertinent stakeholders is essential to design strategies which fit a variety of risk perceptions, expectations, resources, and other constraints. Strategies which ignore stakeholders' perspectives can lead to sub-optimal outcomes. For example, Tripathi and Mishra (2016) found that many Indian farmers continue to overuse groundwater despite knowing the implications of it as they are concerned only about crop production and make some profits. In this case, policymakers provided subsidized electricity to farmers without fully understanding the implications of this move on farmers' behavior. As farmers had cheaper electricity, they invested more in buying submersible pump sets, and digging dipper bore wells to irrigate cash crops like sugarcane and cotton. In the long run, somehow, farmers linked social prestige with having a bore well and number of bore wells hiked exponentially. Moreover, there were no regulations (e.g., usage metering for groundwater, a tariff for groundwater use) to check liberal use of groundwater. Also, it seems that adequate measures were not undertaken at least to spread awareness among farmers to promote judicious use of groundwater. Consequently, many districts faced water scarcity due to the overuse of groundwater. Thus, policies based on inaccurate perceptions of farmers failed to motivate farmers to adopt water-efficient technologies.

In another instance, farmers residing in Northern India continue to burn crop residues on a massive scale though they understand the consequences of their action that leads to tremendous air pollution (Jain, Bhatia, & Pathak, 2014; Sidhu, Humphreys, Dhillon, Blackwell, & Bector, 2007). In this case, policies and interventions are quite mismatched with farmers' perception due to which many North Indian farmers (mainly from Punjab state) continued this unsustainable practice of rice and wheat stubble burning. For example, farmers find stubble/crop residue burning beneficial as it kills weeds, weed seeds and harmful insect-pests (and their eggs). Moreover, farmers look at crop residue burning as one of the cheapest ways to clear farms and to cultivate next crop. Whereas, for a long time policymakers passively encouraged farmers not to burn crop residues. In recent years, considering the magnitude of the situation, State Governments declared financial assistance to farmers to clean their fields using other ways. However, farmers continued stubble burning as most of them did not receive funds

(on time). Hence, considering the perceptions of farmers, interventions like (i) subsidy for harvester machines that clear out stubbles (ii) subsidy for seeders that allow farmers direct drilling of next crop in stubbles (iii) subsidy to promote machines that process stubbles/crop residues for making paper and cardboard (iv) Promotion of paddy straw mushroom to create value for rice straw, and other similar interventions.

Therefore, a comprehensive understanding of individual and collective perceptions, priorities, and sustainability prospects of stakeholders (related to agricultural sector) is imperative to formulate and implement the strategies to mitigate the socio-economic and environmental impacts of climate change.

1.2 Objectives of the study

The large size and complexity of India's Agricultural Extension System (AES) is shown in Figure 1. Large systems, like Indias' AES, generally need more time for decision-making and their efficiency highly depends on other constituents of the system due to the interconnectedness. Considering the urgency and criticality of climate-related risks for the Indian agricultural sector, the AES has to become more proactive and responsive to resolve the challenges of climate change faced by farmers. So, well planned (or policy-driven) and incentivized adaptation strategies (Tripathi & Mishra, 2016), can be implemented to disseminate technologies through extension system that could promote food security and sustainable livelihood among developing countries like India.

In addition, the adaptation process varies from sector to sector and is highly determined by location-specific vulnerabilities, the adaptive capacity of local inhabitants, climate-related extremes, natural endowments, and resources utilization pattern. In developing countries such as India, numerous policy recommendations are made at the national level and implemented uniformly across the nation. The majority of stakeholders are often excluded from the decision-making process and treated merely as beneficiaries of welfare schemes. A thorough understanding of people and their interaction with the environment is essential to understand and devise the appropriate adaptation policies. However, the first major limitation is an incomplete understanding and information of stakeholders' perceptions of climate change, and the adaptation to climate change. Previous studies largely focus on the technical aspects of adaptation measures and show limited or no concern for the social dimension of the adaptation process. A second limitation is that the majority of previous studies focus on specific crops or

commodities, and the results cannot be generalized. Too much specificity of research and diversified nature of agricultural research areas makes prioritization and policy formulation difficult in a heterogeneous sector such as agriculture. A third limitation of the process of adaptation policymaking is that most existing studies propose recommendations based on either only one level of governance in the system or considering only one type of stakeholder. For example, many studies propose adaptation strategies solely based on farmers' perception or some studies do it by carrying out investigations at a policymaking level and completely neglect intermediate and lower levels of the system.

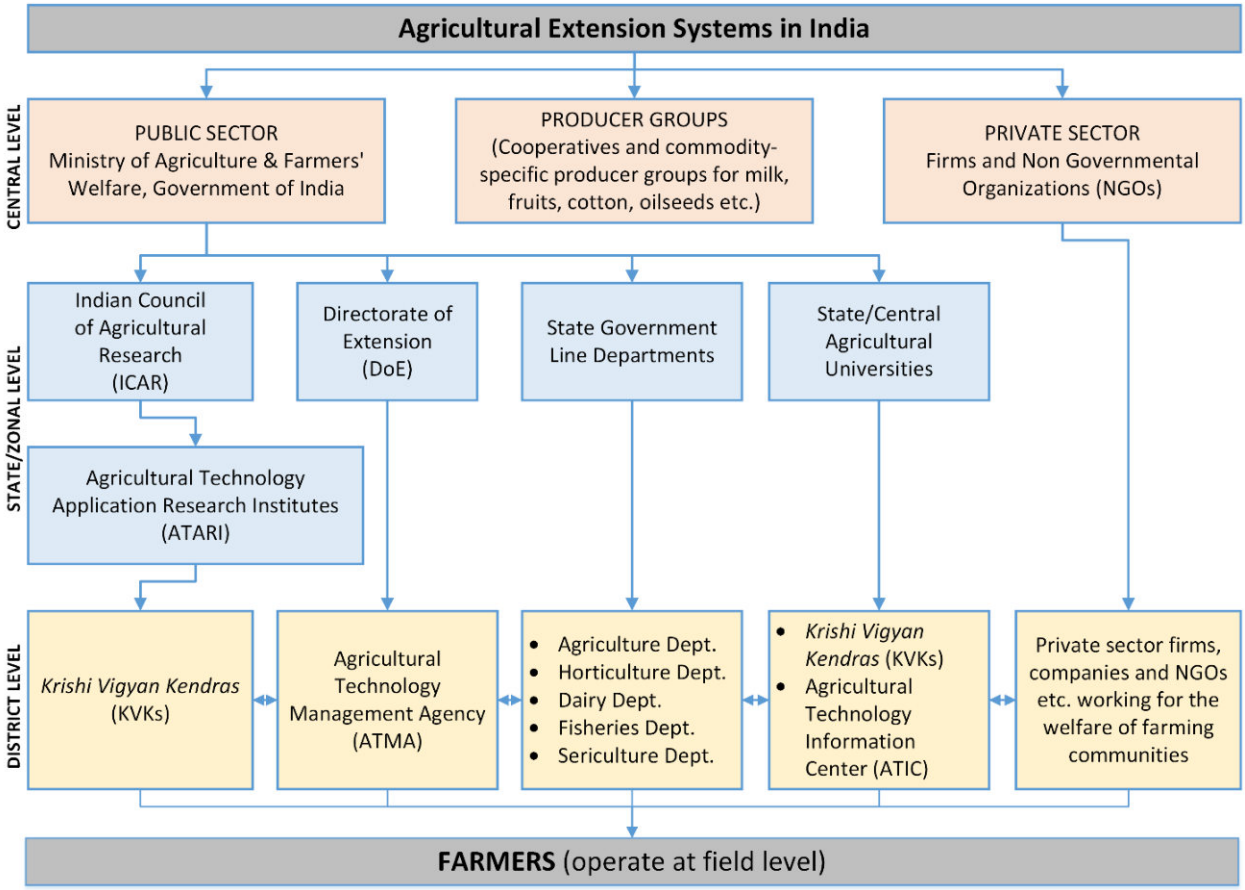

Figure 1. Agricultural Extension Systems (AES) in India, indicating the three levels of operation and various institutional stakeholders [adopted from Meena, Singh, and Swanson (2015)]

Therefore, this dissertation is aimed at developing an understanding of perception, priorities, and prospects of stakeholders of AES, at all levels of governance, using a multi-method and multi-stakeholder approach, for the Northeastern region of India (NER). This investigation is first of its kind in the Northeastern region of India (and probably in the Indian agricultural sector), to use a combination of Delphi technique, SWOT analysis and Semi-structured farmers' interviews for creating a knowledge base to devise adaptation strategies to mitigate the socio-

economic and environmental impacts of climate change by systematically investigating the views and concerns of multiple stakeholders. This dissertation utilizes different research methods and datasets (primary as well as secondary) to answer the following research questions that are firmly interconnected to each other.

I. How do the farmers of NER perceive climate change (and its impacts on their livelihood as well as agricultural systems) and which socio-economic factors determine farmers' perception of climate change?
II. Which are the adaptations adopted by farmers and are there any constraints experienced by the farmers of NER that hinder the adaptation process?
III. Which organizational management strategy would be appropriate for ARES of NER considering its strengths, weaknesses, opportunities, and threats in the climate change scenario?
IV. Considering opportunities, strengths, weaknesses, and threats, which adaptation strategies are feasible and desirable to compensate adverse climate change impacts in NER?
V. Which are the most pressing challenges for sustainable farming in NER? Which policy measures can foster socio-economic development in NER?
VI. Which climate-resilient technologies need urgent investment to safeguard the environment in NER by appropriate policy interventions?
VII. Which competencies do farmers and change agents (in the agricultural sector) need to promote sustainable development in NER?
VIII. Which institutions are important to improve the education of farmers and change agents to execute sustainable development policies under changing climate?

To answer the research questions listed above, different research methods are utilized (Table 1). Different types of sampling methods were used to obtain a sample of appropriate respondents. The sampling procedure, sample size, and data collection procedures used in this dissertation are briefly provided in individual chapters (a summary is indicated in Table 1).

Table 1. Chapter wise summary of methods, stakeholders, and sample used for the study

Chapter number	Research questions addressed	Method	Stakeholder	Sample	Objective of research
Chapter 2	I, II	Semi-structured interviews	Farm households	797 farm households	To explore farmers' perception of climate change, impacts, causes, determinants of perception, adaptions by farmers and constraints to adaptation
Chapter 3	I, II	Semi-structured interviews	Farm households	797 farm households	
Chapter 4	III, IV, VIII	Brainstorming technique and SWOT analysis	Group of the scientific and technical staff of KVKs in NER	21 brainstorming sessions (6-12 participants in each brainstorming session)	To explore internal strengths and Weaknesses as well as external opportunities and threats of ARES of NER
Chapter 5	V, VI	Delphi technique	Scientists of ICAR and Heads of KVKs in NER	21 experts from ICAR and 14 from KVKs	To forecast the strategy options to recognize challenges for NER, identify priorities for investments to foster socio-economic development in NER and to forecast the competency development issues for farmers as well as change agents in NER
Chapter 6	VII, VIII	Delphi technique	Scientists of ICAR and Heads of KVKs in NER	21 experts from ICAR and 14 from KVKs	

(Source: author)

1.3 Study area

This scientific investigation was carried out in the NER. The total geographical area of NER is 262230 KM^2 which is recognized as an extraordinarily diverse region due to the existence of floral and faunal bio-diversity (Verghese, 2013). NER stretches across 25.5736° N, 93.2473° E, and shares an international border with Nepal, Bhutan, Tibet, China, Myanmar (Burma) and Bangladesh. NER accounts for 8 percent of the total geographical area of India. The NER is a

group of eight states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and Tripura. Figure 2 illustrates the study area (i.e., NER) in the map of India along with adjoining countries.

Arunachal Pradesh (28.2180° N, 94.7278° E) is the geographically largest state in the Northeastern region which is mostly occupied by forest and hills (Tesia & Bordoloi, 2012). This state has varied elevations, and climate ranges from humid sub-tropical to sub-tropical highland climate and receives 2000-5000 mm of average rainfall. Four districts were sampled from Arunachal Pradesh state namely Tawang, East Kameng, Papum-pare, and Lower Dibang Valley to interview farmers and conduct brainstorming sessions for data collection. Farmers prefer the cultivation of Rice, Maize, Rapeseed, Soybean, Pulses, Orange, Pineapple, Banana, Guava and seasonal vegetables. The region of Arunachal Pradesh is vulnerable to floods, drought, and water stress.

Assam (26.2006° N, 92.9376° E) is the second largest state in the Northeastern region, which is popular for Assam tea and Assamese silk. Approximately, 85% of the state population resides in Brahmaputra river valley, which is a fertile plain. Paddy is the main crop in Assam's plains. In addition, Rapeseed and Mustard, Sugarcane, Potato, and Vegetables are traditionally also grown by farmers of Assam. The shifting cultivation is prevalent in hilly areas of Assam and practiced by tribal farmers (Mandal, 2014). The regular occurrence of floods is a major bottleneck of the agricultural development in Assam, and it destroys the standing crop, harvest, livestock as well as creates water logging and encourages soil erosion at many damaged sites (Goyari, 2005; Mandal, 2014) making them unfit for cultivation. Bongaigaon and Chirang districts of Assam were chosen for data collection from farmers. Moreover, to conduct brainstorming sessions seven districts namely Chirnag, Dhubri, Kokrajhar, Lakhimpur, Bongaigaon, Dhemaji, Dibrugarh were sampled. Most of the population depends on agriculture, fishery, livestock, and forest produce. Paddy, Jute, Mustard, Potato, Wheat, Lentil, Black Gram are widely cultivated crops in this state. The average temperature ranges from 12°C to 31°C.

Manipur (24.6637° N, 93.9063° E) is one of the Northeastern states of India, which borders with Myanmar. The oval-shaped Imphal valley is surrounded by mountains. Senapati and Churachandpur districts were chosen for farmers household' data collection from Manipur state. In addition, brainstorming sessions were conducted in two districts namely Senapati and Thoubal. Rice, Maize, Potato, Cabbage, and Cereals are prominently cultivated crops in the

state. Agriculture is a primary occupation and the farmers of Manipur practice terrace farming as climatic conditions are ideal for horticultural crops. The temperature ranges between 12°C to 27°C and annual rainfall is recorded around 1400 mm. Manipur's vulnerability is identified as water stress due to changing weather pattern.

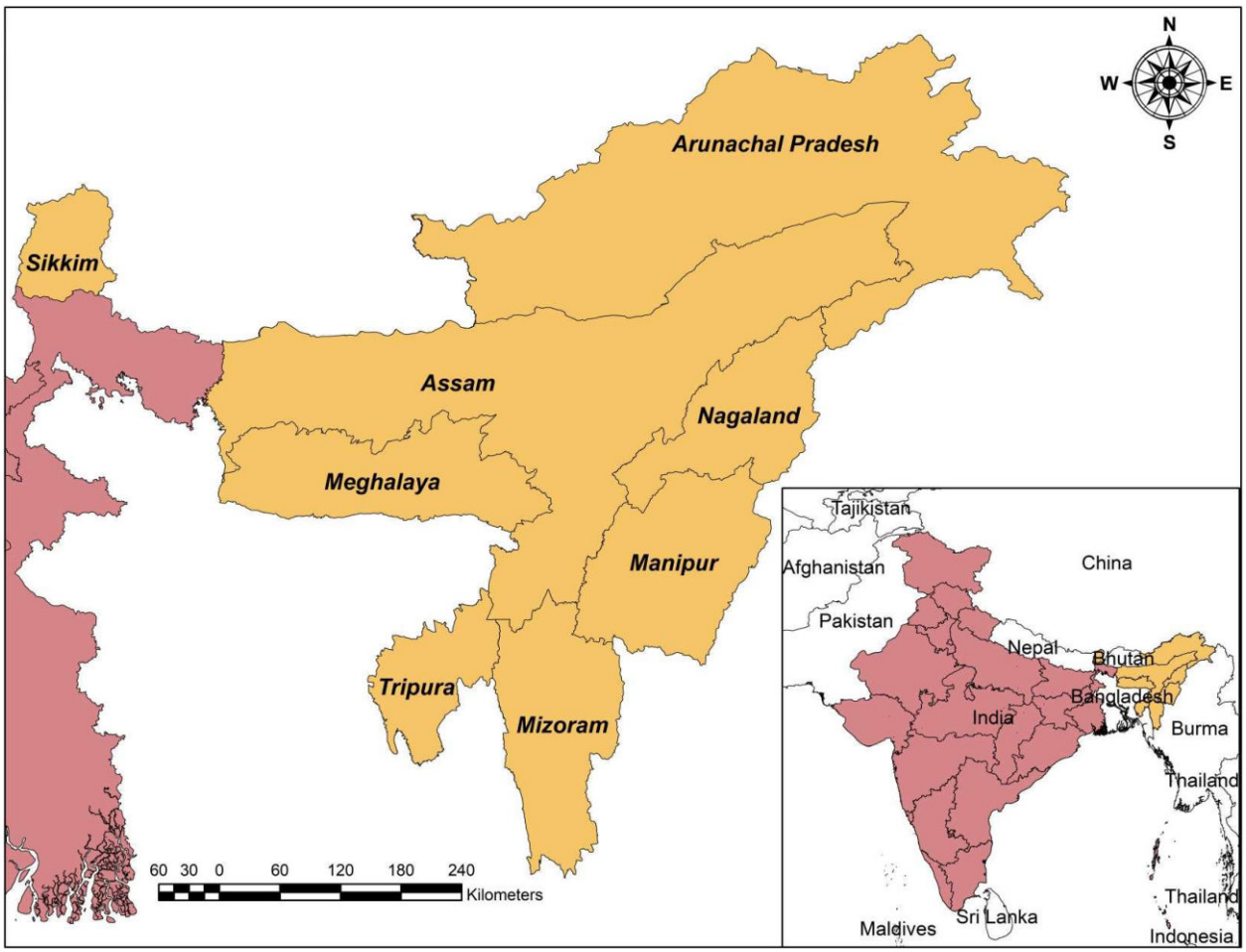

Figure 2. Map of India indicating the study area, Northeastern region of India along with adjoining countries (Avishek, 2014; GADM, 2015)

Meghalaya (25.4670° N, 91.3662° E) is the wettest state (average annual rainfall 12000mm) in India hence called as 'the adobe of clouds.' Around 70 area is under forest cover, and Meghalaya is the agriculture-based economy. West Garo Hills, West Khasi Hills and Jaintia Hills districts from Meghalaya state were selected for data collection from farmers and conducting brainstorming sessions. Agriculture is resource poor, and Potatoes, Rice, Maize, Pineapples, Bananas, Papayas, Turmeric, Ginger are the significant crops in this locality. Water stress is a major vulnerability of this state.

Lunglei, Serchhip and Aizawl districts from the Mizoram state of Northeastern India were also identified for data collection. Mizoram (23.1645° N, 92.9376° E), a land of rolling hills shares an

international border with Myanmar and Bangladesh. Almost 60% population of Mizoram depends on agriculture that is subsistence farming. During the pre-independence era, shifting agriculture was dominant but now declining due to interventions of change agencies. Rice is a principal crop in the state, and other popular farm produce includes Anthurium, Roses, Banana, Ginger, Turmeric, Passion Fruit, Orange, and Chow-chow. Bamboo of Mizoram is also a well-known and economically significant commodity. Mizoram is prone to water stress due to rainfall fluctuations though it receives an average of 1200 mm rainfall annually.

Nagaland (26.1584° N, 94.5624° E) is one of the states of Northeastern region India, famous for the traditional fashion. Around 68% of Nagaland's population depends on agriculture for subsistence. Paddy is prime crop followed by Potato, Linseed, Maize, Soybean, Jute, Gram, Pulses and variety of vegetables. Shifting cultivation is also practiced by tribal communities for their livelihood. The annual rainfall in the state is 1800-2500mm and temperature ranges between 21°C - 40°C. Tropical and sub-tropical forests of Nagaland shelters vast range of flora and fauna. Mon and Mokokchung districts of Nagaland were sampled for the field study. Nagaland is vulnerable to recurring droughts and water stress.

Sikkim (27.5330° N, 88.5122° E) is a nest land in the Himalayas surrounded by Nepal, China, and Bhutan. Sikkim is endowed with rich biodiversity, natural resources and variety of germplasm. Agriculture in the state is practiced as terrace farming because of hilly and rocky terrain that makes agricultural operations difficult. Approximately, 65% of Sikkim's population is engaged in agriculture. Sikkim has a sub-tropical climate in the lower part and tundra in the upper northern region. Average annual temperature is around 18°C and high hills of north side receive snowfall. Rainfall is well distributed in the state, and some places receive rainfall up to 5000mm annually. North Sikkim and South Sikkim districts were sampled for field research, as Sikkim is vulnerable to soil erosion and water stress. Rice, Maize, Millet, Wheat, Barley, Orange, Tea, Tuber crops, Vegetables, and Cardamom are popular crops among the farmers of Sikkim. In general, farmers of Sikkim are inclined towards organic farming and perform agricultural activities in harmony with nature. Sikkim is declared as India's first organic farming state.

Tripura (23.9408° N, 91.9882° E) is also a landlocked state in the Northeast region of India and is encircled by Bangladesh on its North, South and West side. Tripura has a tropical savanna climate, and average annual rainfall is around 2500mm. Tripura is also an agrarian state where 50% of its population is engaged in agriculture and allied activities as a primary source of

income. South Tripura and Dhalai districts of Tripura were also sampled for data collection. Rice is the principal crop in the state followed by Potato, Sugarcane, Mesta, Pulses, Tea and Jute. The fishery is also prominent is Tripura. Furthermore, the area under rubber cultivation is rapidly increasing that may threaten the food grain production in the state. Tripura is prone to vulnerabilities caused by cyclones.

NER is a homeland of almost 200 indigenous tribes who are living in close association with nature and natural resources for their livelihood. NER is a part of Indo-Burma biodiversity hotspot, which is severely endangered due to climate change, and pressure of continuously increasing population. Majority of inhabitants in NER are solely dependent on agriculture and allied activities such as livestock farming, poultry farming, sericulture, beekeeping, fishery, and other similar enterprises. More than 45 percent of NERs' geographical area is under forest cover and practice of shifting cultivation (*slash and burn farming*) is predominantly followed in some parts of the region, for which forest area is cleared. As most of the agriculture in NER is conventional (i.e., driven by traditional farming approaches), the productivity is less, and still, the majority of farmers are living under poverty. However, to foster the socio-economic development and to complement the food security in the nation, India is planning to bring out a second green revolution (using modern agronomic practices and farm mechanization). Therefore, this study was conducted with the various stakeholders of Agricultural Research and Extension system operational in NER to envisage strategies to mitigate the socio-economic and environmental impacts of climate change that would support policymakers and managers at various levels to make decisions for fostering climate-resilient agricultural development. The individual chapters incorporated in this dissertation also discuss the key features of NER.

In the NER, agricultural research and extension activities are mainly carried out by the National Agricultural Research System (NARS) which is one of the largest organizational mechanism in the world, dedicated to the welfare of Indian farmers. The Indian Council of Agricultural Research (ICAR), 102 research institutes operating under ICAR, and 73 (State and Central) Agricultural Universities across India are the principal constituents of NARS. ICAR institutions, State and Central Agricultural Universities (SAUs and CAUs) have separate departments/directorates for extension (i.e., transfer of technology) to develop, test and refine the technologies that are needed by the farming communities. The *Krishi Vigyan Kendras* or KVKs (Farm Science Centers), are district-level agricultural technology knowledge and resource

centers, which work in close liaison with various agricultural stakeholders in District (such as farmers, NGOs, farmers' groups, and all concerned developmental agencies in the district). The KVKs are entrusted with the mission to deliver demand-driven agricultural products and services to farming communities through various mandated activities that consist of (i) on-farm testing of novel technologies, (ii) organization of Front Line Demonstrations of potential technologies in farmers' field (iii) conducting demand-based vocational trainings for farmers and (iv) impart trainings for extension personnel to foster technology dissemination in district. KVKs also provide technical inputs to the Agricultural Technology Management Agency (ATMA), which is a scheme funded by Department of Agriculture Cooperation and Farmers Welfare (DAC&FW) and a district level society of key agriculture-related stakeholders for promoting sustainable development by integrating research-extension activities. The schematic representation of Agricultural Extension System (AES) functional in India is illustrated in Figure 1. AES is a subsystem of NARS that is dedicated to farmers' welfare through the transfer of technology. This dissertation sampled different types of stakeholders from NARS and AES to explore strategies/strategy options to deal with climate change impacts.

1.4 Data and Methods

The use of multiple methods to collect data from various stakeholders belonging to the agricultural sector of NER is one of the novel traits of this investigation. Use of three different methods allowed this dissertation to systematically investigate and compare the perceptions and priorities of multiple stakeholders that operate at three different levels. This study profoundly relied on primary data collected from three levels of stakeholders including intermediate (state/zonal), district, and field levels. Triangulation of data was an integral part of data collection procedure, to ensure higher reliability of results. Notably, the information collected through the brainstorming approach and Delphi technique provided consensus-based data which has higher reliability than mere surveys. Various (descriptive and inferential) statistical methods were used for three different methods to draw insightful conclusions from data.

Firstly, Chapter 2 and Chapter 3 are based on *Ex-post facto* design of research. The conclusions were drawn from the systematic analysis of primary data, collected from 797 farm households to investigate the farmers' perception of climate change risks, impacts, causes and adaptations to climate change. In Chapter 3, a logistic regression analysis approach is performed to identify

major determinants that shape farmers' perception of climate change. The existing literature pertaining to farmers' adaptation (to climate change) in the context of NER is inadequate as it largely focuses on technical aspects of adaptation. Most of the available studies are restricted to small areas (e.g., district) and deal with a particular crop or farming type. Moreover, most of the available studies do not integrate the farmers' perspective in the adaptation process. Therefore, these chapters attempt to fill the gap in existing literature and incorporate farmers' perspective in the adaptation process by exploring their perception and other socio-economic factors.

Secondly, Chapter 4 analyzes primary data collected from 21 brainstorming sessions using systematic content analysis to formulate strategies based on SWOT analysis. Hierarchical cluster analysis was also performed to explore the homogeneous clusters that reveal associations among individual factors. The internal factor evaluation matrix and external factor evaluation matric approach were utilized to identify appropriate strategies for sampled districts in NER. This is the unique (may be the first) attempt in NER to integrate the consensus-based perspectives of district-level professionals (pertaining to agricultural sector), in the process of strategy formulation to mitigate the adversities of climate change. This approach not only identifies the strategies for the agricultural sector but also provides insights (recommendations based on SWOT analysis) to adjust organizational management to implement those strategies successfully.

Thirdly, in Chapter 5 and Chapter 6, systematic content analysis was used to analyze qualitative data from the first Delphi round. Quantitative data generated in subsequent rounds' were analyzed using inferential as well as descriptive statistics such as mean, mode, Inter Quartile Range (IQR), and Quartile Deviation (QD). A non-parametric test, Kendell's coefficient of concordance or Kendall's W was also used along with Friedman's χ^2 test to explore the robustness of consensus among sampled experts. These chapters innovatively extract future concerns/perspectives of potential policymakers (PPMs) for sustainable development of NERs' agricultural sector through Delphi technique. It is first of its kind investigation in NER to investigate and recommend strategies/strategy options through several questions which are answered by multi-disciplinary experts who are functional in the NER.

1.5 Structure of the dissertation

This dissertation includes a total of seven chapters. The first chapter contains a general introduction to the dissertation. The seventh and last chapter synthesizes the results of the overall dissertation. From the remaining five main chapters, two are submitted to peer-reviewed journals, and three are likely to be submitted soon. All five chapters (i.e., chapter 2, 3, 4, 5 and 6) are formatted as research articles, and the author of the dissertation is the lead (first) author for all of them. The first author played a pivotal role in planning the dissertation, acquiring funding to conduct research and data collection, planning and execution of data analysis, chapter writing and submitting articles to peer-reviewed journals. This dissertation is multidisciplinary and utilizes methods from various social science disciplines that include agricultural economics, agricultural extension, geography, management, natural sciences, sociology, and statistics. This dissertation, through various chapters, provides socio-economic perspectives (related to climate change) that can assist policymakers on plausible strategy formulation for NER to deal with the negative impacts of climate change (Table 1).

Chapter 2 and 3 focus on farmers' perceptions and deal with farm-level aspects of climate change vulnerability, impacts, risk perceptions, adaptation, determinants of adaptation and constraints. These chapters (2 and 3) probe information from farmers through semi-structured interviews and represent farmers' side in the process of strategy formulation by exploring dimensions of farmers' vulnerability, sensitivity and adaptive capacity to climate change. Further, these chapters intend to highlight the constraints to the process of adaptation and socio-economic factors that determine the adaptation among farming communities.

Chapter 4 uses the SWOT method to explore the internal strengths and weaknesses as well as external opportunities and threats for ARES of NER. The successful implementation of any strategy (to combat climate change impacts) highly depends on human resource functional in the system. Appropriate utilization of collective strengths of human resource (operating at district-level) and region-specific opportunities has vast potential to foster sustainable development. However, the strategy formulation must consider the internal weakness and external threats to the system that could compromise the successful implementation of the strategy. Therefore, chapter 4 utilizes the brainstorming method to conduct SWOT of ARES of NER in changing climate scenario and provides information that would eventually assist policymakers to figure out plausible strategy. Furthermore, chapter 4 also provides insights in

district-specific strategy requirements as a single strategy would not be suitable to all studied districts.

Chapter 5 and 6 are intended to explore forecasts to assist strategy formulation, investment prioritization, and competency development to safeguard environment as well as farmers' livelihood security in climate change scenario. Chapter 5 and 6, incorporates the experiential wisdom of intermediate-level professionals (operating at state/zonal level) to the process of strategy formulation through the Delphi method. These chapters identify the contemporary challenges in NER, explore policy-components to stabilize the socio-economic conditions in NER, prioritize investments for sustainable development, highlight policy components to safeguard the environment, identify and prioritize the competency development needs for change agents as well as farmers, and to prioritize the institutional response to deal with climate change.

These chapters exhibit the bottom-up approach of strategy formulation wherein systematic methods are used to incorporate the views, concerns, and priorities of associated stakeholders.

Chapter 2: How do tribal farmers of Northeastern India perceive and respond to climate change?

Abstract

India's monsoon dependent agriculture is highly vulnerable to the impacts of climate change, and inadequate policies contribute to socio-economic difficulties in farming communities. Many current policies and strategies to combat climate change impacts are largely focused on technical aspects of adaptations whereas little research is done to understand the socio-economic dimension, particularly farmers' perspectives. To address this gap, we conducted systematic semi-structured interviews of 797 farm-families residing in the Northeastern Region of India (NER), an Eastern Himalayan ecosystem that is highly vulnerable to the climate changes adversities.

Results show that most farmers perceive changes in climate and are well aware of its agricultural as well as socio-economic impacts. The majority of farmers from all eight NER states experienced unusual climatic events in NER. About two-third believe that humans are responsible for this catastrophe and there is an urgent need to take appropriate action. Many farmers observed declining water availability and soil fertility across NER. To sustain crop farming, some farmers already adopted specific adaptations measures including mixed farming, new varieties, and soil conservation. Livestock farmers adopted measures to safeguard their animals regarding shelter, sanitation, vaccination, and others. A majority of fish farmers mainly implemented adaptations to safeguard ponds and maintain its water quality. In conclusion, there is a need to provide holistic adaptation packages to farmers of NER which comprises of awareness promotion with low-cost inputs and credit facility to overcome the barriers of adaptations.

Keywords: Adaptation, Agricultural vulnerability, adaptation barriers, Climate change, Northeastern India

2.1 Introduction

India, a home to 1.3 billion people and the world's sixth-largest economy, has experienced phenomenal increase in the frequency of floods, droughts, heat waves, and cyclones that are driven by global climate change (U. De, Dube, & Rao, 2005; Guhathakurta et al., 2011; Mall, Gupta, Singh, Singh, & Rathore, 2006). Changes in the Asian summer monsoon threaten food production in India (and other monsoon dependent nations) which may destabilize food security (P. Aggarwal, 2007; Auffhammer, Ramanathan, & Vincent, 2012; Chetia, Ahmed, Singh, & Feroze, 2015; S. N. Kumar et al., 2011). Without adequate adaptations and support for vulnerable sections of society, the increase in temperature is likely to reduce a life expectancy and increase hardships for rural population (Burgess, Deschenes, Donaldson, & Greenstone, 2017). Climate change impacts are especially noticeable in the agricultural sector where farmers and regional authorities often keep detailed records on crop production and yields. Climate change is also a stress aggravator, and Carleton (2017) found that crop-damaging temperatures increased suicides among Indian farmers. In the last twenty years, more than million farmers committed suicides, and a low resilience against adverse impacts of climate change on agricultural livelihoods is considered to be a contributing factor (Kennedy & King, 2014; Mishra, 2014). To reduce the undesirable consequences of climate change, effective adaptation strategies are needed (Azhoni & Goyal, 2018; Bhadwal et al., 2013; Boonwichai, Shrestha, Babel, Weesakul, & Datta, 2018; Shaffril, Krauss, & Samsuddin, 2018).

The (IPCC, 2001) defined adaptation as an adjustment in human or natural systems to current or expected climate stimuli to moderate losses and exploit beneficial opportunities. Deressa, Hassan, Ringler, Alemu, and Yesuf (2009) emphasize the importance of adaptation for farmers in vulnerable regions to mitigate adverse impacts. Potential adaptations to maintain or complement farmers' livelihood at farm-level include the installation of water harvesting and irrigation systems, soil conservation, afforestation, adjustments of planting dates and fertilizer applications, improvement of the physical infrastructure (i.e. roads, dams, canals, etc.) financial management to diversify risk, and social activities (such as awareness campaigns, social forestry) (Boonwichai et al., 2018; Bryan, Deressa, Gbetibouo, & Ringler, 2009; Shaffril et al., 2018). However, numerous factors restrict or promote the successful adoption of adaptations (Bryan et al., 2009; Moser & Ekstrom, 2010). Several studies show that perceptions, indigenous knowledge, beliefs and experiences of farmers (or target clients) considerably affect adaptive behavior (Deng, Wang, & Yousefpour, 2017; Grothmann & Patt, 2005; Li, Tang, Luo, Di, & Zhang,

2013). Therefore, information about these cognitive characteristics including observations on previous adaptation behavior is important to formulate effective and acceptable policies. However, fewer studies are reported from the Northeastern region of India that systematically explore above discussed dimensions and support policymaking at regional as well as state level. In addition, existing literature on adaptions to climate change has given little emphasis to socio-economic factors that either speed-up or slow down the process of adaptation.

Subsequently, there is little controversy in the scientific community about the reality of climate change (IPCC, 2001, 2007, 2014a; Oreskes, 2004). While greenhouse gas emissions from current crop and livestock production activities are substantial, there exist ample opportunities for emission reduction (Barker et al., 2007; McCarl & Schneider, 2000). Many studies have identified technical and economic potentials of emission abatement in agricultural systems (Schneider & McCarl, 2003; Zech & Schneider, 2019). However, these studies generally do not consider social (science) aspects of adaptation. To understand farmers' motivation for adaptation against climate change, it is important to understand their perception of climate change. For the design of regional adaptation programs for the farming communities in the Northeastern region of India, it is also essential to understand how these perceptions differ within the entire farming community.

Therefore, through this article, we briefly illustrate the farmers' perception and currently adopted adaptions to climate change. As the regional and state level studies are recommended to formulate tailor-made adaptation strategies that meet particular needs and constraints of different countries and groups of farmers (Bryan et al., 2009). Our investigation aims at providing a better understanding of farmers' perceptions of climate change and adaptations adopted by farmers along with the constraints to deal with climate change. Specifically, this article answers the following three research questions:

1. How do farmers perceive the impacts of climate change on agricultural systems?
2. Which risks do farmers perceive for livelihoods and income?
3. Which adaptation measures are undertaken by farmers and are there any constraints that hinder the process of adaptation?

2.2 Data and methods

Ex Post Facto design of research was utilized for this investigation as the levels of the explanatory variables are already determined before conducting the research (Kerlinger, 1966).

The study is performed in the Northeastern region of India (NER) which comprises eight states, 86 districts, and almost 44000 villages (NECS, 2015). The NER is of high importance due to its geographical location (i.e., proximity to international borders) and regarded as severely threatened biodiversity hotspot in the world according to Conservation International (CI, 2018). The NER is rich in terms of flora, fauna, diversity, and variety of natural resources (Chitale, Behera, & Roy, 2014; Khumbongmayum, Khan, & Tripathi, 2006; Venkataraman & Sivaperuman, 2018). The natural resources of NER are still underutilized and offer many opportunities for economic development (K. Dikshit & J. K. Dikshit, 2014c). The total geographical area of NER is 262 thousand km^2, which is almost 8% of India's geographical area. NER's economy is dominated by agriculture and supports the livelihoods of 45 million peoples (3.7% of the population of India) (NECS, 2015). However, NERs' contribution to national GDP is rather meager (2.5%), and even today 70% of inhabitants are directly or indirectly engaged in the agricultural sector (NECS, 2015). To boost the socio-economic development in NER and to ensure the food security of the nation, the Indian Government has targeted NER for a second green revolution (PIB, 2018). Therefore, we find it much appropriate to sample farmers from NER for this investigation, as the results would be readily available for planners and policymakers.

2.2.1 Interview schedule (questionnaire) development

We formulated a variety of questions to understand the pattern of farmers' behavior concerning climate change and how he/she is making decisions about farming as well as a livelihood (De Vaus & de Vaus, 2013). The questionnaire integrated several qualitative and quantitative sections such as the socio-economic profile of farmers, their household information, current farming practices, socio-institutional participation, perception about climate change and the responsive adaptations practiced by farmers. We conducted a systematic literature review before designing this interview schedule (Muhammad Abid, Schilling, Scheffran, & Zulfiqar, 2016; Dubey, Trivedi, Chand, Mandal, & Rout, 2016; Negi, Maikhuri, Pharswan, Thakur, & Dhyani, 2017; Tesfahunegn, Mekonen, & Tekle, 2016). Structured questions (i.e., close-ended questions) were incorporated to obtain quantitative information. For example, fill in the blanks, tick the appropriate, or rank the most appropriate item in the list. We incorporated open-ended question also to obtain information about farmers' perception on impacts of climate change, farmers' adaptations to climate change, and institutional support needed by farmers of NER to cope up with the impacts of climate change. The interview

schedule was pre-tested before the survey, and necessary corrections were made to ease the data collection process for farmers as well as enumerators.

2.2.2 Sampling and data collection

To get a representative view, we interviewed farm families in the NER to obtain both qualitative and quantitative data through semi-structured interview schedules. The data collection from farmers of NER was conducted from October 2017 until January 2018.

Table 2. Classification of districts based on elevation and valid sample

Category	Criteria	Districts (HQ)	Valid sample
Lower-elevation districts	Elevation less than 500 meters	East Kameng	40
		West Garo Hills	40
		PapumPare	30
		Dhalai	40
		Bongaigaon	30
		Chirang	39
		North Tripura	40
Mid-elevation districts	Elevation in between 500 to 1000 meters	Senapati	30
		North Sikkim	40
		Churachandpur	40
		Lower Dibang Valley	40
		Serchhip	40
		Lunglei	40
		Mon	40
Higher-elevation districts	Elevation above 1000 meters	Tawang	40
		Lower Subansiri	30
		West Khasi Hills	38
		West Jaintia Hills	40
		Mokokchung	40
		South Sikkim	40
		Aizawl	40
		Total	***797***

(Source: own 2018 survey data analysis)

The interview schedule was pre-tested in October 2017 to judge the reliability and validity of measuring instrument. The reliability of the interview schedule was verified using the test-retest method, and appropriate changes were made in questions through which reliable responses could be achieved (De Vaus & de Vaus, 2013; Kerlinger, 1966). Farmers' interviews were conducted in-between November 2017 to January 2018. This period was chosen considering the agricultural operations and availability of farmers for interview sessions.

We adopted multi-stage stratified random sampling for this study. In the first stage, we used the agro-climatic classification of India wherein entire NER is classified as Eastern Himalayan

Zone-II (S. N. Kumar et al., 2011; P. Singh, 2006). As NER has 86 districts, we classified them into three categories based on the elevation of district headquarter as presented in Table 2. From each classified list, seven (7) districts were randomly sampled in the second stage. 21 districts sampled from eight NER states are indicated in Figure 3. In the third stage, we randomly selected four (4) villages from each district in consultation with the local staff of Farm Science Centers.

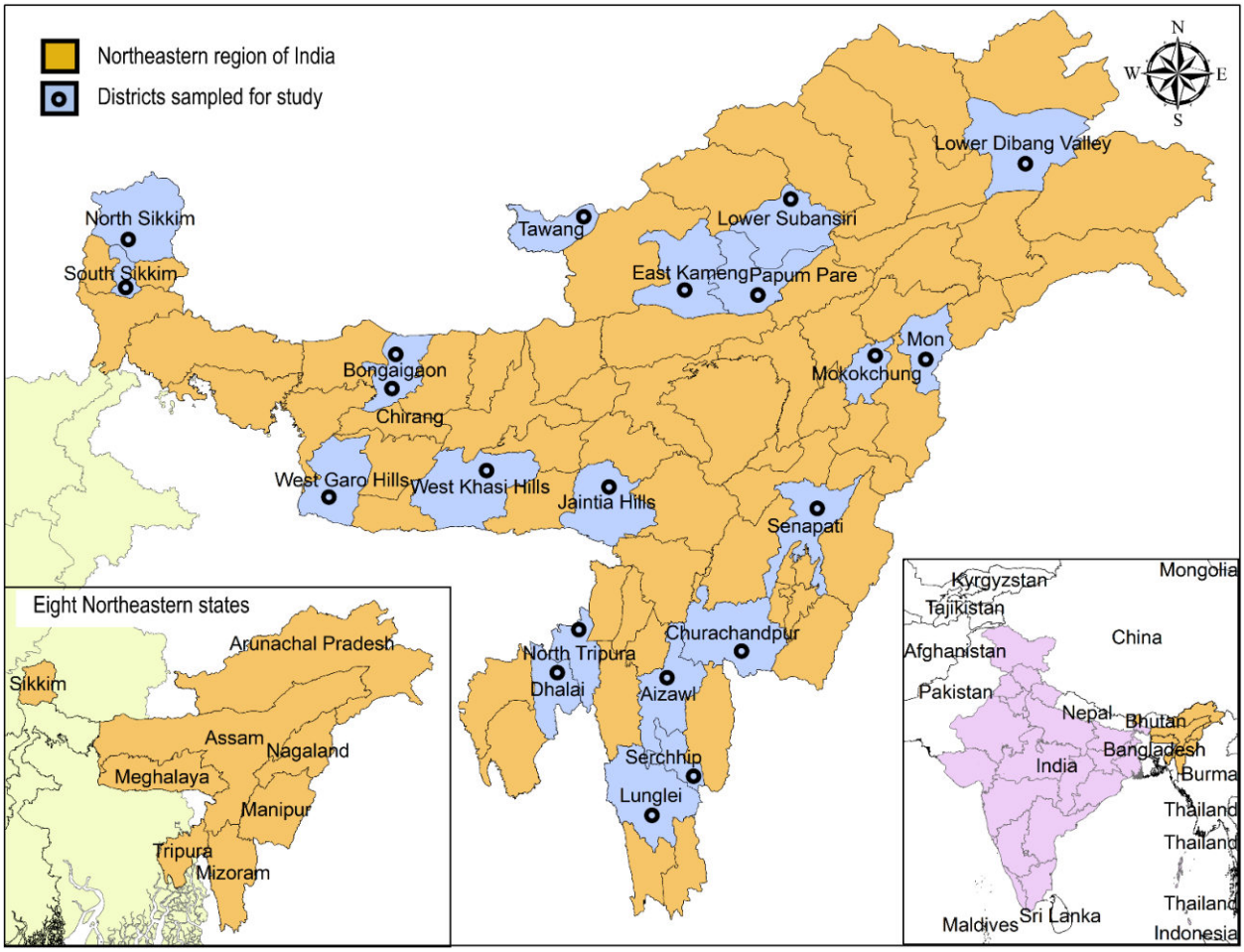

Figure 3. Map of India indicating the location of research locale, eight Northeastern states and sampled districts for conducting farmer interviews (Avishek, 2014; GADM, 2015).

In the last step, the Farm Science Centers provided lists of farmers from sampled villages for sampling respondents. Farmers having farming experience less than ten years were omitted from the list. Finally, ten (10) farm families from each village were randomly drawn for conducting interviews. Thus, a target of interviewing 840 farm families, from 84 villages was estimated before conducting interviews. However, due to safety guidelines issued by local administration, enumerators could not reach few villages, and only 811 farm families were interviewed by the end of January 2018. Ultimately, 797 responses were found fit for data

analysis as we rejected questionnaires with incomplete information. As illiteracy is high in rural areas of NER, personal interviews were considered a suitable instrument to gather reliable information from multi-lingual farmers. NER residents are very diverse in terms of their languages. Thus communicating with farmers in their tribal language/dialect was challenging. To overcome this obstacle, scientific and technical staff of Farm Science Centers from respective district facilitated the process of data collection among tribal farmers. We followed appropriate research ethics while conducting this study. The interviewers explained the aims and objectives of this study to farm families. All respondents were assured that collected data would be used for research and publication purpose. Informal permission was acquired from a farm family head to record the information related to household and farming. The farmers' family was treated as a basic unit of analysis and head of the family was interviewed. In addition, remaining family members were also allowed to participate in the process of discussion. The Farm Science Centers (*Krishi Vigyan Kendras*) provided necessary information (list of farmers) to decide the sampling frame and identify respondents for an interview. As we approached farm families through the staff of Farm Science Centers in respective district, the refusal rate was almost zero. However, this study covers only 797 farm families that are quite a small sample to generalize results at national level. Hence, the recommendations could be appropriate for state and regional level management.

2.2.3 Characteristics of research locale

NER of India is a frontier region, which shares a border with neighboring countries like Nepal, China, Bhutan, Myanmar, and Bangladesh. The location of NER stretches between latitudes 21°57′ and 29°28′N and longitudes 89°40′ and 97°25′E. Eastern Himalayan foothills, meadows, water bodies as well as dense forests occupy most of the region which makes an accessibility a prime limitation. K. Dikshit and J. K. Dikshit (2014e) describe this NER as the rainiest region in India wherein varieties of flora and fauna are abundantly present. Brahmaputra and Barak are major river valleys in this region, and most of the plain area is a shelter for endangered birds, animals, flowering and medicinal plants (K. Dikshit & J. K. Dikshit, 2014b). This region is recognized as a hub of rice germplasm (B. Das et al., 2013) and center of origin of citrus fruits (K. Dikshit & J. K. Dikshit, 2014e). Tribal communities have played a key role in the conservation of local traits of agriculturally important crops (K. R. Dikshit & J. K. Dikshit, 2014).

The population density of this region is 148/KM^2, which is much less than the national average of 389/KM^2. Interestingly, more than 200 ethnic groups (tribes) are found in Northeastern

region making it diverse in terms of dialects, food habits, traditions, lifestyle, belief and value systems (K. Dikshit & J. K. Dikshit, 2014c). Until the early 1990s, socio-economically Northeastern region was a bit behind than the rest of country because of constraints like traditional and subsistence farming, meager industrialization, less education penetration, insurgency, regional instability, poor connectivity and transport issues (Barah, 2006; Baruah, 2007; Verghese, 2013). However, in the last 20 years, the pace of infrastructure development and socio-economic advancement is remarkable. Still, the inter-state, intra-state and intra-community conflicts are reported in Northeast region that hamper the socio-economic prosperity in the long run (K. Das, 2017; Verghese, 2013).

The research locale also exhibits some social and economic attributes that are mostly homogeneous. Crop farming and livestock rearing is the major income generating activity in NER. Among all states of NER, on an average, almost 60% or more population depends on farming for livelihood (K. Dikshit & J. K. Dikshit, 2014a). Majority of the population is tribal, and penetration of education is rapidly increasing in all states of NER (K. Dikshit & J. K. Dikshit, 2014d). Furthermore, almost all NER state indicate similarity about the average household size that ranges in between 4.3 to 5.4 (NECS, 2015). NER states have better sex ratio than the rest of India (NECS, 2015) and women play a key role in the farming sector (U. K. De, Pal, & Bharati, 2017). The slash-and-burn cultivation is commonly observed in many NER states, which is reducing (NITI Aayog, 2018) and farmers prefer modernization of farming. The natural farming or farming without chemicals is also a common trait found in almost all NER hills. In general, NER states also share commonality concerning changes in climate and vulnerabilities faced by farmers. Water stress and erratic rainfall are the commonly experienced vulnerabilities in hilly areas (Jamir, Sharma, Sengupta, & Ravindranath, 2013; Maiti et al., 2017; Ravindranath et al., 2011) and riverside plains are exposed to flooding (Chaliha, Sengupta, Sharma, & Ravindranath, 2012; Mahanta & Das, 2017). In fact, climate change is additional stress faced by NER agriculture that will adversely affect the food-production in the region (Ravindranath et al., 2011).

2.3 Results and discussion

This section contains the findings of 797 household interviews and discussion pertaining to the insights that are categorized into sub-sections as (i) farmers awareness of climate change; (ii) farmers risk perceptions of changes in climate (iii) perceived vulnerabilities of water and (iv) land resources; (v) perceived impacts on income; and (vi) adaptations to changing climate.

2.3.1 Farmers' awareness of and beliefs about climate change

We investigated farmers' general opinion on climate change, by posing a direct question "are you aware of changing climate?" that could be answered with 5-point rating scale (1= I strongly disagree that there is climate change and I am not aware of it, and 5 = I strongly agree that there is climate change and I am aware of it, 0=neutral or undecided).

The results are presented in Figure 4, which reveal that across all states of NER, more than 70% of farmers are aware that climate is changing. The farmers of Tripura (58.8%), Assam (43.5%) and Sikkim (40%) rated their awareness at stronger agreement levels. Farmers of Manipur (81.4%), Nagaland (71.3%), Meghalaya (63.6%), Mizoram (59.2%) and Arunachal Pradesh (53.2) also indicated positive agreement with their state of being aware of changes in climate. A very small fraction of farmers from all state indicated disagreement at meager levels (0% to 8.3%). This indicates that farmers from all states, hills as well as plains are aware of the happening of climate change. These results are consistent with the similar kind of research conducted by Shukla, Kumar, Pala, and Chakravarty (2016) in villages of Sikkim.

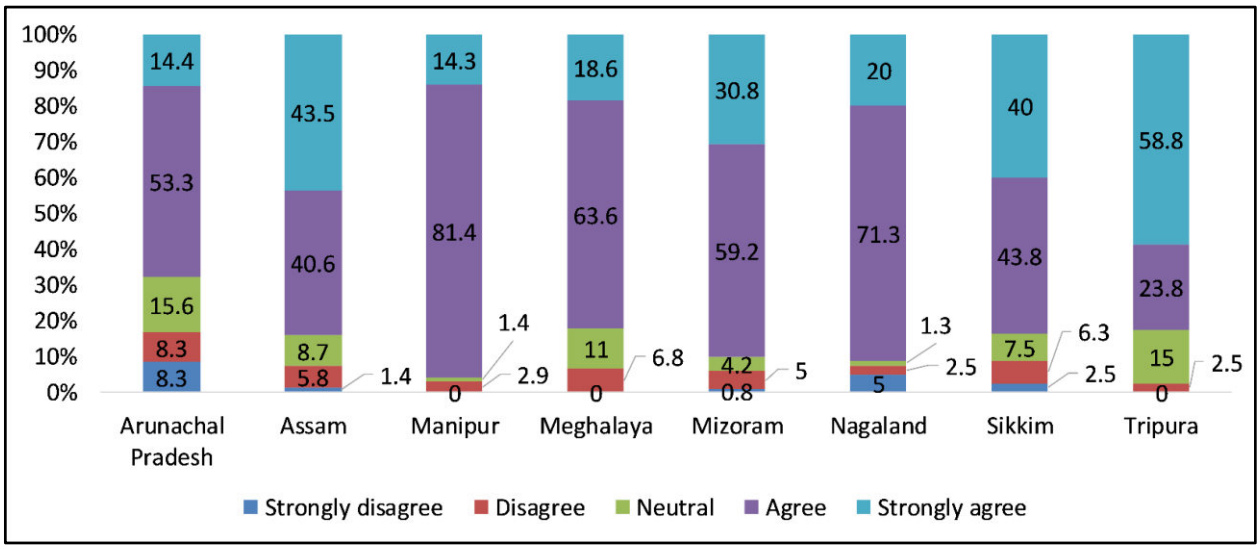

Figure 4. Farmers' awareness of climate change. A response of NER farmers to statement "I am aware about climate change."

Furthermore, the awareness dimension was investigated a bit more, by asking a rating type question (as above) that necessitated farmer to think of unusual climatic events occurred in the last 10 -15 years. The findings reveal that more than 80% of farmers from all states have experienced unusual climatic events either on the agreement or on strong agreement levels (Figure 5). Except for Arunachal Pradesh state, farmers from all state have demonstrated as a unanimous agreement that something unusual is happening with respect to climate events.

State of Meghalaya, Sikkim, and Tripura have reported consistent agreement about unusual climatic changes than Assam and Manipur. Sixteen (16) percent farmers of Arunachal Pradesh have reported in the neutral zone and could not decide about the climatic events in the past. This finding is analogous to the studies conducted in NER by Rama Rao et al. (2018) and Sati and Vangchhia (2017) and affirms that farmers of NER are well aware of unusual changes in climate.

Moreover, to support farmers' awareness of climate change, we asked two questions to explore their beliefs on this issue. Firstly, farmers were requested to rate the statement "Climate change is man-made, we are responsible for it" on the same 5-point rating scale. The findings reveal that across all states almost 65% of farmers agreed that climate change is a man-made catastrophe and we humans are responsible for it (Figure 5). Farmers of Tripura (48.8 %) and Assam (44.9%) strongly agreed with this belief of being responsible for climate change. Respondents from Manipur (62.9%), Mizoram (57.5%), Arunachal Pradesh (57.2%), Meghalaya (51.7%), Nagaland (51.2%) also firmly agreed with this belief.

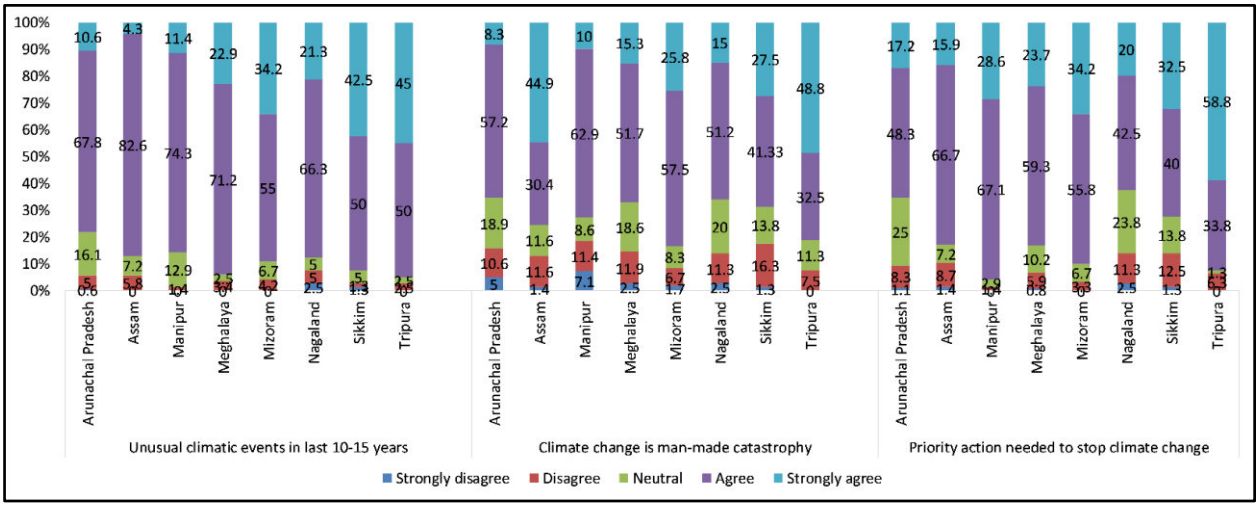

Figure 5. Farmers' perception towards climate change as unusual events, human-made catastrophe and need of action to stop climate change

Secondly, we asked respondents to rate the statement, "we must act as early as possible to stop climate change" on the same scale. The findings reveal that from all states significantly higher level of agreement (65% and above) is reported, and farmers hint out the need for priority action against climate change (Figure 5). Farmers from Manipur (strongly agree: 28.6%, agree 67.1%); Tripura (strongly agree: 58.8%, agree 33.8%); Mizoram (strongly agree: 34.2%, agree 55.8%); Assam (strongly agree: 15.9%, agree 66.7%); Meghalaya (strongly agree: 23.7%, agree 59.3%) much firmly support the belief that 'it is a time to act'. State of Arunachal Pradesh (25%) and Nagaland (23.8%) received bit higher percentage of neutral responses.

The findings of this section adequately support that farmers of NER are aware of the happening of climate change which is consistent with the results of Hyland, Jones, Parkhill, Barnes, and Williams (2016). A significant number of farmers experienced unusual climatic events. Similarly, farmers unanimously affirm the belief that climate change is a man-made catastrophe and we all must act now. Our findings exhibit no contradiction within farmers' awareness and beliefs, thus demonstrate that farmers of NER perceive climate change.

2.3.2 Farmers' risk perceptions based on climatic indicators

We systematically enquired changes in key farm related climatic indicators to explore farmers' perception of climate change as a risk. Rainfall is the most crucial factor in farming. Here we asked farmers to rate some rainfall related factors on the three-point scale that quantifies the increase, decrease or no change for individual factor, by considering their farming experience of last 10-15 years. The results of this inquiry are presented in Figure 6.

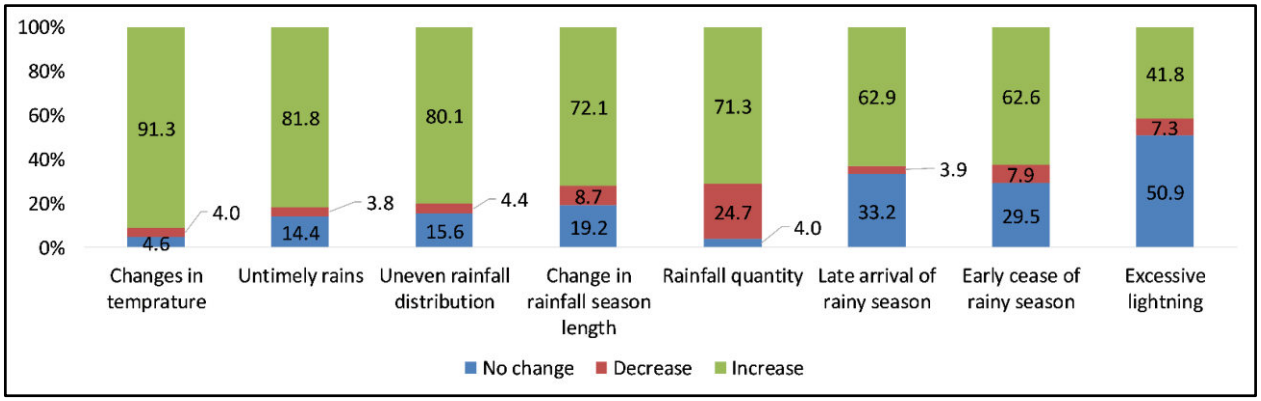

Figure 6. Perceived changes in meteorological indicators of climate change

We found that a significantly higher proportion of respondents reported variation about changes in temperature, rainfall quantity, untimely rains, uneven rainfall distribution and changes in rainfall season length. Farmers of NER reported significant changes in rainfall quantity and 71.3 percent of farmers reported increase whereas 24.7 percent reported a decrease. Around 91.3 percent respondents affirmed about the increase in temperature. In the same way, a substantial proportion of respondents (around 80%) affirmed untimely rains and uneven rainfall distribution in NER. The findings also indicate that 72 percent of respondents supported changes in rainfall season length are increasing. Majority of respondents also conveyed that rainy season is arriving late (increase reported by 62% respondents) than usual and the events of early cease of the rainy season are increasing (increase reported by 62.6% respondents). However, the mixed response is reported on excessive lightning in NER. 50.9

percent of farmers support that there is no change concerning lightning whereas 41.8 percent voted for an increase in lighting that could harm humans, livestock or can cause damage to property. In a nutshell, findings conclude that temperature and rainfall variability is increased in NER (Figure 6). Our results and farmers' responses are fitting with the findings of various rainfall related studies in NER which emphasize on rainfall fluctuations and increased seasonal variability in NER (S. Das, Tomar, Saha, Shaw, & Singh, 2015; Deka, Mahanta, Nath, & Dutta, 2016; Pai, Sridhar, Badwaik, & Rajeevan, 2015).

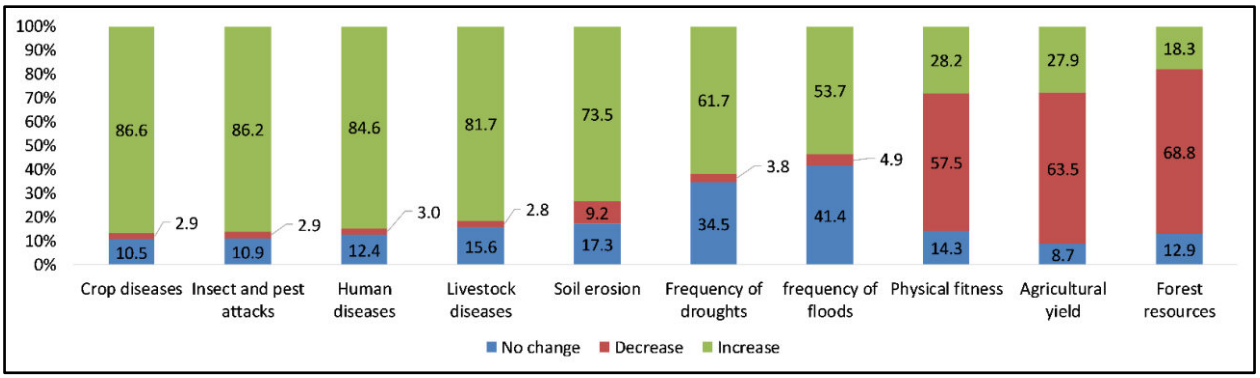

Figure 7. Perceived impacts of climate change on biophysical factors in terms of farmers' observations

In the next step, we appraised farmers understanding about the impacts of increased temperature and rainfall variability in NER. Respondents were requested to record their observations concerning key risk factors such as diseases, farming, floods, droughts erosion, etc. Respondents had three choices for each factor as increase, decrease or no change about the individual risk factor. According to the findings summarized in Figure 7, farmers of NER perceive that crop diseases (86.6%), insect and crop pest attacks (86.2), diseases in humans (84.6%), diseases in livestock (81.7%) and soil erosion (73.3%) are most significantly increased risk factors. These findings also point out that the frequency of droughts (61.7%) and floods (53.7%) is also increased. However, droughts and floods are not reported from all sampled districts.

To triangulate the farmers understanding on impacts of climate change, we tested their ratings for physical fitness, agricultural yield, and forest resources. All three factors consistently reported decrease according to the farmers' perception Figure 7. Tribal inhabitants of NER regularly harvest non-timber forest products such as wild fruits, berries, medicinal plants and barks, orchids, mushrooms, etc. (Gupta, 2000) to support their livelihood. However, in present times 68.8 percent respondents reported the decrease in forest resources. In addition, 63.5 percent of farm families reported that agricultural yield is also declining and perceived as the

impact of climate change. Similarly, almost 53.5 percent of respondents affirmed that overall, physical fitness is also decreased and they associate it with climate change. These findings sustain that farmers perceive impacts of climate change and there are no incongruities about their responses.

2.3.3 Perceived vulnerability of water resource

Though the NER is the rainiest landmass in India, farmers are pointing out that rainfall variability is adversely affecting them. Water stress is becoming severe than ever in most of the districts. Water plays a pivotal role in crop farming, fish and livestock production, which is the source of livelihood for millions of households in NER. Therefore, to understand the farmers' concerns over water resources, we investigated about the availability of water in their locality. Three close-ended questions were asked about the availability of water, quality of irrigation water and the quality of drinking water. Four options were provided to answer these questions (1=improved, 2=not changed, 3= decreased, 4= don't know) and respondents recorded their response accordingly. The results of this section are summarized in Figure 8. The findings reveal that more than half of farm households from Meghalaya (67.8%), Mizoram (54.2%) and Manipur (51.4%) reported that water availability is decreased. Forty-one percent of farmers from Sikkim and around 30 percent from Arunachal Pradesh as well as Nagaland claimed that water resource is declining. On the contrary, a significant proportion of farmers from Tripura (71.3%) reported increased availability of water. For the considerable proportion of farmers from Nagaland (47.5%), Assam (46.4%), Arunachal Pradesh (38.3%) and Sikkim (36.3%) water availability was not changed. These findings make it clear that hill states are facing water shortages.

Concerning drinking water in NER, more than half of households from Assam (68.1%), Meghalaya (55.1), Mizoram (51.7) and Manipur (51.4%) reported a decline in quality (Figure 8) whereas farmers of Sikkim (58.8%), Nagaland (56.3%) and Arunachal Pradesh (40.6%) reported that quality of drinking water is not changed. In contrast, the households from Tripura (53.8%) conveyed that drinking water quality is increased.

The data about the quality of irrigation water probed and finding suggest that significant extent of households from Assam (56.5%), Meghalaya (50.8%), Mizoram (44.2%), Manipur (35.7%) and Arunachal Pradesh (31.7%) are experiencing decrease in the quality of irrigation water that may adversely harm crop production (Figure 8). The irrigation water quality remains

unchanged for a substantial amount of farmers from Tripura (56.3%) and Sikkim (51.2). Whereas the majority from Nagaland (60.0%) reported that, they do not know about the increase or decrease of irrigation water quality.

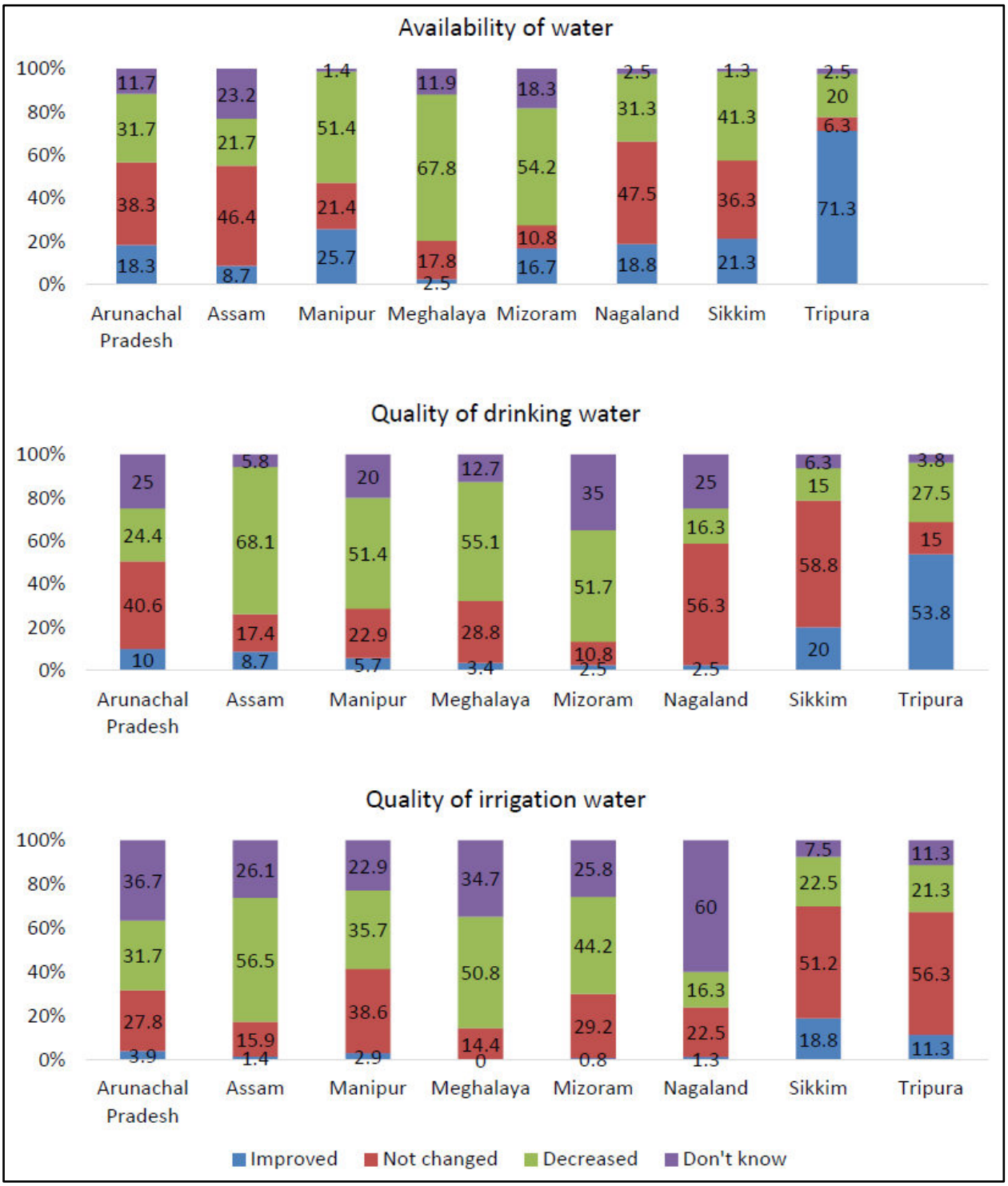

Figure 8. Perceived impacts of climate change on water resources in NER

To estimate or judge the quality of irrigation and drinking water, interviewer requested farmers to consider factors like the color of water, the taste of water, the smell of water, etc. However,

some farmers (who recently conducted soil and water testing with government departments) affirmed their perception about the quality of water considering the results of water testing provided by Government officials. The findings of studies conducted by N. Singh and Singh (2015), Parida and Oinam (2015), Pandey, Kumar, Pandey, and Thongbam (2014), and Bawa and Ingty (2012) also signify the water stress issue in NER, with which our results are congruent.

2.3.4 Perceived vulnerability of arable land (soil) resource

Farmers' perception about the current state of land resources was investigated using three close-ended questions that probed about the fertility of soil, waterlogging in the soil, and soil salinity. Out of four, farmers were requested to choose only one appropriate response and results are presented in (Figure 9). According to the findings, significant number farmers sampled from Tripura (78.8%), Manipur (78.6%), Meghalaya (77.0%), Assam (76.8%), Mizoram (64.2%) and Nagaland (56.3%) reported decreased land fertility. Farmers from Arunachal Pradesh and Sikkim had mixed perceptions about land fertility. 38.3 percent of Sikkim farmers reported decreased fertility whereas around 32 percent reported no change about the fertility of the soil. Besides, from Arunachal Pradesh, 35 percent farmers noticed soil fertility remains unchanged and approx. Twenty-seven percent rated for decreased fertility. The finding on the decrease in land fertility is in accordance with the conclusion of a study conducted by Clair and Lynch (2010) that links declined land fertility with climate change.

Subsequently, we enquired about water logging status of agricultural fields in NER and state wise results are presented in (Figure 9). Findings affirm that considerable extent of farmers from Nagaland (55.0%), Mizoram (50.0%), Meghalaya (46.6%), Arunachal Pradesh (41.1%) and Manipur (38.6%) couldn't judge the waterlogging in farms. For some extent of farmers of Sikkim (46.3%), Tripura (75.5%) and Nagaland (26.3%) waterlogging were not changed and they perceived this factor as the way it was before. However, a slight increase in waterlogging is reported from Meghalaya (31.4%), Assam (30.4%), Manipur (30.0%) and Mizoram (27.5%). In many cases, the low-lying fields, also called as low lands are often prone to waterlogging conditions.

Finally, the third question queried about the status of soil salinity. The soil salinity is the amount of salt in the soil. In the NER, mineral weathering has the potential to trigger the process of salinization. The findings of the current perception of farmers about soil salinity are presented in (Figure 9). Findings demonstrate that throughout the NER, except Tripura, more

than half of respondents could not perceive the increase or decrease of soil salinity and preferred for don't know option.

Figure 9. Perceived impacts on the arable land resource in NER

A considerable proportion of farmers from Tripura (42.5%) stated that the soil salinity is decreasing. These findings conclude that a decrease in soil fertility is mostly perceived by NER

farmers. The water logging is a secondary issue for farmers that is mainly faced by low-lying fields. However, the soil salinity is not considerably perceived by NER farmers.

2.3.5 Perceived impacts on income

As farmers evaluate the performance of their occupation with the yardstick of seasonal earning, we asked information about the impacts of climate change on their seasonal Income. In general, Indian monsoon dependent agricultural (cropping) seasons are classified as *Kharif* and *Rabi*. The *Kharif* season duration is from July to October and *Rabi* season spans from October to March. Subsequently, the crop season during March up to June is regarded as summer (Zaid) season. We asked farmers to answer questions about their income status in all three cropping seasons and provided three closed-ended choices as increase, decrease and not changed. The findings of this section are presented in (Figure 10). Firstly, the results reveal that significant proportion of respondents reported a decrease in Kharif season income and they are from Meghalaya (78.8%), Mizoram (60.0%), Assam (58.0%) and Sikkim (42.5%). These results are in consistency with the conclusion of Auffhammer et al. (2012) and S. N. Kumar et al. (2011) that emphasize declined yield in *Kharif* season. On the contrary, the considerable number of farmers from Tripura (58.8%), Nagaland (42.5%) and Sikkim (38.8%) conveyed that income in *Kharif* season is increased. Whereas, a large chunk of farmers of Arunachal Pradesh and Manipur indicated that agricultural income from *Kharif* season is not changed.

Secondly, findings demonstrate that *Rabi* season income is decreased in most of the NER states (Figure 10). A significant proportion of farmers reported decrease which are sampled from Meghalaya (89.8%), Assam (63.8%), Mizoram (61.7%), Manipur (52.9%), and Tripura (51.2%). Around 33 percent farmers from Nagaland and Arunachal Pradesh also reported a decline in the *Rabi* season income. However, the increase of income during the *Rabi* season is also considerably reported from Sikkim (46.3%), Tripura (42.5%), Nagaland (33.8%) and Arunachal Pradesh (25.0%). Around 41 percent of farmers form Arunachal Pradesh, 32 percent from Manipur as well as Nagaland, and 28 percent from Mizoram reported that there is neither increase nor decrease concerning *Rabi* season income.

Finally, the findings of summer season indicate that a significant proportion of farmers from all states of NER perceive that summer season income remains unchanged for them (Figure 10). However, the substantial number of farmers from Sikkim (89.8%) and Tripura (89.8%) reported an increase in summer season income. On the contrary, almost 34 percent respondents from

Meghalaya, 33 percent from Manipur and 26 percent from Nagaland conveyed decline in summer season income.

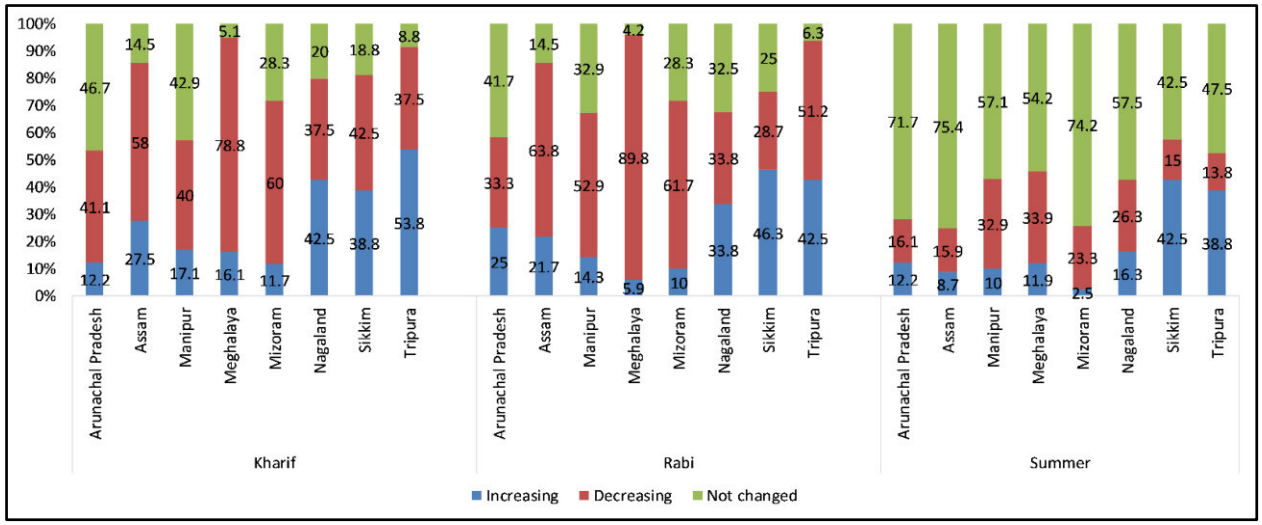

Figure 10. Perceived impacts of climate change on farmers' season income in various seasons

These findings conclude that there is enormous state-to-state variability with respect to changes in farmers' income during the various cropping season. A significant percentage of farmers from Meghalaya, Mizoram, Assam, and Manipur reported declined income in almost all cropping seasons. Likewise, a considerable proportion of farmers from Tripura, Nagaland, and Sikkim reported increased income during all farming seasons.

2.3.6 Adaptations to climate change

The results regarding adaptations adopted by respondents to sustain crop farming are presented in Table 3. The findings show that a significant number of farmers adapted mixed cropping (65.8%), use of different varieties (48.5%), soil conservation practices (35.3%), some changed planting time (32.7%), and some changed crop type (30.8%) to minimize losses due to climatic variability in NER. Mixed cropping allows farmers to cultivate more than one crop in the field, in the same season, which complements each other. It minimizes the risk of complete crop failure and enables the farmer to sustain a livelihood. In addition, almost 26 percent of farmers opted for crop diversification and water conservation as adaptation measures.

With respect to livestock farming, significant number of respondents provided shelter to livestock (57.8%), adopted regular cleaning and sanitation practices (41.2%), timely vaccination (34.1%), improved livestock housing (31.7%), change of breeds (21.3%) and adopted scientific feeding practices for livestock (20.2%) (see Table 4). These findings indicate that farmers are trying their level best to protect livestock from erratic climate events.

Fish farmers of NER adopted various adaptations such as repair of ponds (29.7%), application of lime (calcium carbonate) in ponds (20.5%) which increases the alkalinity of water and enhances the microbial activity in pond, application of cow dung in ponds (13.5%), addition of fresh water in pond (9.6%), and use of quality fingerlings (9.5%) (see Table 5).

Table 3. Adaptations by respondents for crop farming (n=797)

Description	Yes	No	X^2 test
Mixed cropping	525 (65.87)	272 (34.13)	0.0001
Use of different varieties	387 (48.56)	410 (51.44)	0.415
Soil conservation	282 (35.38)	515 (64.62)	0.0001
Changed planting time	261 (32.75)	536 (67.25)	0.0001
Changed crop type	246 (30.87)	551 (69.13)	0.0001
Crop diversification	212 (26.60)	585 (73.40)	0.0001
Increased efforts for water conservation	210 (26.35)	587 (73.65)	0.0001
Adopted use of pesticides	163 (20.45)	634 (79.55)	0.0001
Adopted irrigation for crops	134 (16.81)	663 (83.19)	0.0001
Changed fertilizers	99 (12.42)	698 (12.42)	0.0001
Community changed land-use pattern	92 (11.54)	705 (88.46)	0.0001
Fertilizer doses changed	82 (10.29)	715 (89.71)	0.0001
Shifted farm site	66 (8.28)	731 (91.72)	0.0001
Shortened growing period	64 (8.03)	733 (91.97)	0.0001
Wind breaks guarding installed	63 (7.90)	734 (92.10)	0.0001
Augmented crop farming by livestock	56 (7.03)	741 (93.35)	0.0001
Improved grain storage methods	53 (6.65)	744 (93.35)	0.0001
Zero tillage practices adopted	39 (4.89)	758 (95.11)	0.0001
Renting of cropland	38 (4.77)	759 (95.23)	0.0001
Accessed crop insurance	36 (4.52)	761 (95.48)	0.0001

Figures in parentheses indicate percentage.

X^2, Chi-square test (two-tailed test); significant at probability level, $p \leq 0.05$; *Not significant at $p \geq 0.05$

Table 4. Adaptations by respondents for livestock farming (n=797)

Description	Yes	No	X^2 test
Providing shelter to livestock	461 (57.84)	336 (42.16)	0.0001
Regular cleaning and sanitation	329 (41.28)	468 (58.72)	0.0001
Timely vaccination	272 (34.13)	525 (65.87)	0.0001
Improved livestock housing	253 (31.74)	544 (68.26)	0.0001
Change of breeds	170 (21.33)	627 (78.67)	0.0001
Scientific feeding practices adopted	161 (20.20)	636 (79.80)	0.0001
Extra care of livestock during pregnancy	139 (17.44)	658 (82.56)	0.0001
Started cultivating fodder crops	127 (15.93)	670 (84.07)	0.0001
Use of cross breeds	101 (12.67)	696 (87.33)	0.0001
Artificial insemination	73 (9.16)	724 (90.84)	0.0001
Isolation of animals	68 (8.53)	729 (91.47)	0.0001
Shifted to improved breeds	68 (8.53)	729 (91.47)	0.0001
Reduced open grazing	50 (6.27)	747 (93.73)	0.0001
Livestock insurance adopted	49 (6.15)	748 (93.85)	0.0001
Change in (population) quantity of livestock	36 (4.52)	761 (95.48)	0.0001
Shifted to local breeds	32 (1.02)	765 (95.98)	0.0001
Marketing dates shifted	23 (2.89)	774 (97.11)	0.0001

Figures in parentheses indicate percentage.
X^2, Chi-square test (two-tailed test); significant at probability level, $p \leq 0.05$; *Not significant at $p \geq 0.05$

Table 5. Adaptations by respondents for fish farming (n=797)

Description	Yes	No	X^2 test
Repair of ponds	237 (29.74)	560 (70.26)	0.0001
Application of lime	164 (20.58)	633 (79.42)	0.0001
Application of cow dung	104 (13.05)	693 (86.95)	0.0001
Addition of fresh water in pond	77 (9.66)	720 (90.34)	0.0001
Quality fingerlings	76 (9.54)	721 (90.46)	0.0001
Changed fish type	71 (8.91)	726 (91.09)	0.0001
Harvesting dates shifted	62 (7.78)	735 (92.22)	0.0001
Change in population	57 (7.15)	740 (92.85)	0.0001
Plantation on pond dyke	56 (7.03)	741 (92.97)	0.0001
Increased pond dike height	56 (7.03)	741 (92.97)	0.0001
Application of fertilizers	50 (6.27)	747 (93.73)	0.0001
Changed feeding	47 (5.90)	750 (94.10)	0.0001
Preventive measures	44 (5.52)	753 (94.48)	0.0001
Desilting of ponds	42 (5.27)	755 (94.73)	0.0001
Pumping of saline water	40 (5.02)	757 (94.98)	0.0001

Figures in parentheses indicate percentage.
X^2, Chi-square test (two-tailed test); significant at probability level, $p \leq 0.05$; *Not significant at $p \geq 0.05$

Our findings of this section are consistent with various studies conducted in NER. For example, Adi tribe farmers of Arunachal Pradesh preferred the use of improved varieties (paddy and

maize), diversified farming, diversification of livestock and complementing income by non-farm activities as an adaptation strategy to sustain livelihood (R. K. Singh et al., 2017). G. Sharma and Sharma (2017)Sharma and Sharma (2017) proposed the implementation of agroforestry in Sikkim state as an adaptation measure that has the potential to strengthen livelihood sustainability among poorer sections. The study conducted by Sati and Vangchhia (2017) in Mizoram state revealed that conservation of water for irrigation, use of insecticides, and government assistance were reported as an adaptation by tribal farmers. The essence of our results also resembles with the findings of (Ingty, 2017) wherein potential adaptations are farming diversification, income diversification and communal pooling for effective production and marketing of farm produce. Similarly, other adaptation-related studies reported from NER also communicate similar findings as our results (Kharumnuid, 2011; Maiti et al., 2014; Neog et al., 2016; G. Sharma, Partap, Dahal, Sharma, & Sharma, 2016; H. C. P. Singh, Rao, & Shivashankar, 2013; N. Singh & Singh, 2015).

2.3.6.1 Constraints to the process of adaptation

Adaptation to climate change is a gradual process. There are some factors that either speed-up or slow-down this process. We investigated the constraints that slow-down the process of adaptation and farmers' responses are summarized in Table 6. According to the farmers of NER, the high cost of agricultural inputs (68.1%), less awareness about adaptation technologies (67.0%), shortage of credit facilities (56.9%) and poor soil fertility (50.0%) are the prime constraints that hinder the process of adaptation. Azhoni and Goyal (2018) also highlighted similar kind of challenges in Sikkim, and our findings are in line with them.

Subsequently, the considerable amount of farmers reported that high transportation cost (48.4%), shortage of cultivable land (44.5%), labor shortage for farming (43.7%), shortage of farm inputs (39.5%), deficiency of trainings from experts (37.2%) and inadequate water for irrigation (37.0%) are also adversely hampering the process of adaptation against climate change.

Table 6. Constrains to adaptation process as perceived by NER farmers (n=797)

Description	Yes	No	X^2 test
High cost of inputs	543 (68.13)	254 (31.87)	0.0001
Awareness about adaptation technologies	534 (67.00)	263 (33.00)	0.0001
Lack of credit services	454 (56.96)	343 (43.04)	0.0001
Poor soil fertility	399 (50.06)	398 (49.94)	**0.972***
High transportation cost	386 (48.43)	411 (51.57)	**0.376***
Shortage of cultivable land	355 (44.54)	442 (55.46)	0.0021
Labor shortage for farming	349 (43.79)	448 (56.21)	0.0001
Shortage of farm inputs	315 (39.52)	482 (60.48)	0.0001
Lack of trainings	297 (37.26)	500 (62.74)	0.0001
Lack of water for irrigation	295 (37.01)	502 (62.99)	0.0001
Market accessibility	261 (32.75)	536 (67.25)	0.0001
lack of information	250 (31.37)	547 (68.63)	0.0001
Fear of failure	228 (28.61)	569 (71.39)	0.0001
Lack of confidence	189 (23.71)	608 (76.29)	0.0001
Conflicts and clashes in community	156 (19.57)	641 (80.43)	0.0001
Lack of motivation	121 (15.18)	676 (84.82)	0.0001
Electricity supply for farming	109 (13.68)	688 (86.32)	0.0001
No support from public sector	103 (12.92)	694 (87.08)	0.0001
Less institutional linkages	90 (11.29)	707 (88.71)	0.0001
Non-rewarding activity	82 (10.29)	715 (89.71)	0.0001
My own behavior	78 (9.79)	719 (90.21)	0.0001
Cultural compatibility issues	61 (7.65)	736 (92.35)	0.0001
No support from family members	20 (2.51)	777 (97.49)	0.0001

Figures in parentheses indicate percentage.
X^2, Chi-square test (two-tailed test); significant at probability level, $p \leq 0.05$; *Not significant at $p \geq 0.05$

These findings are congruent with various studies reported from NER and rest of the India such as Rama Rao et al. (2018), G. Sharma and Sharma (2017), Sati and Vangchhia (2017), G. Sharma et al. (2016), Panda and Singh (2016) and Sinha (2003). These constraints not only hamper the process of adaptation against climate change but also impede the overall socio-economic development of NER.

2.4 Conclusions and policy making

Climate change is a high challenge for Indian agriculture. The Indian farming community needs policies that enhance farmers' adaptive capacity against climatic changes and thus reduce their vulnerability. The success of these adaptation policies depends on how farmers perceive climate changes and associated risks. In this paper, we conduct and analyze a large survey in NER India to assess farmers' perceptions of climate change, climate change impacts, and adaptation actions.

We find a considerable proportion (around 70%) of farmers from NER being aware of climate change believing in its manmade nature and in need of interventions that could support their livelihood. According to our survey, farmers attributed increases in mean temperature and variability of rainfall during the *Kharif* and *Rabi* seasons as significant factors for income losses. Increasing incidences of crop diseases, insect and pest attacks, and human and livestock diseases throughout the entire study region led to noticeable reductions in agricultural yields and non-timber harvests from forests. Except in the state of Tripura, farmers reported a declining availability of irrigation water and a lower quality of drinking water. In all states of NER, farmers associated climate change with declining soil fertility.

Many of the sampled farmers have already adopted adaptation measures in order to cope with climate change. On cropland, farmers have employed mixed cropping systems, changed crop varieties, implemented soil conservation measures, and adjusted planting times. Livestock farmers have provided more shelters for animals, maintained cleanliness and sanitation of livestock shelters to check infections, used timely vaccinations, improved livestock housing conditions, chose more suitable livestock breeds, and adopted scientific feeding practices. Fish farmers have repaired ponds and applied lime, cow dung, or fresh water to ponds. Furthermore, fish farmers used higher quality fish fingerlings and switched to more productive fish types.

Our results provide evidence that farmers do not only perceive climate change but also are willing to adapt their farming practices to secure livelihood. However, we also find a tremendous potential to improve current adaptation efforts. The main barriers to adaptation include unawareness of adaptation options, the high cost of inputs, and lack of financial credits. Thus, political efforts should increase awareness for suitable adaptation options and provide more support for farm credit programs. Therefore, there is a need to provide holistic adaptation packages to farmers that include low-cost inputs during awareness programs along with access to credit linkages. Adaptation policies should also account for health consequences. The integrated approach is required to reduce soil erosion and improve the soil fertility in NER. The cultivation of summer season crops can provide additional income to marginal farmers. To compensate for adverse impacts of increased rainfall variability on crop yields, integrated approaches for water harvesting, water conservation, moisture conservation, and lifesaving irrigation are desirable.

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Chapter 3: Farmers' perception of climate change and its determinants

Abstract

Individual perceptions often have a strong influence on a person's behavior and decisions. Understanding the perceptions that shape decisions thus enables policymakers to design customized awareness campaigns and policies to steer behaviors into desired directions. In this paper, we survey the perception of climate change by farmers in the Northeastern region of India, in order to formulate adaptation strategies that will support the livelihood of poor farming communities in the future. We used a semi-structured survey to interview 797 farmers to collect qualitative and quantitative data about socio-economic profiles, farmers' awareness about climate change, information sources, farmers' perceptions of changes in weather and climate patterns, and farmers' beliefs about the causes of climate change. We then analyzed the data using descriptive statistics, Chi-square (χ^2) test and Logistic regression.

Results show that farmers strongly agree that climate change is real and happening. They believe that deforestation and pollution, are primarily responsible for climate change. The majority of farmers realized the reality of climate change through their own experience and emphasized changes in rainfall and temperature as prime indicators of climatic changes. A significant proportion of farmers reported decreasing income from crop farming but increasing income from livestock farming. Factors significantly influencing farmers' perception on climate change are the gender of the family head, access to agriculture-related welfare schemes, cattle ownership, the experience of uneven rainfall distribution, changes in the harvest of non-timber forest resources, and distance from farm to nearest market. Based on the results, we recommend the implementation of extension (advisory service) modules to educate farmers on climate change along with climate-smart adaptation packages. Gender-specific adaptation modules, promotion of livestock farming and specific targeting of younger farmers will boost the process of adaptation among farming communities in NER.

Keywords: climate change adaptations, farmers' perception, Northeastern India, perception determinants

3.1 Introduction

India is the sixth most vulnerable country to climate change impacts as deadly heat waves, prolonged droughts and erratic rainfall events continue to affect millions of people (Eckstein, Künzel, & Schäfer, 2017). Monsoon dependency is a key feature of Indian farming, which is facing a severe decline in production due to rainfall variability (Auffhammer et al., 2012). Pressure on farming and natural resources has been steadily increasing because of population growth and climate change (IPCC, 2014b). The food security of billions is already at risk (Bandara & Cai, 2014). Besides, India's vulnerability to climate change may cause disturbances in the global food economy (Schmidhuber & Tubiello, 2007).

According to the Intergovernmental Panel on Climate Change (IPCC), climate change vulnerability is a function of exposure, sensitivity and adaptive capacity (Adger, 2006; IPCC, 2001). In an agricultural context, exposure is the extent to which farming operations face droughts, floods, crop-damaging hailstorms or cyclones, and other climate events. Sensitivity measures how exposure to certain climate events translates into consequences for farming communities. Finally, adaptive capacity describes the capability of farming communities to counteract the adverse consequences of climate change. These three elements are widely used by researchers to estimate the vulnerability of communities to climate change.

Various studies conducted in the Northeastern region of India (NER), an Eastern Himalayan landmass and fragile agro-ecosystem, emphasize that NER is highly vulnerable to climate change (Bhattacharya, Krishnaswamy, & Rao, 2012; Bhave, Mishra, & Groot, 2013; Chaliha et al., 2012; Ravindranath et al., 2011). As most of the households in NER are either fully or partially dependent on farming (Grogan, Lalnunmawia, & Tripathi, 2012; Jamir et al., 2013; Rai, 2007), they are highly exposed to climate and the adversities of climate change. Fischer et al. (2005) argued in the perspective of climate change that adaptation of agriculture-related adaptation in the appropriate socio-economic context will play a significant role in bridging the gap between developed and developing nations and limit the potential damages from climate change. Therefore, to increase the option space for adaptations among farmers of NER, enhancement of adaptive capacities are desirable. Subsequently, effective strategies to enhance the adaptive capacities of farmers are essential to support the well-being of the entire region (Smit & Skinner, 2002), which shelters more than 45 million people. Increase in adaptive capacity will enable farmers to adapt successful adaptations at a faster rate that would

neutralize the adversities of climate change (Carleton & Hsiang, 2016; Challinor, Simelton, Fraser, Hemming, & Collins, 2010).

The success of any adaptation (program or strategy) is strongly dependent on its acceptance by local communities (Moser & Ekstrom, 2010). Hence, public or private stakeholders designing adaptation programs should take into account the farming communities' understandings, beliefs, and perceptions related to climate change (Panda & Singh, 2016; M. H. Rahman & Alam, 2016; Sati & Vangchhia, 2017). Duly customized (i.e., socially acceptable, economical, eco-friendly, easy to use) technical adaptations not only enhance the acceptance but also enhances the diffusion of strategies across the social system (Rogers, 2010), which compliments the efforts of advisory/extension services. Cooper et al. (2008) through their research experience in sub-Saharan Africa, conclude that development of climate risk management strategies according to the needs of farmers and stakeholders is key to dealing with climatic variability. An understanding of farmers' perceptions related to climate change is therefore imperative for convincing them of adopting novel climate-smart practices (Grothmann & Patt, 2005).

Furthermore, knowledge and understanding of factors that speed up the process of dissemination and adaptation of novel practices in the social system of rural farmers is also highly relevant for the planning of adaptation strategies (Bryan et al., 2013; Deressa et al., 2009; Hassan & Nhemachena, 2008; Mait et al., 2016). Further, R. R. Banerjee (2015) stressed the importance of understanding farmers' perception in developing adaptation plans to tackle the adverse effects of climate variability and shocks. In another example, Tripathi and Mishra (2016) argued that some farmers perceived climate change but rather than responding to it, they changed their farming practices to deal with socio-economic changes and concluded this behavior as a passive adaptation. It shows that farmers have an inclination towards adaptation and appropriate strategies matching with the socio-economic context of farming communities could foster the adoption of adaptation. Some of the recent studies on adaptations also claim that higher risk perception towards climate change leads to more adaptation of adaptation measures (Deng et al., 2017; Shi, Visschers, & Siegrist, 2015; Tiyo, Orach-Meza, & Edroma, 2015).

Presently, very few adaptation studies are reported from NER that enable farmers to deal with climate change (S. Banerjee, Bisht, & Mahapatra, 2015; Nair, Ravindranath, Sharma, Kattumuri, & Munshi, 2013; Neog et al., 2016; Prakash, Kumar, Dwivedi, Rao, & Mishra, 2016; G. Sharma & Sharma, 2017). Out of existing studies, very few are considering the socio-economic factors and

perception of farmers or stakeholders to formulate adaptation strategies (Barua, Katyaini, Mili, & Gooch, 2014; Kharumnuid, 2011; Poudel & Duex, 2017; N. Singh & Singh, 2015; R. K. Singh et al., 2017). Further, not a single study is reported from NER that investigates the determinants of farmers' perception of climate change, in order to formulate appropriate adaptation strategies. Therefore, the goal of this study is to explore farmers' perceptions of climate change in NER and identify associated socio-economic and biophysical factors that influence the process of adaptation. Through this investigation we want to answer the following research questions:

1. Are the farmers of NER aware of changes in climate?
2. In the farmers' perceptions, which factors cause climate change in NER?
3. What are the farmers' sources of information related to climate change?
4. Which biophysical indicators shape farmers' perceptions of climate change?
5. Which factors determine the farmers' perception related to climate change?

3.2 Methods

3.2.1 Study area and population

The investigation was conducted in the Northeastern region of India (NER, Figure 11), a complex of eight states which is classified as a single agro-climatic zone. The region is a very diverse and fragile agro-ecosystem, most of which belong to the Indo-Burma biodiversity hotspot, (Venkataraman & Sivaperuman, 2018), which is critically threatened due to anthropogenic activities and climate change (Barah, 2006; Chitale et al., 2014; Gupta, 2000). The total geographical area of NER is 262230 square kilometers, shares boundaries with Nepal, China, Bhutan, Myanmar, and Bangladesh, and elevation ranges from 15 to 7000 meters above mean sea level. NER receives a greater proportion of rainfall than the rest of India (K. Dikshit & J. K. Dikshit, 2014e). According to the 2011 census, the population of NER is almost 45 million, which is approximately 4% of India's total population (NECS, 2015).

Throughout NER, agriculture is the primary occupation as well as a source of income for the majority of inhabitants. Rice, Wheat, Maize, Millets, Gram, Pigeon Pea (*Arhar*), Soybeans, Rapeseed, and Mustard, are the most commonly cultivated crops in NER. The region is also

famous for fruits such as Oranges, Limes, Bananas, Pineapples, and Mango, as well as spices Like Turmeric, Ginger, Black Pepper, Cinnamon and Cardamom.

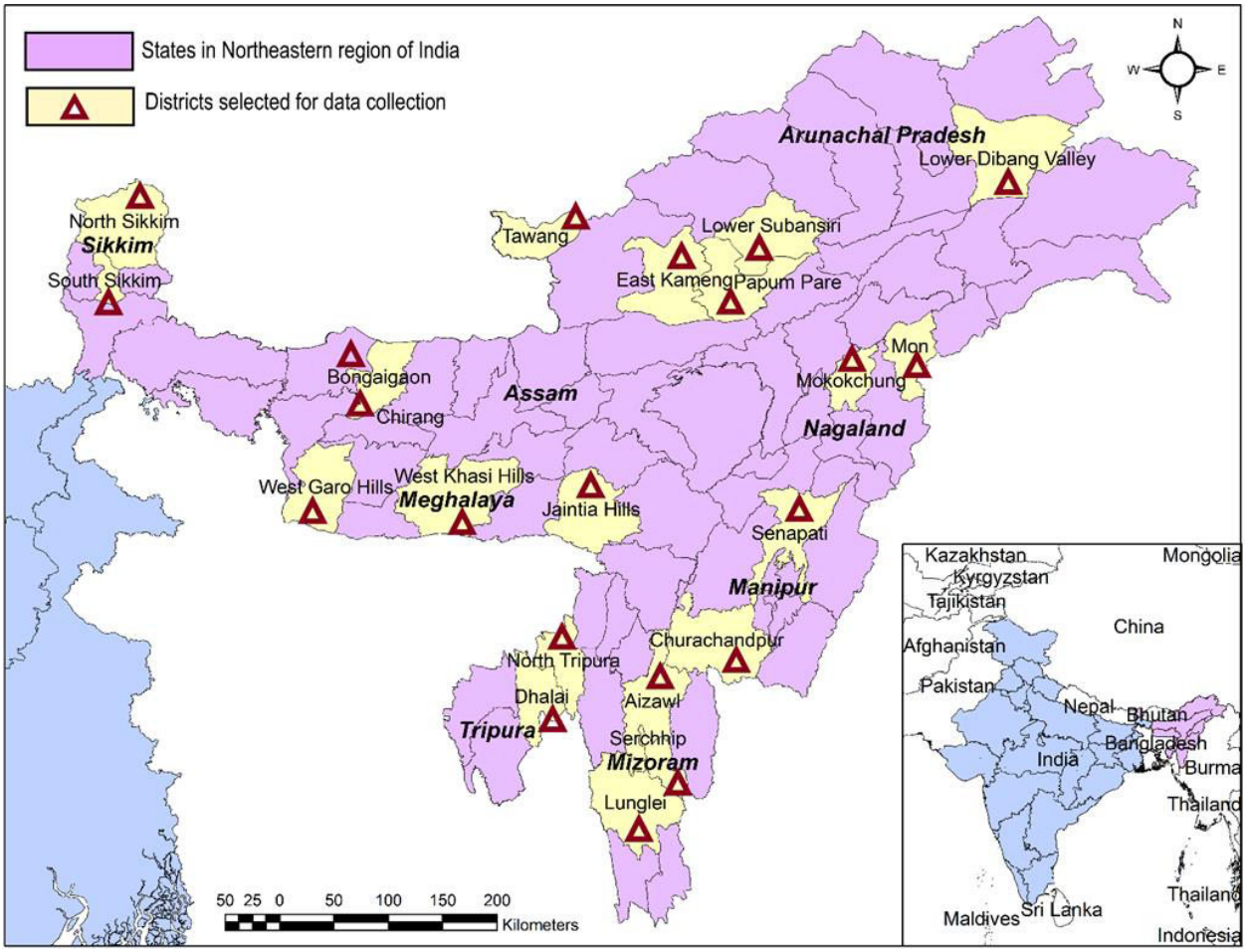

Figure 11. The location and map of the Northeastern region of India. Districts highlighted yellow were sampled in this study (Avishek, 2014; GADM, 2015).

The majority of farmers practices rain-dependent traditional farming. Some tribal farmers also practice slash-and-burn farming (Grogan et al., 2012; Kerkhoff & Sharma, 2006; S. Nath, Nath, Lal, & Das, 2015; Raman, 2001; Teegalapalli & Datta, 2016).

We purposively selected the region as a study area due to its diversity, fragility, and high vulnerability to climate change. Researchers can obtain diversified information about climate change and its impacts that may lead to more nuanced and effective policymaking.

3.2.1.1 Sampling and sample size

NER consists of 86 districts and eight states. In order to acquire a representative sample of all environmental conditions, we used the elevation of the district headquarters to sort each district into one of three height classes: (1) low elevation districts (<500m), (2) mid-elevation

districts (500m to 1000m), (3) high elevation districts (>1000m). From each elevation class, seven districts were randomly selected. Subsequently, from each district, we randomly sampled four villages, and from each village, ten farmers with at least ten years of farming experience. Of the 840 interviews, 797 were kept for further analysis as some of the respondents had farming experience less than ten years. The Farm Science Centers located in the chosen districts rendered assistance in collecting data from the selected farmers. The sampling and data collection took place from November 2017 to January 2018.

3.2.1.2 Interviews and data collection

A semi-structured questionnaire was developed for the interviews with the intent to acquire qualitative as well as quantitative data. The goal was to gather information about (i) socio-economic parameters, (ii) farmers' asset profiles, (iii) household attributes, (iv) farm related information, (v) institutional access, and (vi) farmers' perceptions and awareness of climate change in NER. The questionnaire was tested before the actual survey to gauge its reliability and appropriateness, and necessary adjustments were made to fine-tune the questions. Only well-experienced professionals were chosen to interview the farmers, with the first author closely monitoring the process. Throughout the process, ethical guidelines were strictly followed by all personnel, and explicit consent of each farmer was obtained before commencing with the interview.

3.2.2 Analysis of data

We first used a Chi-square (χ^2) test to measure the significance of the association between two nominal or categorical variables. The Chi-square (χ^2) test works well for nominal or categorical variables and, unlike with the t-test, a normal distribution of data is not required.

Subsequently, we used a binary logistic regression model to identify the determinants of farmers' perception on climate change (Tesfahunegn et al., 2016), as our dependent variable is binary i.e., dichotomous (*0 = farmer did not perceive climate change; 1 = farmer perceived climate change*) and the explanatory variables comprised of various continuous, categorical and discrete variables (Retherford & Choe, 2011). Unlike the discriminant analysis, the logistic regression does not demand the assumption of normality of independent variables and equal variance within each group (Southavilay, Nanseki, & Takeuchi, 2012). The additional advantage is that using a logistic regression enabled us to carry out an analysis with a combination of dichotomous, continuous and categorical variables as independent variables, which is not

possible in a discriminant analysis (Peng, Lee, & Ingersoll, 2002; Sreejesh, Mohapatra, & Anusree, 2014).

The binary logistic regression function, which estimates the effect of a set of independent variables on the dependent variable, is mathematically illustrated as:

$$\ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \cdots + \beta_k x_k \quad (1)$$

where:

$\left[\frac{P}{1-P}\right]$ = likelihood ratio

P = probability that farmer perceives climate change

1-P = probability that farmer does not perceive climate change

β_0 = intercept (model constant)

$\beta_1, \beta_2, \ldots \beta_k$ = regression coefficients of the independent variable $x_1, x_2, \ldots x_k$

The logistic regression coefficient signifies the ability of the predicted log-likelihood to change the dependent variable by one unit. If the value of the likelihood ratio is > 1, then the independent variable influences the dependent variable in a positive relationship. If the value of the likelihood ratio is < 1, the relationship is negative, and if the likelihood ratio equals 1, there is no relationship between dependent and independent variables (Sreejesh et al., 2014; Tesfahunegn et al., 2016).

Table 7. Description of explanatory variables used for binary logistic regression and their presumed effects on the dependent variable

Variable	Description of Variable	Effect
Dependent variable		
Farmers' perception of climate change	Dummy takes the value of 1 if the farmer is aware of climate change, 0 otherwise	
Independent: Socio-economic variables		
Age	Age of farmer in years (continuous)	(±)
Gender	Dummy takes the value of 1 if the farmer is male, 0 otherwise	(±)
Family type	Dummy takes the value of 1 if nuclear family, 0 otherwise	(±)
Education status	Dummy takes the value of 1 if the farmer is literate (primary and above), 0 otherwise	(+)
Monthly income	Monthly income of farm family in Indian Rupees (INR) (continuous)	(+)

Income from non-farming activities	Dummy takes the value of 1 if farmer earns from non-farm activities, 0 otherwise	(-)
House type	Dummy takes the value of 1 if the house is strong (built with cement + bricks), 0 otherwise	(-)
Electricity access	Dummy takes the value of 1 if household has regular access to electricity, 0 otherwise	(-)
Transportation assets possessed	Dummy takes the value of 1 if a farmer owns any transportation asset, 0 otherwise	(-)
Social security schemes availed	Total number of social security schemes availed by farm family (continuous)	(±)
Independent: Farming related variables		
Farming experience	Farming experience of the family head in years (continuous)	(±)
Access to agriculture-related schemes	Total number of agricultural schemes availed by farm family (continuous)	(-)
Landholding in Hectares	Farming area owned by a farmer in Hectares (continuous)	(+)
Farming diversification interests	Dummy takes the value of 1 if farmer practices diversified farming, 0 otherwise	(+)
Cattle ownership	Dummy takes the value of 1 if a farmer owns cattle, 0 otherwise	(+)
Poultry birds	Dummy takes the value of 1 if a farmer owns poultry birds, 0 otherwise	(+)
Pigs owned	Dummy takes the value of 1 if a farmer owns pigs, 0 otherwise	(+)
Number of farm assets owned	Total number of farm assets and implements owned by farmers (continuous)	(±)
Soil fertility perception	Dummy takes the value of 1 if farmer perceives farmland as fertile, 0 otherwise	(-)
Willingness to migrate to urban areas	Dummy takes the value of 1 if farmer agrees to migration, 0 otherwise	(+)
Independent: Perception of environmental conditions (biophysical variables)		
Rainfall quantity	Dummy takes the value of 1 if farmer perceives changes in rainfall quantity, 0 otherwise	(+)
Changes in temperature	Dummy takes the value of 1 if farmer perceives changes in temperature, 0 otherwise	(+)
Uneven rainfall distribution	Dummy takes the value of 1 if farmer perceives uneven rainfall distribution, 0 otherwise	(+)
Untimely rains	Dummy takes the value of 1 if farmer perceives untimeliness of rains, 0 otherwise	(+)
Changes in rainfall season length	Dummy takes the value of 1 if farmer perceives changes in rainfall season length, 0 otherwise	(+)
Human diseases	Dummy takes the value of 1 if farmer perceives changes about human diseases, 0 otherwise	(+)
Livestock diseases	Dummy takes the value of 1 if farmer perceives changes about livestock diseases, 0 otherwise	(+)
Crop diseases	Dummy takes the value of 1 if farmer perceives changes in crop diseases, 0 otherwise	(+)

Insect and pest attacks	Dummy takes the value of 1 if farmer perceives changes about insect and pest attacks, 0 otherwise	(+)
Forest resources	Dummy takes the value of 1 if farmer perceives changes about forest resources, 0 otherwise	(+)
Independent: Institutional access variables		
Farm to market distance	Distance in kilometers (continuous)	(-)
Farm to agriculture office distance	Distance in kilometres (continuous)	(-)
Farm to KVK distance	Distance in kilometers (continuous)	(-)
Social institution Participation	Dummy takes the value of 1 if the farmer had an association with local social institutions such as village council, NGOs, Self-Help Groups (SHGs), religious organization, farmers' co-operative organization, and farmers' club; 0 otherwise	(+)
Access to advisory institutions	Dummy takes the value of 1 if the farmer had access to extension/advisory services, 0 otherwise	(+)
Total sources of climate information	Total number of information sources of farmers on climate change and weather forecasts (continuous)	(+)

To perform the logistic regression analysis, we considered *farmers' perception related to climate change* as the dependent variable. It is a binary (dichotomous) variable, which is coded as one (1) if the farmer perceives climate change and 0 if not. To select the independent variables we reviewed relevant literature (Mohammad Abid, Scheffran, Schneider, & Ashfaq, 2015; Bryan et al., 2013; Peng, So, Stage, & John, 2002; Silvestri, Bryan, Ringler, Herrero, & Okoba, 2012; Sofoluwe, Tijani, & Baruwa, 2011; Tesfahunegn et al., 2016; Yu, Wang, Zhang, Wang, & Wei, 2013) and chose 36 variables based on this data (Table 7). Selected explanatory (independent) variables are related to farmers' socio-economic status (10), farm-related characteristics (10), biophysical attributes (10) and institutional access (6).

The goodness of fit of the resulting logistic regression model was estimated using the Hosmer-Lemeshow test (Hosmer, Hosmer, Le Cessie, & Lemeshow, 1997) that is based on dividing the sample according to their predicted probabilities. The Hosmer-Lemeshow statistic indicates a poor fit of data if the significance value is less than 0.05, and a good fit if it is closer to 1. We analyzed all data with IBM-SPSS (version 24).

3.3 Results and discussion

3.3.1 Socio-economic characteristics of respondents

This section describes the findings pertaining to the socio-economic characteristics of farm-households, their farm-related attributes, and institutional access attributes. The socio-economic characteristics of interviewed farmers' are presented in Table 8. Household attributes

of sampled farmers of Northeastern region of India (n=797). The average age of respondents was 47 years, where 46% were aged 40-59 years, 30% 25-39 years, 19% 60-79 years, 3% <25 years and less than 2% were aged >80 years. The small number of young farmers is due to our sampling criteria for a minimum of ten years of farming experience. The gender proportion was 62.5% male and 37.5% female. Almost 52% of respondents were residing in a nuclear family of parents and dependent children, 48% in an extended family arrangement with three or more generations. 79% of the interviewed farmers were literate.

Table 8. Household attributes of sampled farmers of Northeastern region of India (n=797)

Socio-economic variables	**Categories**	**Value[a]**	**χ^2 test[b]**
Age (in years)	Average age of household head	47.00 (range 19 - 90); *SD=14.01*	**
Gender	Male	498 (62.48)	**
	Female	299 (37.52)	
Family type	Nuclear family	414 (51.94)	ns
	Joint family	383 (48.06)	
Education status	Illiterate (no formal schooling)	168 (21.08)	**
	Literate	629 (78.92)	
Monthly income (in INR)[c]	Average monthly income from farming and all other sources (in INR)	Rs. 9308 (range 200 - 70000); *SD=8883.34*	**
	Average monthly income from non-farming activities (in INR)	Rs. 1035 (range 00 - 28000); *SD=2470.64*	**
Income from non-farming activities	Yes	310 (38.90)	**
	No	487 (61.10)	
House type	Cement + brick house (strong)	184 (23.00)	**
	Traditionally built house	613 (77.00)	
Electricity access	Irregular	331 (41.53)	**
	Regular	447 (56.09)	
	No Access at all	19 (2.38)	
Transportation assets possessed	Yes	411 (51.57)	NS
	No	386 (48.43)	
Social security schemes availed	Average of number of schemes availed by a farm family	2.75 (range 0 - 16); *SD=2.32*	**
Farming related variables			
Farming experience	Average farming experience of household head	25.73 (range 10 - 75); SD=12.26	**
Access to agriculture-related schemes	Average of number of agricultural schemes availed by a farmer	1 (range 0 - 5); *SD=1.05*	**
Landholding in Hectares	The average land holding of a farm family in Hectares	1.40 (range 0 - 20); *SD=4.77*	
Farming diversification	Practicing farming diversification	575 (72.15)	**

	Not practicing farming diversification	222 (27.85)	**
Cattle ownership	Owns cattle	221 (27.73)	**
	No cattle in a farm	576 (72.27)	
Poultry birds owned	Owns poultry birds	420 (52.70)	NS
	No poultry birds in the farm	377 (47.30)	
Pigs owned	Owns pigs	467 (58.59)	**
	No pigs in the farm	330 (41.41)	
Number of farm assets owned	Average number of farm assets (implements) owned	1.82 (range 0 - 10) ; *SD=1.59*	**
Soil fertility perception	Soil perceived as fertile	674 (87.57)	**
	Soil perceived as not fertile	123 (15.43)	
Willingness to migrate	the farmer is willing to migrate	187 (23.46)	**
	farmer is not willing to migrate	610 (76.54)	
Institutional variables			
Farm to market distance	Average distance to nearest market (in kilometers)	7.30 (range 1 - 70); *SD=7.59*	**
Farm to agriculture office distance	Average distance to nearest the office of the agriculture department (in kilometers)	12.18 (range 1 - 70); *SD=10.61*	**
Farm to KVK distance	Average distance to nearest *Krishi Vigyan Kendra* (in kilometers)	19.92 (range 1 - 92); *SD=18.15*	**
Social institution Participation	Yes, the farmer is active in social institutions	665 (83.43)	**
	No	132 (16.56)	
Access to advisory institutions	Yes, the farmer has access to advisory/extension services	406 (50.94)	NS
	No	391 (49.05)	
Total sources of climate information	Average number of sources on climate-related information	2.71 (range 0 -9); *SD=1.9*	**

** Significant at probability level, p≤0.01; * Significant at probability level, p≤0.05; NS, probability values that are not significant at p > 0.05 levels.

[A] Values in parenthesis are percentages and without parenthesis indicate numbers.

[b] Chi-squared test (two-sided test).

[C] Assumed 1 USD = 70 INR (December 2018)

The average monthly income of a farm family was reported as approximately Rs. 9300, but incomes ranged from Rs. 200 to Rs. 70000, showing a huge income disparity among farmers. Non-farm income was similarly variable, ranging from Rs. 0 to Rs. 28000. Figure 12 illustrates the details of income profiles of respondents. In general, most of the income earned from farming and allied activities such as livestock farming or wages is low i.e., below Rs. 2000. Majority of farm households earning non-farm income (i.e., income from non-agricultural activities) is also below Rs. 2000 per month, which is quite low.

77% of respondents stay in traditionally built houses which are built from locally available material, the remaining 23% in sturdy houses constructed with cement and bricks. 56% of farm families have access to electricity on a regular basis, 41% only have irregular electricity supply, and almost 3% of households do not have any electricity access. Half of the farm households (51.57%) possess transportation assets (such as bikes, motorbikes, cars). Each household takes advantage of or participates in on average three social security schemes implemented by various states or central government.

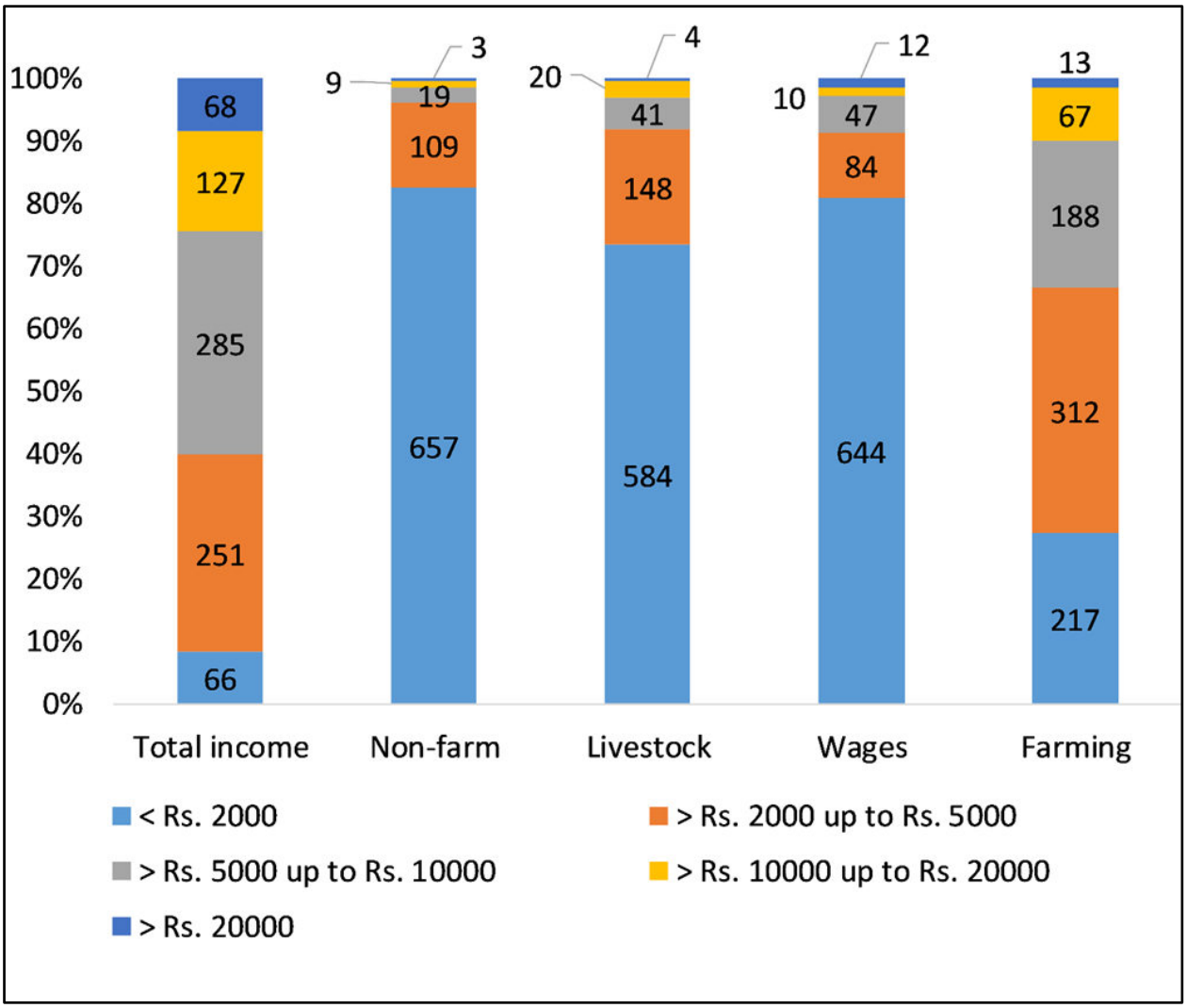

Figure 12. Income of respondents from farming activities, non-farming activities, livestock handling or wages earned on other farms or generally in the agricultural sector. Numbers in bars = total number of farmers in this class. (1 USD = 70 INR)

The farming related attributes show that farming experience of farmers ranges in between 10 to 75 years with an average of 25 years. Unlike social security schemes, farmers only used one farming related scheme on average. The average landholding of sampled households was around 1.40 Hectare, with a range of 0 to 20 Hectares, as some landless farmers who solely

practice livestock farming were also sampled. The farmers of Arunachal Pradesh own more land than the rest of NER states. 72% of farmers practiced diversified farming. Almost 59% of farmers owned pigs, 53% owned poultry birds, and 27% of farmers had cattle on the farm. On average, farmers owned two farm assets such as water pumps, cattle sheds, beehives, solar panels, sprinklers, drip irrigation sets, ploughs, nurseries, or rainwater harvesting units. Almost 77% of farmers did not want to migrate, and a vast majority (87%) perceived their farmland as fertile.

The average distance from farm to the nearest market was 7.3 km, with a range of 1 to 70 km. The average distance from farm to the nearest agricultural office was 12 km (range 1 to 70 km). The average distance from farm to the nearest Farm Science Center was 20 km (range 1 to 92 km). Offices of the State Department of Agriculture and allied offices that work for the welfare of farming communities are usually closer. 83% of farmers are actively associated with various kinds of social institutions such as farmers' organizations, NGOs, self-help groups, religious organizations, etc. Half of the sampled farmers (51%) have access to extension/advisory services. Respondents also reported that they use three sources of information on average for information related to climate change.

3.3.2 Farmers' awareness and beliefs related to climate change

Figure 13 presents the farmers' responses to two questions, which explore farmers' awareness and beliefs related to climate change.

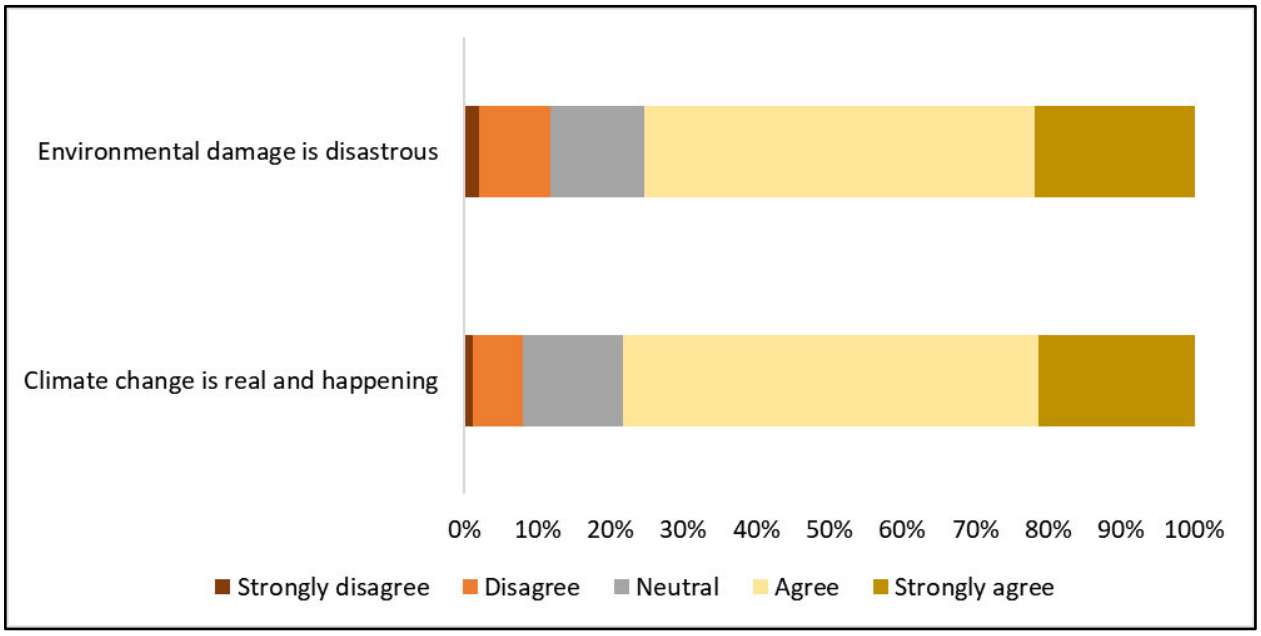

Figure 13. Farmers' awareness and beliefs related to climate change and the impacts of climate change

Two statements were provided to the respondents during interview and respondents were requested to rate them on scale 1 to 5, where 1= strong disagreement, 3=neutral/undecided and 5= strong agreement. Over 78% of farmers agreed or strongly agreed that '*climate change is real and currently happening*.' Further, over 75% agreed or strongly agreed to the statement that '*we have damaged our environment seriously, soon it will be a disaster*.'

3.3.3 Farmers' perception of the causes of climate change

In this section, we explored farmers' perceptions and beliefs about the probable causes of climate change. According to 90% of the surveyed farmers of NER, deforestation is the prime cause of climate change (Table 9). Deforestation is indeed rampant in NER (Bhatt & Sachan, 2004; Lele & Joshi, 2009; Maikhuri, 1991; Sarma, Kushwaha, & Singh, 2010; Sudhakar Reddy et al., 2016), and is caused by a variety of factors such as industrialization, slash and burn farming, timber demand, mining, urbanization, firewood gathering, changes in land use patterns, population pressure, etc.

Table 9. Causes of climate change perceived by farmers of NER (n=797).

Causes of climate change	Farmers' responses		
	Yes	No	χ^2
Deforestation	715 (89.71)	82 (10.29)	0.0001
Increased pollution	656 (82.31)	141 (17.69)	0.0001
Global warming	617 (77.42)	180 (22.58)	0.0001
Increased use of vehicles	587 (73.65)	210 (26.35)	0.0001
Soil degradation	570 (71.52)	227 (28.48)	0.0001
Industrialization	533 (66.88)	264 (33.12)	0.0001
Too much population	527 (66.12)	270 (33.88)	0.0001
Uncontrolled urbanization	501 (62.86)	296 (37.14)	0.0001
Use of pesticides in farming	491 (61.61)	306 (38.39)	0.0001
Excessive use of chemical fertilizers	487 (61.10)	310 (38.90)	0.0001
Drilling for Oil and natural gas	429 (53.83)	368 (46.17)	0.031
Excessive mining of coal	423 (53.07)	374 (46.93)	**0.083***
Intensive cropping	251 (31.49)	546 (68.51)	0.0001
Overgrazing by cattle	245 (30.74)	552 (69.26)	0.0001

Figures in parentheses indicate percentage. Chi-square (χ^2) test (two-tailed test); significant at probability level $p \leq 0.05$; *not significant at $p > 0.05$.

Over three-quarters of farmers also believe that increased pollution and global warming are causes of climate change, and over 60% think that increased use of vehicles, soil degradation, industrialization, overpopulation, uncontrolled urbanization and the use of pesticides and mineral fertilizers in agriculture contribute to climate change.

The findings show that the farmers perceive not only factors originating from the non-agricultural sectors as causes for climate change, but also factors from their (own) sector. This indicates that farmers may be more open to implementing policies for climate-smart agriculture or mitigation/adaptation strategies in the agricultural sector, as they do not need to be convinced about their necessity first.

3.3.4 Farmers' information sources related to climate change

Information sources play a crucial role in the process of diffusion of information, which is why we asked farmers where they had learned about climate change (Table 10). 65% say that they experienced climate change themselves.

Table 10. Farmers' information sources related to climate change

Information sources	Farmers' response to information sources		χ^2 test
	Yes	No	
My own experience	517 (64.87)	280 (35.13)	0.0001
Television/radio	385 (48.31)	412 (51.69)	**0.3390***
Extension services	316 (39.65)	481 (60.35)	0.0001
Neighbouring farmer	287 (36.01)	510 (63.99)	0.0001
Newspaper print media	256 (32.12)	541 (67.88)	0.0001
Village leader	148 (18.57)	649 (81.43)	0.0001
Social media	111 (13.93)	686 (86.07)	0.0001
Internet	76 (9.54)	721 (90.46)	0.0001
Input dealers	63 (7.90)	734 (92.10)	0.0001

Figures in parentheses indicate percentage. Chi-square (χ^2) test (two-tailed test); significant at probability level $p \leq 0.05$; *not significant at $p > 0.05$.

Other sources of information were television/radio, extension services, neighboring farmers and newspaper/print media, but each were used by less than 50% of farmers. The findings show that to reach farmers and effectively disseminate information about climate change, the communication channels need to be strengthened, and a variety of media need to be used.

3.3.5 Farmers' perception of the biophysical indicators of climate change

From a literature review, we identified 18 indicators of climate change (Nesshöver et al., 2017; Prakash et al., 2016; Shirsath, Aggarwal, Thornton, & Dunnett, 2017; Tesfahunegn et al., 2016; Zhang et al., 2018), and asked farmers if they had experienced a change in these indicators and if so, if the trend was decreasing or increasing (Table 11).

Table 11. Farmers' perception on biophysical indicators of climate change in the Northeastern region of India (n=797)

Climate change indicator	Respondents			Respondents' observation		
	No	Yes	χ^2 test	No change	Decrease	Increase
Rainfall quantity	32 (04.02)	765 (95.98)	0.001	32 (04.02)	197 (24.72)	568 (71.27)
Changes in temperature	37 (04.64)	760 (95.36)	0.001	37 (04.64)	32 (04.02)	728 (91.34)
Human diseases	99 (12.42)	698 (87.58)	0.001	99 (12.42)	24 (03.01)	674 (84.57)
Livestock diseases	124 (15.56)	673 (84.44)	0.001	124 (15.56)	22 (02.76)	651 (81.68)
Crop diseases	84 (10.54)	713 (89.46)	0.001	84 (10.54)	23 (02.89)	690 (86.57)
Insect and pest attacks	87 (10.92)	710 (89.08)	0.001	87 (10.92)	23 (02.89)	687 (86.20)
Uneven rainfall distribution	124 (15.56)	673 (84.44)	0.001	124 (15.56)	35 (04.39)	638 (80.05)
Frequency of droughts	275 (34.50)	522 (65.50)	0.001	275 (34.50)	30 (03.76)	492 (61.73)
Frequency of floods	330 (41.41)	467 (58.59)	0.001	330 (41.41)	39 (04.89)	428 (53.70)
Late arrival of rainy season	265 (33.25)	532 (66.75)	0.001	265 (33.25)	31 (03.89)	501 (62.86)
Early cease of rainy season	235 (29.49)	562 (70.51)	0.001	235 (29.49)	63 (07.90)	499 (62.61)
Untimely rains	235 (29.49)	562 (70.51)	0.001	115 (14.43)	30 (03.76)	652 (81.81)
Changes in rainfall season length	153 (19.20)	644 (80.80)	0.001	153 (19.20)	69 (08.66)	575 (72.15)
Excessive lightening	406 (50.94)	391 (49.06)	**0.600***	406 (50.94)	58 (07.28)	333 (41.78)
Soil erosion	138 (17.31)	659 (82.69)	0.001	138 (17.31)	73 (09.16)	586 (73.53)
Agricultural yield	69 (08.66)	728 (91.34)	0.001	69 (08.66)	506 (63.49)	222 (27.85)
Forest resources	103 (12.92)	694 (87.08)	0.001	69 (08.66)	506 (63.49)	222 (27.85)
Change in health (fitness)	114 (14.30)	683 (85.70)	0.001	114 (14.30)	458 (57.47)	225 (28.23)

Figures in parentheses indicate percentage. Chi-square (χ^2) test (two-tailed test); significant at probability level $p \leq 0.05$; *not significant at $p > 0.05$.

96% of farmers reported that they perceive a change in rainfall quantity, and 71% reported that it is increasing. 95% observe changes in temperature, mostly increasing (91%). This perception is supported by scientific studies, which show that monsoon rainfalls exhibit a spatially coherent

declining trend whereas pre and post-monsoon rains are increasing (Deka et al., 2016). Most of the other indicators listed in Table 11 are correlated to the changes in rainfall and temperature, such as the highly perceived (>80%) changes in crop, insect and human disease prevalence, insect pest occurrences, uneven rainfall distributions, soil erosion, changes in rainfall season length, changes in yields and production of forest resources. Except the indicator 'excessive lightening', where perceptions were split evenly between yes and no, the majority of farmers recorded similar observations for most indicators, even though NER is an immensely diverse region.

The perceived changes follow an upward trend in most cases, that is farmers report an increase in temperatures (91%), crop diseases (86%), insect pest attacks (86%). The exception are changes in yields, forest resources, and personal health, which are perceived to be declining by a majority of farmers (63.5%, 63.5%, 57.5%, respectively).

The results highlight the areas adaptation and/or mitigation policies should target first. Even though a perceived threat or change may not necessarily be a scientifically proven threat or change, it is an area where farmers are open for change.

3.3.6 Farmers' perception of the impacts of climate change on income from various types of farming

One of the crucial dimension to investigate is how farmers of NER associate climate change with their income from farming and allied activities. 45.5% of farmers perceive an increase in income from livestock farming, but a decrease in income from crop production (Figure 14). These perceptions are consistent with a simulation study conducted by Martin and Magne (2015). The study shows that increased agricultural diversity enhances the adaptive capacity of livestock farming, which may yield higher profits due to lower feeding costs and self-sufficiency. As NER is diverse in terms of farming types, crop types and natural vegetation, feeding materials are aplenty, and livestock farmers can generate profits consistently. Concerning income from fish farming, as most of our respondents were not fish farmers, a large proportion of them preferred to remain undecided (66.4%), but 22% still perceived an increase in income.

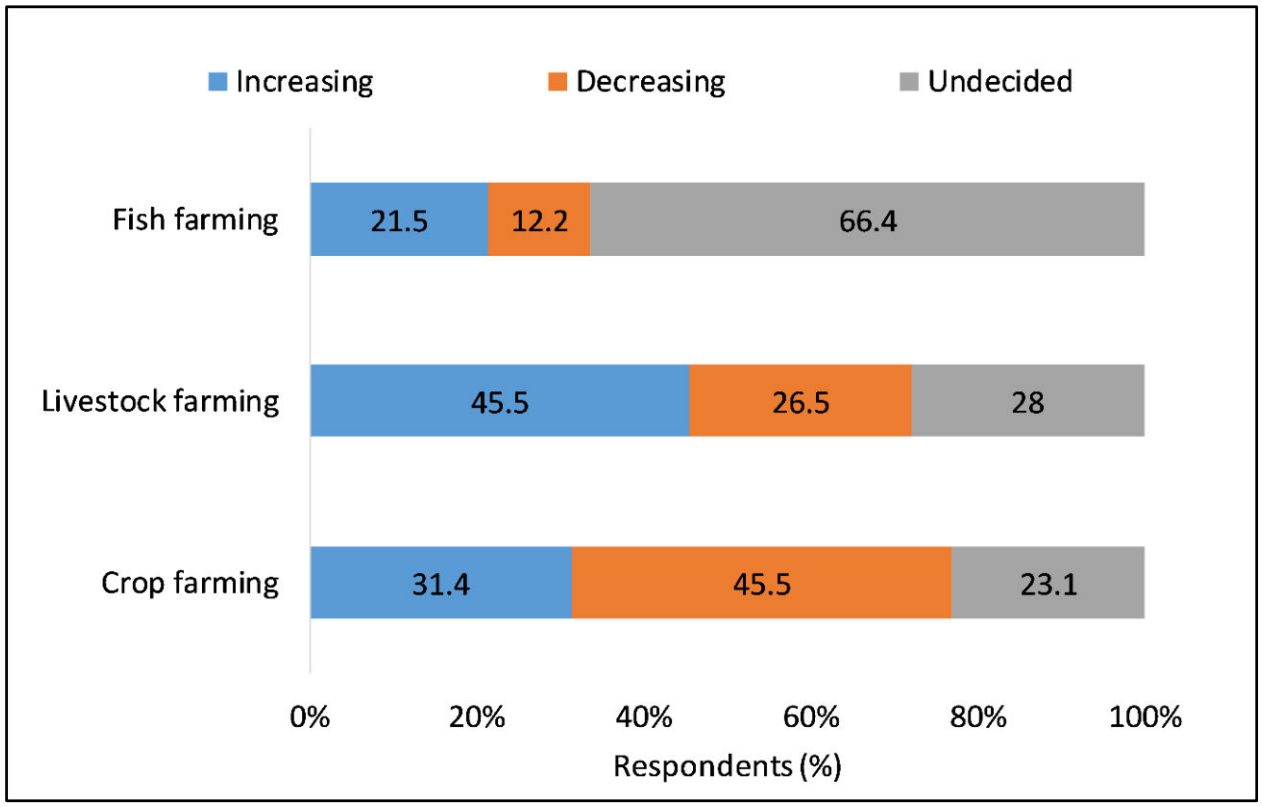

Figure 14. Farmers' perceptions about the impacts of climate change on income from different farming activities.

3.3.7 Determinants of farmers perception related to climate change

The binary logistic regression approach is utilized to identify the factors that influence or determine farmers' perception of climate change. The results of the regression model are presented in Table 12. The logistic regression model supports the significant association between the dependent variable (farmers' perception related to climate change) and a set of independent variables by displaying the model chi-squared ($\chi 2$) value 151.18, P = 0.000; and correctness of model prediction above 85%. Subsequently, the Hosmer-Lemeshow test also validates the goodness of fit of the regression model (Chi-square = 7.983, P=0.435) as the p-value of chi-square statistics is not significant. The log likelihood chi-square statistics (-2 Log likelihood = 586.19) and pseudo R2 (Nagelkerke pseudo R2 = 0.286) also affirm the model adequacy to investigate the determinants and to drive suitable conclusions from the analysis.

Table 12 reveals that out of 36 independent variables, 11 variables influence the dependent variable (i.e., farmers perception related to climate change). Higher Wald statistic value refers to the greater influence of an independent variable on the dependent variable, which is considerably high for all 11 statistically significant independent variables. The estimated coefficients of the regression model (β) indicate that except access to agricultural schemes and

distance to nearest Agricultural Department Office, all remaining factors exhibit a positive influence on the dependent variable.

The odds ratio, commonly regarded as a measure of association between exposure and outcome, indicates smaller ratio for estimated coefficients, which are significant at 0.05 level, and marginal ratios for estimated coefficients, which are significant at 0.01 level. In our model, odds ratios for negative estimated coefficients are less than 1. It means that farmers' are less likely perceive the climate change if they have access to more agricultural schemes or if the distance between farmers' farm/house and Agriculture Department Office is increased.

Positive values of estimated coefficients with an odds ratio greater than 1 indicate that there is an increasing likelihood of probability of falling into the target group, i.e., farmers who perceived climate change. For example, male farmers are 2.094 times more likely to perceive climate change than female farmers. Likewise, the farmers who own the cattle are 2.272 times more likely to perceive climate change than remaining who do not possess cattle. This finding is consistent with the results of a study conducted by Deressa et al. (2009) that positively links livestock ownership with farmers perception and more adaptation to climate change.

Table 12. Explanatory variables estimates derived from the binary logistic regression model for the dependent variable of farmers' perception towards climate change in the Northeastern region of India

Variable	**β**	**S.E.**	**Wald[a]**	**Sig.**	**Odds ratio[b]**
Independent: Socio-economic variables					
Age	**0.395**	0.183	4.645	**0.031***	1.485
Gender	**0.739**	0.235	9.906	**0.002****	2.094
Family type	-0.315	0.235	1.789	0.181	0.730
Education status	**0.604**	0.285	4.490	**0.034***	1.830
Monthly income	-0.037	0.111	0.112	0.738	0.963
Income from non-farming activities	-0.260	0.237	1.203	0.273	0.771
House type	0.007	0.277	0.001	0.980	1.007
Electricity access	-0.273	0.249	1.206	0.272	0.761
Transportation assets possessed	-0.406	0.242	2.804	0.094	0.666
Number of social security schemes availed	-0.154	0.133	1.344	0.246	0.857
Independent: Farming related variables					
Farming experience	-0.084	0.131	0.407	0.523	0.920
Access to agricultural schemes	**-0.612**	0.206	8.851	**0.003****	0.543
Land holding in Hectares	-0.140	0.106	1.734	0.188	0.869
Farming diversification interests	**0.558**	0.243	5.292	**0.021***	1.748

Poultry birds	0.264	0.237	1.238	0.266	1.302
Cattle ownership	**0.821**	0.298	7.581	**0.006****	2.272
Pigs owned	0.335	0.239	1.968	0.161	1.398
Number of farm assets owned	0.026	0.085	0.096	0.757	1.027
Soil fertility perception	0.274	0.302	0.826	0.363	1.315
Willingness to migrate to city	0.298	0.285	1.095	0.295	1.348
Independent: Biophysical variables					
Rainfall quantity	0.681	0.550	1.531	0.216	1.975
Changes in temperature	0.469	0.539	0.759	0.384	1.599
Uneven rainfall distribution	**1.074**	0.349	9.480	**0.002****	2.927
Untimely rains	0.262	0.364	0.518	0.472	1.299
Changes in rainfall season length	0.281	0.334	0.707	0.400	1.324
Human diseases	-0.203	0.428	0.225	0.635	0.816
Livestock diseases	-0.523	0.431	1.471	0.225	0.593
Crop diseases	-0.156	0.573	0.074	0.786	0.856
Insect and pest attacks	-0.346	0.525	0.434	0.510	0.707
Forest resources	**0.981**	0.329	8.871	**0.003****	2.666
Independent: Institutional variables					
Farm to market distance	**0.706**	0.155	20.739	**0.000****	2.026
Distance to Agriculture office	**-0.261**	0.116	5.004	**0.025***	0.771
Farm to KVK distance	0.145	0.094	2.382	0.123	1.156
Social institution Participation	-0.453	0.327	1.925	0.165	0.635
Access to advisory institutions	-0.307	0.245	1.562	0.211	0.736
Total sources of climate information	**0.135**	0.067	4.074	**0.044***	1.145
Model Constant	**-2.630**	0.997	6.967	**0.008****	0.072
Model chi-squared (χ^2)	**151.18**			**0.000****	
Model Nagelkerke (pseudo) R^2	0.286				
-2 Log likelihood	586.19				
Hosmer and Lemeshow Test (chi-square)	7.983			0.435	
Model correct prediction	85.6%				

β: estimated coefficient; SE: standard error; Pseudo R^2: a measure of goodness of model fit

** Significant at probability level, p≤0.01; * Significant at probability level, p≤0.05

[a] The Wald statistic is the square of the ratio of the estimated coefficient and its standard error, closely approximates to the chi-square distribution

[b] Represents Exp(β) which is the ratio of change in the odds of the event of interest to a one unit change in the predictor

The farmers who observed unevenness of rainfall distribution (or changes in rainfall distribution) are 2.927 times more likely to perceive climate change than remaining ones. Arslan, McCarthy, Lipper, Asfaw, and Cattaneo (2014) also reasoned that rainfall variability is a crucial determinant factor for adoption of conservation farming as an adaptation strategy. In

the same way, the farmers who observed changes in production/harvest of forest resources are 2.666 times more likely to perceive climate change than a group of farmers who did not recognize changes in forest resources.

It is important to note that farm to market distance is operationalized as a continuous variable. Hence, it can be inferred as every one-unit increase in the distance of market from the farm, will increase the odds of the likelihood of farmer perceiving the climate change by 2.026 times. The results also show that increase in age of farmer (1.485 times), increase in education status (1.83 times), increase in farm diversification (1.748 times) and increase in sources of information (1.145 times) will marginally increase the odds of farmer perceiving the climate change.

3.4 Conclusion

Our findings on the socio-economic characteristics of farmers illustrate the diversity and income disparity of the farming community in NER. The institutions of agricultural development are often far from farmers' locations, which hinders the process of information flow. Institutional interactions with farming communities need to be improved to increase the exchange of information and raise awareness among farming communities in NER.

A significant proportion of farmers in NER agree or strongly agree that climate change is happening and that the human-made damage to the environment is severe. They primarily attribute climate change to deforestation, pollution, global warming, and excessive vehicle use. The majority of farmers report that instead of being informed about climate change (i.e., causes of climate change, how it affects agriculture, available adaptations, Governmental schemes to adapt adaptations and other relevant information) by agricultural offices/ministries, they mainly perceive it themselves. However, some farmers also use television/radio, extension services, neighboring farmers and print media as sources of information on climate change. These results show that farmers already clearly perceive the impacts of climate change, making them potentially more receptive for adaptation strategies, but that the channels of communication between farmers and change agencies need to be improved. As farmers of NER does not have adequate information on climate change, its causes, impacts, and technologies available to neutralize climate change adversities, they need advisory and assistance to make the right decisions about adapting adaptations.

Asked about the specific indicators of climate change they had observed, farmers listed changes in rainfall quantity and temperature, increased prevalence of diseases and increased insect and

pest attacks. They also reported a decrease in income from crop farming and an increase in income from livestock farming. This finding highlights the possibility of increasing livelihood sustainability in NER through livestock promotion (i.e., popularising the adaptation of poultry birds, goats, cattle, and other livestock enterprises to diversify sources of income).

The results of the logistic regression model show that gender (male), cattle ownership, the perception of uneven rainfall distribution, the perception of changes in forest produce, and longer farm to market distance have a significant positive effect on shaping the perception of a farmer of climate change. Farmers who had access to agricultural welfare schemes (seeds, inputs, insurance, irrigation, subsidies and other similar components related to agriculture) and lived closer to the agricultural department offices were less likely to perceive negative climate change impacts.

We conclude that there is no need to launch general awareness campaigns to educate farmers about climate change, as they seem to be aware of changes in climate and changes in their incomes already. There is, however, a need for technology transfers and information campaigns about possible adaptation strategies to enhance the adaptive capacity of farmers in NER. As gender is also an influential attribute for perceiving climate change, advisory services must design gender-specific interventions to increase the acceptability of adaptations. Subsequently, advisory services should attempt to provide all-inclusive agricultural welfare schemes to the farmers of NER to minimize the income disparities.

3.5 Acknowledgment

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Chapter 4: A systematic SWOT analysis of Agricultural Research and Extension System of Northeastern India: a strategy formulation approach to deal with climate change impacts

Abstract

The Northeastern region of India (NER) is a land of opportunities for bringing a second green revolution that can greatly complement the food security of an ever-growing population. To avoid the undesirable consequences of scientific interventions, while implementing the second green revolution in NER, meticulous strategic planning (i.e., resource efficient and climate-smart planning) is highly recommended to promote sustainable agriculture in climate change scenario. As the Agricultural Research and Extension System (ARES) is a flag bearer of bringing the second green revolution in NER, we conducted strengths, weaknesses, opportunities, and threats (SWOT) analysis of ARES by using a brainstorming approach. We conducted 21 brainstorming sessions in different districts of NER representing various agro-ecological zones (and sub-zones) and explored the SWOT analysis as the first step to strategic planning for strategy formulation. Results show that the ARES of NER has more external opportunities than threats and more weaknesses than strengths.

Moreover, the majority of strengths and weaknesses are arising from organizational management issues that are hampering the overall organizational performance. Participants reported that institutional collaborations, rich biodiversity and use of social media are key strengths of ARES. The inadequacy of staff, shortage of policies that promote climate-resilience and inadequate funding are prime internal weaknesses of ARES. However, NER also has enormous opportunities regarding the promotion of indigenous high-value crops, germplasm conservation, and the export of high-value agricultural products. Conversely, erratic rains and weather aberrations (hailstorms), indiscriminate use of agro-chemicals and frequent outbreaks of insect-pests and diseases are the most reported threats for ARES of NER. The defensive strategies are highly recommended for the majority of districts in NER due to over dominance of internal weaknesses and external threats.

Keywords: Brainstorming, climate-resilient agriculture strategies, sustainable farming, SWOT

4.1 Introduction

Population growth, climate change, and resource depletion threaten food security in India, a country with currently almost 1.3 billion people (Lal, 2013; Von Braun, Gulati, Hazell, Rosegrant, & Ruel, 2005). Numerous scientific investigations reported stagnation in the food-grain production process and climate change is a prime threat that can endanger the food security of the Indian sub-continent (P. Aggarwal, 2007; Bandara & Cai, 2014; B. Chakraborty & Hazari, 2017; Chauhan, Mahajan, Randhawa, Singh, & Kang, 2014; Duncan, Saikia, Gupta, & Biggs, 2016; Parida & Oinam, 2015; N. Singh & Singh, 2015). A frequently proposed solution is the implementation of a so-called second green revolution. In the late 1960s, India witnessed the massive success of the first green revolution that drastically reduced famines and made India self-sufficient in terms of food grain production (Chakravarti, 1973; Khush, 2001; Parayil, 1992; Yamauchi, 2007). However, the green revolution of the 1960s has been criticized for numerous adverse consequences including environmental damage, groundwater depletion due to excessive irrigation, loss of indigenous germplasm (Shiva, 1991; R. Singh, 2000), and human health problems. Some studies also blame the green revolution for increasing regional disparities and socio-economic imbalances (gender disparity, dowry) in farming communities (Cleaver, 1972; Dhanagare, 1987; Prahladachar, 1983).

At present, the Indian government is considering the Northeastern region (Figure 15) as a pioneering region for a second green revolution. This revolution attempts to include small farmers, areas with adequate rainfall, more crops, more commodities and intends to promote the sustained use of natural resources. It also capitalizes on the use of various emerging innovations and technologies by mainstreaming them through various ongoing development programs/schemes in NER. To avoid similar problems as encountered after the first green revolution, scientific guidance with a detailed and comprehensive assessment of alternative scenarios is desirable. Hence, meticulous planning of the NER agricultural sector is crucial to minimize the undesirable consequences of the second green revolution. The Agricultural Research and Extension System (ARES) of NER is the vital mechanism to revolutionize the agricultural sector by means of research, extension, training and other scientific interventions (Suresh Chandra Babu, Huang, Venkatesh, & Zhang, 2015; Suresh C Babu, Joshi, Glendenning, Asenso-Okyere, & Rasheed Sulaiman, 2013; S. Pal & Byerlee, 2003; S. Pal & Singh, 1997; Randhawa, 1979). This study explores and analyses the strengths, weaknesses, opportunities, and threats (SWOT analysis) of ARES of NER as it is one of the widely used tools for strategic

planning (Agarwal, Grassl, & Pahl, 2012; Brudermann, Mitterhuber, & Posch, 2015; Dyson, 2004; Houben, Lenie, & Vanhoof, 1999; Terrados, Almonacid, & Hontoria, 2007).

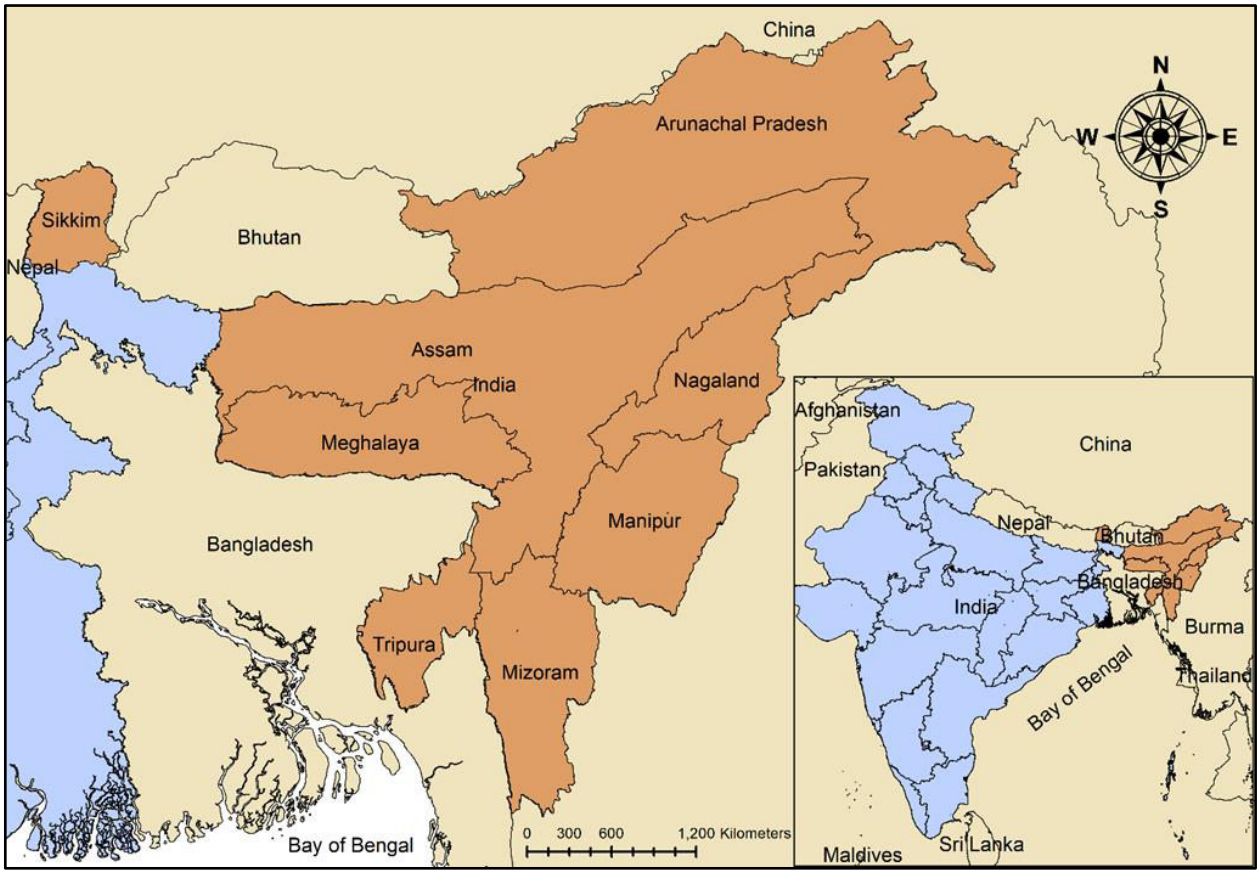

Figure 15. Map of India indicating the Northeastern region (in brown color) (Avishek, 2014; GADM, 2015)

In this investigation, we consider ARES of NER as a group of agencies, institutions, organizations, stakeholders, and individuals who engage in research and extension to improve the agricultural sector (Figure 16). Presently, the active components of ARES of NER are (i) Indian Council of Agricultural Research and its institutions; (ii) State Departments of Agriculture, Horticulture, Livestock and Veterinary, Fisheries. from different NER states; (iii) State Agricultural Universities; (iv) Central Agricultural University; (v) Farm Science Centers which are popularly recognized as *Krishi Vigyan Kendras* or KVKs; (vi) Agricultural Technology Management Agency (ATMA) (vii) National Agricultural and Rural Development Bank (NABARD); (viii) Public and private sector banks; (ix) Industry sector companies and agricultural input providers; (x) Non-governmental organizations; (xi) farmers' organizations and co-operatives; and (xii) Self Help Groups (SHGs); etc. Additionally, farmers of NER were also considered as one of the major stakeholders of ARES (Figure 16) as farmers are treated as active partners of the change process rather than just beneficiaries of welfare schemes.

Figure 16. Key stakeholders of the Agricultural Research and Extension System in the Northeastern region of India

The purpose of this study is to aid strategic planning for the agricultural sector of NER by exploring the strengths, weaknesses, opportunities, and threats of ARES. Through this study, for the first time in the NER, a series of 21 brainstorming sessions are conducted to formulate strategies to promote the sustainability of farming in changing climate scenario. Active dialogue with grass-root level agricultural experts, in the form of a brainstorming approach, was used to explore real-time information in SWOT quadrants. Moreover, experts were allowed to express their concerns and record their observations in a group manner and then the group of experts decided on the priorities of the SWOT quadrants by their (mutual) agreement.

The ultimate goal of this scientific endeavor is to use SWOT information to derive conclusions in the form of strategies that promote climate resilience and sustainable development of the agricultural sector of NER. This study addresses the gap between “where we are now” and

"where we want to reach" by providing a clear picture of internal factors, i.e., strengths and weaknesses as well as external factors, i.e. opportunities and threats pertaining to ARES of NER. This information and understanding of internal and external factors aid policymakers by systematically elucidating the (positive and negative) performance concerns faced by system components. We hope that this investigation will act as an informative foundation for decision-making, at different levels of AERS of NER.

4.2 Methods

4.2.1 Study area

The Northeastern region of India is a group of eight Indian states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim. The eighth state belonging to NER is Sikkim which is located in the Eastern Himalayas and shares international borders with Bhutan, Nepal, and Tibet (Figure 15). This entire region is socio-economically dependent on traditional farming methods and recognized as an agriculture-centric economy. This study was conducted in the 21 districts of the NER which is a very diverse region in terms of agro-ecological (Table 13) conditions due to the existence of climatic factors, soil properties and physiographic settings (i.e., topography and drainage). Hence, while sampling the districts, we ensured the inclusion of experts belonging to diversified agro-ecological zones and sub-zones to acquire holistic views (Table 13).

4.2.2 Data collection

We conducted 21 group-brainstorming sessions in the Northeastern region of India that represents 21 districts. Brainstorming is a popular group research method to induce creativity among groups to comprehend out-of-box solutions to complex problems (Osborn, 1953). We conducted brainstorming sessions to derive relevant insights into four quadrants of the SWOT matrix, which is a widely used strategic planning tool (Tassabehji & Isherwood, 2014). SWOT analysis enables practitioners to systematically analyze and understand strength, weaknesses opportunities and threats of any organization, system, person or any similar entity (Brudermann et al., 2015; Fan & Xue, 2018; Nikolaou & Evangelinos, 2010; Paschalidou, Tsatiris, & Kitikidou, 2016; Santopuoli, Marchetti, & Giongo, 2016; Suh, 2014). The combined use of SWOT with brainstorming enabled researchers to collect, well-synthesized group data rather than individualized questionnaires (Figure 17).

Table 13. List of 21 districts sampled from Northeastern region of India (NER) where brainstorming sessions were conducted. The number of strengths, weaknesses, opportunities, and threats reported from the individual district are indicated.

State	Major agro-ecological conditions of state	Name of the district	DT[a]	S[b]	W[c]	O[d]	T[e]
Arunachal Pradesh	Alpine zone, Mid tropical hill zone, Mid tropical plain zone, Subtropical hill zone, Temperate sub-alpine	Lower Dibang Valley	LD	12	14	13	15
		East Siang	ES	11	7	15	18
		Papumpare	PP	8	11	11	18
		Lower Subansiri	LS	9	18	27	14
Assam	Barak valley zone, Upper Brahmaputra zone, Costal Brahmaputra zone, Lower Brahmaputra valley zone	Chirang	CH	11	18	13	17
		Dhubri	DB	9	24	19	21
		Kokrajhar	KK	11	16	17	16
		Lahimpur	LK	11	16	16	16
		Bongaigaon	BG	14	16	27	13
		Dhemaji	DH	6	11	14	10
		Dibrugarh	DG	7	15	17	12
Mizoram	Humid mild tropical zone, Humid sub-tropical hill zone, Humid temperate sub-alpine zone	Aizwal	AZ	11	10	11	11
		Lunglei	LG	10	11	8	9
		Serchhip	SC	10	11	10	10
Manipur	Subtropical plain zone, Subtropical hill zone, Temperate sub-alpine zone, Mid-tropical hill zone	Senapati	SP	10	13	10	14
		Thoubal	TB	13	17	19	17
Meghalaya	Tropical zone, Sub-tropical zone, Temperate zone	Jaintia Hills	JH	14	12	19	16
		West khasi Hills	WK	12	14	16	10
Sikkim	Tropical zone, Sub-tropical zone, Temperate zone, Temperate alpine zone	South Sikkim	SS	11	14	13	6
		North Sikkim	NS	13	10	10	16
Tripura	Humid sub-tropical zone, Mild tropical plain zone	North Tripura	NT	11	14	12	18

[a] District code of sampled district which is used in subsequent tables for providing information
[b] Number of strengths reported
[c] Number of Weaknesses reported
[d] Number of Opportunities reported
[e] Number of Threats reported

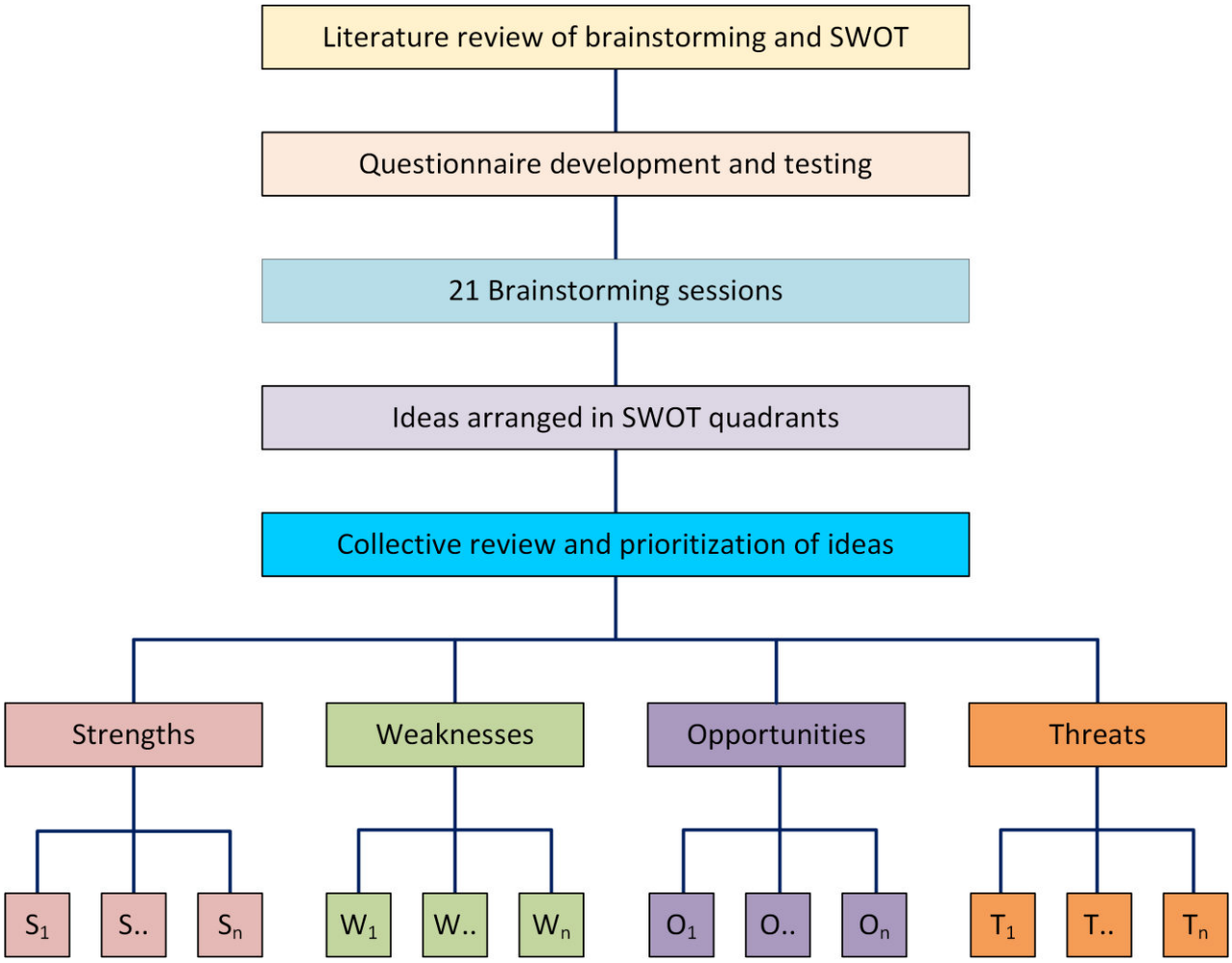

Figure 17. Flowchart explaining steps followed to conduct brainstorming sessions in NER to explore strengths, weaknesses, opportunities and threats of agricultural research and extension system.

In addition, the brainstorming incorporated an element of creative group thinking in this exercise that enhances the reliability and acceptability of policy recommendations (Al-Maghawry, 2012; Boddy, 2012; Daim & Oliver, 2008; Goldenberg & Wiley, 2011; Hender, Rodgers, Dean, & Nunamaker, 2001; Oslapas, 1993).

In the first phase, we purposively identified 21 districts from Northeastern region that represent various agro-ecological zones. Then we circulated the questionnaire containing brainstorming exercises among the scientific staff of the 21 *Krishi Vigyan Kendras* from selected districts. In the second phase, the first author visited the *Krishi Vigyan Kendras* (located in all sampled districts) to conduct a group brainstorming sessions. This group approach was followed as it allowed participants to generate creative and relevant ideas concerning their settings. We provided participants with a non-judgmental environment to think freely and independently during the brainstorming session. The goal of this scientific inquiry was to explore the strategies that

promote climate-resilience and sustainable development of the agricultural sector of the Northeastern region of India. Hence, we conducted this brainstorming exercise around four basic themes (quadrants) of the SWOT analysis matrix (strengths, weaknesses, opportunities, and threats). We used the following four thematic questions to probe information in each SWOT quadrant.

Que.1 What are the strengths of the agricultural research and extension system of NER in a climate change scenario?

The first question is aimed to explore and examine the internal strengths of the agricultural research extension system of NER. It primarily explores the human side of the system and the collective strengths, for example, aspects related to leadership, coordination, staffing, and reputation.

Que 2. What are the weaknesses of the agricultural research and extension system of NER in a climate change scenario?

The second question aims to explore and examine the internal weaknesses of NER's agricultural research and extension system. To a greater extent, this question examines the human side of the system, which contains weaknesses of management, coordination, and staffing.

Que 3. What are the opportunities for agricultural research and extension systems of NER in a climate change scenario?

The third question explores and examines external opportunities for NER's agricultural research and extension system. This question compels participants to think out of the box and creatively articulate logical thoughts into new opportunities. As an example, prospects for growth, recent discoveries, and innovations, changes in demographics, changes in legislature, events of national/international significance can be considered while exploring opportunities.

Que 4. What are the threats to the agricultural research and extension system of NER in a climate change scenario?

The fourth question aims to explore and examine external threats for NER's agricultural research and extension system. This question intends to probe potential threats for all components of agricultural research and extension system. For example, recent disease

outbreak, disasters, natural calamities, population dynamics, food habits, resource consumption patterns are some of the external factors considered while exploring threats.

However, as we operationalized agricultural farmlands and farming communities as a part of ARES, the facilitator welcomed specific strengths, weaknesses, opportunities, and threats that are directly or indirectly related to them.

In each brainstorming session, the scientific and technical staff of the *Krishi Vigyan Kendras* actively participated. For each session, the number of participants varied from 6 to 14, which is an ideal setting for this method. As the staff of *Krishi Vigyan Kendra* is multidisciplinary, we had participants from diverse backgrounds, experiences, and expertise. Moreover, the KVKs are administratively controlled by their host organizations such as ICAR institutions, State Agricultural Universities, State Departments of Agriculture and allied wings, NGOs. The KVKs also work in close liaison with the IACR-Agricultural Technology Application Research Institutes for funding and reporting of technical achievements. KVKs also maintain regular contacts with SHGs, farmer organizations and a variety of farmers residing in districts to perform their mandated activities like on-farm testing of new technologies, frontline demonstrations, training, awareness camps. Moreover, this diversified networking of KVKs with other stakeholders offers them valuable prospects to understand the other components of ARES. Hence, we purposively sampled KVKs to conduct the SWOT analysis of ARES in the NER.

All participants were allowed to think creatively and independently, without any criticism and interruption during the first phase of brainstorming which is also called 'green phase,' aimed at no discussion and only generating a variety of possible ideas, which are pertinent to problems as perceived by individual participants. It allows for the generation of creative and even wild ideas by participants as facilitators encouraged freewheeling. In the second phase called 'red phase,' the entire group collectively discussed and evaluated every idea reported under the four SWOT quadrants. This red phase allowed participants to objectively review all ideas and form a group understanding to prioritize them. The first author acted as a facilitator of all brainstorming sessions and documented outcomes of all exercises.

4.2.3 Data and information analysis

We analyzed collected qualitative data using the systematic content analysis method. Firstly, a catalog of all strengths, weaknesses, opportunities, and threats reported from 21 districts was created. Then we used Nvivo software (package 11) for thematic grouping and merging identical

nodes of information. Secondly, a thematic classification of data allowed us to categorize data into thematic sections and derive insights from it.

4.2.3.1 Hierarchical cluster analysis

Further, we conducted a hierarchical cluster analysis to explore the homogeneous clusters, which facilitate the understanding of associations and connections among individual factors (SPSS-version 24). For *n* number of objects, the results of the hierarchical analysis are represented in a binary tree (Dendrogram) with *n-1* nodes, through a stepwise algorithm, that merges two objects in each step that show the least dissimilarity. In this article, individual matrixes of strengths, weaknesses, opportunities, and strengths, alongside their respective district-wise reporting (1= Yes, 0=No) were analyzed for hierarchical clustering. The average linkage method (also known as UPGMA or an *unweighted pair-group method using arithmetic averages*) was utilized for analysis wherein dissimilarities of objects were averaged at each step to form homogeneous clusters. The Euclidian distance (i.e., a geometric distance in multi-dimensional space) is utilized as distance measure in hierarchical clustering analysis that was calculated as the square root of the sum of the squared differences between two objects. The results of the analysis are provided in the form of Dendrograms, which elucidate the step-wise joining of clusters (indicated by vertical lines) and the distance between clusters (dissimilarity) at the time of joining the clusters, indicated by the position of the line on the scale. The observed distances are rescaled in between 1 to 25 in such a way that ratio as original distance matches with the ratio of rescaled distance. The objects that are close together and show smaller dissimilarity are linked at a smaller distance (near to 0). The objects linked at larger distance (near to 25) exhibit greater dissimilarities. Association (links) in between two or more objects are considered for interpretation of results displayed in Dendrogram.

4.2.3.2 SWOT matrix for strategy formulation

In addition, we used data, collected during brainstorming sessions for devising the most plausible strategies for the sampled districts in NER. The approach of strategy formulation is illustrated in Figure 18.

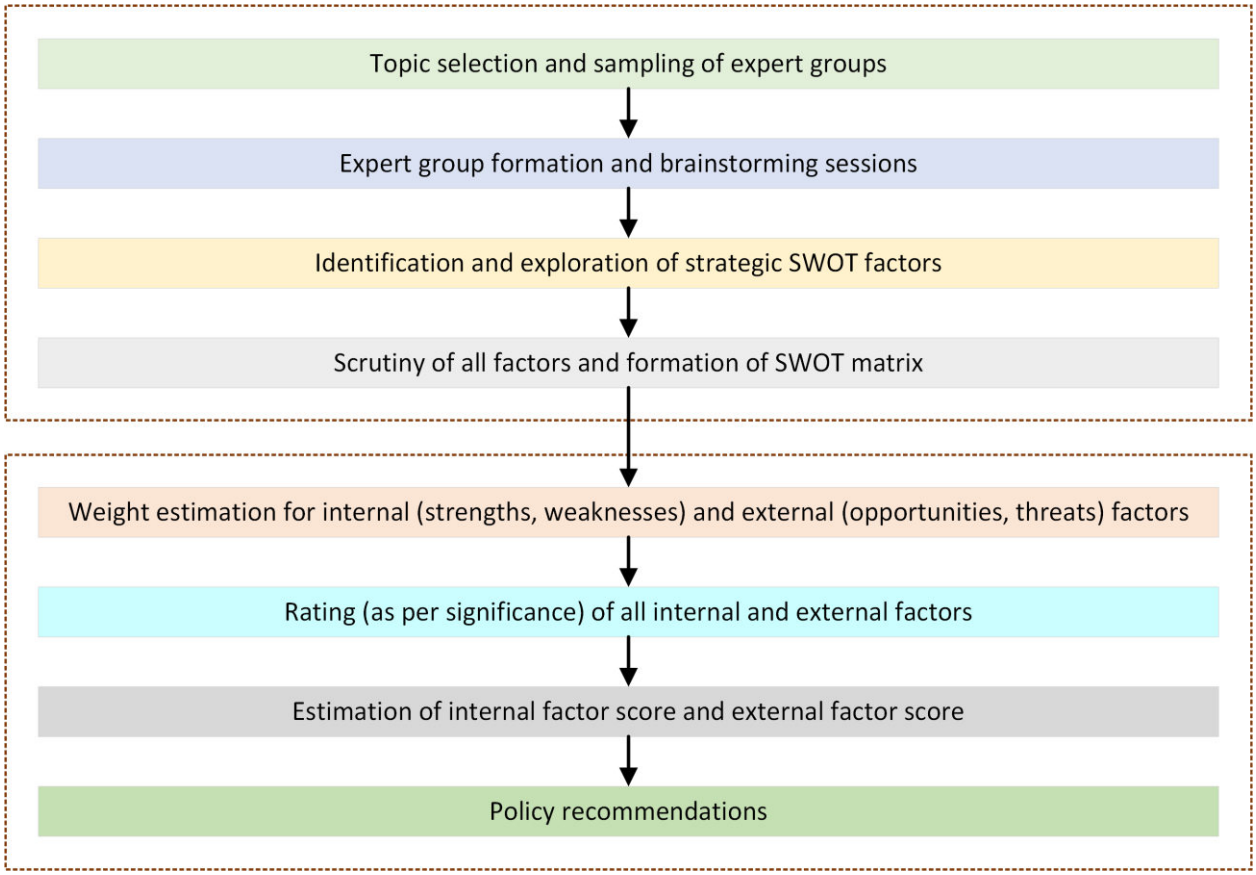

Figure 18. Schematic representation of the strategy formulation approach using SWOT matrix

Firstly, experts were encouraged to identify strengths, weaknesses, opportunities, and threats in all four quadrants of SWOT. Secondly, experts scrutinized all brainstormed factors and developed consensus among themselves to appropriately modify brainstormed factors, merge identical factors or remove irrelevant or inappropriate factors.

In the third step, thoroughly scrutinized factors were then arranged into (i) external factor evaluation matrix and (ii) internal factor evaluation matrix (Wasike, Magothe, Kahi, & Peters, 2011). The internal factors analyze context specific strengths and weaknesses of any organization, system or entity that are mainly internal. In general, the strengths empower organization/system to function normally to attain its goals. However, the weaknesses are impediments, hindrances or limiting factors that hamper the normal performance of organization/system, which makes goal attainment difficult. Similarly, an analysis of external factors helps researchers to recognize relevant opportunities and threats that are available in the external environment of organization/system, which may positively or negatively affect the performance (Wasike et al., 2011). Hence, SWOT approach is combined with the analysis of (i)

external factor evaluation matrix and (ii) internal factor evaluation matrix, which facilitates the assessment of strategic factors for appropriate decision-making (Mondal & Haque, 2017).

Further, in the fourth step, the experts weighted each factor from internal factor evaluation matrix, in between 0.0 (least important) to 1.0 (highest importance); according to its importance, in such a way that a sum of all weights in the internal matrix is 1. Group of experts collectively assigned more weight to the factors that are more effective or important in their context. The same procedure was applied for the external factor evaluation matrix and experts assigned weights until the column sum reached 1.

Subsequently, in the fifth step, each factor from external factor evaluation matrix as well as internal factor evaluation matrix was rated in-between 1 to 4, using predetermined rule (Table 14) to reaffirm the prominence (i.e., major factor or minor factor) represented by an individual factor.

Table 14. Rules utilized to assign ratings to the factors of external factor evaluation matrix and internal factor evaluation matrix

Rating score	Interpretation for the external factor evaluation matrix	Interpretation for the internal factor evaluation matrix
1	Major threat	Major weaknesses
2	Minor threat	Minor weaknesses
3	Minor opportunity	Minor strength
4	Major opportunity	Major strength

In the sixth step, a weighted score was calculated by multiplying weight with the rating assigned to factors in both matrices. Finally, (i) internal factor score and (ii) external factor score were estimated to identify the appropriate strategy for each district. It was done by plotting (i) internal factor score and (ii) external factor score of each district on Strategic Position and Action Evaluation Matrix (also called as SPACE matrix).

In a subsequent step, if a particular district has external factor score more than 2.50, then opportunities are considered more than threats. In contrast, if the external factor score is less than 2.50 then external threats dominant than the opportunities. Similarly, if the internal factor score is more than 2.50, then internal strengths are considered as more than the internal weakness of the system. However, internal factor score lesser than 2.50 symbolizes more internal weaknesses than that of strengths. Considering the dominance of internal or external factor score, the SPACE matrix facilitates the identification of appropriate strategy by plotting

the district into one (out of four) strategy quadrant which is recognized as conservative strategy, defensive strategy, competitive strategy, and aggressive strategy. These four strategies are consistent with the strategy formulation approach using SWOT matrix (Figure 19).

Internal factors / **External factors**	Strengths (S) related to ARES of NER S1 S2 . . S41	Weaknesses (W) related to ARES of NER W1 W2 . . W42
Opportunities (O) related to the ARES of NER O1 O2 . . O39	**SO (Maxi-Maxi)** Use the strengths to harness the opportunities at maximum possible extent **(Aggressive strategy)**	**WO (Mini-Maxi)** Minimize weaknesses by maximizing opportunities **(Conservative strategy)**
Threats (T) related to the ARES of NER T1 T2 . . T56	**ST (Maxi-Mini)** Maximize the strengths and minimize the threats, **(Competitive strategy)**	**WT (Mini-Mini)** Minimize weaknesses and minimize threats, **(Defensive strategy)**

Figure 19. SWOT matrix scheme illustrating the strategy formulation approach by considering the internal and external factors.

Firstly, the aggressive strategy of the SWOT matrix is recommended when strengths and opportunities are predominantly found in the district. Secondly, if the particular district has dominant strengths as well as greater external threats, then the competitive strategy is recommended to eliminate threats using the internal strengths of the organization. Thirdly, conservative strategy is advocated wherein external opportunities are more, along with organizations' internal weaknesses. Conservative strategy calls for maximization of external opportunity exploitation and minimization of internal weaknesses to sustain the organization or system. Finally, the SWOT matrix recommends defensive strategy, wherein the district has predominant internal weaknesses as well as external threats. Defensive strategy advocates the operation of the organization in such a way that it minimizes the internal weaknesses and eliminates external threats for the survival of the organization. Once the appropriate strategy is identified for the district, most relevant policy recommendations are proposed from the contextual interpretation and analysis of information generated during brainstorming sessions.

4.3 Results and discussion

4.3.1 Strengths of NERs' agricultural research and extension system

Data collected through 21 brainstorming sessions revealed 41 unique strengths of ARES of NER Table 15. A detailed account of district wise strengths reported from NER is enclosed as Appendix G. According to Appendix G, the Jaintia Hills district of Meghalaya and the Bongaigaon district of Assam reported maximum strengths (14). However, the Dhemaji district of Assam reported a minimum number of strengths (6). Systematic content analysis revealed that institutional collaborations and linkages are the major as well as most reported strength of ARES of NER (Table 15). In general, the *Krishi Vigyan Kendra* as an institution works in close liaison with their host organizations (Ex. ICAR institutes, SAUs, State Department of Agriculture, etc) and depend mainly on ICAR for funding. This setup enables *Krishi Vigyan Kendras* to collaborate and establish linkages with other institutions. Besides, *Krishi Vigyan Kendras* also collaborate with other line departments, public sector organizations, ATMA, private sector companies, NGOs and other development stakeholders to implement programs for the welfare of agriculture. As *Krishi Vigyan Kendras* have a sound rapport with local farmers, many stakeholders approach *Krishi Vigyan Kendra* for conducting training, awareness programs, vaccination camps and producing (and purchasing) quality agricultural inputs.

The second most rated strength is related to the natural resources of NER. Participants convey that rich biodiversity and forest cover of NER is a unique strength of NER. Prima-facie, it seems that this is a kind of external factor, but participants collectively affirmed that it is the internal strength of the system. They feel that rich biodiversity and abundant germplasm is the foundation for crop breeding to develop high yielding varieties through genetic improvement. As farming communities are part of ARES of NER, this strength enables them to practice traditional slash and burn farming. Huge forest cover produces a variety of forest produce, which is a source of livelihood for many tribal inhabitants.

As NER terrain has a variety of connectivity and accessibility issues, reaching larger numbers is quite a difficult task. In the rainy season, this situation aggravates even more and sometimes communication is completely halted. However, ARES of NER uses social media and Information Communication Technologies (ICTs) to remain in contact with farmers due to which ARES perceives it as one of the crucial strengths.

Table 15. Strengths reported from the sampled districts of NER

Serial number	Strength description	Reporting frequency	Thematic grouping of strengths
1.	Institutional linkages and collaborations	20	⊖⊗
2.	Rich biodiversity and agricultural germplasm*	15	⊕
3.	Use of social media and ICTs for extension	13	⊕
4.	Technology refinement and customization	12	⊕
5.	Abundant natural resources for diversification*	11	⊕⊖
6.	Farmer-friendly approach and dedication	11	⊗
7.	Technical knowledge credibility	11	⊗⊙
8.	Cooperative farmers (stakeholders)*	10	⊗⊛
9.	Favorable climatic conditions for farming*	10	⊕⊖
10.	Energetic extension professionals	9	⊗⊙
11.	Creative and efficient use of local resources	8	⊕⊗⊙
12.	Traditional knowledge and expertise of farmers*	7	⊖⊛
13.	Digital documentation and publication	6	⊕⊙
14.	Fertile soils, less polluted*	6	⊕⊖
15.	Huge potential for organic farming*	6	⊕⊖⊛
16.	Participatory Technology Development (PTD)	6	⊗
17.	Capacity building initiatives	5	⊗⊘
18.	Need-based research and extension	5	⊗⊘
19.	Productive and efficient teamwork (coordination)	5	⊗⊙
20.	Adequate water resources for farming/fishing*	4	⊕⊖
21.	Good infrastructure for research and extension	4	⊗⊘
22.	Objective oriented leadership	4	⊗⊙
23.	The social cohesion of farming communities*	4	⊛
24.	Competitive mindset for excellence	3	⊗⊙
25.	Efficient human resources in TOT	3	⊗⊘⊙
26.	Energetic youth in Research and Extension	3	⊗⊙
27.	Government support	3	⊗⊘
28.	Human relation approach of leaders	3	⊗⊙
29.	regular and efficient monitoring	3	⊗⊘
30.	Climate-sensitive research and extension	2	⊕⊗
31.	Skillful design and implementation of technology	2	⊗⊙
32.	Agriculture-centric state economy*	1	⊗⊛
33.	Community approaches for farm mechanization	1	⊖⊛
34.	Efficient financial management	1	⊗⊘⊙
35.	Empowered women	1	⊗⊛
36.	Entrepreneurial promotion	1	⊗⊘
37.	Good quality of inputs and service	1	⊗⊘⊙
38.	Improved *Jhum* farming	1	⊗⊛
39.	Fewer insect pest and disease attacks	1	⊖⊗
40.	Motivating work culture	1	⊗⊙
41.	Secondary agricultural scope	1	⊕⊖

*Strengths indirectly associated with the AERS

⊕ = Climate/weather related strengths, appeared 12 times

⊖ = Natural resource endowments related strengths, appeared 10 times
⊗ = Organizational management related strengths, appeared 29 times
⊘ = Policy formulation and implementation related strengths, appeared 10 times
⊙ = Agricultural input related strengths, appeared 1 time
⊛ = Human resource related strengths, appeared 13 times
⊛ = Society and community-related strengths, appeared 8 times

Similarly, technology refinement and customization according to the need of the local farming community is also a key strength of ARES. This strength is prominently associated with *Krishi Vigyan Kendras* of India. Technology testing and refinement are one of the prime objectives of *Krishi Vigyan Kendras.* This unique feature is an asset of *Krishi Vigyan Kendras* that has a more substantial impact on farming communities due to its relative importance and increased applicability in a particular area. Participants also emphasized that a farmer-friendly approach of operation, as well as technical knowledge credibility of *Krishi Vigyan Kendras,* are also equally significant strengths.

In addition, participants highlight that (i) cooperative farmers, (ii) energetic staff, (iii) ample natural resources, (iv) indigenous traditional knowledge possessed by farmers, (v) creative use of local resources, (vi) digital documentation, (vii) fertile and less polluted soils, and the (viii) immense potential for organic farming are also noteworthy strengths for NERs' ARES.

The thematic grouping of all strengths is presented in Table 15. It is evident from Table 15 that the majority of strengths (29) of NERs' ARES are associated with the organizational management. Participants also underline that human resource management is a crucial strength (13) that is associated mainly with organizational management. Mainly, the participant accord equalizes the strengths related to natural endowments of NER (10) with strengths related to policy formulation and implementation (10). Similarly, climate-related strengths and community-related strengths share equal importance. Least reported strengths are associated with agricultural input supply in NER.

The hierarchical clustering of strengths is presented in Figure 20, which indicates the associations between the various strengths. The highly reported strength of institutional collaborations and linkages are closely associated with (i) technology refinement and customization, (ii) Use of social media and ICTs for an extension, and (iii) Technical knowledge credibility. The cluster of strengths is linked with a farmer-friendly approach of service that contributes prominently to the successful transfer of technology.

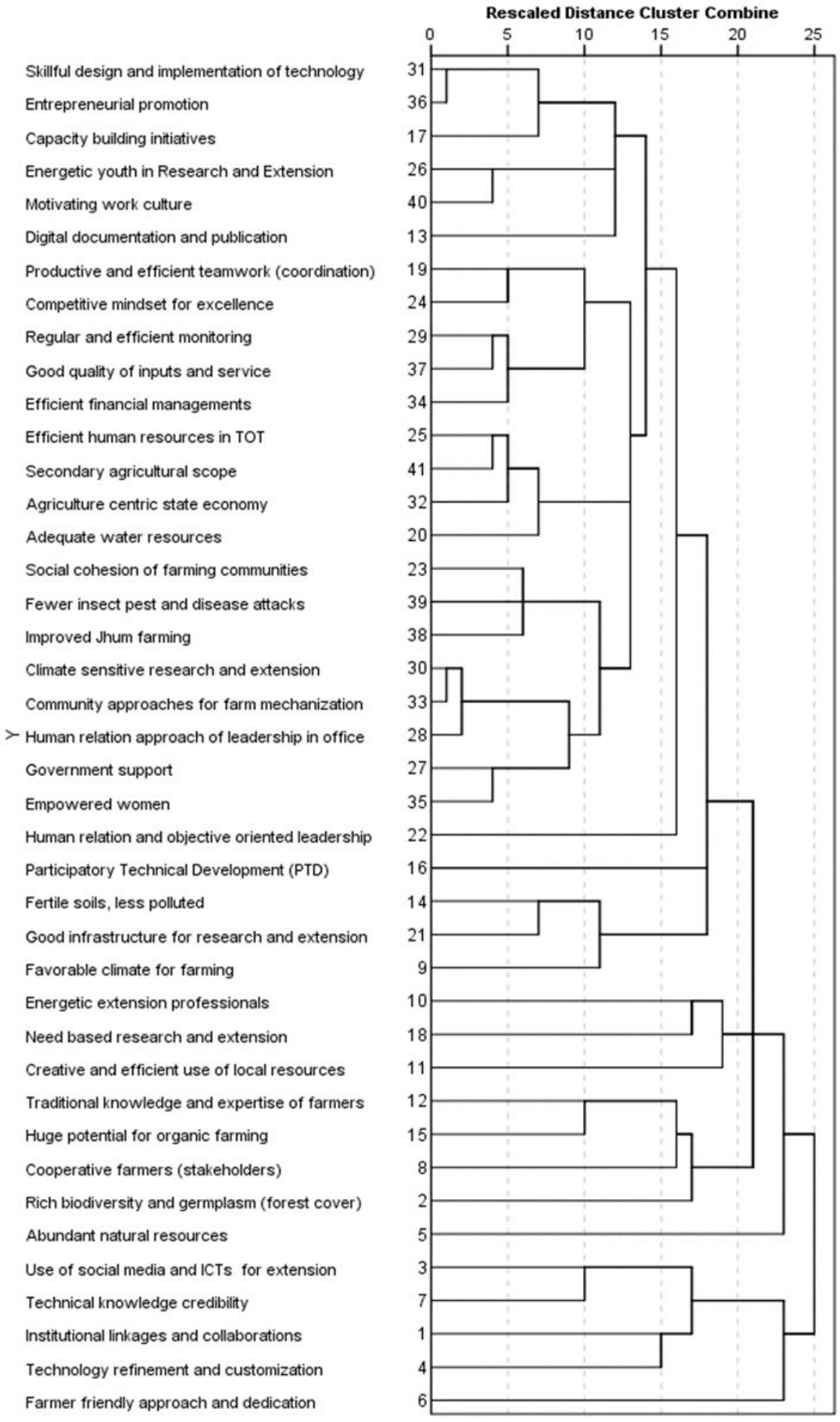

Figure 20. Dendrogram of hierarchical cluster analysis of strengths of ARES of NER (using average linkage, between groups)

The second major strength of rich biodiversity and germplasm is associated with traditional knowledge of farmers, the expertise of farmers, and cooperativeness among farmers. It is interesting to see that the substantial organic farming potential in NER is linked with indigenous knowledge of farmers and their expertise to cultivate lands in harmony with nature.

In addition, a favorable climate for farming is linked with fertile and less polluted soils of NER. Both factors are essential for creating synergetic infrastructure for research and extension. It is also revealed that empowered women are linked with government support and these two strengths are associated with the human relation approach in offices, climate-sensitive research, and extension, as well as community approaches for farm mechanization. Moreover, these strengths are connected with social cohesion of farming communities and improved *jhum* (slash and burn) farming in NER.

Cluster analysis of strengths also reveals that adequate water resources are associated with efficient human resources in extension services, which is crucial for promoting secondary agriculture and the agriculture centric economy of NER. The energetic youth in the research and extension system of NER is a kind of pivotal strength in a changing climate scenario as it is linked with motivating work culture, skillful design, and implementation of technology, entrepreneurial promotion, capacity building initiatives, digital documentation and publication towards the welfare of NERs' agriculture.

Need-based research and extension, along with creative as well as efficient use of local resources are the attributes associated with energetic extension professionals which share a direct connection with abundant natural resources in NER.

Furthermore, Figure 20 shows that the competitive mindset for excellence is linked with productive and efficient teamwork and these strengths are associated with efficient financial management and regular monitoring. Regular and efficient monitoring is a link between good quality of inputs and services provided by ARES of NER.

4.3.2 Weaknesses of NERs' agricultural research and extension system

The weaknesses are the internal impediments of the system, which hamper the overall performance of its constituents. Participants of the 21 brainstorming sessions reported 44 weaknesses (Table 16). The Dhubri district of Assam state reported a maximum number of weaknesses (24) while the lowest number was reported from the East Siang district of

Arunachal Pradesh (7) Appendix H. According to Table 16, the most reported weaknesses from NERs' ARES are (i) an inadequate staff for research and extension; (ii) the shortage of climate and farmer-sensitive agricultural policies; (iii) untimely as well as inadequate funding; and (iv) generally, the fund acquisition and utilization procedures are complex, lengthy and highly bureaucratic. These weaknesses are followed by (i) poor logistic support for research and extension; (ii) inappropriate, confusing as well as demotivating human resource policies; (iii) inadequate and poor infrastructure; (iv) costly agro inputs that are inadequate and mostly unavailable when needed. Von Braun et al. (2005) highlighted a similar kind of strategic issues for Indian agriculture and recommended investments in infrastructure as well as agricultural research.

With respect to *Krishi Vigyan Kendras* of NER, participants reported fundamental weaknesses as (i) excessive reporting because of which they do not find enough time for scientific activities; (ii) inappropriate and inconsistent work distribution is also a critical weakness pertaining to work allocation in organizations; and (iii) participants reported that they feel overburdened due to non-mandated activities. Some of the notable weaknesses down the list are (iv) fewer interdepartmental linkages; (v) little research on bio-input development; (vii) inappropriate beneficiary targeting for research and extension related activities; (viii) inadequate research and extension for irrigation; (ix) multiple bossing; and (x) unscientifically designed human resource development programs without need assessment of trainees (Table 16).

Table 16. Weaknesses reported from the sampled districts of NER

Weakness description	Reporting frequency	Thematic grouping
Inadequate staff for research and extension	25	⊗⊘⊙
Shortage of climate and farmer sensitive policy	21	⊗⊘
Untimely and inadequate funding, complex procedures	21	⊗⊘⊙
Lack of location-specific technology	20	⊗⊙
Poor logistic support for research and extension	19	⊗⊘⊙
Inappropriate and demotivating human resource policies	16	⊗⊘⊙
Inadequate and poor infrastructure	15	⊗⊘⊙
Inadequate, costly and untimely input supply	14	⊕⊗⊙
Excessive reporting and less time for scientific work	12	⊗⊘⊙
Overburdened by non-mandate activities	11	⊗⊙
Inappropriate and inconsistent work distribution	10	⊗⊙
Poor coordination with other departments	9	⊗⊙
Little research on bio-inputs for organic farming	8	⊗⊙⊙
Inappropriate beneficiary targeting	7	⊗⊘⊛
Inadequate research and extension for irrigation	7	⊗⊘
Multiple bossing	7	⊗⊘⊙

Unscientific HRD programs without need assessment	7	⊗⊘⊙
Lengthy, bureaucratic hierarchy	6	⊗⊘⊙
The absence of market research and poor reforms	6	⊗⊘
Transport connectivity and accessibility	5	⊕⊖⊛
Fewer efforts to produce quality seed	4	⊗⊙
No scope for creativity and monotony of work	4	⊗⊘⊙⊙
Political interference in science	4	⊗⊘
Lack of scientific and authenticate data	3	⊗⊙
Inadequate post-harvest technologies	3	⊗⊘
Poor networking and communication (organizational)	3	⊗⊙
The poor state of policy implementation	3	⊗⊘⊙
The miserable state of germplasm conservation	3	⊕⊗⊙
Inadequate soft skill development trainings	2	⊗⊘⊙
Inadequate R & D vaccines and medicines for livestock	2	⊗⊙
The insufficient and miserable state of post-harvest research	2	⊗⊘⊙⊙
Too much dependency on government	2	⊗⊘⊙
Financial mismanagement	1	⊗⊙
Inadequate extension services	1	⊗⊘⊙
Insufficient technological customization	1	⊗⊙
Deficiency of (timely) weather information	1	⊕⊗⊙
No recognition for hard work	2	⊗⊘⊙
Miserable documentation and publications	1	⊗⊙
Trifling validation of indigenous traditional knowledge	1	⊗⊙⊛
Monsoon dependent Research and extension	1	⊕⊖⊙⊙
Shifting cultivation	1	⊖⊙⊛
Social instability and inequality	1	⊖⊛

⊕ = Climate/weather related weaknesses, appeared 5 times
⊖ = Natural resource endowments related weaknesses, appeared 4 times
⊗ = Organizational management related weaknesses, appeared 38 times
⊘ = Policy formulation and implementation related weaknesses, appeared 22 times
⊙ = Agricultural input related weaknesses, appeared 7 times
⊙ = Human resource related weaknesses, appeared 31 times
⊛ = Society and community-related weaknesses, appeared 5 times

The thematic grouping of all weaknesses is represented in Table 16, which reveals that most of the internal weaknesses are associated with organizational management (38), human resource related issues (31) and policy (formulation and implementation) related aspects of ARES (22). Comparatively lesser significant connections are found for weaknesses related to agricultural inputs (7), climate (5), society (community) (5), and natural resource endowments (4) of NERs' ARES. Thematic grouping analysis indicates that most of the internal weaknesses are arising from organizational management, human resource policies, and overall agricultural policy formulation and implementation in NER. The majority of weaknesses are interconnected between these aforementioned three categories, as they are highly interlinked.

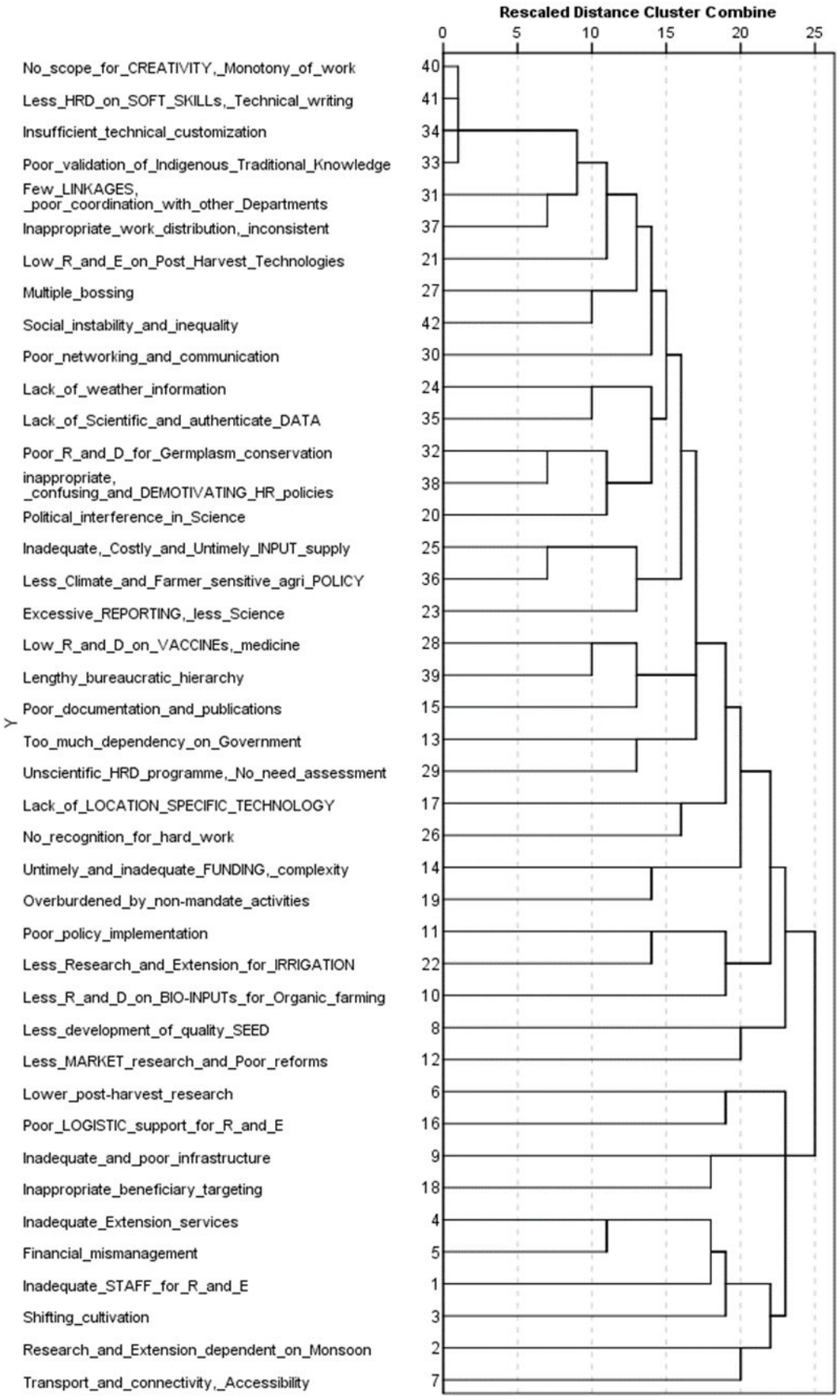

Figure 21. Dendrogram of hierarchical cluster analysis of weaknesses of ARES of NER (using average linkage, between groups)

This interlinking of weaknesses is explained by hierarchical cluster analysis that is presented in Figure 21. It reveals that the topmost reported weakness (i.e., inadequate staff) is directly linked with inadequate extension services which are associated with financial mismanagements. The transport and accessibility in NER is directly linked with research and extension dependency on monsoon as heavy rainfall interferes with the communication process in hilly terrain.

Shortage of climate and farmer-sensitive policies are directly linked with untimely as well as the inadequate supply of essential inputs not only to farmers but also to the researchers and extension professionals. Moreover, the high cost of inputs due to additional transport is one of the biggest impediments of quality research and extension work in NER.

Above mentioned weaknesses are associated with excessive reporting which is time-consuming and leaves no time for scientific activities in many developmental organizations. Due to the paucity of administrative staff, serving employees are also stressed, as they have to perform additional duties which delay inter-institutional financial transactions. It is notable to mention that all funding related weaknesses are also associated with overburdening of non-mandated activities.

Furthermore, poor departmental and institutional co-ordination are associated with several weaknesses, such as (i) the monotony of work and no scope for creativity; (ii) fewer training on soft skills and scientific writing; (iii) insufficient technical customization; and (vi) poor validation of indigenous knowledge. Inappropriate as well as inconsistent work distribution is associated with poor coordination. All weaknesses mentioned above are interconnected with multiple bossing *(a situation wherein numerous tasks are assigned to a particular employee, within small timeframe by two or more authorities)* and poor communication as well as unprofessional networking. These weaknesses contribute to subsequent weaknesses in the system as (i) lack of weather information; (ii) shortage of authentic data; (iii) futile conservation efforts; (iv) confusing and demotivating human resource policies. All these factors produce a highly bureaucratic system which is less responsive to the farmers and their needs because of which a lower number of location-specific technologies are generated. Many participants reported that there is no recognition for the hard work and its one of the prime demotivating factor for researchers and extension professionals of NER.

In a nutshell, the mother of all these weaknesses is an inappropriate policy formulation and implementation. In one way or other, the undesirable outcomes of policy formulation are the

inadequacy of bio-inputs for organic farming, the inadequacy of quality seeds, little market research and poor market reforms, as well as insufficient post-harvest and processing measures, poor logistic support to researchers and extension professionals, inadequate and poor quality of infrastructure. Figure 21 reveals a pattern of association highlighting that almost 75 percent of weaknesses are interlinked with inadequate and poor infrastructure for research and extension. To tackle some of these prominent weaknesses of the extension system, some policy options are recommended which include (i) enhancing institutional convergence; (ii) a provision for flexibility and innovation; (iii) increasing accountability to foster research and extension linkages; (iv) fostering public-private partnership; (v) improvement of human resource development strategy; (vi) communication strategy for extension reforms; (vii) long-term finance strategy; (viii) change oriented monitoring, etc. (Suresh C Babu et al., 2013). However, the present state of weaknesses indicates that there is a considerable gap between theory and practice.

4.3.3 Opportunities for NERs' agricultural research and extension system

Opportunities are external factors that have considerable potential for positive impacts on the system. Table 17 indicates opportunities reported from sampled districts. According to Appendix I, which gives a district-wise account of opportunities, a maximum number of opportunities are reported from the Bongaigaon district of Assam and the Lower Subansiri district of Arunachal Pradesh (27). The Lunglei district of Mizoram reported the minimum number of opportunities (8).

According to Table 17, as NER is rich in biodiversity, the first most reported opportunity is research and extension on indigenous high-value crops. A variety of spices, condiments, medicinal plants, and their products are abundantly available in NER. However, the scientific approach for their commercialized production and marketing will bring enormous economic prosperity to the region. Moreover, it will also the reduce exploitation of biodiversity and contribute massively towards conservation as well as upgradation of germplasm, which is the number two opportunity for ARES of NER. This conservation approach coupled with scientific cultivation of high-value crops will be a critical boost for export promotion in NER, an opportunity with the third rank.

Next, in the line, the most reported opportunity is scientific production of meat, pork as well as fish. Current practices of meat production in most of the rural areas of NER are traditional. Also, due to the frequent occurrence of infectious diseases among livestock (e.g., swine flu, bird flu), scientific and hygienic practices of meat production are widely advocated by experts. The rich biodiversity of NER produces a considerable quantity of indigenous fruits and forest products that are generally consumed by local peoples. Many scientific studies have supported the nutritional and medicinal properties of most of these exotic fruits and medicinal plants (A. Aggarwal & Chauhan, 2014; Hazarika et al., 2016; Kshirsagar & Upadhyay, 2009; Tangjang, Namsa, Aran, & Litin, 2011). In fact, some of the products have huge markets across borders, which bring opportunities for value addition and export of such fruits. Likewise, to check the exploitation of forest products of NER and optimize the production of local fruits, research on Indigenous Traditional Knowledge (ITK) is also recommended as a vibrant opportunity (Table 17). It will facilitate the identification, validation, and dissemination of potential wisdom nurtured by tribal communities of NER. Systematic research on ITKs will open many frontiers for research and extension on the ornamental fishery, ornamental birds, poultry birds, scientific hatchery, orchids farming, flower species, exotic spices, and condiments. The strategy paper published by IFPRI (International Food Policy Research Institute) in 2005 has proposed similar recommendations to exploit new opportunities based on production and marketing of high-value agricultural products (Von Braun et al., 2005).

Table 17 also points out that the organic farming potential of NER is probably the most pulsating and plausible opportunity (A. Das et al., 2017; N. Ghosh, 2003). However, unavailability of bio-inputs hinders the adoption of organic farming practices among the majority of farmers across the NER (H. Rahman, Karuppaiyan, Kishore, & Denzongpa, 2009). To elaborate, across India there is a massive demand for biofertilizers, bio-pesticides, organic insecticides but supply is extremely poor (Nandi, Gowdru, Bokelmann, & Dias, 2015). Also, most of the bio-insecticides are less effective, and crop damages are high due to low efficacy of these bio-insecticides. Hence, this constraint could be turned into an opportunity by systematic research and extension on production as well as the use of bio-inputs for organic farming. The organic production of ginger, spices, oranges, black scented rice, mushroom, kiwi and other indigenous fruits will be an impetus for further value addition, marketing and export to fetch higher prices.

Table 17. Opportunities reported from the sampled districts of NER

Opportunity description	Reporting frequency	Thematic grouping
Promotion of indigenous high-value crops	29	⊕⊖⊘⊙
Germplasm conservation and upgrading	22	⊖⊗
Promotion and export of high-value agricultural products	20	⊕⊘⊙
Scientific meat, pork, fish and milk production	19	⊕⊖
Value addition and processing of local fruits for export	18	⊕⊘⊙⊛
Indigenous traditional knowledge	18	⊖⊗
Promotion of ornamental fishery, birds, and hatchery	15	⊕⊖⊗
Organic farming promotion	14	⊕⊖⊙
Export of medicinal and aromatic plants (and products)	12	⊕⊘⊙
Scope for Bio-inputs, insecticides, fertilizer production	11	⊕⊖⊙
Orchids farming, protected floriculture	11	⊕⊖⊘
Export promotion of ginger, spices, and orange	10	⊕⊖⊘⊛
Tapping the export potential of black scented rice	8	⊕⊖⊗⊛
Promotion of integrated farming systems	8	⊕⊖
Tapping the export potential of bamboo processing and export	8	⊕⊘⊙⊛
Promotion of resilient cropping and agroforestry	7	⊗
Rich biodiversity, rainfall adequacy, and healthy climate	7	⊖
Diversification of protected farming	6	⊕⊙
Introduction of dual-purpose breeds of livestock	6	⊖⊙
Livestock breeding and bird hatchery for diversification	5	⊕⊖⊛
Oilseeds and pulses production in the winter season	5	⊕⊖⊙
Sericulture, lac farming, apiculture for diversification	5	⊕⊖⊘⊛
pulses and oilseeds processing	4	⊕⊙
Low-cost livestock feed production	4	⊕⊖⊙⊙⊛
Promotion of terrace cultivation	4	⊗
Efficient irrigation system development	4	⊕⊙
Farm mechanization	4	⊙
Kiwi production and export	4	⊕⊘
Mushroom farming and export	4	⊕⊘⊙⊛
The high potential of agro eco-tourism	3	⊕⊗⊛
Tapping potential of hydroponics (aquaculture)	3	⊕⊖⊙
Beekeeping	3	⊕⊖⊙
Drudgery reduction inputs	3	⊖⊙
Integrated insect, pest, disease and nutrient management	3	⊕⊖⊗⊛
Rainwater harvesting	3	⊕⊖⊙
Development of small and marginal enterprises	2	⊕⊛
Credit linkage development	2	⊕⊖
Exploration of the positive impacts of climate change	2	⊖
Promotion of high-value tuber crops	1	⊕⊖⊙

⊕ = Income enhancing opportunities, appeared 30 times
⊖ = Agricultural research and extension related opportunities, appeared 25 times
⊗ = Germplasm conservation opportunities, appeared 8 times
⊘ = Exports and trade-related opportunities, appeared 10 times
⊙ = Agricultural input related opportunities, appeared 10 times
⊙ = Value addition and processing related opportunities, appeared 11 times

⊛ = Low-cost interventions related opportunities, appeared 11 times

The thematic grouping of opportunities reveals that in Table 17 most of the opportunists have a direct effect on enhancing the income of NER farmers (30) which are followed by opportunities for agricultural research and extension in the region (25). The thematic grouping also conveys that there are enough opportunities for export promotion of exotic fruits and spices (10). The value addition and processing of farm produce (11) are essential for export, which is also a key opportunity for emerging entrepreneurs and farmer associations in NER, providing a valuable opportunity to the agriculture input sector (10) which can fulfill the needs of NER farmers. Some opportunities also promote conservation of germplasm and biodiversity in NER (8). In addition, 11 opportunities are originating from low-cost interventions (such as the use of poultry for farm diversification, use of green manures, construction of farm ponds for life-saving irrigations and similar activities) and demonstrate that entrepreneurship development is also possible in a variety of areas with minimal investment.

The interlinking of opportunities is explained by hierarchical clustering (Figure 22). The research and extension on the promotion of high-value indigenous crops are linked with research on traditional knowledge and scientific germplasm conservation. Altogether, these opportunities are a trigger for the export of high-value agro-products from NER. Similarly, processing and export of bamboo products are associated with the processing and export of medicinal (*Renanthera imschootiana, Hibiscus manihot, Abroma augusta, Acalypha indica,* etc.) and aromatic plants (*Cymbopogon winterianus, Cymbopogon flexuosus, Dendrobium chrysotoxu*) from NER, which is interconnected directly, with the promotion of scientific organic farming.

In the second prominent cluster, skill development on ornamental fishery, bird and poultry hatcheries has a close association with scientific livestock production for meat, milk, and fish. These factors are linked with the scientific promotion of sericulture, apiculture, lac farming, pulses and oilseed cultivation in rice fallows and export of high-value mushroom. This entire cluster shows links with production and export of high-value rice (Ex. black scented rice, *joha* rice, aromatic rice, exotic rice) from NER to the rest of the world. In addition, scientific promotion of orchid cultivation, protected floriculture is associated with the processing of local fruits for export Figure 22.

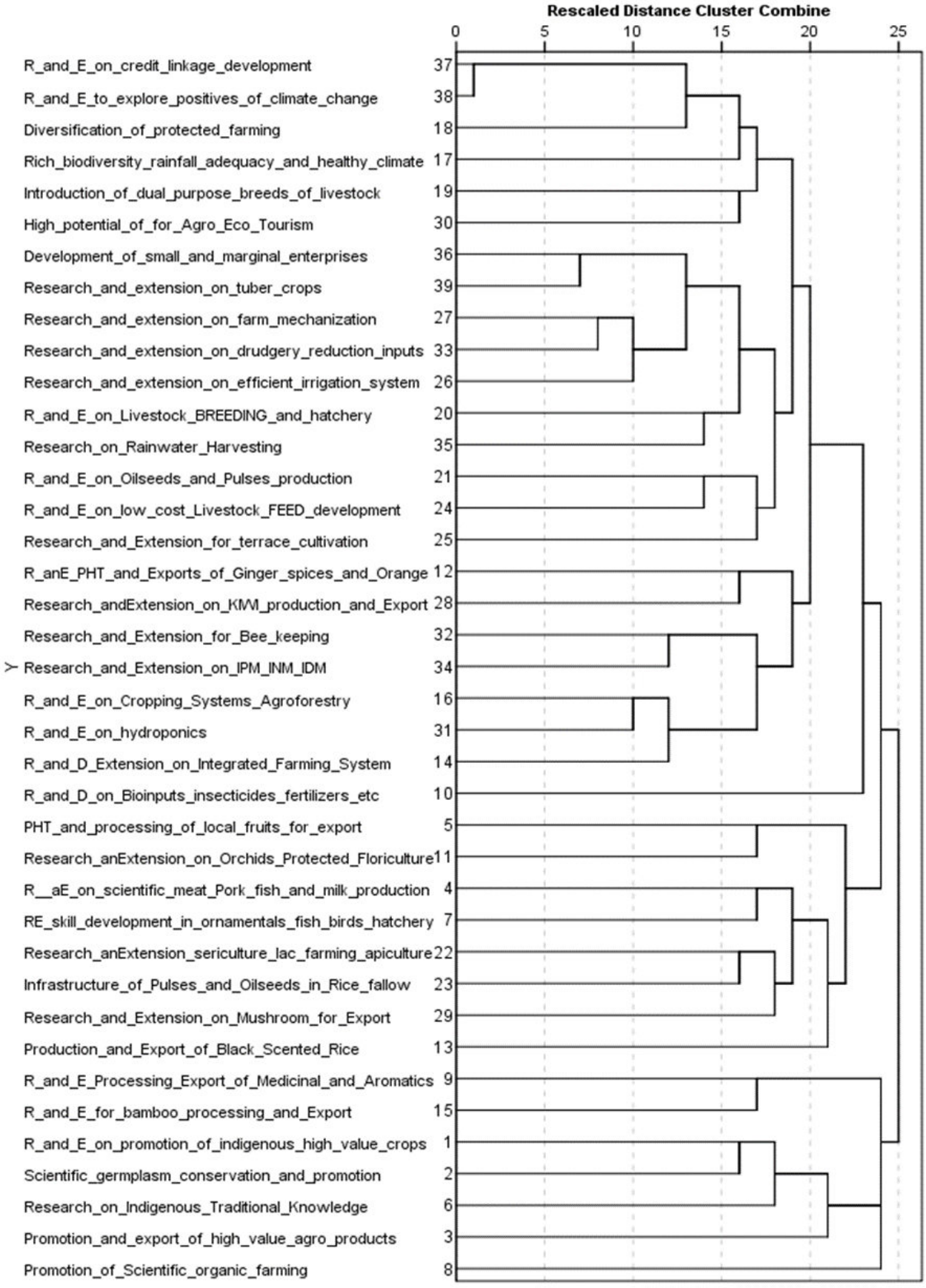

Figure 22. Dendrogram of hierarchical cluster analysis of opportunities of ARES of NER (using average linkage, between groups)

In the third important cluster, research and extension on hydroponics as an opportunity is associated with cropping system and agroforestry research, which is linked with research, extension, and development of Integrated Farming System (Figure 22).

These opportunities are associated with beekeeping in NER that is closely connected with integrated management of insect pests, diseases, and nutrients, which are eco-friendly in general. This entire cluster of opportunities shows a direct association with scientific research, extension, and processing of Ginger, spices, and oranges from NER and kiwi production and export is also linked with it.

Farm mechanization in NER is one of the promising opportunities for NER farming. It shows direct links with drudgery reduction implements and opportunities for an efficient irrigation system. The research and extension on tuber crops are associated with opportunities to develop small and medium enterprises in rural areas of NER. Farm mechanization also exhibits linkages with opportunities that consists of rainwater harvesting, livestock breeding, hatchery development for fisheries, and oilseeds as well as production and small-scale processing of pulses, oil extraction and low-cost feed development for livestock and enables farmers to practice terrace cultivation in hilly areas (Figure 22).

4.3.4 Threats for NERs' agricultural research and extension system

Fifty-six (56) different types of threats are reported from 21 SWOT brainstorming sessions as presented in Table 18. The Dhubri district of Assam reported a maximum number of 21 threats whereas the North Sikkim district of Sikkim state reported six threats Appendix J. On an average, each district reported 14 threats, which may adversely harm ARES of NER.

The outcome of 21 brainstorming sessions highlighted that erratic and untimely rain is the biggest threat to ARES of NER followed by erratic weather aberrations like hailstorms, which destroy standing crop and livestock (Table 18). On the third rank, indiscriminate and unscientific use of agro-chemicals is reported as a critical threat whereas the fourth-ranked threat is an insect, pest and disease outbreaks in NER. Middlemen dominance and illegal trade is a fifth-ranked threat followed by corruption and malpractices. Moreover, as a result, farmers are abandoning agriculture and opting for other jobs which are also rated as a threat to the seventh position. Besides these, illegal and rampant deforestation, massive and recurrent floods,

transboundary livestock diseases, as well as deficits in research and development on market reforms are also communicated as pressing threats (Table 18).

On the 12th position, climate change impacts in the form of global warming is also highlighted as a threat for NER. Nevertheless, from the above mentioned top ten threats, five are directly or indirectly connected with global climate change. Participants of brainstorming sessions also emphasized that illegal natural resource exploitation, natural calamities, no biodiversity conservation, illegal hunting and poaching (Aiyadurai, 2011), slash and burn cultivation, unplanned urbanization, illegal and inappropriate fishing, illegal migration(A. Kumar, 2010), illegal mining of hills and rivers, and changes in seasonal pattern (i.e. monsoon fluctuations) are also noteworthy threats (Table 18).

The thematic grouping of threats is represented in Figure 23, which reveals that most of the threats are arising due to inadequate policy measures on a variety of issues (37). The second category is over-exploitation of natural resources (24) that is prominently responsible for triggering threats in NER. A significant number of threats originate from unscientific farm management practices (16), illegal means of doing business, (14) and unethical practices that are mostly unsustainable. Mismanagement of human resources (12) is also an origin of critical threats, which leads to ineffectiveness and low performance of the system. The threats directly linked to climate-related aspects are comparatively less but are the direct or indirect repercussions of climatic changes (11).

Table 18. Threats reported from the sampled districts of NER

Threats description	Reporting frequency	Thematic grouping
Erratic and untimely rains	22	⊕
Erratic weather aberrations (hailstorms)	18	⊕
Indiscriminate and unscientific use of agro-chemicals	16	⊗⊘
Insect, pest and disease outbreaks	16	⊕⊗⊘
Middleman dominance and illegal trade	15	⊖⊙
Corruption and malpractices	13	⊖⊙⊛
Farmers leaving agriculture (job shift)	11	⊗⊙
Illegal and rampant deforestation	11	⊖⊗⊙
Massive and recurrent floods	11	⊕⊗⊙
Transboundary diseases (livestock)	10	⊖⊙
No research and development on market reforms	9	⊗⊙
Climate change impacts (global warming)	8	⊕⊗⊙
Illegal natural resource exploitation	8	⊕⊗⊘⊙
Natural calamities (earthquake)	8	⊕⊗
No germplasm (biodiversity) conservation	8	⊗⊘⊙

Illegal hunting and poaching	7	⊖⊙
Slash and burn cultivation	7	⊗⊘
Unplanned urbanization	7	⊖⊙
Illegal and inappropriate fishing	6	⊖⊗⊘⊙
Illegal migration (illegal immigrants)	6	⊖⊙
Illegal mining in hills and rivers (coal mining)	6	⊖⊙
Changes in the seasonal pattern (monsoon fluctuations)	5	⊕⊗
Land fragmentation	5	⊙
Soil erosion and degradation due to landslides	5	⊗⊘⊙
Social instabilities and insurgency (extremism)	5	⊗⊛
Futile (zero) quarantine measures on border areas	5	⊙⊛
Intensive cash cropping (ex. Rubber)	4	⊗⊙
Political interference in science	4	⊙⊛
Epidemics in the livestock sector (bird flu, swine flu)	3	⊕⊖⊘⊙
The higher temperature in winter season	3	⊕⊗
Policy apathy towards farmers and agriculture	3	⊙⊛
Unscientific and unhygienic meat production	3	⊘
Drug addiction	2	⊖
Inappropriate talent retention policies	2	⊙⊛
Lack of scientific information among farmers	2	⊙⊛
Pollution and garbage (inadequate waste management)	2	⊗⊙
Rodent outbreak during bamboo flowering	2	⊛
Unethical and exploitative mindset	2	⊖⊙⊛
Wildlife conflict (increasing attacks)	2	⊖⊙⊛
Cellphone radiation from towers	1	⊙
Drying of streams and rivers	1	⊕⊗
Groundwater table depletion	1	⊗⊙⊛
Hydropower projects	1	⊙
Indiscriminate use of artificial insemination (in livestock)	1	⊗⊘⊙
Indiscriminate and unscientific use of plastic	1	⊗⊙
Labor shortages for farming	1	⊗⊙⊛
Inadequate research and development on effective irrigation	1	⊙
Less research and development on water harvesting	1	⊙
Natural enemies of insects (beneficial insects) are vanishing	1	⊗⊘
No or inadequate bio-input support for farmers	1	⊘⊙⊛⊘
Open grazing of livestock (during winter and summer)	1	⊘
Poor nutrition management of infants (livestock)	1	⊘
Population explosion	1	⊖⊙
Wildlife outbreak (Rodents)	1	⊘⊛

⊕ = Climate/weather-related threats, appeared 11 times
⊖ = Threats due to illegal means of business, appeared 14 times
⊗ = Threats due to overexploitation, appeared 24 times
⊘ = Threats due to unscientific farm management, appeared 16 times
⊙ = Threats due to inadequate policy measures, appeared 37 times
⊛ = Threats due to human resource mismanagement issues, appeared 12 times
⊛ = Other threats, appeared 2 times

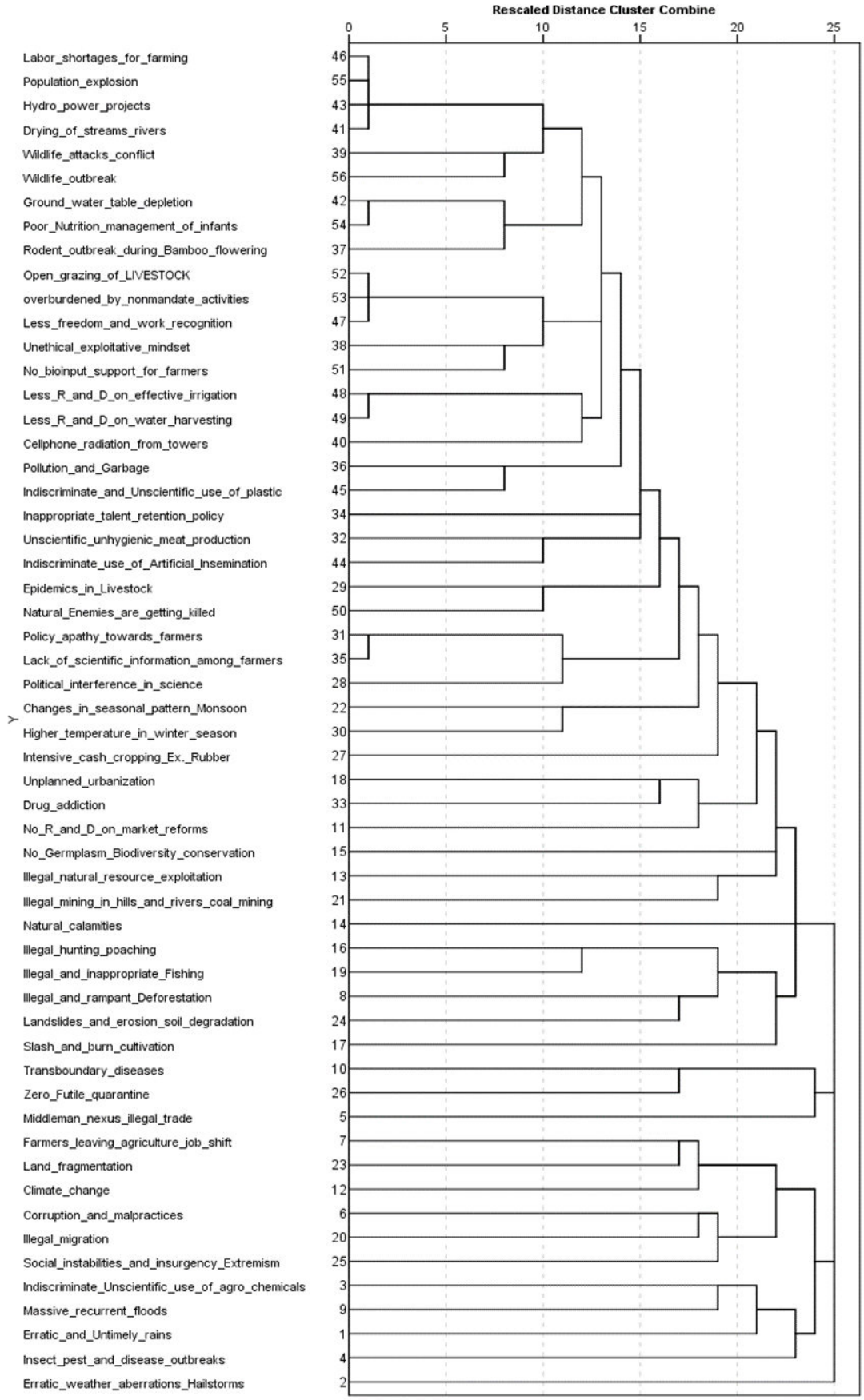

Figure 23. Dendrogram of hierarchical cluster analysis of threats of ARES of NER (using average linkage, between groups)

Figure 23 represents the results of hierarchical clustering of threats reported on ARES of NER and explains the internal connections among them. Erratic weather and aberrations like hailstorms are linked with natural calamities. Insect pest and disease outbreaks in NER show a direct link with (i) indiscriminate and unscientific use of agro-chemicals, (ii) erratic and untimely rains, and (iii) massive recurrent floods. Cross-border illegal migration is connected with corruption and malpractices, which is linked to social instability and insurgency in the NER. Another group directly connected with this cluster reveals that climate change and land fragmentation are key factors, which force farmers to leave farming and shift towards other livelihood options.

Similarly, futile quarantine measures are linked with transboundary diseases that are enhanced by illegal trade practices used by middlemen for quick profits. Another prominent cluster in Figure 23 discloses that slash and burn cultivation is associated with (i) illegal and inappropriate fishing linked with illegal hunting of wildlife animals, and (ii) illegal and rampant deforestation linked with landslides, soil erosion as well as soil degradation. Also, illegal mining in river valleys and illegal coal mining that is connected with illegal natural resource exploitation exhibits close links with loss of biodiversity as it contributes to the failure of conservation measures.

Policy apathy towards farmers and agriculture is associated with the deficiency of scientific information among farmers, which is a major cause of threats arising from mismanagement of farms. For example, unscientific meat production is linked with the indiscriminate use of artificial insemination among livestock. Similarly, pollution and massive garbage production show a direct connection with indiscriminate and unscientific use of plastic products in the agricultural sector (Figure 23). Threats like this are occurring due to the unawareness among farming communities regarding overuse of agriculture-related inputs. Concerning human resource in NER, it is notable that less freedom of work and recognition for work is associated with continued work pressure arising from non-mandated activities. These issues are linked with an unethical and exploitative mindset of some of the managers in the system. The exploitation of the scientific workforce is a matter of concern, which impedes quality work directly beneficial to farmers and society.

Farmers of NER are increasingly facing a menace of wildlife conflicts (A. Choudhury, 2004). Figure 23 also reveals that wildlife attacks, wildlife conflicts, and outbreaks are associated with hydropower projects, drying of streams, population explosion and depletion of the groundwater

table. In addition, a threat of labor shortage for farming is also closely associated with this cluster.

4.3.5 Implications of brainstorming on strengths, weaknesses, opportunities, and threats for policymaking to promote resilience

Brainstorming sessions enabled researchers to systematically introspect crucial internal factors (strengths and weaknesses) as well as external factors (opportunities and threats) to formulate policies that promote climate resilience. The outcomes of this study are foundation for further research to explore strategies to mitigate the adverse impacts of climate change in NER.

The exploration of information in the four quadrants of the SWOT framework provided a thoughtful guideline to all participants. Many participants of brainstorming sessions were surprised to see the results which had an eye opener effect on groups as it was the result of a goal-oriented dialogue. The outcomes of brainstorming sessions are presented in a district-wise as well as consolidated manner, which enables participants as well as planners to formulate appropriate action plans for effective system management.

Moreover, the thematic grouping of SWOT constituents provides a clear view and understanding of grouping of particular items. It is evident from Table 15 and Table 16 that the majority of strengths and weaknesses of ARES of NER arise from the organizational management. It reveals that there is a need to correct the internal organizational governance, which has a considerable potential to resolve the weaknesses arising from the mismanagement of human resource. Table 17 shows that agricultural research and extension activism is strongly linked with income enhancing opportunities, germplasm conservation opportunities, and food processing opportunities. Likewise, Table 18 provides evidence that policy inadequacy has direct linkages with external threats arising from illegal means of business, overexploitation of natural resources and unscientific farm management. So there is an urgent need to customize agricultural sector policies and policies to streamline organizational management.

Similarly, much valuable information is revealed by cluster analysis of SWOT quadrants. It interprets the interconnections of data nodes in the form of Dendrogram that is much easier to understand. The Dendrogram assist researchers to understand the relationship between two factors and yield new perspectives that can help planners to make appropriate decisions. Concisely, this approach facilitates decision making to correct the course of action rather than the mere faultfinding.

4.3.6 Strategies for Agricultural Research and Extension System to minimize the impacts of climate change

This section provides the brief account of strategy formulation approach to deal with the adverse impacts of climate change for NER, using SWOT matrix. In this section, results of internal factor evaluation matrix and external factor evaluation matrix, and SPACE matrix are provided to formulate appropriate strategies for ARES of NER.

Table 19. Districts sampled for SWOT exercise from NER along with the computed external and internal factor score.

	District sampled for SWOT	External factor score	Internal factor score	Inference
1.	Aizwal	2.63	1.72	More opportunities[1] + Lesser strengths[2]
2.	Bongaigaon	2.20	1.98	Lesser opportunities[3] + Lesser strengths
3.	Chirang	2.85	2.26	More opportunities + Lesser strengths
4.	Dhemaji	2.36	1.96	Lesser opportunities + Lesser strengths
5.	Dhubri	2.30	2.01	Lesser opportunities + Lesser strengths
6.	Dibrugarh	2.24	1.95	Lesser opportunities + Lesser strengths
7.	East Sinag	2.67	2.47	More opportunities + Lesser strengths
8.	Jaintia Hills	2.47	2.53	Lesser opportunities + More strengths[4]
9.	Kokrajhar	2.81	3.00	More opportunities + More strengths
10.	Lakhimpur	2.81	2.82	More opportunities + More strengths
11.	Lower Dibang Valley	2.56	2.55	More opportunities + More strengths
12.	Lower Subansiri	2.31	2.05	Lesser opportunities + Lesser strengths
13.	Lunglei	2.58	2.21	More opportunities + Lesser strengths
14.	North Sikkim	2.27	2.31	Lesser opportunities + Lesser strengths
15.	North Tripura	2.41	2.59	Lesser opportunities + More strengths
16.	Papumpare	2.45	2.33	Lesser opportunities + Lesser strengths
17.	Senapati	2.67	2.56	More opportunities + More strengths
18.	Serchhip	2.28	2.49	Lesser opportunities + Lesser strengths
19.	South Sikkim	2.61	2.65	More opportunities + More strengths
20.	Thoubal	2.59	2.19	More opportunities + Lesser strengths
21.	West Khasi Hills	2.36	2.33	Lesser opportunities + Lesser strengths

[1] More opportunities imply that external threats are comparatively lesser
[2] Lesser strengths imply that internal weaknesses are comparatively more
[3] Lesser opportunities imply that external threats are comparatively more
[4] More strengths imply that internal weaknesses are comparatively lesser

4.3.6.1 Analysis of internal and external factor scores for sampled 21 districts

The internal and external factor scores for each district were calculated separately using the predetermined rules, and are presented in Table 19. The internal factor scores and external

factor scores were plotted against SPACE matrix to find out an appropriate strategy for each district. The SPACE matrix generated for 21 sampled districts, on the basis of internal and external factor score is illustrated in Figure 24 that indicates an appropriate strategy quadrant for each district.

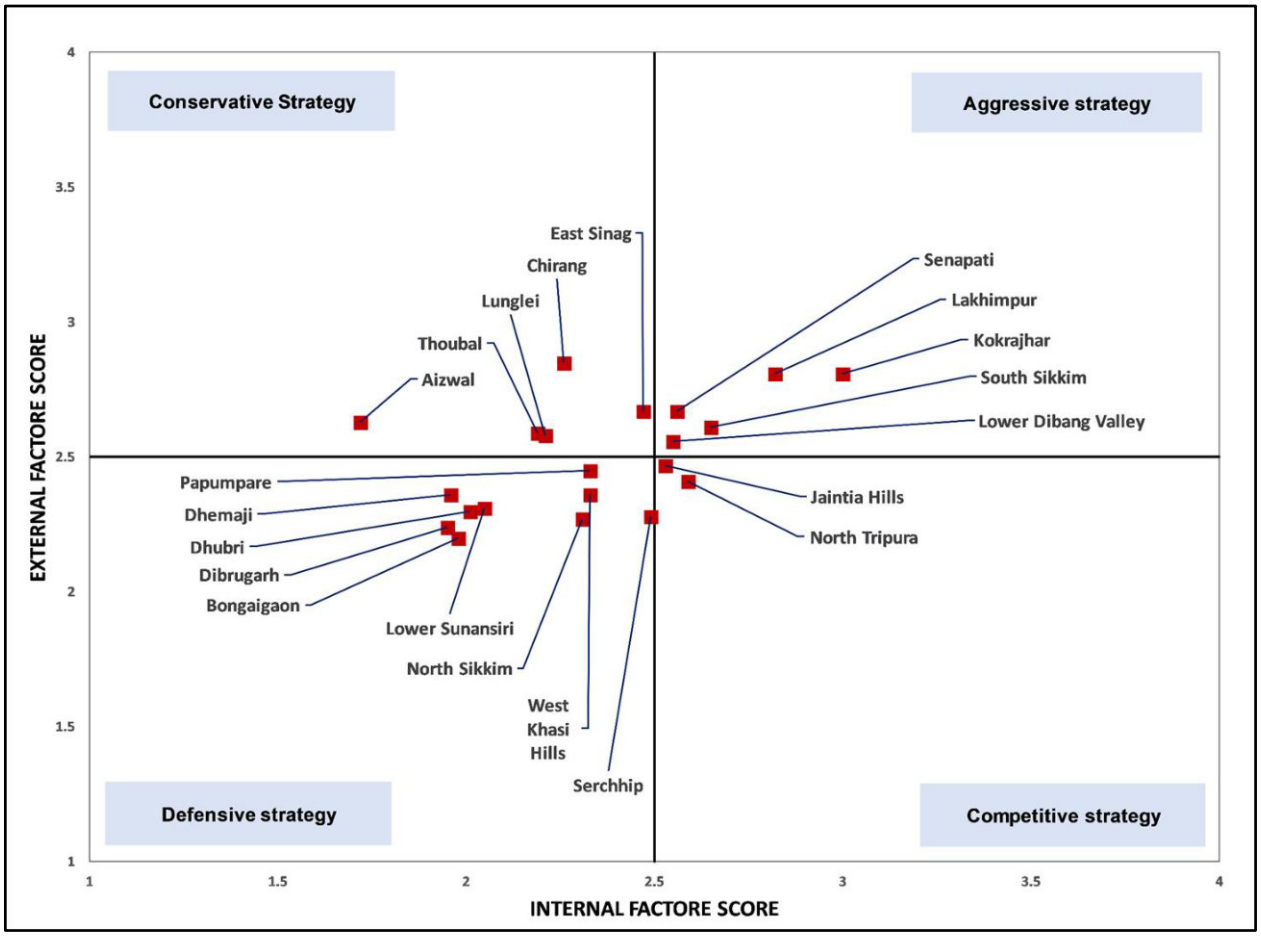

Figure 24. SPACE matrix indicating the sampled NER districts into various strategy quadrants, based on the external and internal factor scores.

Figure 24 indicates that one single strategy will not work out for all districts of NER to enhance the resilience against climate change. Out of 21 sampled districts, nine (43 percent) districts are advised to adopt defensive strategy as internal weaknesses, and external threats hinder the performance of overall ARES. Conservative strategy is suitable and recommended for five (24 percent) districts as external opportunities can be used there to minimize internal weaknesses. For another five (24 percent) districts, an aggressive strategy is suggested as the internal strengths, and external opportunities are in dominant position. Only two (10 percent) districts, Jaintia Hills, and North Tripura are recommended for a competitive strategy as internal strengths of ARES can be used to overcome external threats. The policy recommendations for all four types of strategies are discussed below.

4.3.6.2 A defensive strategy for ARES of NER

Defensive strategy is recommended for so-called worst-case scenario wherein external threats and internal weaknesses exceedingly hamper the performance of organization or systems. The defensive strategy for ARES operational in nine districts aims to cover up internal weaknesses and avoid external threats. As the majority of internal weaknesses are associated with policies related to the agricultural sector as well as organizational management, most of the defensive strategies attempt to recommend managerial measures to deal with threats like erratic weather aberrations, indiscriminate use of chemicals in farming, and outbreaks of crop disease as well as frequent insect-pest attacks. The defensive strategies for ARES of NER are presented in Table 20.

Table 20. Defensive strategies for ARES to minimize threats and weaknesses

1.	Recruiting more number of scientific staff with skills and efficiency to manage the adversities of erratic weather aberrations, and to provide the highest possible safety and security of agricultural produce, livestock, infrastructure, etc. (W1, W2, W36, W40 + T1, T2, T9, T12, T14, T22, T24, T30, T8)
2.	Systematic research and development of climate-resilient technologies that require less or no agro-chemicals, and are eco-friendly to use in the farm. (W2, W4, W13, W21, W39 + T3, T8, T30, T49, T50)
3.	Network projects for real-time surveillance and management of insect-pests outbreaks, disease outbreaks and facilitates quarantine with stricter supervision. (W26, W27, W30, W39 + T4, T10, T26, T29, T32, T35, T49, T51)
4.	Empowerment of farming communities with market reforms and infrastructural support that eliminates intermediaries (middlemen) as well as illegal trade. (W12, W14, W19, W21, W27, W32, W34 + T5, T6, T7, T8, T11, T16, T19, T23, T31, T38, T42, T44, T45, T46, T47, T50)
5.	Formulation of organizational norms and policies that allocate 80 % of (researcher or extension professionals') time for research, extension and other welfare activities in collaboration with farmers, and only 20 % for reporting activities. (W6, W9, W10, W11, W12, W13, W14, W15, W16, W17, W22, W23, W25, W28, W29, W30, W31, W34, W35, W38 + TT11, T15, T17, T28, T31, T34, T35, T44, T47, T48, T50, T52)
6.	Digitized money/finance management system for all kinds of staff that ensures transparency and fair utilization of public money and allows direct transfer of benefits to the beneficiaries (i.e., farmers). (W3, W5, W8, W9, W14, W18, W33, W38 + T5, T6, T31, T34)
7.	Reforms to recruit and manage the human resource to promote research aptitude, sustainable thinking as well as actions, accountability, and professionalism in overall system (unlike current recruitment approach, which profoundly relies on the academic performance of candidate). (W1, W2, W3, W6, W8, W9, W10, W11, W12, W13, W14, W16, W17, W18, W22, W26, W27, W29, W37, W41, W42 + T3, T12, T18, T27, T28, T30, T31, T34, T39, T44, T45, T46, T52, T53, T54)

8.	Installing a *high-power strategic surveillance system* to curtail illegal exploitation of natural as well as human resources, and fosters sustainable and ethical performance in the system (and society). (W9, W10, W11, W14, W16, W23, W27 + T3, T5, T6, T7, T8, T13, T15, 17, T18, T19, T20, T21, T25, T27, T37, T40, T41, T43, T45, T54)
9.	Enhanced funding provisions for research and extension via ARES to actively engage with farmers and fulfill their tangible technological needs. (W1, W2, W3, W5, W7, W8, W17, W18, W21, W23, W25, W29, W31, W38, W40 + T11, T17, T31, T34, T35, T38, T45, T46, T47, T50)
10.	Reinforcement of professional and commercial aptitude among the ARES stakeholders to enhance the autonomous resource generation and utilization for the welfare of farming communities (W1, W4, W5, W6, W7, W8, W11, W12, W13, W14, W15, W20, W22, W34, W37 + T3, T5, T6, T7, T11, T31, T35, T50
11.	Mainstreaming of ARES professionals (stakeholders) with greater authority, autonomy and operational power to perform in bureaucratic setup. (W1, W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W14, W16, W17, W18, W20, W22, W24, W29, W32, W37 + T5, T6, T11, T13, T16, T17, T18, T19, T20, T21, T25, T26, T28, T31, T32, T34, T35, T36, T38, T44, T45, T50, T53)

These strategies primarily emphasize correcting internal weaknesses with policy reforms and call for adequate funding to implement projects that would effectively manage external threats.

4.3.6.3 Conservative strategy for ARES of NER

The conservative strategies are recommended for scenario wherein a particular system/organization has numerous external opportunities and plans to use them to reduce internal weaknesses. India is one of the biggest food markets in the world that has diverse requirements throughout the year. Considering the present state of people's awareness of healthy diet and food consumption pattern, demand for exotic, organic and indigenously grown food is continuously increasing. The agricultural sector of NER has potential to harness these opportunities by providing a plethora of indigenous high-value crops, agricultural products, non-timber forest products, fruits, flowers, spices, medicine compounds, essential oils, and similar products. Further, the ARES of NER can utilize this opportunities to build up their strengths. The conservative strategies to eliminate internal weaknesses and harness external opportunities are illustrated in Table 21. These recommendations apply to five NER districts namely Aizwal, Thoubal, Lunglei, Chirang, and East Siang.

Table 21. Conservative strategies for ARES to minimize weaknesses and maximize opportunities

1.	Comprehensive policy reforms, which endorses pro-activeness, creativity, minimal bureaucracy and resource generation autonomy in the system to attract and retain talent (human resource). (W1, W3, W5, W6, W7, W8, W9, W10, W11, W16, W17, W18, W22, W23, W26, W27, W29, W30, W32, W38 + O1, O3, O4, O5, O6, O7, O8, O9, O10, O11, O12, 13, O15, O21, O22)
2.	Policy reforms to minimize bureaucracy from science and promoting technocracy in ARES (W1, W3, W5, W6, W7, W8, W9, W10, W11, W16, W17, W18, W22, W23, W27, W29, W33, W34, W37 + O1, O2, O3 ,O4, O5, O6, O7, O9, O10, O11, O12, O15, O20, O21, O22, O23, O26, O27, O28, O30, O35, O37)
3.	National and state-wise agriculture policy formulation that promotes climate resilience (at all levels) and use of bio-inputs for farming in NER (W2, W3, W4, W5, W6, W7, W8, W9, W10, W11, W12, W13, W14, W15, W19, W21, W25, W27, W28, W30, W31, W36, W39, W40, W41 + O1, O2, O3, O4, O5, O6, O7, O9, O10, O11, O12, O13, O14, O15, O16, O17, O18, O19, O20, O21, O22, O23, O26, O27, O28, O30, O32, O33, O35, O37)
4.	Implementation of e-market to eradicate malpractices from the sale of agricultural produce (W7, W8, W12, W15, W19, W20, W21, W22, W26, W42+ O1, O3, O4, O5, O7, O9, O11, O12, O15, O22, O28, O29, O31, O32, O39)
5.	Uniformity and streamlining of training policy for scientific and technical human resource in ARES (W2, W4, W6, W11, W13, W15, W17, W18, W22, W24, W26, W27, W34, W35, W39 + O1, O2, O3, O4, O5, O6, O7, O9, O10, O11, O12, O14, O15, O16, O20, O22, O24, O31, O33, O34, O35, O36)
6.	Review and customization of existing research and extension policy to promote sustainable farming (W1, W2, W4, W5, W6, W7, W9, W10, W11, W12, W13, W14, W15, W16, W18, W22, W23, W24, W25, W26, W27, W34, W35 + O1, O2, O5, O6, O8, O9, O10, O11, O14, O16, O17, O18, O25, O26, O30, O32, O34, O35, O38)
7.	Use of Research and extension opportunities to establish commercial clusters of food processing and certification by stakeholders of ARES (W1, W3, W5, W7, W8, W9, W11, W13, W25, W31, W39 + O1, O3, O4, O5, O6, O8, O9, O12, O13, O15, O22, O24)
8.	Conducting work distribution exercises for a human resource of ARES to allocate more amount of time for agricultural welfare and promoting self-accountability (W1, W6, W9, W10, W11, W12, W16, W17, W22 + O6, O8, O14, O16, O25, O36, O37, O38, O39)
9.	More fund allocation to ARES with enhanced autonomy (freedom) to carry out research and extension work along-with optimum logistic support (W1, W3, W5, W6, W7, W8, W20, W33 + O1, O3, O6, O8, O9, O14, O16, O19, O25, O34, O35, O39)
10.	Advisory services with added responsibility to provide quality inputs to farmers (W1, W2, W3, W5, W8, W9, W10, W11, W13, W14, W18, W16, W20, W26, W31, W34, W35 + O3, O4, O5, O7, O9, O10, O22, O23, O24, O26, O31, O32, O33, O36)
11.	Projects for rainwater harvesting and enhancing irrigation potential in NER (W2, W7, W8, W12, W15, W35 + O3, O4, O5, O7, O9, O14, O16, O17, O26, O27, O31, O33, O35)

4.3.6.4 Aggressive strategy for ARES of NER

The aggressive strategy is recommended in a scenario wherein internal factors, and external opportunities are equally dominant. It is considered the most favorable setting for system/organizational performance. It allows internal strengths to exploit external opportunities for maximum expansion and development, as it is easy to deal with internal weaknesses as well as external threats if any.

Table 22. Aggressive strategies to fully utilize strengths and opportunities by expanding business activities

1.	Flagship programs to boost the cultivation and production of high-value indigenous crops (O1, O5, O9, O11, O12, O13, O15, O28, O29 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S15, S20)
2.	Focused research projects for germplasm conservation and upgradation (O2, O6, O9, O11, O13, O15, O39 + S1, S2, S5, S6, S8, S9, S12, S14, S35, S38, S41)
3.	Development of strategic agro-processing and export promotion hubs at various locations across NER (O1, O2, O3, O4, O5, O7, O8, O9, O11, O13, O15, O22, O29, O30 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S14, S15, S26, S27, S30, S35, S36)
4.	Development of state-of-art non-vegetarian food production, processing, marketing clusters in NER (O3, O4, O7, O8, O17, O19, O22, O30, O36 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S15, S19, S20, S21, S23, S36)
5.	Development of feed industries for livestock and fisheries sector of NER (O2, O3, O4, O5, O6, O7, O8, O9, O10, O14, O15, O16, O17, O18, O19, O20, O21, O22, O23, O24, O25, O26, O27, O34, O36, O37, O39 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S27, S31, S37)
6.	Research and development on bio-inputs to complement organic farming in NER (O2, O5, O6, O8, O9, O10, O14, O16, O17, O18, O34, O37 + S1, S2, S3, S4, S5, S7, S9, S11, S12, S14, S15, S16, S17, S18, S19, S21, S24, S26, S27, S30, S31, S36, S39)
7.	Research, validation, and standardization of Indigenous traditional Knowledge to promote sustainable farming across NER (O1, O2, O6, O9, O10, O11, O12, O14, O16, O24, O29, O31, O32, O39 + S2, S4, S5, S6, S7, S8, S9, S10, S11, S12, S14, S15, S16, S17, S18, S28, S30, S33, S36, S38)
8.	Development of climate-resilient Integrated Farming System models with organic farming packages (O2, O3, O4, O5, O6, O7, O8, O9, O10, O11, O12, O14, O15, O16, O17, O18, O19, O20, O21, O22, O23, O24, O25, O26, O27, O28, O29, O30, O31, O32, O34, O37, O39 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S23, S25, S26, S27, S29, S30, S31, S35, S38)
9.	Digitized marketing platforms to connect farmer with input markets and consumers (O1, O3, O4, O5, O7, O8, O9, O10, O11, O12, O13, O22, O28, O29, O30, O32, O39 + S1, S3, S6, S7, S8, S9, S10, S11, S12, S13, S15, S16, S19, S22, S23, S24, S25, S26, S27, S29, S30, S31, S32, S34, S35, S36, S37, S38, S40, S41)
10.	Develop spice production, processing and export hubs in NER, in partnership with farmers (O1, O3, O5, O6, O8, O9, O10, O12, O14, O16, O17, O18, O25, O26, O30, O33, O35, O37 + S1, S2, S3, S4, S5, S6, S7, S8, S9, S10, S11, S12, S13, S14, S15, S16, S19, S20, S21, S23, S26, S27, S29, S33, S35, S37, S38)

The aggressive strategies for five districts of NER (namely Senapati, Lakhimpur, Kokrajhar, South Sikkim and Lower Dibang Valley), are presented in Table 22. These strategies allow ARES to take up strategic initiatives to boost the production of high-value crops, their processing, systematic marketing and export to harness maximum profits.

4.3.6.5 Competitive strategy for ARES of NER

The competitive strategies are recommended for those who have adequate internal strengths to beat down external threats. In this scenario, the dominant strengths of system/organization are utilized to take competitive actions that facilitate continuous growth. Diversification is wieldy followed in this strategy quadrant to harness competitive advantages.

Competitive strategies are found suitable for two districts in NER namely Jaintia Hills and North Tripura, are listed in Table 23. These recommendations are based on strengths such as institutional collaborations, use of ICTs in ARES, technology customization, technical knowledge and dedicated farmer-friendly approach of the system to beat down external threats. The strategies emphasize on enhancing climate resilience, use of organic agricultural inputs, farmers' empowerment, community management approaches for agro-forestry, market reforms, greater funding for the agricultural sector and stricter laws to beat down illegal trade.

However, these strategies are not perpetual solutions as they are based on data collected during the year 2017-18 but are foundations to encourage a climate-resilience approach in the agricultural sector. Therefore, speedy implementation is indispensable to deal with contemporary weaknesses and external threats, which are highly dynamic and often keep changing with time. In long-term, time-to-time research studies are recommended to customize or relate these strategies with appropriate ones that would match with contemporary needs of the system. Further, the external factors (i.e., opportunities and threats) are also dynamic and keep changing constantly. Therefore, policymakers and managers while implementing these strategies must consider the coexistent state of external factors for appropriate decision-making.

Table 23. Competitive strategies to minimize threats using the internal strengths of ARES

1.	Development and promotion of climate-resilient crop varieties and livestock breeds (S1, S2, S3, S4, S6, S7, S10, S11, S12, S16, S18, S21, S30, S31, S36, S37 + T4, T7, T10, T12, T22)
2.	Boosting protected cultivation set up along with necessary facilities to enhance resilience (S1, S4, S7, S11, S14, S17, S19, S25, S27, S30, S31, S35, S36, S37, S38, S41 + T1, T2, T3, T4, T7, T8, T12, T17, T22, T23, T30, T31, T35, T39, T45, T51)
3.	Promotion of chemical-free farming and emphasis of research and extension on organic production (S1, S2, S3, S4, S5, S7, S8, S9, S14, S15, S16, S18, S20, S23, S27, S32, S38, S39 + T3, T5, T11, T19, T23, T27, T31, T35, T45, T49, T50)
4.	Empowering farmers to use the eco-friendly bio-inputs as well as integrated disease and pest management technologies (S1, S2, S3, S4, S5, S7, S8, S9, S11, S12, S15, S16, S17, S18, S26, S27, S39 + T4, T5, T6, T10, T15, T17, T26, T29, T31, T35, T36, T44, T45, T47, T48, T49, T50)
5.	Market reforms to enhance farmers income and to ensure transparency of business (S1, S3, S6, S8, S13, S19, S22, S23, S25, S26, S27, S29, S32, S34, S35, S36 + T3, T5, T6, T7, T8, T11, T16, T31, T32, T36)
6.	Special schemes (such as doubling farmers' income) and technology packages to retain farmers in the agricultural sector (S1, S3, S4, S5, S6, S7, S16, S17, S18, S22, S26, S27, S28, S30, S31, S33, S35, S36 + T5, T6, T7, T8, T11, T13, T16, T17, T19, T27, T31, T33, T46)
7.	Incentives and rewards for afforestation and community agro-forestry, sustainable forest management, and similar initiatives (S1, S3, S6, S8, S10, S12, S19, S23, S24, S29, S34, S35, S36, S38 + T8, T12, T13, T15, T16, T17, T18, T21, T24, T27, T37, T38, T39, T41, T42, T43, T54)
8.	Awareness campaigns, vaccination camps, and similar programs to reduce disease outbreak among cattle, livestock, and allied ventures. (S1, S3, S6, S8, S10, S13, S21, S23, S25, S26, S27, S40 + T3, T4, T5, T6, T10, T16, T26, T31, T32, T49, T29)
9.	Policy measures and framing stricter laws/regulations to eliminate illegality in trade, resource exploitation, hunting and fishing from NER (S1, S3, S6, S8, S10, S12, S13, S16, S17, S19, S22, S23, S25, S27, S29 + T3, T5, T6, T8, T10, T13, T16, T18, T19, T20, T21, T25, T35, T38, T40, T53)
10.	Provision for responsive disaster management by ARES to minimize agricultural loss/damages (S1, S3, S4, S6, S7, S8, S10, S11, S12, S13, S16, S17, S21, S22, S27, S29, S30 + T1, T2, T9, T14, T22, T24, T39)
11.	Enhancing legislative provisions and political commitments towards sustainable organic farming in NER (S1, S3, S5, S7, S9, S11, S12, S14, S15, S17, S23, S27, S30, S35, S36 + T3, T7, T8, T11, T12, T15, T17, T22, T28, T31, T34, T35, T41, T42, T43, T45, T47, T48, T52, T53)

4.4 Conclusion

Participants reported more quantity of potential opportunities than threats and more weaknesses than strengths. This implies that the correction of internal weaknesses can give an

edge to ARES of NER to deal with emerging challenges and harnesses potential opportunities in the best possible manner. Institutional collaborations, rich biodiversity of NER, use of social media and ICTs for extension services, the expertise of technology refinement and customization are most prominent internal strengths of ARES of NER. The abundance of natural resources, farmer-friendly approaches of extension services, technical knowledge credibility of the workforce and cooperative stakeholders are salient strengths of ARES of NER which has the potential to transform socio-economic scenarios of NER.

However, most of the internal weaknesses are arising from organizational management, policy-related issues, and mismanagement of human resource. The inadequate staff for research and extension, policies that are not sensitive towards farmers and farming in a climate change scenario, inadequate and untimely funding, complex bureaucratic fund utilization procedures, shortage of location-specific technologies and poor logistic support for research as well as extension work are fundamental weaknesses. Most of the reported weaknesses demand immediate interventions to streamline human resource management policies, infrastructure development, timely supply of quality inputs for research, work distribution and minimization of reporting as well as non-mandated work activities.

Participants of brainstorming sessions reported a variety of potential opportunities, and it is evident that NER still holds a tremendous potential to foster socio-economic development by optimal utilization of natural resource endowments. Most of the research development activities are directly linked with the enhancement of economic benefits to farmers as well as the conservation of biodiversity. Scientific promotion of indigenous high-value crops, germplasm conservation and upgradation, export of high-value agricultural products, scientific livestock farming for milk, pork, meat production and value addition and food processing are key opportunities to spread across all the agro-climatic zones of NER. Research on indigenous traditional knowledge and scientific organic farming along with the development of bio-inputs holds immense opportunities for developing sustainable farming scenarios.

However, participants also explored a significant number of threats, which are originating from inadequate policy measures that diminish illegal means of business, overexploitation of natural resources and mismanagement of human resources. Conversely, the most reported threats are closely associated with the climatic changes observed in NER. Erratic and untimely rains, erratic weather aberrations like hailstorms, indiscriminate use of agro-chemicals, frequent outbreaks

of insect pests as well as diseases and dominance of illegal trade practices among middlemen are the vital threats reported from almost all districts of NER. The reporting frequency of some of the threats is lesser but conveys alarming trend of irreversible damage. For example, farmers abandoning farming, illegal deforestation, transboundary diseases, no market reforms, illegal natural resource exploitation, illegal hunting, and poaching, etc. are severe threats to the agro-ecosystem of entire NER.

The threats and weaknesses together have the potential to create disruptive implications for the sustainability of NER. The ARES, at all levels, shall undertake the corrective measures to recognize the strengths and to undertake research and development projects that can harness the dormant opportunities. The corrective measures must begin with the formulation of policies that are considerate about farmers, farming of NER and promote climate resilience throughout the region. Most importantly, effective interventions are required to encourage productivity of available human resources associated with ARES of NER. The uniformity and clarity of rules and regulations concerning human resources are essential to provide a level playing field for achieving optimum performance of a system. The systematic and effective awareness creation among farmers is highly advocated to tackle the menace of indiscriminate use of agro-inputs and over-exploitation of natural resource endowments. The clustering of SWOT components depicts the association and interlinking of various threats and weaknesses. This information needs to be utilized to design strategies that tackle multiple weaknesses and threats simultaneously.

Furthermore, the strategy formulation approach demonstrated (using internal and external factor evaluation matrix) that defensive strategies need to be implemented profoundly, as ARES in most of the districts exhibits dominant internal weaknesses along with greater external threats. The recommended strategies are of great importance and relevance as they pave the way for climate-resilient development of the agricultural sector. The speedy implementation of appropriate recommendations (or a combination of appropriate recommendations) at all managerial levels is highly advocated as they (strategy recommendations) are subject to the dynamics of timescale, and interplay of internal as well as external factors. Further, a systematic SWOT assessment of all districts in NER, at regular intervals by inviting stakeholder from all concerned departments and organizations, is advocated in future to recommend time and location-specific strategies.

In conclusion, the foremost step would be to adopt corrective measures to reduce internal weaknesses of system/organization as they are factors for dissatisfaction (Herzberg, 1966). Inappropriate policies for the agricultural sector, inadequate funding, inadequate logistic support, excessive reporting, and prevalence of complex bureaucracy in science organizations is not only hampering the performance of technocrats but also diminishing the utility of science for society. The system/organization, at all levels, must undertake corrective measures to minimize the bureaucracy in science and facilitate performance of employees by creating a conducive environment. The work allotment to scientific and technical personnel has to be made based on employees' talent as well as ability. Organization/system has to take firm steps to enhance the satisfaction among all employees by offering them equal opportunities for growth, due recognition to the contribution of employees, additional incentives to performers, developing a sense of achievement among employees, and creating an organizational culture of dignity as well as mutual respect. According to Herzberg (1966), the system/organization cannot fully motivate its employees until and unless it eliminates the causes of dissatisfaction and creates conditions for satisfaction.

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Chapter 5: Climate change adaptation strategies for the Northeastern region of India: Insights from a Delphi experiment

Abstract

Socio-economic conditions in the Northeastern region of India (NER) are poor, as a majority of rural inhabitants rely on low-input, low-output subsistence farming. The region is further threatened by the negative impacts of climate change, such as frequent floodings and droughts, which is why strategies to combat these threats are urgently needed. In this study, we identify the most urgent challenges and the most relevant strategy options to combat these challenges by surveying multidisciplinary agricultural experts from the region using the Delphi method. In a Delphi survey, participants pass through several rounds, beginning with brainstorming, followed by a narrowing-down phase and culminating in ranking and consensus forming. The results of the survey show that changes in climate have already adversely affected farming, livelihoods, and sustainability in NER. Organic farming, conservation, efficient irrigation and scientific approaches to farming, such as integrated farming systems, are the most recurring and plausible strategies to combat the challenges identified by the experts. This study is the first to systematically compile the perspectives of multidisciplinary and multi-strata experts on key issues in NER, thus providing a reliable foundation for future policy formulations.

Keywords: Adaptation strategies, Delphi consensus, Delphi forecast, investment priorities, strategy options

5.1 Introduction

The Northeastern region of India (NER) consists of eight states namely Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, and Sikkim (stretched across 89°42'E to 97°25'E longitude and 22°N to 29°25'N latitude) and is dominated by a tribal population (Figure 25). Agriculture forms the main source of income across the region (Nair et al., 2013). Hilly agriculture of NER is typically performed in shifting cultivation patterns of slash and burn farming (Shimrah, Rao, & Saxena, 2015). Due to the extensive dependency on farming, a large section of society remains marginal in terms of socio-economic development (Amoako Johnson & Hutton, 2014). Furthermore, intensive shifting cultivation practices and high demand for agricultural goods due to population pressure have led to significant deforestation (Raman,

2001) and degradation of local biodiversity (Ravindranath et al., 2011; Venkataraman & Sivaperuman, 2018). In addition, both native habitats and agricultural areas of NER are affected by climate change. The Brahmaputra valley, the most fertile rice cultivation belt of NER, experiences frequent floods(Mandal, 2014), crops are damaged due to hailstorms (Chattopadhyay, Devi, John, & Choudhari, 2017) or droughts(Parida & Oinam, 2015), hilly terrains are experiencing fluctuations in the monsoon cycle, and cloudbursts, flash floods (Maiti et al., 2017) and landslides (R. Pal, Biswas, Mondal, & Pramanik, 2016) are reported across NER.

Figure 25. Map of India and the eight Northeastern states (NER), for which the Delphi survey was conducted (Avishek, 2014; GADM, 2015).

The severity, frequency, and duration of these types of adverse impacts have generally increased, and climate change now poses a severe threat to human settlements and the remaining native ecosystems across the region (D. Das, 2016; Duncan et al., 2016; Parida & Oinam, 2015; Ravindranath et al., 2011; U. Sharma & Sharma, 2005; Soora et al., 2013). To mitigate the impacts of climate change in NER and to secure the livelihoods of the already poverty-stricken indigenous farming communities, diversified adaptation strategies are needed (Barua et al., 2014) along with policies to support their adoption.

Many previous studies from India and adjoining countries have explored diverse agricultural adaptation options to climate change, mainly focusing on technical opportunities or economic potentials. Vishnu Prasanth et al. (2017) stressed the need for heat tolerant varieties of rice, and Deb and Babel (2016) suggested composite varieties for sustainable production. Others emphasized diversification as a mitigation and adaptation strategy (Ingty, 2017; Nischalke, 2015; Panda & Singh, 2016; Sati & Vangchhia, 2017; R. K. Singh et al., 2017), or suggested agroforestry as a strategy for sustainable livelihoods and socio-economic development in NER (Afreen, Sharma, Chaturvedi, Gopalakrishnan, & Ravindranath, 2011; Debbarma, Taran, & Deb, 2015; Mait et al., 2016; S. Nath et al., 2015; M. H. Rahman & Alam, 2016; G. Sharma & Sharma, 2017). Most of these studies focus on specific crops or commodities and do not explicitly involve stakeholders, whose involvement is key to the formulation of effective adaptation strategies and policy development, as the adoption of strategies depends on community-level initiatives and the modification of practices to indigenous traditions (Azhoni & Goyal, 2018).

The goal of this study is therefore to facilitate an agreement among experts in NER about necessary adaptation strategies for agricultural communities using the Delphi technique. We communicate with two distinct groups of agricultural experts: active researchers from different institutes of the Indian Council of Agricultural Research (ICAR) and the heads of district level Farm Science Centers (FSCs) in NER. Farm Science Centers are also called *Krishi Vigyan Kendras* or *KVKs* across India. The results of the Delphi survey provide insights into four essential components of policy formulation in NER by answering the following questions:

i. Which are the most important challenges for sustainable farming in NER?
ii. Which policy measures are needed to foster the socio-economic development in NER?
iii. Which climate-resilient technologies and practices need priority investment in NER?
iv. Which policy measures are needed for safeguarding the environment?

5.2 Methods

5.2.1.1 Study design

The objective of this scientific investigation is to identify necessary climate change adaptation and mitigation strategies for farmers in NER by using iterated questionnaires with controlled feedback. This method, called the Delphi method, allows experts to test divergence, to form a

consensus and to prioritize adaptation options. It includes four unique features: i) anonymity, ii) iteration, iii) controlled feedback of individual judgments, and iv) statistical aggregation of group responses (Rowe & Wright, 2001; Skulmoski, Hartman, & Krahn, 2007).

The anonymous treatment of individual judgments removes a common obstacle in collaborative decision-making (Adler & Ziglio, 1996; Mitroff & Turoff, 1975; Powell, 2003; Rowe & Wright, 2001; Somerville, 2007). Through several iterations, participants experience the aggregated perspective of the entire group and have an opportunity to revise their judgment, thus gradually moving towards a consensus (Ilbery, Maye, Kneafsey, Jenkins, & Walkley, 2004). The controlled feedback aims to reduce noise from data deficiencies and other influences (Dalkey, Brown, & Cochran, 1969; Somerville, 2007) and helps to diminish various group background biases. Moreover, it also maintains the focus on the purpose of the study by generating insights based on clear understanding among participants (Hsu & Sandford, 2007).

In this study, we use features from the classical Delphi but modify the process of data collection. Particularly, we use electronic communication (email) and online questionnaires rather than postal mails and printed questionnaires. As we aim at forecasting adequate strategies for policymaking, we adopted also features from a Policy Delphi. A Policy Delphi is a variation to generate innovative solutions for complex problems such as climate change and sustainable development (Mukherjee et al., 2015). Policy Delphi has been applied to generate a broad range of ideas, strategies, and solutions (Hasson & Keeney, 2011; Turoff, 1970).

5.2.1.2 Questionnaire development and administration

The Delphi-approach we chose follows three distinct steps: brainstorming, narrowing-down, and ranking/consensus forming (Schmidt, Lyytinen, & Mark Keil, 2001). In the brainstorming step, we conducted a thorough literature review of potential adaptation strategies to climate change for NER farmers and assembled a catalog. We then synthesized this catalog to prepare a preliminary questionnaire containing 16 questions, 11 of which were open-ended. We pretested the questionnaire with 16 experts not belonging to the pool of experts selected for the main Delphi survey research. They answered all questions and subsequently rated all of them on a 5-point Likert scale (1: not at all relevant, 3: undecided, 5: most relevant) for their relevance in the final Delphi study. We analyzed the responses and used the information to prepare the final Delphi questionnaire for the first round. This adapted questionnaire had 17 thematic questions after incorporating feedback from experts, 12 of which were open-ended. It was e-mailed to all

survey participants with the intention of exploring all possible ideas and relevant information related to adaptation strategy options in NER.

In the narrowing-down step, all valid answers and suggestions from the first step were analyzed, synthesized into seven themes using content analysis, and transformed into 150 Likert-like scale items. However, for this article, we consider only initial 99 strategy options (items) which are arranged under four themes. In the second round of the Delphi experiment, the transformed items were re-administered to the participants, who were asked to rate their opinion agreement from 1 to 7 (1: strong disagreement, 4: neutral/undecided, 7: strong agreement). We then computed the mean value of all rating scores for all items (strategy options) and added this information to the questionnaire. In the third and final round, the consensus formation stage, the questionnaire was re-communicated to the participants. Experts now had the opportunity to reflect on their position and adapt their answers to the group mean or confirm their initial ranking for all 99 strategy options.

In all rounds, we used Google form service to create the online surveys. Only the link was communicated to the experts through email. However, no group emails were sent to maintain the privacy and anonymity of experts. If necessary, follow up emails were sent as reminders for timely submission of responses.

5.2.1.3 Selection of experts

To determine desirable adaptation strategies for farming-dependent livelihoods, we sampled experts from agricultural and agriculture-related institutions in NER. The majority of experts are part of the Indian Council of Agricultural Research (ICAR), which has an extensive network of research institutes, research centers, directorates and Farm Science Centers across India. We solicited experts from ICAR's research institutes, who are professionally active in NER and possess at least five years of working experience in agriculture or allied sectors, i.e., animal husbandry, fishery, beekeeping, silkworm rearing, or poultry farming. While ICAR institutes generally work at the national or regional level, we also wanted to include perspectives from the grass-root level. For this purpose, we included professionals from district-level Farm Science Centers (i.e., KVKs), who have comprehensive insights into local farming communities, their farming patterns and particular problems in the specific district.

From these two pools, 128 agricultural experts were pre-identified as Potential Policy Makers (PPMs) for the Delphi study. Out of 128 e-mail invitations, 41 (32 %) PPMs agreed to participate in this study, of which six were eliminated due to not meeting the minimum work experience criterion of 5 years. In the second and third Delphi rounds of the survey, 91 % and 93.7 % of PPMs participated, respectively.

5.2.2 Analysis of data

To analyze data generated during the Delphi survey rounds we used both qualitative as well as quantitative methods. Open-ended questions were used for the pre-testing and the first Delphi round questionnaire. Similar ideas, various terminologies, and contextual concepts from responses of open-ended questions and suggestions were synthesized using content analysis to narrow down the qualitative data and derive meaningful insights from it. We used Nvivo (version 11) software for all qualitative analyses.

To understand the degree of agreement and consensus among PPMs, we used several descriptive statistics as well as inferential statistical tools. Firstly, we estimated the consensus among PPMs using Inter Quartile Range (IQR) and Quartile Deviation (QD) (De Vet, Brug, De Nooijer, Dijkstra, & De Vries, 2004; Heiko, 2012). IQR is a popular measure of dispersion and widely used in Delphi investigations to estimate the consensus. When using a 7-point rating scale, IQR value less than 1 indicates that 50 % of expert ratings fall within 1 point on the scale, indicating a census (De Vet et al., 2004). The mode value, which signifies the most popular vote in a data series, is also used to re-affirm consensus formation.

Secondly, to assess the degrees to which expert rankings share a common distribution, we used Friedman's X^2 test (Ludlow, 2002). Moreover, the amount of confidence in the degree of agreement is estimated using the nonparametric test called Kendell's coefficient of concordance, or Kendall's W (Brancheau & Wetherbe, 1987). These tests are performed in combination and results are presented along with concerned p-value. If the p-value is lower than 0.05, then the results are considered as statistically significant. In the final ranking/consensus phase of the analysis, we summed the Likert scores of the three "agree"-positions to identify the agreement scores for all 99 items (Mcilfatrick & Keeney, 2003) and used this score to arrange the proposed strategy options by expert agreement. The reliability of the internal consistency of opinion ratings was established by using Cronbach's alpha (Bland &

Altman, 1997; Cronbach, 1951). We performed a statistical analysis of quantitative data using IBM SPSS Statistics Software (Version-24).

Thirdly, to understand the most and least ranked strategy options under all four themes we used a composite score defined as:

$$\text{Composite score} = (s1 * 1) + (s2 * 2) + (s3 * 3) + (s4 * 4) + (s5 * 5) + (s6 * 6) + (s7 * 7)$$

Where *s1* to *s7* denote the number of experts who rated the importance of a strategy option as very low (*s1*), quite low (*s2*), slightly low (*s3*), neutral (*s4*), slightly high (*s5*), quite high (*s6*), or very high (*s7*).

Lastly, as Delphi suffers from stand-alone principal bias, we performed a factor reduction analysis to group 99 strategy options into homogeneous strategy clusters. We conducted principal component analysis on round three Delphi data with ProMax rotation using SPSS version 24. The exercise transformed individual items (strategy options) into common component indexes that can be used as a set of policy recommendations. To test the reliability of the factor analysis, we computed the Kaiser-Meyer-Olin (KMO) statistic along with Bartlett's test measure of sampling adequacy, and discarded items with a value of lower 0.6 of appropriateness (A. Field, 2009). We also examined anti-image correlation values for all items, which measure the strength of the sum of correlations, and discarded items with values below 0.5 (A. Field, 2009). In addition, we extracted Eigenvalues greater than 1.0 (A. Field, 2009) and discarded items with component values below 0.512 as advised by Stevens (2012).

5.3 Results

5.3.1 Respondent summary and their characteristics

The respondents' background is multidisciplinary and includes agricultural social sciences, agronomy, crop improvement, crop protection, fishery science, horticulture and soil science (Table 24). Organisatorically, experts belonging to the ICAR research institute marginally dominate the sample. Their professional designations range from 'scientist' to 'principal scientist.' Agricultural experts from Farm Science Centers are designated as 'senior scientists' and are the heads of their district-level institutions. The pool of PPMs is thus sufficiently diverse to provide knowledgeable, realistic and multi-faceted strategy options. A consistent rate of expert participation also demonstrates the higher credibility of responses.

Table 24. Participation and summary of respondents' characteristics

Variable	Classification criteria	First Delphi round (%)	Second Delphi round (%)	Third Delphi round (%)
Participation	Total invitations sent	128 (100)	35 (100)	32 (100)
	Invitations accepted	41 (32.3)	32 (91.4)	31 (93.7)
	Valid participants*	35 (85.3)	32 (91.4)	31 (93.7)
Designation	Principal Scientist	8 (22.9)	7 (21.9)	7 (22.06)
	Scientist	11 (31.4)	11 (34.4)	10 (32.3)
	Senior Scientist	2 (5.7)	2 (6.3)	2 (6.5)
	Senior Scientist and Head	14 (40.0)	12 (37.5)	12 (38.7)
Academic background	Agricultural social sciences**	4 (11.4)	3 (9.4)	3 (9.7)
	Agronomy	6 (17.1)	6 (18.8)	6 (19.4)
	Animal science	10 (37.1)	10 (37.1)	9 (37.1)
	Crop improvement	3 (8.6)	3 (9.4)	3 (9.7)
	Crop protection	5 (14.3)	4 (12.5)	4 (12.9)
	Fishery	1 (2.9)	1 (3.1)	0 (0.0)
	Horticulture	2 (5.7)	2 (6.3)	2 (6.5)
	Soil science	4 (11.4)	3 (9.4)	4 (12.9)
Professional work experience	5 to 10 years	10 (28.6)	10 (31.3)	10 (32.3)
	10 to 15 years	13 (37.1)	12 (37.5)	12 (38.7)
	> 15 years	12 (34.3)	10 (31.3)	9 (29.0)
Organization	ICAR	21 (60.0)	20 (62.5)	19 (61.3)
	FSCs *(KVKs)*	14 (40.0)	12 (37.5)	12 (38.7)

**Experts having at least five years professional experience in a relevant field in NER*
***Agricultural Economics, Agricultural Extension*

5.3.2 Challenges in NER

Of the 31 items considered in this theme, dependency on rainfall for farming, weak and unstable marketing networks, and floods due to high-intensity rainfall are the top-rated challenges in NER Table 25.

Agriculture in India, including NER, is almost entirely dependent on the monsoon, which is why the agricultural sector is very vulnerable to fluctuations in the monsoon cycle. Most of the fertile plains of India have access to irrigation sources and farm mechanization, however, which enables them to maximize the cropping intensity. Rainfall in the northeastern region of India is more abundant than in the rest of the country, which is why artificial irrigation was not required in the past. Currently, episodes of high-intensity rainfall are occurring more frequently, resulting in floods.

In addition, weak and unstable marketing networks in NER contribute to the farmers' precarious economic situation: Many farmers cannot afford to sell produce on regulated

markets located further away in cities or major towns and are often forced to do sell their perishable commodities in distressed sales, reaping little to no profits. Middlemen take advantage of these situations, pressuring farmers even more with unethical negotiations until farming is no longer profitable. Only stable markets, on-farm value addition, and post-harvest processing can ameliorate the situation, but all three are still in their infancy in NER.

Crop and livestock damage due to weather extremities, inadequate and poor quality seeds, changes in season pattern and the inadequate status of farm mechanization are also dominating the list of challenges. Other notable challenges in NER include high labor costs, energy shortages, low societal resilience to changing the climate, ineffective drought management, unscientific and exploitative farming, costly and scarce inputs, unscientific and resource-poor livestock farming, low policy scheme penetration, inadequate farm income, and massive biodiversity loss. The list shows many crucial challenges are directly linked to climate-related issues. However, many key challenges also point out the subsistence and resource-poor farming trend in NER. Similar kind of challenges are also reported from other poverty-stricken parts of rural India that are adversely affected by climate change (Bastakoti, Bharati, Bhattarai, & Wahid, 2017).

Furthermore, the majority of experts agree that livestock rearing practices and farming practices are largely unscientific and depend on unsustainably exploiting naturally available resources in NER. This situation is connected to the general challenge of farming without adequate resources and having to deal with low-quality seeds, expensive manual labor and electricity shortages. Low farm income, a problem encountered not only in NER, but the whole of India could be increased by adding value to farm produce and proper marketing on stable markets, according to PPMs. However, as long as policymakers mostly ignore the agricultural sector in favor of more profitable ones, welfare schemes do not reach the farmers, and robust market networks cannot be established.

According to experts, challenges with lesser composite score include inadequate integrated farming, low acreage of organic farming, increase in temperature as well as warming, land fragmentation, increasing population, decreasing productivity, low climate change awareness, the complexity of technology use and unsustainable technologies.

Table 25. Challenges for the agricultural sector of Northeastern region of India

Challenges	Composite score	Rank
Rainfall dependency	203	1
Weak and unstable marketing	198	2
High-intensity rainfall and floods	196	3
Low value addition	188	4
Crop and livestock damage due to weather extremities	184	5
Inadequate, poor quality Seeds	179	6
Changes in season pattern	178	7
Inadequate farm mechanization	178	7
High labor cost and energy shortages	176	8
Low societal resilience	175	9
Drought management	175	9
Unscientific and exploitative Farming	174	10
Input cost and scarcity	174	10
Unscientific and resource-poor livestock farming	174	10
Policy apathy and low scheme penetration	171	11
Trivial farm income	171	11
Biodiversity loss	171	11
The little extent of integrated and organic farming	171	11
Temperature increase and warming	169	12
Land fragmentation	168	13
Increasing population and decreasing productivity	166	14
Low climate change awareness	165	15
Complex and unsustainable technologies	164	16
Unsustainable urbanization and industrialization	164	16
Poor institutional access	163	17
Meager credit and subsidy for farming	161	18
Poverty and illiteracy among farmers	159	19
Generalized extension and inadequate demonstrations	156	20
Higher pollution	144	21
Fertilizer inadequate but used indiscriminately	141	22
Excess use of pesticides	139	23

Many of these challenges are hard to combat without proper education. Many rural and tribal farmers in NER are largely illiterate, and therefore find it hard to acquire information about scientifically validated integrated farming technologies, let alone credits and subsidy schemes, for which they would have to approach bureaucratic institutions. Unsustainable industrialization and unchecked urbanization exacerbate the problem. Further challenges include too generalized extension programs, inadequate demonstrations, pollution due to fossil fuel and biomass burning, excess use of pesticides and fertilizers. In general, farmers who live close to cities and towns, have better access to the insecticides and chemical fertilizers but tend to apply more than experts recommend.

5.3.3 Policy components to stabilize socio-economic conditions in NER

Theme-2 has 20 strategy options that represent the most relevant policy components to boost socio-economic development in NER (Table 26). PPMs collectively think that the integrated farming system (IFS) approach is one of the most feasible scientific approaches to boost a farmer's income. Many individual farmers across NER have already adopted the concept, but it could experience a larger boost if it were implemented at the community level. According to PPMs, marketing reforms are highly desired regarding price assurances to farmers along with rationalized price appropriation, as socio-economic stability cannot be fulfilled without a stable market. Indian farmers suffer under price fluctuations and meager minimum support prices for agricultural commodities, coupled with poor agricultural insurances and credit schemes. To deal with the problem, PPMs propose marketing produce through farmers' cooperatives and e-marketing. Presently, many farmers' cooperatives only deal with cultivation related aspects and not marketing issues. The use of e-commerce platforms has the enormous potential to revolutionize agricultural marketing by eliminating middlemen, raising awareness in the general population, and providing a reliable, accessible, transparent and efficient environment for trade.

Table 26. Policy components for stabilizing the socio-economic conditions in NER

Policy components forecasted by Delphi experts	Composite score	Rank
Integrated farming system	196	1
Price assurance and appropriation	194	2
Timely and quality input supply	192	3
Post-harvest value addition	192	3
Scientific crop and livestock farming	190	4
Farming diversification	182	5
Soil, water and resource conservation	181	6
Use of indigenous traditional knowledge	181	7
Cold storage facilities	179	8
Co-operative and e-marketing	179	8
Socially acceptable and efficient technologies	179	8
Multi-stress tolerant breeds and varieties	177	9
Insurance and credit	176	10
Weather advisory and ICTs	176	10
Community approach for farming and awareness creation	175	11
Biodiversity conservation	175	11
Organic farming	173	12
Formulation and execution of national climate plan	169	13
Revamping extension services	169	13
Selective and planned industrialization	156	14

Half of the suggested solutions for improving socio-economic conditions in NER are connected to the effective dissemination of information about scientific farming practices, e.g., scientific crop and livestock farming with diversification. To support farmers in adopting these practices, extension professionals could use Information Communication Technologies (ICTs) to supply them with advice and other timely information, like weather forecasts. However, while promoting scientific farming approaches, professionals should ensure social acceptance as well as the efficiency of the promoted technologies in every step. Lastly, PPMs suggest that value addition and processing facilities should be built in farming communities of NER to facilitate a higher income.

Besides scientific farming, community approaches are also supported by PPMs. Cohesive communities are excellent examples of profitable as well as sustainable farming, as they fully utilize the available Indigenous Traditional Knowledge (ITKs) and practice judicious resource utilization. In such communities, constituents are strongly linked in the social web and information is spread efficiently to create long-lasting awareness. Archer et al. (2014) also supported that recognizing and implementing the community-based *climate change adaptation approaches* is an effective mechanism for transformative change.

As per the Table 26, low ranked strategy options include an overhaul of extension and advisory services to focus more on biodiversity and forest conservation, and the promotion of scientifically validated organic farming practices instead of the resource-poor farming currently practiced in the region. Experts also collectively think that community participation is essential for the formulation and successful execution of ambitious programs like a National Climate Plan.

5.3.4 Investment priorities to enhance resilience against climate change

The top-rated investment priorities for NER are post-harvest processing facilities, the development of value-addition mechanisms and integrated farming systems, intelligence-based market reforms, community seed banks, community nurseries, efficient natural resource utilization, and development as well as the promotion of multi-stress tolerant varieties and breeds (Table 27). These investment priorities highlight the use of market intelligence and the use of digital means to implement market reforms. Moreover, there is a need to empower

farmers of NER with essential training and tools to optimize the natural resource utilization at field and community level.

Further investment priorities include rural infrastructure development, research on policies promoting climate resilience, credits, insurances, training courses, weather forecasting, institutional collaborations, market reforms, use of traditional knowledge to conserve germplasms, crop diversification, adaptive capacity development, conservation, and organic farming promotion. In addition, costly investment priorities include investments in solar energy infrastructure, climate-resilient housing for livestock, nutritive feed development for livestock, efficient energy utilization, carbon sequestration as well as precision farming. As farmers in the region are poor, public funding is essential for a successful implementation of the suggested investments. The past has shown that the communities of NER can efficiently manage public money for specific project activities and that even small investments could significantly enhance the resilience among communities (Achary, Gopinath, & Narsimlu, 2017).

Table 27. Investment priorities for resilience-enhancing technologies, in NER

Investment priorities forecasted by Delphi experts	Composite score	Rank
Post-harvest value addition	193	1
Integrated farming system	192	2
Intelligence based market reforms	183	3
Community seed banks and nurseries	183	3
Efficient natural resource utilization	182	4
Multi-stress tolerant varieties and breeds	182	5
Rural infrastructure development	181	6
Research for climate-resilient policy	181	6
Germplasm improvement using ITKs	180	7
Crop diversification	180	7
Credit and insurance	180	7
Adaptive capacity development among farmers	179	8
Accurate forecasting and institutional convergence	179	8
Organic and conservation farming	177	9
Awareness and training for enhancing resilience	176	10
Climate-resilient housing for livestock	176	10
Nutritive feeding to livestock	175	11
Solar energy infrastructure	174	12
Efficient energy utilization	173	13
Carbon sequestration	167	14
Precision farming	161	15

5.3.5 Safeguarding the environment

The top-rated investment priorities for safeguarding the environment are rainwater harvesting and enhancement of the irrigation efficiency; community afforestation approaches like agro-

forestry, investments into integrated farming systems, organic and sustainable farming, germplasm and biodiversity conservation, infrastructure development, population control and scientific farming with diversification (Table 28). The recent study conducted by Kattumuri, Ravindranath, and Esteves (2017) in southern India also emphasized on the promotion of indigenous farming practices, agroforestry, diversification and livestock farming as a complementary enterprise that enhances employment opportunities for young people.

Table 28. Policy components forasted for safeguarding environment

Policy components	Composite score	Rank
Enhancement of irrigation efficiency and rainwater harvesting	193	1
Community afforestation, agro-forestry	189	2
Integrated farming system	189	2
Organic and sustainable farming	185	3
Germplasm and biodiversity conservation	185	3
Infrastructure development	185	3
Population control	184	4
Scientific farming with diversification	183	5
Technology enhancement research using ITKs	182	6
Market linking and export promotion	182	6
Efficient energy utilization (renewable energy)	181	7
Watershed conservation management	180	8
Planning by regional forecasting and simulation modeling	179	9
Soil conservation to enhance organic carbon	179	9
Carbon management, sequestration	179	9
Farmer centric extension and skill development	178	10
Contingency planning	178	10
Multi stress tolerant breeds and varieties	177	11
Waste reduction and management	177	11
Efficient resource utilization and GHG emission reduction	176	12
Access to low cost, timely and efficient inputs	176	12
Planned land use pattern change	176	12
Price assurance with cheap credit and insurance	175	13
Demonstrations and training for awareness creation	173	14
Community and cooperative farming	170	15
Precision farming	162	16
Subsidy support for technology adoption	158	17

Other measures consist of technology enhancements using traditional knowledge, market linking and export promotion, efficient energy utilization, watershed conservation, regional planning supported by model simulations, soil conservation, and carbon sequestration, farmer-centric extension and skill development, and contingency planning. These results are congruent with the recommendations given by D. Das (2016) and Barua et al. (2014) who advocated for community engagement to manage the environment more efficiently. Shimrah et al. (2015) also

emphasized the immense potential of organic farming in NER, as traditional farming strategies in NER already mainly consist of biodiversity conservation and optimal utilization of natural endowments. S. P. Singh, Singh, and Skutsch (2010) also supported that carbon forestry and manure management by local communities are potential adaptation and mitigation strategies for the Himalayan agro-ecosystem which holds a great deal of sustainable benefits.

5.3.6 Consensus among experts

Many datasets raised in surveys suffer from low quality. To demonstrate the internal consistency of our data and the reliability of the results, we tested the internal reliability of participant responses with Cronbach's alpha, which indicated an excellent internal consistency of the sampled opinions in both Delphi rounds (α = 0.979 and 0.970, respectively).

Table 29. Consensus formation in third Delphi round

Theme 1: Challenges in NER	**Median**	**Mode**	**IQR***	**QD****	**AS*****
High-intensity rainfall, floods	6	7	1	0.5	100
Poor quality seeds	6	6	1	0.5	100
Inadequate and unreliable marketing	6	6	1	0.5	100
Low value addition	6	6	1	0.5	100
Rainfall dependency of farming	7	7	1	0.5	96.77
Inadequate farm mechanization	6	6	1	0.5	96.77
Inadequate farm income	6	6	1	0.5	93.55
Unscientific and resource poor livestock farming	6	6	1	0.5	93.55
Policy apathy and low scheme penetration	6	6	1	0.5	90.32
Drought management	6	6	1	0.5	90.32
Temperature increase and warming	6	6	1	0.5	90.32
High labor cost and energy shortages	6	6	1	0.5	90.32
Unscientific and exploitative farming	6	6	1	0.5	90.32
Crop and livestock damage due to weather extremities	6	6	2	1	93.55
Changes in season pattern	6	6	2	1	90.32
Poor institutional access	5	5	1	0.5	90.32
Low societal resilience	6	6	1	0.5	87.1
Input cost and scarcity	6	6	1	0.5	87.1
Unsustainable urbanization and industrialization	5	5	1	0.5	87.1
Biodiversity loss	6	6	1	0.5	87.1
Little extent of Integrated and organic farming	6	6	1	0.5	87.1
Meager credit and subsidy for farming	5	5	1	0.5	83.87
Low climate change awareness	6	6	1	0.5	80.65
Increasing population and decreasing productivity	6	6	1	0.5	80.65
Poverty and illiteracy among farmers, negative attitude	5	5	1	0.5	80.65
Complex and unsustainable technologies	6	6	1	0.5	77.42
Land fragmentation	6	6	1	0.5	77.42

Generalized Extension and inadequate demonstrations	5	5	1	0.5	77.42
Higher Pollution due to fuel and biomass burning	5	5	1	0.5	61.29
Excess use of Pesticides	4	4	1	0.5	48.39
Fertilizer inadequate but excessively used by many	4	4	1	0.5	45.16
Theme 2: Policy components for stabilizing socio-economic conditions					
Scientific crop and livestock farming	6	6	1	0.5	100
Farming diversification	6	6	0	0	96.77
Timely and quality input supply	6	6	1	0.5	96.77
Use of indigenous traditional knowledge	6	6	1	0.5	96.77
Integrated farming systems	6	7	1	0.5	93.55
Soil, water and resource conservation	6	6	0	0	93.55
Co-operative and e-marketing	6	6	1	0.5	93.55
Price assurance and appropriation	6	7	1	0.5	93.55
Post-harvest value addition	6	6	1	0.5	93.55
Insurance and credit	6	6	1	0.5	93.55
Community approach for farming and awareness creation	6	5	1	0.5	90.32
Formulation and execution of national climate plan	6	6	1	0.5	90.32
Socially acceptable and efficient technologies	6	6	1	0.5	90.32
Weather advisory and ICTs	6	6	1	0.5	90.32
Cold storage facilities	6	6	2	1	93.55
Multi-stress tolerant breeds and varieties	6	6	2	1	90.32
Revamping extension	5	5	1	0.5	90.32
Biodiversity conservation	6	6	1	0.5	87.1
Organic farming	6	6	1	0.5	83.87
Selective and planned industrialization	5	5	1	0.5	77.42
Theme 3: Investment priorities for resilience-enhancing technologies					
Efficient natural resource management and utilization	6	6	0	0	96.77
Integrated farming systems	6	6	1	0.5	96.77
Crop diversification	6	6	1	0.5	96.77
Credits and insurance	6	6	1	0.5	96.77
Post-harvest value addition	6	6	1	0.5	96.77
Solar energy infrastructure	6	6	1	0.5	93.55
Germplasm conservation and improvement using ITKs	6	6	1	0.5	93.55
Research for climate resilient policies	6	6	0	0	93.55
Intelligence-based market reforms	6	6	0	0	93.55
Community seed banks and nurseries	6	6	0	0	93.55
Nutritive feeding to livestock	6	6	1	0.5	93.55
Organic and conservation farming	6	6	1	0.5	90.32
Awareness and trainings for enhancing resilience	6	6	1	0.5	90.32
Accurate forecasting by institutional convergence	6	6	1	0.5	90.32
Climate resilient housing for livestock	6	6	1	0.5	90.32
Rural infrastructure development	6	5	2	1	96.77
Multi stress tolerant varieties and breeds	6	6	2	1	93.55
Precision farming	5	5	1	0.5	93.55

Adaptive capacity development among farmers	6	6	2	1	87.1
Efficient energy utilization	6	6	1	0.5	87.1
Low carbon farming and carbon sequestration	6	6	1	0.5	83.87
Theme 4: Policy components for safeguarding the environment					
Scientific farming with diversification	6	6	0	0	96.77
Germplasm and biodiversity conservation	6	6	0	0	96.77
Technology enhancement research using ITKs	6	6	0	0	96.77
Planning by regional forecasting and simulation modeling	6	6	1	0.5	96.77
Enhancement of irrigation efficiency and rainwater harvesting	6	6	1	0.5	96.77
Integrated farming system	6	6	1	0.5	96.77
Access to low cost, timely and efficient inputs	6	6	1	0.5	96.77
Waste reduction and management	6	6	1	0.5	96.77
Efficient resource utilization and GHG emission reduction	6	6	1	0.5	93.55
Farmer centric extension and skill development	6	6	1	0.5	93.55
Community afforestation, agro-forestry	6	6	1	0.5	93.55
Planned land use pattern change	6	6	1	0.5	93.55
Watershed conservation management	6	6	0	0	93.55
Soil conservation to enhance organic carbon	6	6	1	0.5	93.55
Carbon management, sequestration	6	6	1	0.5	93.55
Infrastructure development	6	6	1	0.5	93.55
Demonstrations and trainings for awareness creation	6	6	1	0.5	90.32
Price assurance with cheap credit and insurance	6	6	1	0.5	90.32
Organic and sustainable farming	6	6	1	0.5	90.32
Market linking and export promotion	6	6	0	0	90.32
Precision farming	5	5	1	0.5	90.32
Adoption of multi stress tolerant breeds and varieties	6	6	1	0.5	87.1
Efficient energy utilization (renewable energy)	6	6	0	0	87.1
Community and cooperative farming	6	6	1	0.5	87.1
Contingency planning	6	6	1	0.5	87.1
Population control	6	6	1	0.5	83.87
Subsidy support for technology adoption	5	5	1	0.5	77.42

*Interquartile range
**Quartile deviation
***Agreement score

The suggested policy and investment priorities for NER cover a wide range of items, which could give the impression that individual PPMs made suggestions based on their region or their background, and we simply assembled the items. To demonstrate that the PPMs agreed on the importance of all items, we measured consensus formation after the last Delphi round. In the third round of the Delphi survey, 12 of the 99 items were rated with IQR = 0 and QD = 0, and 80 items had scores of IQR = 1 and QD = 0.5 (Table 29), indicating a consensus so robust that

further iterations of the survey were deemed unnecessary. A value of 6 was a most popular vote in the data series for 80 of 99 items, which confirms strong consensus among experts. Both results show that an absolute consensus (opinion convergence) was achieved in the positive zone of agreement.

Table 30. Theme-wise analysis of the responses given in round two and three of the Delphi survey using Friedman's X2 test and Kendall's W at significant levels

Round no.	Thematic section (Theme)	PPMs*	Friedman's X^2	Kendall's W	Df**	P-value
Second Delphi round	1. Challenges to be addressed in NER	32	145.5	0.152	30	.000
	2. Policy components for stabilizing the socio-economic conditions	32	70.6	0.116	19	.000
	3. Investment priorities for resilience-enhancing technologies	32	52.2	0.086	20	.000
	4. Policy components for safeguarding environment	32	110.4	0.133	26	.000
	All themes	32	396.8	0.127	98	.000
Third Delphi round	1. Challenges to be addressed in NER	31	225.7	0.275	30	.000
	2. Policy components for stabilizing the socio-economic conditions	31	115.7	0.197	19	.000
	3. Investment priorities for resilience-enhancing technologies	31	54.5	0.088	20	.000
	4. Policy components for safeguarding environment	31	111.0	0.138	26	.000
	All themes	31	577.2	0.190	98	.000

*Number of individual responses, **degrees of freedom.

To re-affirm and triangulate the increasing consensus formation among PPMs from the second to the third Delphi round, we used Friedman's X^2 test. The test measures the degree to which expert ratings share a common distribution, and results showed a significant increase from one round to the next (396.8 to 577.2, Table 30). Kendall's W, a measure of concordance, also increased slightly from round two to three. So we assumed consensus formation in third Delphi round.

5.3.7 Identifying action clusters for policy formulation

In order to facilitate policy formulations, we used a principal components analysis to identify clusters of homogeneous items. We discarded 19 items from theme-1 for the data reduction analysis (Table 31), as their KMO statistic was less than 6 (Table 32). Similarly, one item from theme-2 and two items from theme-4 were removed, as their anti-image correlation value was less than 0.5 (Table 32). The clusters identified in the data reduction analysis for each theme are presented in (Figure 26). Key challenges in NER can be grouped into four sets as: (i) Rainfall-related issues in combination with backward farm practices, (ii) inadequate supply of agro-inputs in combination with farm vulnerability, (iii) inadequate mechanization and food processing in combination with recurring droughts, and (iv) low societal resilience in the face of changes in seasonal weather patterns. Factor reduction analysis for challenges in NER is presented in Table 33.

Table 31. Measurement of sampling adequacy of items for (clustering) data reduction

Theme	**Items**	**Kaiser-Meyer-Olkin Measure of Sampling Adequacy**	**Bartlett's Test of Sphericity**		
			Approx. Chi-Square	**df**	**Sig.**
Theme-1	Items 1-12	0.624	135.1	66	0.00
	items 13-31*	0.474	333.4	171	0.00
Theme-2	items 31-51	0.694	486.7	190	0.00
Theme-3	items 52-72	0.665	558.2	210	0.00
Theme-4	items 73-91	0.719	570.7	171	0.00
	items 92-99	0.706	110.1	28	0.00

Categorization of KMO score and its standard interpretation in the context of sampling adequacy

0.00 to 0.49	*unacceptable*
0.50 to 0.59	*miserable*
0.60 to 0.69	*mediocre*
0.70 to 0.79	*middling*
0.80 to 0.89	*meritorious*
0.90 to 1.00	*marvelous*

*items invalid for factor grouping due to KMO statistic < 0.6

Table 32. Items not suitable for data reduction (cluster formation)

Theme	Item number	Strategy options not suitable for data reduction	Reason for removal
Theme-1	13	Input cost and scarcity	Kaiser-Meyer-Olkin statistic < 0.6
	14	Unscientific and resource-poor Livestock farming	
	15	Policy apathy and low scheme penetration	
	16	Trivial farm income	
	17	Biodiversity loss	
	18	The little extent of Integrated and organic farming	
	19	Temperature increase and warming	
	20	Land fragmentation	
	21	Increasing population and decreasing productivity	
	22	Low climate change awareness	
	23	Complex and unsustainable technologies	
	24	Unsustainable urbanization and industrialization	
	25	Poor Institutional access	
	26	Meager Credit and subsidy for farming	
	27	Poverty and illiteracy among farmers	
	28	Generalized Extension and inadequate demonstrations	
	29	Higher Pollution	
	30	Fertilizer inadequate but used indiscriminately	
	31	Excess use of Pesticides	
Theme-2	48	Organic farming	Anti-image <0.5
Theme-4	80	Scientific farming with diversification	
	91	Waste reduction and management	

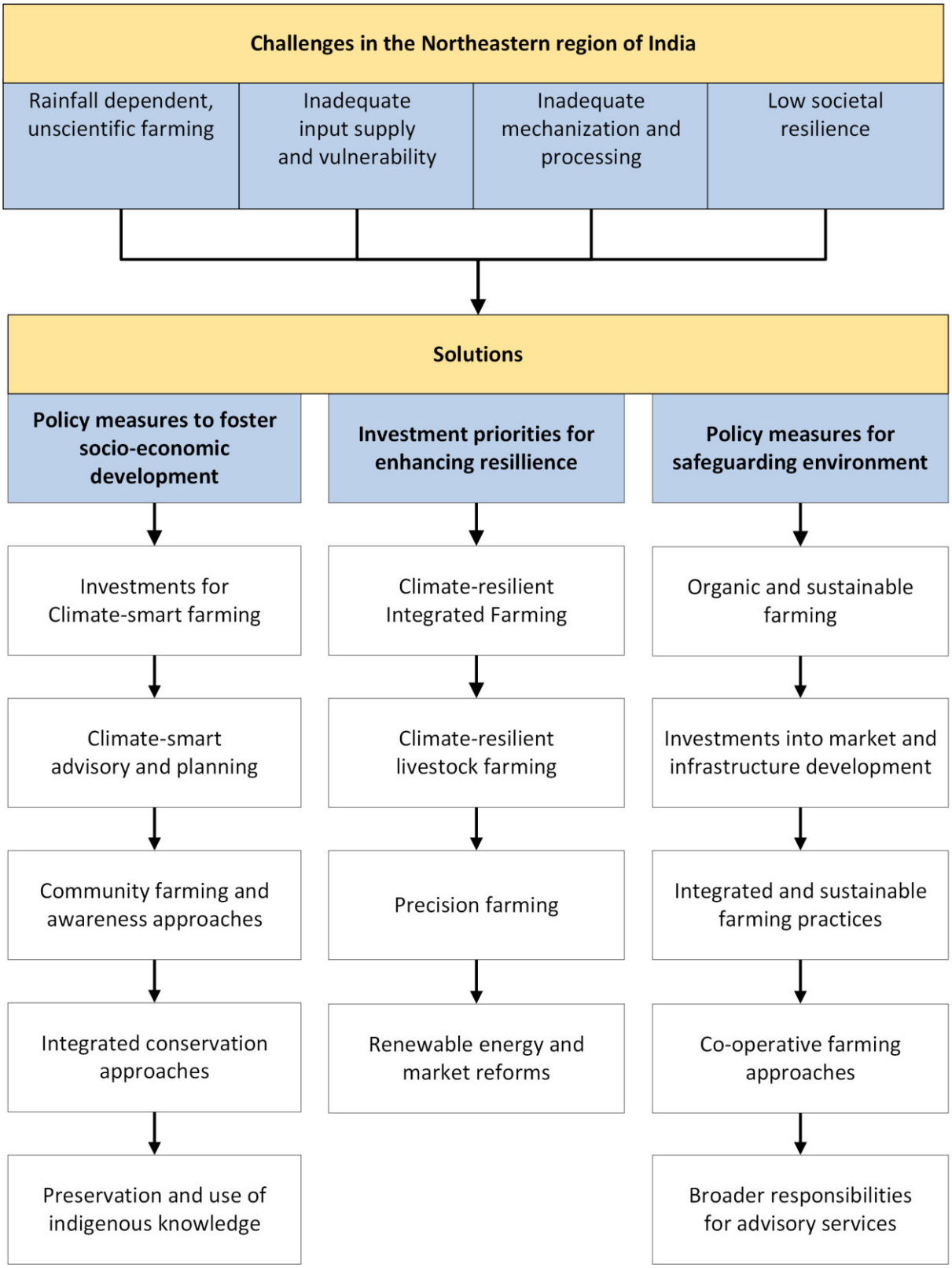

Figure 26. Results of the principal component analysis for each of the four themes of the Delphi analysis (blue boxes). White boxes show the identified action clusters in hierarchical order.

Table 33. Factor reduction analysis of challenges in NER (Theme-1)

Key Challenges (Clustered)	Individual items	Component values			
		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Rainfall dependent, unscientific farming	Rainfall dependency	0.859			
	High-intensity rainfall, floods	0.757			
	Weak and unstable marketing	0.676			
	Unscientific and exploitative farming	0.646			
Inadequate input supply and vulnerability	Inadequate, poor quality seeds		0.824		
	Crop and livestock damage due to weather extremities		0.823		
	High labor cost and energy shortages		0.621		
Inadequate mechanization and processing	Inadequate farm mechanization			0.774	
	Low value addition			0.774	
	Drought management			0.651	
Low societal resilience	Low societal resilience				0.808
	Changes in season pattern				0.731

Action clusters for stabilizing and improving socio-economic conditions in NER are: (i) Widespread investments into the agricultural sector, including infrastructure, research, marketing, and information and technology dissemination. Single items: (ii) establishment of a weather advisory including long-term climate-smart planning, (iii) community approaches for awareness creation, (iv) conservation of biodiversity, soils, water and resources, and (v) preservation and use of traditional indigenous knowledge. These factor groupings are provided in Table 34 as results of the theme-2 PCA.

Investment priorities in NER can be grouped into four clusters: (i) climate resilient integrated farming, including the necessary infrastructure (ii) climate-resilient livestock farming and sustainable resource utilization, (iii) precision farming, and (iv) solar energy harvesting and market reforms. Refer to Table 35 for the detailed results of the theme-3 PCA.

Five action clusters can be identified for safeguarding the environment: (i) community approaches for organic farming and conservation, (ii) investments into research, infrastructure, technologies, and information dissemination, (iii) integrated, sustainable farming practices, (iv) co-operative farming approaches, and (v) broader responsibilities of advisory services, including counseling farmers on GHG reduction, awareness creation, and land use planning. Table 36 provides a detailed account of theme-4 PCAR results.

Table 34. Factor reduction analysis indicating clusters of adaptation strategies for stabilizing socio-economic conditions in NER

Action clusters (strategies)	Individual items	Component values				
Theme 2 - Stabilizing socio-economic conditions		**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**
Investments into climate-smart farming	Farming diversification	0.886				
	Insurance and credit	0.874				
	Timely and quality input supply	0.846				
	Multi-stress tolerant breeds and varieties	0.845				
	Integrated farming system	0.844				
	Cold storage facilities	0.841				
	Post-harvest value addition	0.813				
	Socially acceptable and efficient technologies	0.801				
	Price assurance and appropriation	0.778				
	Scientific crop and livestock farming	0.750				
	Co-operative and e-marketing	0.748				
Climate-smart advisory and planning	Weather advisory and ICTs		0.851			
	Selective and planned industrialization		0.828			
	Formulation and execution of national climate plan		0.786			
	Revamping extension services		0.760			
Community farming and awareness	Community farming and awareness approaches			0.932		
Integrated conservation approaches	Biodiversity conservation				0.834	
	Soil, water and resource conservation				0.633	
Preservation and use of indigenous knowledge	Use of indigenous traditional knowledge					0.640

Table 35. Factor reduction analysis indicating clusters Investment priorities for enhancing resilience among NER farmers

Theme 3 - Investment priorities for enhancing resilience		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Climate-resilient integrated farming	Credit and insurance	0.898			
	Crop diversification	0.822			
	Integrated farming system	0.822			
	Rural infrastructure development	0.820			
	Germplasm improvement using ITKs	0.804			
	Efficient natural resource utilization	0.766			
	Stress tolerant varieties, breeds	0.729			
	Post-harvest value addition	0.724			
	Community seed banks, nurseries	0.710			
Climate-resilient livestock farming	Climate-resilient livestock housing		0.924		
	Carbon sequestration		0.880		
	Nutritive feeding to livestock		0.825		
	Efficient energy utilization		0.805		
	Awareness and training for enhancing resilience		0.803		
	Accurate forecasting and institutional collaborations		0.771		
	Research for climate-resilient policy		0.759		
	Adaptive capacity development		0.720		
	Organic and conservation farming		0.618		
Precision farming	Precision farming			0.879	
Renewable energy and market reforms	Solar energy infrastructure				0.859
	Intelligence based market reforms				0.711

Another approach to identifying high-priority policy recommendations is to group items occurring in more than one theme. Adoption of integrated farming systems was identified as a priority strategy for stabilizing socio-economic conditions in NER, but also for safeguarding the environment and as an investment priority. This underscores the significance of strategy and promises a high return on investment. A similar trend is observed for (i) farming diversification (ii) use of indigenous traditional knowledge, (iii) support of community approaches, (iv) post-harvest value addition, (v) market reforms, and (vi) germplasm and biodiversity conservation. The implementation of these strategy options will have positive impacts not only on socio-economic conditions but also on the environment in NER.

Table 36. Factor reduction analysis indicating clusters of policy measures for safeguarding the environment

Theme 4 - Policy measures for safeguarding the environment		Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Organic and sustainable farming	Carbon management, sequestration	0.899				
	Watershed conservation management	0.898				
	Organic and sustainable farming	0.889				
	Soil conservation to enhance organic carbon	0.861				
	Population control	0.831				
	Irrigation efficiency and rainwater harvesting	0.802				
	Contingency planning	0.795				
	Community afforestation, agro-forestry	0.776				
Investments into market and infrastructure development	Infrastructure development		0.893			
	Market linking and export promotion		0.869			
	Multi stress tolerant breeds and varieties		0.792			
	Planning by forecasting and simulation modeling		0.787			
	Technology enhancement research using ITKs		0.753			
	Farmer centric extension and skill development		0.712			
Integrated and sustainable farming practices	Integrated farming system			0.882		
	Germplasm and biodiversity conservation			0.810		
	Efficient energy utilization (renewable energy)			0.693		
Co-operative farming approaches	Access to low cost, timely and efficient inputs				0.841	
	Community and cooperative farming				0.814	
	Price assurance with cheap credit and insurance				0.748	
	Precision farming				0.728	
Broader responsibilities for advisory services	Efficient resource utilization and GHG emission reduction					0.890
						0.864

	Demonstrations and awareness trainings	0.729
	Subsidy support for technology adoption	0.685
	Planned land use pattern change	

5.4 Discussion and conclusion

The long list of challenges and policy recommendations identified by the surveyed experts suggests that a lot needs to be done in NER on all levels of government and all areas of development. It is a fact that the northeastern region of India was neglected or sidelined from the mainstream development for a long period (U. K. De et al., 2017; Verghese, 2013). Nowadays, even though the region is rich in natural resources and biodiversity, and local authorities try their best to push their region up to the developmental status of the rest of India, it remains underdeveloped (Khan & Padhi, 2017). The socio-economic divide between cities and villages is enormous. Poverty in the rural areas is high and directly affects the food and nutritional security of individuals (K. Das, 2017). In the remote parts of NER (Mizoram, Meghalaya, Nagaland, Arunachal Pradesh, Tripura, and Manipur), many citizens are deprived of even basic facilities like sanitation, healthcare, and higher education (Shadap, 2017). Job opportunities are rare, and many individuals are left with low-input low-output subsistence agriculture, which fails to meet even the local demand (K. Dikshit & J. K. Dikshit, 2014a). Continuous adverse impacts of climate change make the bad situation even worse, threatening the livelihood and security of millions (Bawa & Ingty, 2012; D. Das, 2016; P. Das & Dey, 2011; U. Sharma & Sharma, 2005).

Urgent interventions are needed to combat these problems. Investment priorities need to be established, and the support of local stakeholders needs to be secured (Adhikari & Taylor, 2012). The Delphi approach we used in this study is uniquely suited for the task: Local experts identified the most pressing challenges, formulated adequate investment priorities and refined their positions in several iterations until a group consensus was reached. The approach yielded a variety of region-spanning multi-disciplinary items for policy consideration. Previous studies often focused on only a fewer number of commodities or a smaller area (B. Chakraborty & Hazari, 2017; A. Das et al., 2018; D. Das, 2016; Duncan et al., 2016; Mahanta & Das, 2017; Mait et al., 2016; Saharia, Talukdar, & Johari, 2017; G. Sharma et al., 2016), and thus were not adequate

for regional policymaking. Other studies answered technical questions but did not provide investment priorities (D. Chakraborty et al., 2014; B. U. Choudhury, Fiyaz, Mohapatra, & Ngachan, 2016; Maiti et al., 2014; Phukon & Singh, 2017; Vishnu Prasanth et al., 2017) or suggested a course of action to exclusively promote sustainable livelihoods and food security in NER (Acharya et al., 2012; P. Ghosh et al., 2010; Kharumnuid, 2011; Khatri-Chhetri, Aryal, Sapkota, & Khurana, 2016; A. J. Nath & Das, 2012; Singha, Majumdar, Saha, & Hazra, 2013). Policymakers, however, need a complete picture of challenges and investment priorities in their region to be able to formulate effective policies. In this study, we, therefore, surveyed the four key themes related to regional policy formulation: the main challenges, improvement of socio-economic conditions, investment priorities, and environmental protection. Farm science centers, ICAR institutes, agricultural universities or other research and development organizations can directly implement the suggestions provided by the experts. State governmental departments, NGOs, or national institutes and their regional centers operational in NER can also utilize the results for fine-tuning their policies and setting priorities for upcoming action plans.

Some recommendations may seem too general or vague to be immediately useful, such as "integrated farming systems." Which type of crops should be cultivated in such a system, and which kind of livestock can be kept? Is agro-forestry a part of the system, and what management practices would be performed? Such questions are best answered at the local level, however, and not in this type of study, where the goal was to explore the common understanding of multidisciplinary experts covering a vast and diverse region.

In conclusion, our findings show that agricultural experts in NER experience and are aware of the negative impacts caused by climate change. They identified the interlinking of climatic catastrophes with existing socio-economic and environmental adversities as the key challenge in NER and counsel that a massive amount of strategic investment in a variety of sectors is required to meet this challenge. Subsequently, in order to transfer the general suggestions of the experts into actionable items, regional change agents need to develop locally applicable and implementable strategies, and policymakers need to provide the necessary logistical and financial support for their implementation.

5.5 Acknowledgment

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Chapter 6: Delphi forecasts on competency development to enhance climate-resilient farming in Northeastern India

Abstract

Many inhabitants of the Northeastern region of India (NER) are poor and have to rely on subsistence farming for a livelihood and are therefore vulnerable to negative impacts of climate change. To enhance the resilience of the farmers and the entire agricultural sector of NER, stakeholders need to acquire additional and/or specialized competencies to deal with adverse impacts of climate change. In this study, we systematically identify and prioritize crucial competencies for change agents, farmers, and institutions in NER. We used a modified Delphi method with several iterations to lead experts towards a consensus about the most pressing competencies for each stakeholder group. The items were prioritized using a composite scoring approach.

The findings reveal that for change agents in NER, an open-minded attitude and expertise in linking farmers to markets are highly rated competencies. For the farmers, eco-friendly farming skills and a problem-solving attitude emerged as key competencies. Biodiversity conservation and integrated farming skills are also highly desirable. Concerning the institutions, the *Krishi Vigyan Kendras* (farm science centers) have to play a priority role in implementing policies promoting sustainable and climate-resilient agriculture, as they are the institutional link to farming communities. The experts are confident that the overall sustainability of the agricultural sector in NER can be considerably enhanced by developing these key competencies.

Keywords: Agriculture, Change agents, Climate change, Consensus formation, Institutional response, Policy Delphi

6.1 Introduction

Climate change poses a severe threat to the fragile Himalayan agro-ecosystems. The Northeastern region of India (NER, Figure 27) is a part of the Eastern Himalaya and already experiences a variety of climate change-related phenomena, such as increasing temperatures, cloudbursts, flash floods, hailstorms and monsoon fluctuations (Azhoni & Goyal, 2018; Bhagawati et al., 2017; D. Chakraborty et al., 2014; Chattopadhyay et al., 2017; D. Das, 2016; Moors & Stoffel, 2013; R. Pal et al., 2016). The impacts of these phenomena manifest in the forms of landslides, erosion, siltation, farm inundation, crop destruction, damage to livestock and loss of life as well as property and are threatening the livelihood of the residents of NER (D. Das, 2016; Khataniar, 2018; Mahanta & Das, 2017; Seaman, Sawdon, Acidri, & Petty, 2014; N. Singh & Singh, 2015). The residents of the region are generally poor, and largely depend on farming and other income generating activities related to agriculture, rendering their vulnerability to adverse climate change-related impacts high, but their ability to recover from financial and property losses very low (C. B. Field, 2014).

To protect and support the livelihoods of the inhabitants of NER, and increase their resilience towards the negative impacts of climate change, strategic planning and the systematic implementation of adaptation plans are necessary. For this, competent human resource is essential. The persons responsible for the task are called ‘change agents’ (Rogers, 2003). Change agents are defined as a heterogeneous group of highly educated individuals such as researchers, trainers, consultants, counselors, teachers, and, in some cases, line managers (Ottaway, 1983). For example, in the case of USA, cooperative extension educators are potential change agents in the food system (Clark et al., 2017). In NER, researchers and extension professionals of the Indian Council of Agricultural Research (ICAR), Farm Science Centers (FSCs), State Agricultural Universities (SAUs), and State Agriculture Departments are the vital change agents for the agricultural sector. They possess a set of cognitive, action and communication skills that complement their professional knowledge and help them to advise stakeholders and farmers in their daily operations. In view of the new challenges created by climate change, however, there is a need for further competencies, and change agents may need to upgrade, customize and/or specialize their skillset.

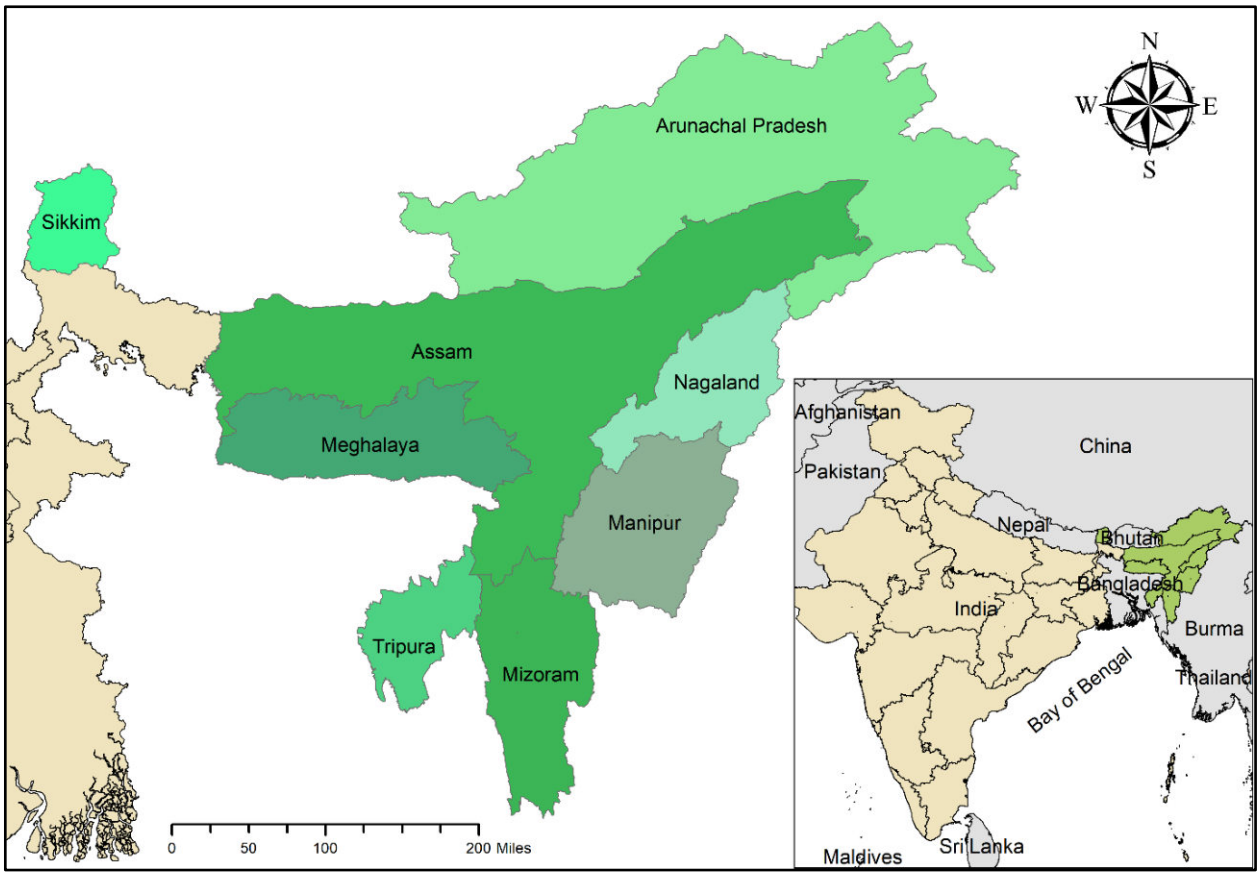

Figure 27. Map of the eight states forming the Northeastern region of India (NER) and location of the study region in India (Avishek, 2014; GADM, 2015).

Presently, only generalized recommendations are given about training needs or technological competencies for change agents and farmers in NER (Pourouchottamane, Venkatasubramanian, Singha, Mishra, & Pankaj, 2012; Raj, 2013; Sajeev & Singha, 2010; Sajeev, Singha, & Venkatasubramanian, 2012), and not a single set of recommendations takes the special challenges of climate change into account. For example, Nongtdu, Bordoloi, Saravanan, Singh, and Singh (2012) conducted an assessment study in the Meghalaya state of Northeastern India and identified key training areas for agricultural extension personnel as soil science, entomology, agronomy, plant pathology, nematology, and horticulture. Similarly, another study conducted for the horticultural sector of NER concluded that protected cultivation, value addition, and mushroom production are key training needs for change agents (Ramanujam, Kumaran, & Atheequlla, 2016). These studies indicate that most of the competency development recommendations are mostly subject matter oriented and show little concern about climate-smart farming promotion in NER.

The goal of this study is, therefore, to determine the competencies change agents need in order to effectively promote sustainable agriculture under climate change in NER. We distill the

recommendations on competency development from an intellectual consensus of experts working in NER, using a structured Delphi survey. A Delphi survey is a method of eliciting and refining group judgments. It allows researchers to utilize subject matter experts from the target area to aid policymaking, and deal with problems of uncertain and/or complex nature (Mukherjee et al., 2015). The consensus obtained during a Delphi survey is empirical evidence for effective decision-making (Hakim & Weinblatt, 1993; Martino, 1993; Rauch, 1979; Rowe & Wright, 1999).

To provide a more comprehensive background, we survey not only the experts on their opinion about essential skills in change agents, but also necessary competencies for farmers and institutions to implement and support the change agents' recommendations. We particularly want to answer the following questions:

1. Which essential competencies are required in change agents to efficiently formulate and implement policies promoting resilience against climate change and sustainability in NER?
2. What competencies do farmers in NER need to implement these policies?
3. Which institutions are best suited to host and educate change agents and farmers and promote the formulation and execution of the policies?

Lastly, we compare the list of essential skills provided by the experts to the list of training courses actually offered by the agricultural extension services in Northeastern India in order to determine areas where additional training courses are needed.

6.2 Methods

6.2.1 Delphi method

The original, classical Delphi method was first described by Dalkey et al. (1969), and in the following years, many modified versions of the method emerged. For this study, we modified the classical Delphi by adding prominent features of policy Delphi Turoff (1970) and e-Delphi Donohoe, Stellefson, and Tennant (2012). This modification enabled us to accomplish our investigation with limited resources. The framework for the Delphi investigation is represented in Figure 28.

6.2.1.1 Selection of experts

Agricultural researchers from the Institutes of the Indian Council of Agricultural Research (ICAR) as well as the heads of *Krishi Vigyan Kendras (KVKs*, or Farm Science Centers) located in NER were solicited for this study. ICAR is an apex public sector body of India that deals with agricultural research and education across the nation. ICAR institutes mainly cater to the research and extension needs of a specific category of farmers. For example, the ICAR National Research Center on Pigs deals with all contemporary research and extension related aspects of pig farming. The researchers of ICAR institutes are mainly concerned with laboratory research and field experiments, and limited teaching and extension activities. We invited experts from three strata of the ICAR organization: scientists (entry-level researchers), senior scientists (middle-level researchers) and principal scientists (upper-level researchers who are eligible for research management posts).

Unlike ICAR institutes, *Krishi Vigyan Kendras* are located in all districts of India, and their sphere of influence is confined to one district. *Krishi Vigyan Kendras* are multidisciplinary by nature. Their mission is to provide trainings and other agricultural extension services, tailored to the needs of the farming community in their particular district. The Heads of *Krishi Vigyan Kendras* are midlevel professionals, equivalent to the senior scientists of ICAR. Their jobs include dynamic outreach and close collaboration with other departments concerned with the welfare of farmers. Constant contact with the farming community across the district provides the heads the *Krishi Vigyan Kendras* with a unique understanding of the current challenges faced by the farmers, making them a valuable addition to our expert pool for the survey. Our multi-strata and multi-disciplinary expert sampling thus ensures that the feedback and concerns from all levels of agriculture research and extension are integrated.

Further criteria the experts from this pool have to meet to be eligible for our survey are (i) educational background in agriculture and/or allied sector (livestock, fishery, horticulture, forestry, etc.), (ii) actively engaged with agricultural research and/or agricultural education and/or agricultural extension activities (iii), a minimum of five years of work experience in NER, and (iv) willingness to participate in the Delphi survey.

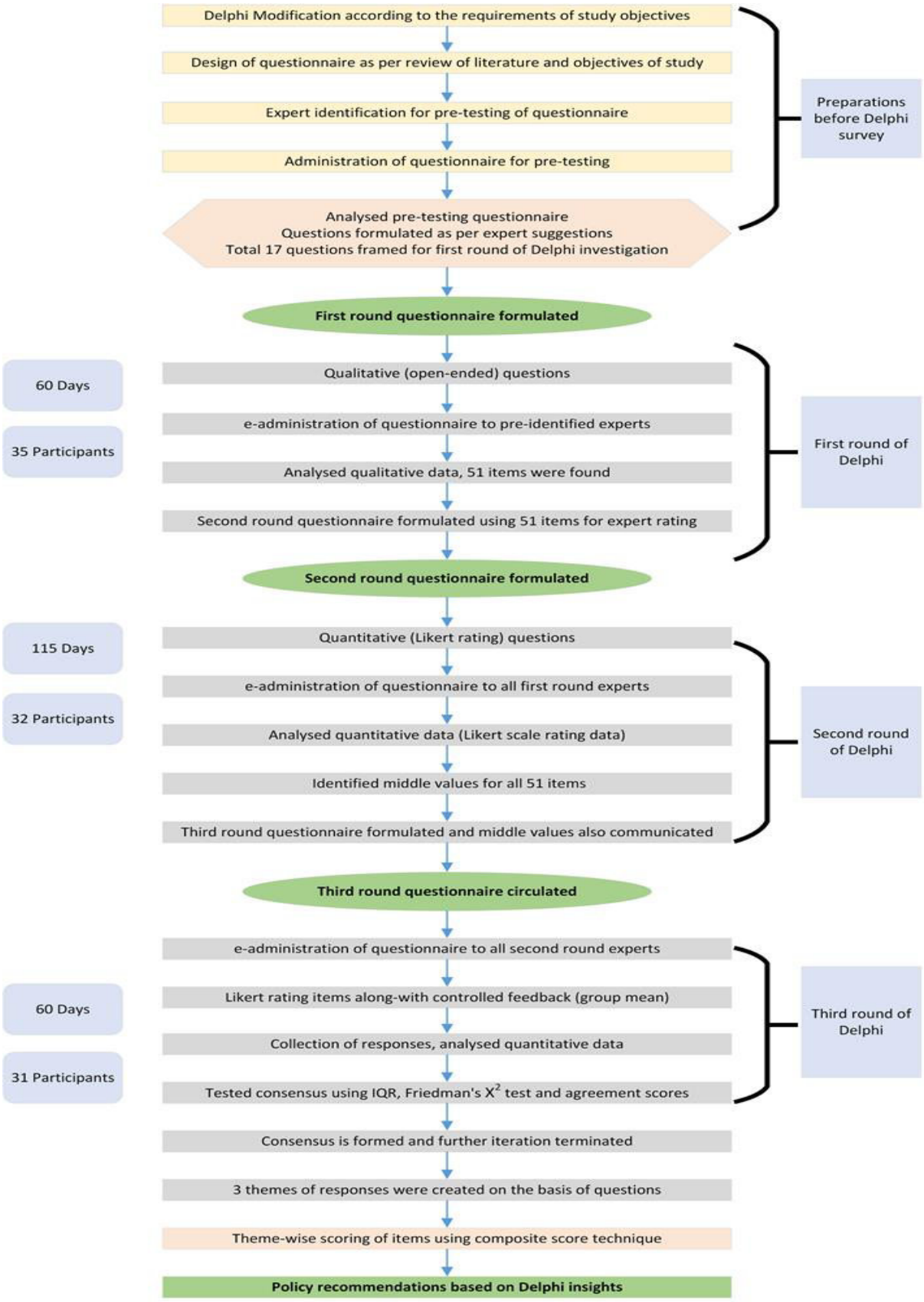

Figure 28. The framework of the Delphi experiment with the pre-testing phase and the first, second and third Delphi round.

We contacted all experts via e-mail. Research questionnaire design, as well as data collection, was performed using online google forms. Experts' email addresses were collected from institutional websites, personal contacts, and social media communications. The email addresses of the heads of the *Krishi Vigyan Kendras* were taken from reports available in the ICAR-Agricultural Technology Application Research Institute in Umiam, Meghalaya.

6.2.1.2 Delphi survey administration

In general, Delphi surveys are iterated until a consensus is reached. Our modified Delphi study consists of three iterations (Parr, Trexler, Khanna, & Battisti, 2007) and a preparation phase. We found the Delphi method as most appropriate (after literature review) and efficient way to synthesize expert knowledge in order to obtain comprehensive as well as coherent conclusions (Curzon & Kontoleon, 2016). Proper care was taken throughout the Delphi experiment to maintain the anonymity of all respondents. No group e-mails were sent, and participants were assured of the strict confidentiality of their data.

6.2.1.3 Preparations before the survey

A semi-structured questionnaire was designed on the basis of a literature review to conduct a pilot survey. Sixteen (16) experts from outside NER were contacted and asked to take the pilot survey to judge the suitability as well as the relevance of the questions. The pilot questionnaire contained two sections. The first section consisted of seven questions. In the first two, email addresses and academic background were collected. In the remaining five questions, the experts' concerns and awareness regarding climate change were assessed using a rating scale from 1 to 5, where 1 = "strongly disagree," and 5 = "strongly agree." In the second section, 11 open-ended questions were presented, and experts were instructed to answer the questions and rate their relevancy from 1 to 5. All questions were rated as relevant by the experts and thus incorporated into the first-round questionnaire. Additional suggestions on how to improve the questionnaire were implemented as well.

6.2.2 First Delphi round

We designed the questionnaire for the first Delphi round on the basis of the pilot survey and the expert recommendations. The webpage link to the first round questionnaire was e-mailed to 128 experts, of which 41 accepted the invitation. Six of the experts did not fulfill the

minimum working criteria of five years. Consequently, only 35 experts and their responses were considered in the first round of the Delphi survey.

The objective of the first round was to generate a variety of answers in response to open-ended questions. Seventeen questions were presented to the selected experts from NER. In the first four, name, designation, the area of expertise and years of experience were queried. In the next, the perspective of the expert on climate change as a threat to Indian agriculture was requested. The remaining questions were open-ended, except for three questions related to competency development, which provided distinct answers.

A systematic content analysis of the collected answers allowed us to merge them into 51 unique homogeneous items, which we used to design the questionnaires for the second and third Delphi rounds.

6.2.3 Second Delphi round

The questionnaire for the second round was developed based on a systematic content analysis of the responses to the first Delphi round questionnaire. It consisted of 51 items (= distinct answers to the open-ended questions) categorized into three themes: 1) crucial competencies for change agents (24 items); 2) essential competencies for farmers (14 items); 3) the importance of institutions (13 items). Experts were instructed to rate the relevancy of each item on a Likert scale of 1 to 7, with 1 = very low; 2 = quite low; 3 = slightly low; 4 = neutral; 5 = slightly high; 6 = quite high; and 7 = very high. The same 35 experts from the first round were invited to take the questionnaire, but this time only 32 responded.

6.2.4 Third Delphi round

The third Delphi round consisted of the same 51 items as the second round, and experts were again requested to rate each item on a scale of 1 to 7. This time, however, the mean of the previous ratings for each item was provided as controlled feedback and respondents were asked to re-evaluate their judgments in the light of this information (Van Cuong, Dart, & Hockings, 2017). Experts thus had the chance to either affirm their stand or align their judgment closer to the group consensus. In this third Delphi round, 31 experts participated. An overview of the response rates to the different Delphi rounds and the characteristics of the respondents can be found in Table 37.

Table 37. Summary of Delphi experiment participants

Particulars	Category	First Delphi round	Second Delphi round	Third Delphi round
Participants	Number of invitations	128 (100)	35 (100)	32 (100)
	Invitation acceptance	41 (32.3)	32 (91.4)	31 (93.7)
	Number of valid experts	35 (85.3)*	32 (91.4)*	31 (93.7)*
Experts from ICAR institutes and regional centers	Principal Scientist	8 (22.9)	7 (21.9)	7 (22.6)
	Scientist	11 (31.4)	11 (34.4)	10 (32.3)
	Senior Scientist	2 (5.7)	2 (6.3)	2 (6.5)
Experts from *Krishi Vigyan Kendras*	Senior Scientist and Head	14 (40.0)	12 (37.5)	12 (38.7)
Professional work experience of experts	5 to 10 years	10 (28.6)	10 (31.3)	10 (32.3)
	10 to 15 years	13 (37.1)	12 (37.5)	12 (38.7)
	More than 15 years	12 (34.3)	10 (31.3)	9 (29.0)

*Experts fulfilled all criterion

6.2.5 Data analysis

6.2.5.1 Delphi Consensus

In contemporary Delphi experiments, the most common approaches to estimate consensus are an interquartile range (IQR) and quartile deviation (QD); median and mode; and Friedman's X^2 test in combination with Kendall's W. In this study, we estimated consensus with IQR and QD. As we used a seven-point Likert rating scale in the second and third Delphi round, we followed the suggestion of Heiko and Darkow (2010) to assume a robust consensus if IQR of the majority of items was less than or equal to 1 with a QD of less than or equal to 0.5; a high to medium level consensus if IQR ranged between 1 and 2 and QD between 0.5 and 1, and no consensus if IQR was greater 2 and QD greater 1. A robust consensus was reached for more than 75% of items after the third round, which is why we chose to forego further iterations (De Vet et al., 2004).

We double-checked consensus formation by calculating the mode value for each item (= the most popular vote). If more than 51% of the ratings were equal to the mode value, a consensus was assumed (Chakravarti, Vasanta, Krishnan, & Dubash, 1998). Lastly, to estimate the degree to which the expert rankings share a common distribution, we used Friedman's X^2 test (Lund, Banta, & Bunting, 2014), and Cronbach's alpha to estimate the internal consistency of the data. We used IBM-SPSS (package 24) to perform all quantitative data analysis, and NVivo (version 11) for the qualitative analysis.

6.2.5.2 Theme-wise ranking of items

Once the consensus was established after the third Delphi round, we used a composite score technique to rank the items in the order of relevance:

Composite score = ($s1$ * 1) + ($s2$ * 2) + ($s3$ * 3) + ($s4$ * 4) + ($s5$ * 5) + ($s6$ * 6) + ($s7$ * 7)

Where,

$s1$ = number of experts who rated the item as very low,

$s2$ = number of experts who rated the item as quite low,

$s3$ = number of experts who rated the item as slightly low,

$s4$ = number of experts who rated the item as neutral,

$s5$ = number of experts who rated the item as slightly high,

$s6$ = number of experts who rated the item as quite high,

$s7$ = number of experts who rated the item as very high.

6.3 Results and discussion

The goal of this study is to determine the competencies change agents need in order to effectively promote sustainable agriculture under climate change in NER, and to identify the necessary competencies farmers and institutions need to implement and support the change agents' recommendations. In the first Delphi round, experts made 24 distinct suggestions for essential competencies for change agents, 14 for necessary competencies for farmers, and 13 for institutions, which they ranked according to relevancy in the second and third Delphi rounds. Based on these rankings, we calculated a composite score for each item and assembled a list for each of the three themes sorted by composite score value.

Results for theme 1 show that the top-rated competencies for change agents are competency in linking farmers to markets and food processing channels, an open-minded attitude and the ability to formulate integrated policies and perform contingency planning. Our finding is consistent with the study of Duram (2000) which stresses that market stability is essential for the success of organic farming, and it can be done via directly *linking farmer with the consumer*. Other top competencies include research on multi-stress tolerant technologies (e.g., crop

varieties that are water-stress tolerant as well as immune to certain diseases) and knowledge about farming with environmental concerns (Table 38).

While four of the five competencies deal with professional knowledge, which can be imparted through targeted science management, an open-minded attitude is an inherent personality trait. In our specific case, the experts stressed that the call for an open-minded attitude is not limited to persons, but also extends to the system, which should allow individuals to share divergent opinions freely. Currently, in the bureaucratic science organizations in India, complex hierarchies, unending work assignments, peer pressure and little scope for creativity suppress many potential ideas (Mashelkar, 2010). Open-minded approaches may facilitate a more creative working environment (Basadur, 2004), where employees can develop innovative solutions to problems like linking farmers to markets and processing channels.

Table 38. Consensus formation and composite score ranking for competencies for change agents

Competency description	Mode	IQR*	QD**	AS***	CS****	Rank
Market linking and processing competence	6	0	0	96.77	186	1
Open minded attitude	6	1	0.5	90.32	186	1
Integrated policy formulation and contingency planning	6	0	0	96.77	183	2
Multi-stress tolerant technology research	6	2	1	90.32	183	2
Farming with environmental concerns	6	1	0.5	96.77	181	3
Effective team work and problem solver	6	1	0.5	96.77	180	4
Sustainable resource management skills	6	1	0.5	96.77	179	5
Real-time information dissemination using ICTs	6	1	0.5	90.32	179	5
Efficient scheme implementer	6	1	0.5	96.77	179	6
Subject matter competence (with innovativeness)	6	1	0.5	93.55	178	7
Efficient water use knowledge	6	1	0.5	87.1	178	7
Quick and dynamic decision making	6	1	0.5	93.55	177	8
Credible demonstrator with strong farmer linkages	6	1	0.5	93.55	177	8
Knowledge of efficient input use	6	1	0.5	93.55	175	9
Environmental assessment	6	1	0.5	93.55	175	9
Vision and problem understanding	6	1	0.5	90.32	175	9
Effective motivator, capacity builder	6	1	0.5	93.55	173	10
Professional soft skills	6	1	0.5	90.32	172	11
Convincing awareness creation	6	1	0.5	90.32	171	12
Data management and interpretation skills	5	1	0.5	90.32	169	13
Impact management training	5	1	0.5	87.1	165	14
Performer and quick learner	5	1	0.5	83.87	163	15
Computing, modeling, GIS, programming skills	5	1	0.5	83.87	161	16
Robotics and nano-technology vision	5	1	0.5	64.52	139	17

*Interquartile range

**Quartile deviation
***Agreement score
****Composite sore

The experts also state that change agents need to be effective team workers and problem solvers, be good at disseminating information, possess knowledge about sustainable resource management, and be able to use information technologies competently. It is interesting to see that experts rated competencies like computing, modeling, GIS, programming, robotics, and nano-technology with much lower relevancy than competency in information technologies. This indicates that effective communication with farmers using modern information technology is of a higher priority than high-tech developments, which may never reach the farmer without systematic communication interventions.

Farmers' involvement in environmental policy formulation along with appropriate trainings will improve their capacity to deal with environmental uncertainties in the agricultural sector (Curry, 1997). Thus, theme 2 of the survey presents the essential competencies that farmers in NER should possess to successfully implement policy recommendations, and contribute to an enhanced resilience against negative impacts of climate change. The top-rated competencies are skills in eco-friendly farming, a problem-solving attitude, knowledge about and implementation of biodiversity conservation, skills in integrated farming and management, and the desire and ability to work in the community with a cooperative spirit (Table 39). Eco-friendly farming practices generally refer to the use of green manures, bio-fertilizers, chemical-free farming, integrated insect and disease management, and use of traditional knowledge. The practices ensure more sustainable agriculture, but their implementation in NER is complicated by insufficient awareness and knowledge about the practices, inadequate extension services and poor availability of alternative pesticides and fertilizers (Kabir, Haque, Uddin, Samsuddula, & Sarker, 2007). Therefore, the localized approach to innovation promotion and constraint removal would be highly pertinent for NER to intensify the adoption of climate-smart agricultural innovations (Makate, Makate, Mango, & Siziba, 2019).

The desire for a problem-solving attitude refers to most farmers' habit of immediately abandoning a practice if it does not yield the desired results right away. Instead of going to the next best alternative, experts would wish that farmers try to find a way to make the first best option work.

Table 39. Consensus formation and composite score ranking for competencies desired among farmers

Competency description	Mode	IQR	QD	AS	CS	Rank
Eco-friendly farming skills	6	1	0.5	93.55	187	1
Problem solving attitude	6	0	0	93.55	187	1
Biodiversity conservation	6	0	0	93.55	183	2
Integrated management farming skills	6	0	0	93.55	183	2
Working in community	6	0	0	93.55	181	3
Water harvesting knowledge	6	0	0	87.1	177	4
Farm management competency	6	1	0.5	90.32	176	5
Knowledge of climate-resilience	6	1	0.5	90.32	176	5
Strong will power and patience	6	1	0.5	87.1	176	5
Market understanding	6	1	0.5	90.32	174	6
Resource smart farming	6	1	0.5	90.32	172	7
Positive consideration for technology use	6	1	0.5	87.1	169	8
Knowledge and resource sharing	6	1	0.5	87.1	169	8
Information access skills (via internet)	5	1	0.5	83.87	160	9

*Interquartile range
**Quartile deviation
***Agreement score
****Composite sore

This could not only benefit the environment but also the farmers themselves, as many of the most successful farm-entrepreneurs are skilled innovators and routinely adapt farming technologies and ideas to serve their needs (Buttner & Gryskiewicz, 1993; Griffin & Guez, 2014). The wished-for competencies in biodiversity conservation and integrated farming system approaches are closely linked to eco-friendly farming and can contribute towards more sustainable land use and higher profits for farmers (Dar et al., 2018). Parker (2013) Proposed approach wherein culture of the community, as well as traditions, are integrated with the conservation policy and similar method of conservation training could be much pertinent for the farmers of NER. Lastly, community approaches and cooperation at the village level can help to pool knowledge, tools, and experiences, and facilitate successful farming and problem to solve where individuals may have failed (Lyson, 2005). In theme 3, experts were asked to rate the importance of institutions for supporting change agents and farmers in their endeavor to move towards a more climate-change resilient agriculture. Top-rated institutional stakeholders are *Krishi Vigyan Kendras*, village level initiatives, individual farm families, farmer cooperatives and community level efforts Table 40.

Table 40. Consensus formation and composite score ranking for Institutional response prioritization

Institutions	Mode	IQR	QD	AS	CS	Rank
Krishi Vigyan Kendras (KVKs)	7	1	0.5	96.77	199	1
Village level initiatives	7	1	0.5	96.77	196	2
Individual farm family level actions	6	1	0.5	96.77	195	3
Farmers co-operatives and Community level efforts	6	1	0.5	96.77	192	4
NGOs / Self Help Groups interventions	6	1	0.5	93.55	189	5
State level programs	6	1	0.5	93.55	188	6
Ministry level initiatives	6	1	0.5	90.32	187	7
Organization level initiatives	6	2	1	96.77	185	8
Initiatives of State Agricultural Universities	6	0	0	96.77	183	9
National level plans and programs	6	0	0	90.32	181	10
Zonal interventions	6	1	0.5	93.55	179	11
District level management	6	1	0.5	90.32	175	12
Interventions by international organizations	5	1	0.5	80.65	155	13

*Interquartile range
**Quartile deviation
***Agreement score
****Composite sore

The responses to theme 3 highlights that experts think the excellent rapport *Krishi Vigyan Kendras* have to the farming communities and cooperatives should be exploited and expanded to promote climate-resilient agricultural practices further. They are situated ideally to develop key competencies among farmers through appropriate training programs and result in oriented awareness programs. The experts' recommendations further show that the outreach officers of *Krishi Vigyan Kendras* should use a community-level approach to implement village level- as well as individual farmer level initiatives to enhance resilience against climate change. In a recent study, Sellberg, Ryan, Borgström, Norström, and Peterson (2018) emphasized that adaptive governance can be successfully enhanced with resilience planning that includes local and collaborative approaches. The mandate of *Krishi Vigyan Kendras* deems much fit for promoting climate-resilience among rural farmers to ensure sustainable agriculture as they generally work with local farmers through collaborative extension activities. It is also noteworthy that according to the experts, individual farm families should assume more responsibility for the successful implementation of sustainability, climate-resilience related policies, as the actions of individual farm families, and farming communities can decide the success or failure of any agriculture-related policy. This finding is congruent with the conclusion

of a study conducted by Islam and Nursey-Bray (2017) which advocates formal institutions for building culturally compatible partnerships with community-based informal institutions for enhancing the process of adaptation against climate change. In a nutshell, in the context of developing countries, we agree with the argument of Adenle, Azadi, and Arbiol (2015) which affirms that policy and institutional change are imperative to tackle the climate change impacts using agricultural innovation systems.

6.3.1 Statistical analysis of results

To test the internal consistency of the sampled data, we calculated Cronbach's alpha for the third Delphi round. The value of 0.968 shows that the internal consistency is excellent and the reliability of the data is high. The consensus among experts was high for 95% of the items (IQR<1 and QD <0.5, Table 38, Table 39, Table 40). Similarly, the mode values confirm the strong consensus formation: 81.71 % of items were rated with a mode value greater than six. A significant increase in Friedman's X^2 test statistics was found from round two to round three (382.9 to 578.3, Table 41), indicating an alignment of opinions to a common distribution from the second to the third round. Kendall's W also increased from 0.148 in the second to 0.23 in the third round, validating the finding. All statistical measures confirm that a significant level of consensus was achieved in the third Delphi round.

Table 41. Theme-wise analysis of the responses given in round two and three of the Delphi survey using Friedman's X^2 test and Kendall's W at significant levels.

Round no.	Thematic section	PPMs*	Friedman's X^2	Kendall's W	df**	P-value
2	Crucial competencies for change agents	32	106.0	0.144	23	.000
	Essential competencies desired among farmers	32	50.9	0.123	13	.000
	Institutional response prioritization	32	48.8	0.127	12	.000
	All themes	32	382.9	0.148	81	.000
3	Crucial competencies for change agents	31	127.6	0.179	23	.000
	Essential competencies desired among farmers	31	65.4	0.162	13	.000
	Institutional response prioritization	31	86.7	0.233	12	.000
	All themes	31	578.3	0.230	81	.000

*Number of individual responses, **degrees of freedom.

6.3.2 Deficiencies in current trainings programs imparted by *Krishi Vigyan Kendras*

In order to determine in which areas the extension services, especially *Krishi Vigyan Kendras*, need to extend their training programs to teach the essential skills listed above, we reviewed the reports of the ICAR-Agricultural Technology Application Research Institute (ATARI) Umiam for the years 2010-2017. ATARI is the nodal agency that yearly reviews and monitors the overall performance of *Krishi Vigyan Kendras* in NER. *Krishi Vigyan Kendras* implement various training programs, awareness camps, skill workshops, etc. to advance competencies among farmers as well as extension personnel in the concerned district, sometimes cooperating with other change agencies to offer trainings that are more specialized.

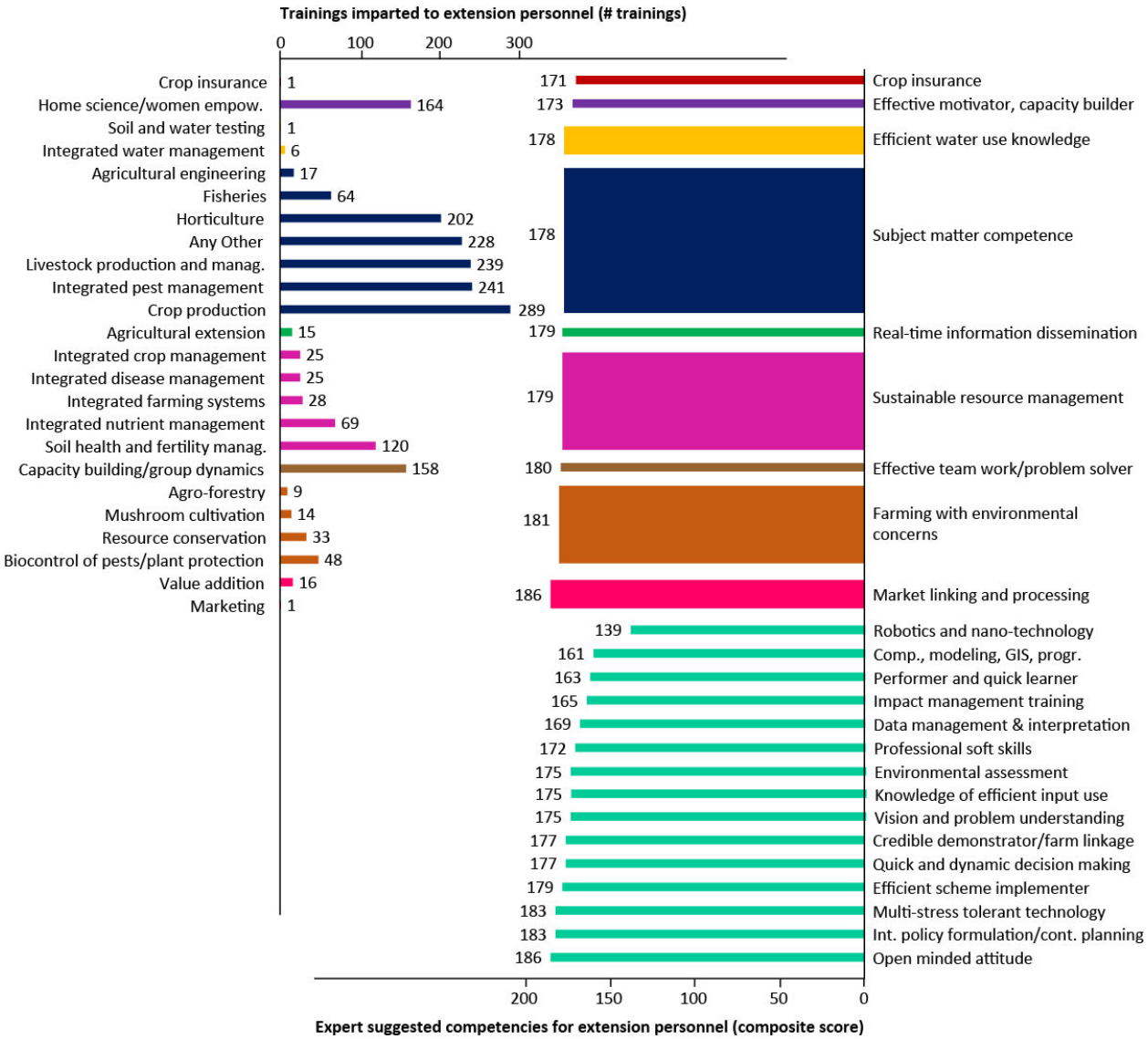

Figure 29. Left: Training imparted to the extension personnel of NER by the *Krishi Vigyan Kendras* during 2011-2017. Right: Essential skills recommended by experts in NER and their composite score.

Figure 29 shows the number of training courses imparted to extension personnel working in NER during 2010-2017 (see Appendix M for details). The majority of the courses dealt with the enhancement of subject matter competence like crop production, integrated pest management, livestock production, and horticulture science related courses. Marketing skills, competencies in post-harvest processing or soft skills like efficient policy formulation and planning received little to no training time. The comparison of skills ranked highly in the Delphi consensus, and actual training imparted to change agents/extension personnel thus undoubtedly highlights that competencies required to enhance climate-resilience are not adequately covered (Figure 29).

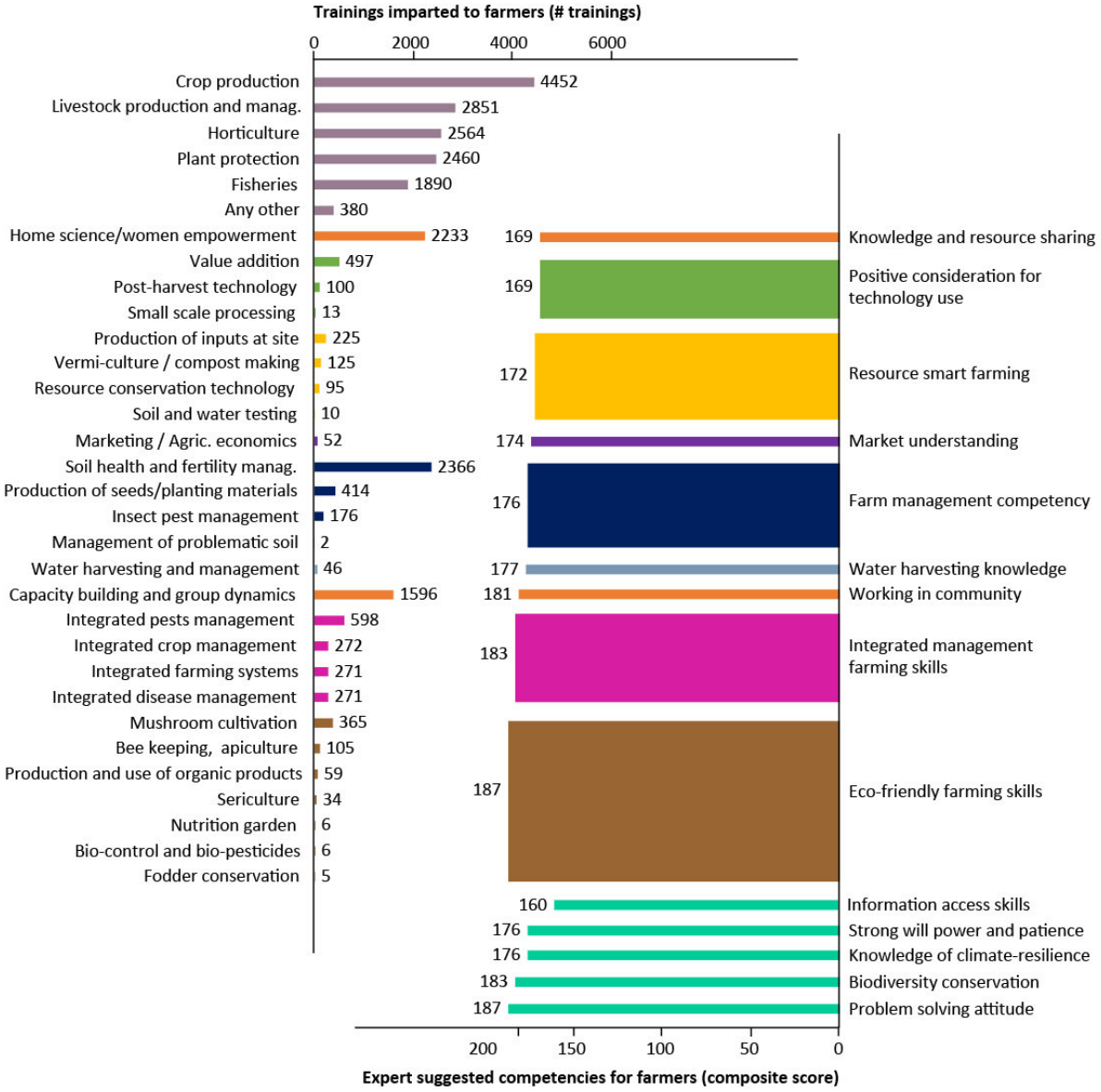

Figure 30. Left: Trainings imparted to the farmers of NER by the *Krishi Vigyan Kendras* during 2011-2017. Right: Essential skills recommended by experts in NER and their composite score.

The trainings imparted to the farmers of NER are presented in Figure 30. It shows that most of the contemporary training programs for farmers and rural youth are focusing on crop production, horticultural crop farming, livestock production, and crop protection measures. Experts recommended skills in eco-friendly farming and biodiversity conservation, or soft skills like approaches towards problem-solving are not covered well by the current curriculum. However, some of the current training programs are consistent with the experts' recommendations, even though the number of courses does not reflect the importance the experts attributed to them. These include courses covering topics like income generating activities, women empowerment, group formation and dynamics, integrated crop farming, integrated pest, and disease management and nutrient management.

The reports also show that the training policy of *Krishi Vigyan Kendras* is already progressing towards the right direction since 2014/15 (see Appendix K and Appendix L for details), and that extension personnel is already contributing to the sustainability of the NER farming sector. Furthermore, this finding reaffirms the results shown in Figure 30, that *Krishi Vigyan Kendras* have a leading role to play to empower farmers through various village level initiatives and scientific interventions and help them deal with the impacts of climate change.

6.4 Conclusion

When looking at the necessary competencies of change agents, farmers and institutions to deal with the problems of climate change in the agricultural sector of NER, an upgrade of managerial competencies are essential. Change agents must be able to efficiently link farmers to markets, as marketing is one of the major problems of farmers in NER, and be open-minded at all levels of management to facilitate innovative problem-solving. Farmers need to be competent in the areas of eco-friendly farming and biodiversity conservation and should assume a more active role in innovation and problem solving, preferably at the community level, where resources can be pooled and experiences shared. The *Krishi Vigyan Kendras* have to play a priority role in implementing policies promoting sustainable and climate-resilient agriculture, as they are the institutional link to farm families, farming communities and rural villages in NER. As experts request a more active involvement of villages, farm families and farming communities to combat the negative impacts of climate change, policies should primarily target these entities. Experts are confident that the overall sustainability of the agricultural sector of NER can be considerably enhanced by these measures.

6.5 Acknowledgment

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Chapter 7: Summary and Conclusions

This dissertation was motivated by the ongoing impacts of climate change in India which especially affect the agricultural sector and threaten the food security of billions. The Northeastern region of India, which is a part of a fragile Indo-Burma biodiversity hotspot and located close to the eastern Himalayan range, was selected as a study area. The first chapter of this dissertation provides background information on agriculture in Northeastern India and discusses the need for a multi-method and multi-stakeholder approach for formulating strategies to mitigate the socio-economic and environmental impacts of climate change. The dissertation seeks to understand the perception and priorities of concerned stakeholders in order to establish contextualized strategies which reduce the adversities of climate change in the NER. Considering the damages triggered by climatic aberrations in NER, climate-resilient technologies offer enormous potential to sustain the livelihoods of indigenous people and to mitigate climate change impacts in the agricultural sector. Local adaptation strategies require a good understanding of the vulnerabilities of local inhabitants to climate change. These strategies also foster adaptive capacity development in affected regions through the participation of farming communities.

The dissertation has provided evidence that indigenous farmers are aware of climate change and its impacts and are seeking interventions to sustain their farming dependent livelihood. Farmers in NER have experienced a rise in temperature and variability in rainfall cycle that is responsible for recurring damage to agricultural production. Many farmers experienced income losses during the Kharif and Rabi seasons and noticed a decline in water availability and soil fertility. Their autonomous adaptations include mixed cropping, change of crop varieties, soil conservation, shelters for livestock, vaccinations, and scientific feeding regimes. These adaptations are basic management adjustments but may not provide adequate resilience against future climate change as the frequency and intensity of impacts is increasing in NER. Consequently, farm profitability is jeopardized as farmers are deprived of advanced interventions to provide optimum climate-resilience. While farmers are willing to adapt, they face certain impediments such as costly inputs, unawareness of adaptation technologies, and insufficient access to investment credits. My analysis shows that farmers need support to continue farming and secure their fragile livelihood. Chapter 2 emphasizes that farmers need to be empowered with holistic adaptation packages that combine appropriate advisory, credit,

and technology to enhance climate resilience. Integrated farming approaches deem adequate for the agricultural sector of NER due to their multiple advantages such as profitability, enhanced productivity, cost minimization, and environmental safety.

This dissertation has also contributed to the understanding of factors which (according to the perception of NER farmers) were responsible for aggravating climate extremes and incurred heavy losses in the agricultural sector. Farmers of NER have little doubt about the reality of climate change and have perceived changes in rainfall pattern, temperature increase and frequent insect pest attacks on crops which drastically reduced their income from crop farming. A logistic regression model was used to examine various socio-economic determinants of farmer's perception of climate change. It revealed that the gender of a farmer (i.e., male), cattle ownership, understanding of uneven rainfall distribution, the realization of changes in non-timber forest produce, and farm-to-market distance significantly contribute to an affirmative perception. Farmers with access to agriculture-related schemes and farmers who lived nearby agricultural department offices are less likely to perceive climate change impacts. The results of Chapter 3 also highlight the need for gender-specific interventions to increase adaptations and to reduce income disparities in society.

Chapter 4 examines the internal strengths and weaknesses and external opportunities and threats using a brainstorming approach. The unanimous agreement (of participants of 21 brainstorming sessions) revealed that internal weaknesses were biggest impediments to harness external opportunities in the agricultural sector of NER. The results showed numerous weaknesses arising from organizational management lacunas (such as staff inadequacy, insufficient funding, and poor logistic support to extension professionals), policy-related issues (i.e. unavailability of state wise agricultural policies / lesser emphasis on climate-sensitive policy making) and mismanagement of human resource (e.g. excessive reporting, inadequate assessment programs, and lesser growth opportunities). Due to the dominance of this kind of weaknesses, a defensive strategy is recommended for half of the sampled districts in NER. The recommended strategies in all quadrants indicate that a single policy will not work for the districts of NER, but AERS in all districts shall undertake priority measures to enhance climate-resilience of the agricultural sector. The SWOT analysis results recommended elimination of internal weaknesses as a first and foremost step to create an ideal work environment for all employees that would be conducive for improved performance. Adequate funding for research

and extension activities, logistic support to professionals, and firm steps to reduce bureaucracy are some of the key recommendations.

This dissertation uses a Delphi methodology to incorporate the perspective of intermediate and higher level professionals who are active in the agricultural sector of NER. The results emphasize important challenges including rainfall dependency of farming, unsound marketing of farm produce, recurring floods, and inadequate supply of quality inputs to the farming community in NER. The Delphi experiment reveals that investments in integrated farming systems, market reforms, timely supply of quality agricultural inputs and promotion of value addition in the agricultural sector have a vast potential to improve socio-economic conditions of farming communities in NER. The research (Chapter 5) had examined expert consensus and emphasized the need for massive investment in the agricultural sector of NER, to meet the present and future challenges imposed by climate change impacts.

Finally, the dissertation has answered questions concerning the competency development among change agents as well as farmers in NER (Chapter 6). The results showed that there is a need to connect farmers with markets, and change agents could develop this competency along with increased open-mindedness to serve the farming community in a better way. To foster sustainable development and to deal with climate change impacts, farmers also need to develop competencies like eco-friendly farming, biodiversity conservation, innovative problem-solving and community approaches. In NER, the *Krishi Vigyan Kendras* are important institutions for promoting climate-resilient agricultural technologies because of their strong links to farming communities. Agricultural experts through Delphi surveys affirm that farm families, farmers' cooperatives, and voluntary organizations (i.e., NGOs, SHGs) have a crucial role to play for combating climate change impacts through active involvement and partnership with change agencies (such as *Krishi Vigyan Kendras*, State Agricultural Universities, and similar organizations).

In a nutshell, the intermediate and zonal level must address the policy discrepancies in the agricultural sector and ensure regular and adequate funding to change agencies. At all levels of governance and management, existing policies must be corrected to eliminate internal weaknesses which are impeding the performance of the system and causing dissatisfaction among professionals. Firstly, the NARS must help its employees to perform optimally, before haphazardly helping farmers. At the field level, the system needs to equip extension

professionals of *Krishi Vigyan Kendras* and other extension workers with appropriate logistic support to empower farmers with technological interventions. The active involvement of farm families, villagers, farmers' cooperatives and is crucial for the successful implementation of strategies to mitigate the impacts of climate change and ensure livelihood sustainability of indigenous farmers. Moreover, this requires substantial funding and appropriate competency development among change agents as well as farmers in NER.

The results of this dissertation support strategic planning and provide empirical evidence for policymakers and managers at all levels of decision-making. The use of a multi-method approach and the involvement of multiple stakeholders provides robust, comprehensive, and relevant conclusions for the current socio-economic context of NER. As natural, technical, and social-economic conditions change, so do optimal strategies. To dynamically update policy and decision makers, Delphi surveys, SWOT exercises, and farm household interviews should be repeated at regular intervals. In future studies, more emphasis can be given to livestock and fishery sector while sampling experts for policymaking. Considering the diversity of NER, district-specific strategies are desirable to address the specific needs of diverse indigenous farming communities and to foster climate-resilience through the dissemination of adaptation options.

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Appendices

Appendix A. Questionnaire developed to collect data from farmers

Strategies to Mitigate the Socio-Economic and Environmental Impacts of Climate Change: a Case of Northeastern India

Personal interview schedule for farmers in Northeastern region of India

Place of Interview: _____ Date of interview: _____

Name of Interviewer: _____

==========

IMPORTANT INSTRUCTIONS FOR INTERVIEWER

i. Please read all the instructions before initiating interview.
ii. Please read all the questions and sections in the interview schedule before going to interview (at least twice).
iii. In case of any difficulty regarding a question or its answer, please contact PI of the project before the interview
iv. Follow the question sequence (see "go to" column) and translate the question with most possible care.
v. Greet the farmer with a smile and build a good rapport with him, initiate a talk.
vi. Inform him/her about ICAR institute, the aim of the project and why are you doing this interview?

vii. Tell him / her background information for this study
=> This study is aimed to formulate the strategy to minimize the adverse impacts of climate change. Farmers' participation is essential to prepare and execute such kind of strategies. Hence, I come here to ask you a few questions about your farm, family, your village and which problems you are facing in agriculture. We are trying to help you. In the long run, it will protect our environment and farming.

viii. Explain why his / her response matters?
=> The information will be used for research purpose. The results of the research will be used to formulate an action plan which will improve the resilience among the farming community. Your crop will be protected, and in case of damage, you may claim benefits from insurance. It will help us to make farming profitable. Your participation is essential to protect our future generations and their wellbeing from changing the climate.

ix. Please don't make any false promise to farmers.
x. Tell them that its bit long survey, about 1 and 1/2 hour time is required. Stay focused, don't divert.
xi. Please don't comment or explain the question if the farmer does not understand, the repeat the question again.
xii. Questions with an asterisk (*) mark are not group questions. So ask them individually.
xiii. Encourage farmer to speak. Please don't use negative words or gestures. Appreciate him/her.
xiv. Take help of flashboards and flip charts to collect responses from farmers.
xv. Take the appropriate photographs of interview sessions for the record.
xvi. Refrain yourself from disclosing the information of this survey. Maintain the confidentiality of answers.

Open Ended Questions (Fill in the blanks)	Multiple Choice Questions (Tick the appropriate)	* Indicates Personal Questions

1. SOCIO-ECONOMIC AND ASSET PROFILE OF RESPONDENT

- ❖ Tick the appropriate option by darkening the circle (① = ❶) of a response option
- ❖ Use dark color pens (Blue gel pen) with a bold pointer for easy markings
- ❖ Don't reveal the options to farmers, seek their views and opinions.
- ❖ Don't write full sentences for open-ended questions, just write key words, ideas, and phrases

Sl. No.	Question	Response codes *(Tick the appropriate or write the response)*	Go to
1.1	Name of respondent*		⬇
1.2	Village		⬇
1.3	District		⬇
1.4	State		⬇
1.5	Age (in years)*	_____ Years	⬇
1.6	Reservation category*	① General ② Scheduled Caste ③ Scheduled Tribes ④ Nomadic Tribes ⑤ Other Backward Classes ⑤	⬇
1.7	Gender*	① Male ② Female ③ Third gender	⬇
1.8	Family type*	① Joint family ② Nuclear Family	⬇
1.9	Education status*	① Illiterate ② Primary ③ Secondary ④ Higher secondary ⑤ Under Graduate ⑤ Post Graduate and above	1.12
1.10	Income of farmer*	…….. (Rs./month) Ask average income for a month	2.1
1.11	Sources of income*	① Farming……% ② Wages and Salary……..……..% ③ Livestock……..% ④ Non-farm Business……..……..% ⑤ Other……..……%	1.18
1.12	House type of respondents* *(you can observe and write the correct answer)*	① Cement+brick constructed house with a concrete roof (strong) ② Cement+brick constructed house with metal sheet roof (semi-strong) ③ Wood constructed house with metal sheet roof ④ Bamboo hut house with metal sheet roof ⑤ Bamboo hut house without metal sheet roof ⑥ Traditionally built a house (Hut made up of locally available resources)	⬇
1.13	Electricity access*	① Regular ② Irregular ③ No access at all	⬇
1.14	Transportation assets/ vehicles of respondents*	① Bike/cycle ② Motor-cycle ③ Four-wheeler vehicle ④ Tractor with trolley ⑤ mini-van / tempo ⑥ Bullock Cart ⑦ Horse ⑧ Hand-pulled cart ⑨ Other	⬇
1.15	Household utilities*	① LPG connection ② Traditional stove ③ LED bulbs ④ Refrigerator ⑤ Music player/radio	⬇
1.16	Modern sources of information/ICT tools*	① Cell-phone ② Smartphone ③ Internet connection ④ Computer/laptop ⑤ Tablet ⑥ Landline phone ⑦ Television ⑧DTH connection ⑨Other	⬇
1.17	Financial empowerment tools*	① Bank Account ② ATM/Debit card ③ Credit card ④ Aadhar Card ⑤Net banking ⑥Telephone banking	1.11
1.18	Major living expenses of last month (in Rupees)* (Ask a farmer how much he spent?)	①Food ……. ₹ ②Clothing……... ₹ ③Education……₹ ④Housing…..…..₹ ⑤Transport…….. ₹ ⑥Health-care……. ₹ ⑦Festivals……..₹ ⑧Ceremony…….₹ ⑨investment…… ₹ ⑩Mobile phone…. ₹ ⑪……..…₹ ⑫……..₹ ⑫Are you forced to travel? (Yes/No) …….. ; ⑬Why? ……	1.19
1.19	Major agricultural costs of last season (in Rupees)*	①Seed……...₹ ②Land preparation……₹ ③Insecticides……..₹ ④Electricity…....₹ ⑤Labor…….₹ ⑥ Feed and fodder…….₹ ⑦Transport……..….. ₹ ⑧Irrigation……..₹ ⑨ Fuel……..₹ ⑩Land revenue……₹ ⑪ Fertilizer……..…..₹ ⑫Storage ……..…₹ ⑬Hiring implements…….. ₹ ⑭_____.....₹ ⑮_____.....₹	2.5

2. HOUSEHOLD INFORMATION OF RESPONDENT

2.1 Since how long you are residing in this village?* ..... years

2.2 Household size, On-farm and Off-farm employment status of family*

Age group	Number of members	Number in school	Full time on the farm	Part-time on the farm	Full-time off-farm	Part-time off-farm	Status of off-farm	Type of migration
<15 years								
15 to 65 years								
> 65 years								

2.3 Since how long you are practicing agriculture (in years)* ..... years

2.4 What are your families' Non-vegetarian and livestock dependent food choices?* → 2.7

①Milk ②Bird meat ③Pork ④ Mutton ⑤Beef ⑥Fish ⑦Eggs ⑧..... ⑨.....

2.5 What is the minimum cash you need for a month to run your household normally* ..... Rs. (INR) → 2.6

2.6 Assuming all the basic needs of your family as 100%, to what extent do you think they are satisfied today?* ..... % → 1.10

2.7 Are you receiving any social security benefits/assistance from the central or state government to support your livelihood?*

③Food items	④Health care	⑤Free education	⑥Sanitation
⑦Transport	⑧Drinking water	⑨*Jan-dhan*	⑩LPG subsidy
⑪Agricultural support	⑫Housing	⑬farming subsidy	⑬Pension
⑭Child birth	⑮Electrification	⑯Skill development	⑰Employment
⑱Youth development	⑲Crop insurance	⑳	

2.8 Are you receiving any agriculture and the weaker section related social security scheme?*

③Soil Health card	④Neem coated urea	⑤Atal Pension Yojana (APY)
⑥Irrigation Scheme	⑦Food Security Mission	⑧Horticulture Mission
⑨Sustainable agriculture	⑩Marketing Scheme	⑪Minimum Support price
⑫Rashtriy Krishi Vikas Yojana	⑮Paramparagat Krishi Vikas Yojana (Organic farming)	
⑬Pradhan Mantri Jeevan Jyoti Bima Yojana (PMJJBY)		
⑭Pradhan Mantri Suraksha Bima Yojna (PMSBY)		

2.9 Recently occurred diseases/health related issues in family members (since last 10 years)*

①No diseases	②Malaria	③Diabetes	④Cholera	⑤Diarrhea
⑥Hepatitis	⑦Jaundice	⑧Typhoid	⑨ Dengue	⑩Japanese encephalitis
⑪Flu	⑫Chikungunya	⑬Kidney stone	⑭Cancer	⑮Tuberculosis
⑯Asthama	⑰			

2.9.1 Reasons for the frequent occurrence of observed diseases?

1. .....
2. .....

2.10 What is a source of your drinking water?*

①River	②Canal	③Tube well	④Pond
⑤Hand-pump	⑥Tap water	⑦spring	⑧Other

2.11 Do you process/purify water before drinking? * ①Yes; Always ②Sometimes ③Never

3. FARM /AGRICULTURE RELATED INFORMATION

3.1	Land holding*	..... Acres or ..... Hectare
3.2	What is your Farming interest?*	①Agriculture ②Horticulture ③Animal husbandry ④Fishery ⑤Agro-forestry ⑥Other
3.3	Complementary and allied farm ventures adapted by the farmer?*	①Poultry birds ②Mushrooms ③Cattles (No =.....) ④Pigs ⑤Rabbit ⑥Honeybees ⑦Goat /sheep ⑧Fishes ⑨Dog breeding ⑩Crabs ⑪ ⑫
3.4	Farm assets/implements possessed by respondent:*	

①Drip irrigation	②Well	③Farm pond	④Cattle shed	⑤Poultry house
⑥Solar panel	⑦Nursery	⑧Bee-hives	⑨Piggery units	⑩Poly-house
⑪Plough	⑫Sprinkler	⑬Mini processing kit	⑭Rainwater harvesting unit	
⑮	⑯	⑰	⑱	

3.5	How do you assess the soil fertility of your farmland?*	①Very High ②High ③Average ④Low ⑤Very low ⑥Infertile
3.6	Do you know, How many farmers on average each year left the farming and migrated to city from your village?	①..... (permanently migrated) ②..... (temporarily migrated)
3.7	Will, you also prefer to migrate to another city in case you get the opportunity to earn better than farming?*	①Strongly disagree ②Disagree ③Neutral ④Agree ⑤Strongly agree
3.8	Migration is a much convenient option than practicing farming with changing climate*	①Strongly disagree ②Disagree ③Neutral ④Agree ⑤Strongly agree
3.9	In the present situation, what are the main factors, do you consider for making farm decisions?	

①Weather ②Monsoon forecasts ③Soil fertility ④Past experience
⑤Market demand ⑥Own preferences ⑦Availability of inputs ⑧Price of inputs
⑨Transportation ⑩Livestock ⑪Water availability ⑫Crop condition
⑬Expert advice ⑭Investment potential ⑮Season ⑯Indigenous knowledge
⑰Farm labor ⑱Type of insect ⑲Type of disease ⑳Traditions 21. Associated risk 22. Expected profits 23. Trend in village 24. Market availability
25._____ 26._____ 27._____ 28._____

Serial no.	Decision category	Factors considered for making a decision (write numbers)
I.	Crop choice / crop rotation	
II.	Date of sowing	
III.	Fertilizer type	
IV.	Fertilizer quantity	
V.	Soil Tillage	
VI.	Pest control methods	
VII.	Disease control method	
VIII.	investment for irrigation	
IX.	Harvesting of produce	
X.		

3.10	What is your main objective of farming?*	①To maximize yield ②To sustain a family livelihood ③To maintain present yield levels ④To sustain the environment ⑤To ensure sustainability for all ⑥.....

4. INSTITUTIONAL DATA (Participation, Representation and decision-making)

4.1	What is the distance of your farm from the nearest market?	.....KM
4.2	What is the distance of your farm from the nearest paved road?	.....KM
4.3	What is the distance of your home from an education institute (school)?	.....KM
4.4	What is the distance of your home from the health-care facility?	.....KM
4.5	What is the distance of your home from a banking institution?	.....KM
4.6	What is the distance of your home from the office of Agriculture Officer (AO)?	.....KM
4.7	What is the distance of your home from Farm Science Center (KVK)?	.....KM
4.8	What is the distance of your home from the Police station?	.....KM
4.9	What is your social participation/membership status?* ①NGOs ②Village council ③Religious institution ④SHGs ⑤Farmers' club ⑥Farmers' co-operative ⑦.....	Participation Frequency ①High ..... ②Mediocre ..... ③Poor .....
4.10	Is there any functional organization working for the betterment of farmers?	①Yes ② No

4.11 Which institutes/agencies provide you information/ awareness regarding climate change?

Agency / source	Quality of service ①High ②Reasonable ③Poor	The frequency of contact/access ①weekly ②forthnightly ③Monthly ④Bimonthly ⑤Seasonally
I. State department of agriculture	①②③	①②③④⑤
II. Institutes of ICAR	①②③	①②③④⑤
III. *Krishi vigyan Kendras* (farm Science centers)	①②③	①②③④⑤
IV. State / Central Agricultural universities	①②③	①②③④⑤
V. Private input (seed/ fertilizer etc.) companies	①②③	①②③④⑤
VI. Neighboring/ progressive farmers	①②③	①②③④⑤
VII. Other.....	①②③	①②③④⑤

4.12 Access and use of different Institutional services in **RABI** and ***KHARIF*** season 2015-16

Institutional services	Do you have access to these asked institutional services ① Yes ② No	Did you use the asked services ? ① Yes ② No	What was the source of a particular service? ①Own ②Relative/friend/ fellow ③Government agency ④Private/ NGOs ⑤Media (TV/Newspaper/ internet) ⑥Other	How would you rate the **quality** of the support services for? High-----① Reasonable---② Poor--------③	The frequency of contact/access ①weekly ②forthnightly ③Monthly ④Bimonthly ⑤Seasonally
a) Agricultural credit	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
b) Machines/Tractors	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
c) Supply and repair of farm tools	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
d) Marketing of produce	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
e) Post-harvest processing	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
f) Extension services	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
g) Weather forecast	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
h) Seasonal forecast	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
i) Market information	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
j) Crop insurance	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
k) Soil testing	①②	①②	①②③④⑤⑥	①②③	①②③④⑤
l) Water testing	①②	①②	①②③④⑤⑥	①②③	①②③④⑤

5. CLIMATE CHANGE PERCEPTIONS, ADAPTATIONS, CONSTRAINTS

	Choose: ①Strongly disagree; ②Disagree; ③Neutral; ④Agree; ⑤Strongly agree	
5.1	I am aware of the changing climate/climate change?*	① ③ ② ④ ⑤
5.2	I have observed unusual climate events in last 10-15 years*	① ③ ② ④ ⑤
5.3	Climate change is man-made; we are responsible for it.*	① ③ ② ④ ⑤
5.4	Climate change is real, and it's currently happening*	① ③ ② ④ ⑤
5.5	We have damaged our environment seriously; soon it will be a disaster*	① ③ ② ④ ⑤
5.6	We must act as early as possible to stop it*	① ③ ② ④ ⑤
5.7	I am concerned about CC, and I will contribute for sustainability*	① ③ ② ④ ⑤

5.8 Where do you learn(ed) about climate changes?* (sources of info. on climate change) YES= ①; NO=⓪

1.	Neighboring farmer	① ⓪	2.	Extension services	① ⓪
3.	Village leader	① ⓪	4.	Input dealers	① ⓪
5.	Newspaper (print media)	① ⓪	6.	My own experience	① ⓪
7.	Television, radio	① ⓪	8.	Internet	① ⓪
9.	Social media	① ⓪	10.		① ⓪
11.		① ⓪	12.		① ⓪

5.9 Tell us the increase or decrease concerning following climate change indicators: What kind of events have you observed which had not occurred in your area before, and what was their frequency?

Climate change indicators		Experienced change?		Impact on indicator	
		YES	NO	Increased	Decreased
I.	Rainfall quantity	①	⓪	①	⓪
II.	Changes in temperature	①	⓪	①	⓪
III.	Human diseases	①	⓪	①	⓪
IV.	Livestock diseases	①	⓪	①	⓪
V.	Crop diseases	①	⓪	①	⓪
VI.	Insect and pest attacks	①	⓪	①	⓪
VII.	Uneven rainfall distribution	①	⓪	①	⓪
VIII.	Frequency of droughts	①	⓪	①	⓪
IX.	Frequency of floods	①	⓪	①	⓪
X.	The late arrival of the rainy season	①	⓪	①	⓪
XI.	Early cease of the rainy season	①	⓪	①	⓪
XII.	Untimely rains	①	⓪	①	⓪
XIII.	Changes in rainfall season length	①	⓪	①	⓪
XIV.	Excessive lightening	①	⓪	①	⓪
XV.	Soil erosion	①	⓪	①	⓪
XVI.	Agricultural yield	①	⓪	①	⓪
XVII.	Forest resources	①	⓪	①	⓪
XVIII.	Change in health condition/fitness	①	⓪	①	⓪
XIX.	Don't know any of the above	①	⓪		

5.10 Climate variables that affect **Crops/livestock/ fishery /environment** as experienced by NE farmers

Climate Variable	Attributes of impact/damage (What type of damage occurred?)	frequency of damage (how many times in a year)
a) Cyclones and storms		
b) Hail storms		
c) Erratic rains		
d) Temperature		

e) Flooding		
f) Cold / Chilling winter / frost		
g) Drought		
h) Heat waves		
i) Wind		

5.11 How would you rate the changes in your area since last decade?

Water quality parameters	Improved/ Increased	Not Changed	Worse/ decreased	Don't know
Availability of water	①	②	③	④
Quality of irrigation water?	①	②	③	④
Land water-logging?	①	②	③	④
Land/ Soil salinity?	①	②	③	④
Land fertility?	①	②	③	④
Ground water table?	①	②	③	④
Quality of drinking water?	①	②	③	④

5.12 Impact on income from various farm activities*

Income category	Increasing	Decreasing	Not Changed
Income from (agriculture) crop farming	①	②	⓪
Income from livestock	①	②	⓪
Income from fishery	①	②	⓪
Income from agro-forestry	①	②	⓪
Income from organic farming	①	②	⓪
Income from integrated farming	①	②	⓪
Income and yield during *Kharif* season (rainy)	①	②	⓪
Income and yield during *Rabi* season (winter)	①	②	⓪
Income and yield during Summer season	①	②	⓪

Other impacts / changes (Mountains / rivers/ plains / hills) perceived because of climate change

Impacts/changes perceived by local people	**Reasons**

5.13 What are the causes of climate change in the Northeastern region of India?

⓪Strongly disagree; ①Disagree; ②Neutral; ③Agree; ④Strongly agree

a) Deforestation	⓪①②③④	b) Use of pesticides	⓪①②③④
c) Soil degradation	⓪①②③④	d) Use of vehicles	⓪①②③④
e) Global warming (CO2)	⓪①②③④	f) Too much population	⓪①②③④
g) Pollution (all)	⓪①②③④	h) Urbanization	⓪①②③④
i) Intensive cropping	⓪①②③④	j) Industrialization	⓪①②③④
k) Overgrazing	⓪①②③④	l) Excessive mining	⓪①②③④
m) Excess use of fertilizers	⓪①②③④	n) Oil/gas drilling	⓪①②③④
o)	⓪①②③④	p)	⓪①②③④

Any other causes: ……
……
……

5.14 Coping measures adopted by Farmers (Tick the appropriate category)

a) Use of subsidies	b) Contact with extension wing	c) Training from experts
d) Changed earning source	e) SMS alerts for weather	f) Attending exhibitions
g) Migration to urban areas	h) No measures adopted	i) Attending farmers' fairs
j) Post-harvest treatment	k) Proper packaging	l) Market linkages established
m) Integrated farming	n) Complementary activity started	o) Accessed weather information
p) Organic farming	q)	r)

Crop farming	**Livestock rearing**	**Fish farming**
I. Mixed cropping	1. Providing shelter	a) Repair of ponds
II. Changed crop type	2. Improved livestock housing	b) Plantation on pond dyke
III. Changed planting time	3. Cleaning and sanitation	c) Increased pond dike height
IV. Use of different varieties	4. Timely vaccination	d) Pumping of saline water
V. Soil conservation	5. Isolation of animals	e) Application of lime
VI. Crop diversification	6. Change of breeds	f) Addition of fresh water
VII. Shortened growing period	7. Scientific feeding	g) Application of fertilizers
VIII. Changed fertilizers	8. Extra care during pregnancy	h) Application of cow dung
IX. Windbreaks / guarding	9. Shifted to improved breeds	i) Changed fish type
X. Fertilizer doses changed	10. Change in population	j) Change in population
XI. Use of pesticides	11. Artificial insemination	k) Changed feeding
XII. Renting of cropland	12. Use of crossbreeds	l) Preventive measures
XIII. Shifted farm site	13. Reduced grazing	m) Desilting of ponds
XIV. Changed land-use pattern	14. Livestock insurance	n) Harvesting dates shifted
XV. Adopted irrigation	15. Marketing dates shifted	o) Quality fingerlings
XVI. Improved storage methods	16. Shifted to local breeds	p)
XVII. Water conservation	17. Cultivating fodder crops	q)
XVIII. Augmented by livestock	18.	r)
XIX. Crop insurance	19.	s)
XX. Zero Tillage	20.	t)
XXI.	21.	u)
XXII.	22.	v)

5.15

Other adaptations (Nature base solutions) / responses to cope up with the impacts of climate change

Interventions/ adaptation measures / community responses	**Reasons**

5.16

What is the impact of climate change on “conflicts” and “cooperation”? (1=low; 3=high, 0=neutral)

CONFFLICT	Attribute / variable	COOPERATION
⓪ || ③ ← ② ← ① ←	Land sharing, land-use	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Water exchange	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Forest Produce	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Wildlife	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Neighborhood relations	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Agricultural resources, inputs	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Family, household issues	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Labor for farming	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Riverine resources	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Fishing	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Livestock rearing, Grazing	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Marketing of produce	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Information sources	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Institutional linkages	→ ① → ② → ③ ⁞ ⓪

5.17

In the long run, which crops/ventures will perform POSITIVELY or NEGATIVELY in changing the climate?

POSITIVE PERFORMANCE	Attribute / variable	NEGATIVE PERFORMANCE
⓪ || ③ ← ② ← ① ←	Rice	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Fishery	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Pig farming	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Maize	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Wheat	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Pulses	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Oilseeds	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Vegetables	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Plantation crops	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←		→ ① → ② → ③ ⁞ ⓪

5.18	Constraints faced by farmers while adopting measures to cope up with the climate change impacts (tick the appropriate)	⬇

a) Shortage of land		b) Lack of awareness		c) The high cost of inputs	
d) Poor soil fertility		e) Lack of credit/money		f) High transportation cost	
g) Labor shortage		h) Lack of water		i) Conflicts and clashes	
j) Shortage of farm inputs		k) Lack of market access		l) Lack of confidence	
m) Lack of information		n) Lack of training		o) Fear of failure	
p) Cultural compatibility issues		q) Electricity/power supply		r) No support from the public sector	
s) My behavior		t) Lack of motivation		u) Non-rewarding activity	
v) No institutional linkages		w) No family support		x)	
y)		z)		aa)	

5.19	Which services/support you need from the government (ICAR, KVK, State Department of Agriculture, Ministry of Agriculture, etc.) or private sector to practice sustainable farming in changing the climate? i. …… ii. …… iii. …… iv. …… v. …… vi. ……	⬇
5.20	Which are your worst fears? What makes you panic? * ①Thunderstorms ②Floods ③Earthquakes ④insect pest attack ⑤crop damage ⑥sickness / epidemics ⑦wildlife conflicts ⑧landslides ⑨Hailstorms ⑩Heatstroke ⑪…… ⑫……	⬇
5.21	Which things/situations make you happy?* ①Bumper yields ②good market price ③optimum rainfall ④winning award ⑤support from govt. ⑥…… ⑦…… ⑧…… ⑨…… ⑩…… ⑪…… ⑫……	⬇

6. WILLINGNESS TO MITIGATE THE IMPACTS

	Statements	**Agreement**	
6.1	Are you able to suffice your family's nutritional needs?*	①Yes ②No ③Don't know	⬇
6.2	Are you able to suffice your family's Educational needs?*	①Yes ②No ③Don't know	⬇
6.3	Are you able to suffice your family's health-care needs?*	①Yes ②No ③Don't know	⬇
6.4	Are you able to suffice your family's security needs?*	①Yes ②No ③Don't know	⬇
6.5	Are you able to suffice your family's social needs?*	①Yes ②No ③Don't know	⬇
6.6	Are you able to make some savings every year?*	①Yes ②No ③Don't know	⬇
6.7	Do you believe that climate change is real?*	①Yes ②No ③Don't know	⬇

6.8	Do you think that because of the changing and unpredictable climate you are spending more and not able to save?*	①Yes ②No ③Don't know	⬇
6.9	How much you can pay to mitigate the impacts of global warming?*	①…….. % of annual income ②can't pay anything	⬇
6.10	How you can pay to shape up sustainable future?* (Mitigation of impacts)		⬇

Expense category	Agreement
i. Can you pay more to buy organic / bio-friendly food products?*	①Yes ②No ③Undecided
ii. Can you pay more to buy clean energy?*	①Yes ②No ③Undecided
iii. Can you pay more to purchase energy saver appliances?*	①Yes ②No ③Undecided
iv. Can you pay more to buy a solar panel to utilize solar energy?*	①Yes ②No ③Undecided
v. Can you pay more to buy bio-diesel or bio-fuels?*	①Yes ②No ③Undecided
vi. Can you take a loan from the bank to do any of (M,N,O,P,Q)?*	①Yes ②No ③Undecided
vii. Can you pay more for bio-fertilizers, bio-pesticides, etc.?*	①Yes ②No ③Undecided

6.11	Which sentence describes your dedication towards climate change impact mitigation programmes? ①I will fully engage myself with CCIMP ②I will partially engage myself with CCIMP ③I will occasionally engage with CCIMP ④I cannot engage with myself with CCIMP	
6.12	Besides money, how can you engage yourself in other ways to mitigate the impacts of changing the climate? Please choose from the following items. (Tick/strike the appropriate) ①*Awareness Programme* ⑨*Tree Planting Campaigns* ⑰*Shramadan (Volunteering)* ②*Kitchen gardening* ⑩*Use of eco-friendly ways* ⑱*Influencing others for good* ③*Adopting healthy lifestyle* ⑪*Rainwater harvesting* ⑲*Clean India campaign* ④*Timely vaccination* ⑫*Use of public transport* ⑳*Support local farmer* ⑤*Fund raising* ⑬*Sharing resources* *21. Solid waste management* ⑥*Composting of waste* ⑭*Waste classification* *22. Imparting education* ⑦*No to plastic/carry bag* ⑮*Use of LPG/CNG* *23. Less processed food* ⑧*Less use of paper* ⑯*Less use of water* *24. Less use of wood* *25.* _____ *26.* _____ _____ *27.* _____	⬇
6.13	To whom you prefer to pay more for your safety and security (as a matter of trust/faith)? ①*Private input companies* ⑦*Government service provider* ⑬ *Disaster relief fund* ②*NGOs* ⑧*Religious organization* ⑭*Central government* ③*Insurance companies* ⑨ *Universities* ⑮*State government* ④*Local administration* ⑩ *Academicians* ⑯*Political parties* ⑤*I prefer to pay my income tax* ⑪*Scientists / researchers* ⑰_____ ⑥*None, I have my own plans* ⑫*Doctors /hospitals* ⑱_____	⬇
6.14	Presently, how much you can pay to participate in / promote climate change adaptation /mitigation programme?* ①*Rs. 10* ②*Rs. 20* ③*Rs. 50* ④*Rs. 100* ⑤*Rs. 200* ⑥*Rs.500* ⑦*Rs. 1000* ⑧*Rs. 1500* ⑨*Rs.2000* ⑩*Rs. 5000* ⑪*Rs.10000* ⑫*More than Rs. 10,000*	⬇

7. FARMERS' PERSPECTIVE ABOUT ORGANIC FARMING

	Statements	**Response**	
7.1	Are you aware of organic farming?*	①Yes ②No ③I am not sure	⬇
7.2	At present, are you practicing Organic cultivation on your farm?*	①Yes ②No ③I am not sure	⬇
7.3	I practice organic farming because of*; ①I am a poor farmer, don't have access to modern inputs ④I prefer not to use chemicals in farm ②My farm location is not good for modernized farming ⑤I wanted to earn more ③It's my choice, I know how it is beneficial for us ⑥I am not sure about my farming style		⬇

7.4	What do you think about organic farming?	
7.5	Why you like Organic farming? (Which advantages you get from it)	
7.6	Why do you hate organic farming? (Disadvantages) alternatively, Why you do not want to go for it?	
7.7	Why you are not opting for organic farming? What are the obstacles? Difficulties?	
7.8	What support you need to fully adopt organic farming?	
7.9	What will be the cost for you to adopt organic farming?	..... Rupees *
7.10	How can we convince/pursue (motivate) other farmers to opt for organic farming?	

7.11	Are you connected with social media networks? * ①*Facebook* ②*Whats app* ③*Twitter* ④*Email account* ⑤	
7.12	Farmers' overall comments. (If respondent want to say something besides interview schedule)* 1. ..... 2. ..... 3.	

For Interviewer only:

i.	Was the interviewee: 1. Cooperative 2. Interested 3. Uninterested 4. Off-hand in responding	①②③④
ii.	Has the interviewer felt that he/she was getting thoughtful and realistic responses?	Yes ① No ⓪
iii.	Were there some of the issues raised that were not in the interview schedule? Details please:	

Greet the farmer and thank him / her after you complete the interview session

Appendix B. Brainstorming questionnaire developed for SWOT analysis

Strategies to Mitigate the Socio-Economic and Environmental Impacts of Climate Change: a Case of Northeastern India

Brainstorming questionnaires for the Subject Matter Specialists of KVKs in Northeastern region of India

Place of Interview: _____

Date of interview: _____

==========

-: MPORTANT INSTRUCTIONS FOR PARTICIPANT OF GROUP EXERCISE :-

A. Kindly read all instructions before filling questionnaire
B. Fill out the sections from 1.1 to 3.14 as it is a personal opinion based information (Time 20 Mins.)
C. Write down your name once again before starting section 4.
D. All exercises from section 4 are group exercises, so please wait for the instructions from facilitator

==========

1. PERSONAL PROFILE

Sl. No.	Question	Response code *(Tick the appropriate or fill in the blanks)*	Go to
1.1	Name of participant		⬇
1.2	District and State		⬇
1.3	Institute		⬇
1.4	Designation		⬇
1.5	Specialization		⬇
1.6	Age (in years)	..... Years	⬇
1.7	Gender	①Male ②Female	⬇
1.8	Education status	①Under-Graduate ②Post-Graduate ③Doctorate	⬇
1.9	Annual income	..... INR. (Rs. Per year) approx.	⬇
1.10	Work experience	..... Years	⬇
1.11	Sources of information on changes in weather/climate	①Cell-phone (SMS) ②Smartphone (Multimedia) ③Internet/websites ④Newspaper ⑤Television ⑥Scientific networks ⑦Radio ⑧Social media (FB, Twitter, WhatsApp) ⑨Research journals /publications ⑩ ⑪ ⑫	⬇
1.12	The frequency of updating information/knowledge about weather/climate?	①Daily ②Weekly ③Fortnightly (15 days interval) ④Monthly ⑤Bi-monthly ⑥Few times a year ⑦Whenever required ⑧Not sure	

2. CLIMATE CHANGE PERCEPTIONS, ADAPTATIONS, CONSTRAINTS

	Choose: ①Strongly disagree; ②Disagree; ③Neutral; ④Agree; ⑤Strongly agree	
5.22	I am aware of the changing climate/climate change?*	① ③ ② ④ ⑤
5.23	I have observed unusual climate events in last 10-15 years*	① ③ ② ④ ⑤
5.24	Climate change is man-made; we are responsible for it.*	① ③ ② ④ ⑤
5.25	Climate change is real and it's currently happening*	① ③ ② ④ ⑤
5.26	We have damaged our environment seriously; soon it will be a disaster*	① ③ ② ④ ⑤
5.27	We must act as early as possible to stop it*	① ③ ② ④ ⑤
5.28	I am concerned about CC, and I will contribute for sustainability*	① ③ ② ④ ⑤

5.29 Tell us the increase or decrease concerning following climate change indicators: What kind of events have you observed which had not occurred in your area before, and what was their frequency?

Climate change indicators	Experienced change?		Impact on indicator	
	YES	NO	Increased	Decreased
I. Rainfall quantity	①	⓪	①	⓪
II. Changes in temperature	①	⓪	①	⓪
III. Human diseases	①	⓪	①	⓪
IV. Livestock diseases	①	⓪	①	⓪
V. Crop diseases	①	⓪	①	⓪
VI. Insect and pest attacks	①	⓪	①	⓪
VII. Uneven rainfall distribution	①	⓪	①	⓪
VIII. Frequency of droughts	①	⓪	①	⓪
IX. Frequency of floods	①	⓪	①	⓪
X. The late arrival of the rainy season	①	⓪	①	⓪
XI. Early cease of the rainy season	①	⓪	①	⓪
XII. Untimely rains	①	⓪	①	⓪
XIII. Changes in rainfall season length	①	⓪	①	⓪
XIV. Excessive lightening	①	⓪	①	⓪
XV. Soil erosion	①	⓪	①	⓪
XVI. Agricultural yield	①	⓪	①	⓪
XVII. Forest resources	①	⓪	①	⓪
XVIII. Change in health condition/fitness	①	⓪	①	⓪
XIX. Don't know any of the above	①	⓪		

5.30 Climate variables that affect **Crops/livestock/ fishery /environment** as experienced by NE farmers

Climate Variable	Attributes of impact/damage (What type of damage occurred?)	frequency of damage (how many times in a year)
j) Cyclones and storms		
k) Hail storms		
l) Erratic rains		
m) Temperature		
n) Flooding		
o) Cold / Chilling winter / frost		
p) Drought		
q) Heat waves		
r) Wind		
s)		

5.31 How would you rate the changes in your area since last decade?

Water quality parameters	Improved/ Increased	Not Changed	Worse/ decreased	Don't know
Availability of water	①	②	③	④
Quality of irrigation water?	①	②	③	④
Land water-logging?	①	②	③	④
Land/ Soil salinity?	①	②	③	④
Land fertility?	①	②	③	④
Ground water table?	①	②	③	④
Quality of drinking water?	①	②	③	④

5.32 Impact on income from various farm activities*

Income category	Increasing	Decreasing	Not Changed
Income from (agriculture) crop farming	①	②	⓪
Income from livestock	①	②	⓪
Income from fishery	①	②	⓪
Income from agro-forestry	①	②	⓪
Income from organic farming	①	②	⓪
Income from integrated farming	①	②	⓪
Income and yield during *Kharif* season (rainy)	①	②	⓪
Income and yield during *Rabi* season (winter)	①	②	⓪
Income and yield during Summer season	①	②	⓪

5.33 Other impacts / changes (Mountains / rivers/ plains / hills) perceived because of climate change

Impacts/changes perceived by local people	Reasons

2.12.A. Have you observed migration among farming communities? Please explain
Observations about Temporary migration pattern:

Observations about Permanent migration pattern:

5.34 What are the causes of climate change in the Northeastern region of India?

⓪Strongly disagree; ①Disagree; ②Neutral; ③Agree; ④Strongly agree

q) Deforestation	⓪①②③④	r) Use of pesticides	⓪①②③④
s) Soil degradation	⓪①②③④	t) Use of vehicles	⓪①②③④
u) Global warming (CO2)	⓪①②③④	v) Too much population	⓪①②③④
w) Pollution (all)	⓪①②③④	x) Urbanization	⓪①②③④
y) Intensive cropping	⓪①②③④	z) Industrialization	⓪①②③④
aa) Overgrazing	⓪①②③④	bb) Excessive mining	⓪①②③④
cc) Excess use of fertilizers	⓪①②③④	dd) Oil/gas drilling	⓪①②③④
ee)	⓪①②③④	ff)	⓪①②③④

5.35 Coping measures adopted by Farmers (Tick the appropriate category)

1. Use of subsidies	2. Contact with extension wing	3. Training from experts
4. Changed earning source	5. SMS alerts for weather	6. Attending exhibitions
7. Migration to urban areas	8. No measures adopted	9. Attending farmers' fairs
10. Post-harvest treatment	11. Proper packaging	12. Market linkages established
13. Integrated farming	14. Complementary activity started	15. Accessed weather information
16. Organic farming	17.	18.

Crop farming	**Livestock rearing**	**Fish farming**
I. Mixed cropping	1. Providing shelter	a. Repair of ponds
II. Changed crop type	2. Improved livestock housing	b. Plantation on pond dyke
III. Changed planting time	3. Cleaning and sanitation	c. Increased pond dike height
IV. Use of different varieties	4. Timely vaccination	d. Pumping of saline water
V. Soil conservation	5. Isolation of animals	e. Application of lime
VI. Crop diversification	6. Change of breeds	f. Addition of fresh water
VII. Shortened growing period	7. Scientific feeding	g. Application of fertilizers
VIII. Changed fertilizers	8. Extra care during pregnancy	h. Application of cow dung
IX. Wind breaks/guarding	9. Shifted to improved breeds	i. Changed fish type
X. Fertilizer doses changed	10. Change in population	j. Change in population
XI. Use of pesticides	11. Artificial insemination	k. Changed feeding
XII. Renting of cropland	12. Use of crossbreeds	l. Preventive measures
XIII. Shifted farm site	13. Reduced grazing	m. Desilting of ponds
XIV. Changed land-use pattern	14. Livestock insurance	n. Harvesting dates shifted
XV. Adopted irrigation	15. Marketing dates shifted	o. Quality fingerlings
XVI. Improved storage methods	16. Shifted to local breeds	p.
XVII. Water conservation	17. Cultivating fodder crops	q.
XVIII. Augmented by livestock	18.	r.
XIX. Crop insurance	19.	s.
XX. Zero Tillage	20.	t.
XXI.	21.	u.
XXII.	22.	v.

5.36 Other adaptations (Nature base solutions) / responses to cope up with the impacts of climate change

Interventions/ adaptation measures / community responses	**Reasons**

5.37 What is the impact of climate change on “conflicts” and “cooperation”? (1=low; 3=high, 0=neutral)

CONFFLICT	Attribute / variable	COOPERATION
⓪ || ③ ← ② ← ① ←	Land sharing, land-use	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Water exchange	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Forest Produce	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Wild-life	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Neighborhood relations	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Agricultural resources, inputs	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Family, household issues	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Labor for farming	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Riverine resources	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Fishing	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Livestock rearing, Grazing	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Marketing of produce	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Information sources	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Institutional linkages	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←		→ ① → ② → ③ ⁞ ⓪

5.38 In the long run, which crops/ventures will perform POSITIVELY or NEGATIVELY in changing the climate?

POSITIVE PERFORMANCE	Attribute / variable	NEGATIVE PERFORMANCE
⓪ || ③ ← ② ← ① ←	Rice	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Fishery	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Pig farming	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Maize	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Wheat	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Pulses	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Oilseeds	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Vegetables	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←	Plantation crops	→ ① → ② → ③ ⁞ ⓪
⓪ || ③ ← ② ← ① ←		→ ① → ② → ③ ⁞ ⓪

5.39 Constraints faced by farmers while adopting measures to cope up with the climate change impacts (tick the appropriate)

a. Shortage of land		b. Lack of awareness		c. The high cost of inputs	
d. Poor soil fertility		e. Lack of credit/ money		f. High transportation cost	
g. Labor shortage		h. Lack of water		i. Conflicts and clashes	
j. Shortage of farm inputs		k. Lack of market access		l. Lack of confidence	
m. Lack of information		n. Lack of training		o. Fear of failure	
p. Cultural compatibility issues		q. Electricity/power supply		r. No support from the public sector	
s. My behavior		t. Lack of motivation		u. Non-rewarding activity	
v. No institutional linkages		w. No family support		x.	
y.		z.		aa.	

Other causes in your observation/opinion:

Manmade causes:

Natural causes:

3. WILLINGNESS TO MITIGATE THE IMPACTS

	Statements	Agreement
6.15	Are you able to suffice your family's nutritional needs?*	①Yes ②No ③Don't know
6.16	Are you able to suffice your family's Educational needs?*	①Yes ②No ③Don't know
6.17	Are you able to suffice your family's health-care needs?*	①Yes ②No ③Don't know
6.18	Are you able to suffice your family's security needs?*	①Yes ②No ③Don't know
6.19	Are you able to suffice your family's social needs?*	①Yes ②No ③Don't know
6.20	Are you able to make some savings every year?*	①Yes ②No ③Don't know
6.21	Do you believe that climate change is real?*	①Yes ②No ③Don't know
6.22	Do you think that because of changing and unpredictable climate you are spending more and not able to save?*	①Yes ②No ③Don't know
6.23	How much you can pay to mitigate the impacts of global warming?*	①…….. % of annual income ②can't pay anything

6.24 How you can pay to shape up sustainable future?* (Mitigation of impacts)

Expense category	Agreement
a. Can you pay more to buy organic / bio-friendly food products?*	①Yes ②No ③Undecided
b. Can you pay more to buy clean energy?*	①Yes ②No ③Undecided
c. Can you pay more to purchase energy saver appliances?*	①Yes ②No ③Undecided
d. Can you pay more to buy a solar panel to utilize solar energy?*	①Yes ②No ③Undecided
e. Can you pay more to buy bio-diesel or bio-fuels?*	①Yes ②No ③Undecided
f. Can you take a loan from the bank to do any of (M,N,O,P,Q)?*	①Yes ②No ③Undecided
g. Can you pay more for bio-fertilizers, bio-pesticides, etc.?*	①Yes ②No ③Undecided

6.25 Which sentence describes your dedication towards Climate Change Impact Mitigation Programmes?
①I will fully engage myself with CCIMP ②I will partially engage myself with CCIMP
③I will occasionally engage with CCIMP ④I cannot engage with myself with CCIMP

6.26 Besides money, how can you engage yourself in other ways to mitigate the impacts of changing the climate? Please choose from the following items. (Tick/strike the appropriate)

①*Awareness Programme* ⑨*Tree Planting Campaigns* ⑰*Shramadan (Volunteering)*
②*Kitchen gardening* ⑩*Use of eco-friendly ways* ⑱*Influencing others for good*
③*Adopting healthy lifestyle* ⑪*Rainwater harvesting* ⑲*Clean India campaign*
④*Timely vaccination* ⑫*Use of public transport* ⑳*Support local farmer*
⑤*Fund raising* ⑬*Sharing resources* *21. Solid waste management*
⑥*Composting of waste* ⑭*Waste classification* *22. Imparting education*
⑦*No to plastic/carry bag* ⑮*Use of LPG/CNG* *23. Less processed food*
⑧*Less use of paper* ⑯*Less use of water* *24. Less use of wood*
25. _____ *26. _____* *27. _____*

6.27 To whom you prefer to pay more for your safety and security (as a matter of trust/faith)?

①*Private input companies* ⑦*Government service provider* ⑬ *Disaster relief fund*
②*NGOs* ⑧*Religious organization* ⑭*Central government*
③*Insurance companies* ⑨ *Universities* ⑮*State government*
④*Local administration* ⑩ *Academicians* ⑯*Political parties*
⑤*I prefer to pay my income tax* ⑪*Scientists / researchers* ⑰_____
⑥*None, I have my own plans* ⑫*Doctors /hospitals* ⑱_____

6.28 Presently, how much you can pay to participate in / promote climate change adaptation /mitigation programme?*
①*Rs. 10* ②*Rs. 20* ③*Rs. 50* ④*Rs. 100* ⑤*Rs. 200* ⑥*Rs.500*
⑦*Rs. 1000* ⑧*Rs. 1500* ⑨*Rs.2000* ⑩*Rs. 5000* ⑪*Rs.10000* ⑫*More than Rs. 10,000*

NAME OF THE BRAINSTORMING SESSION PARTICIPANT: _____

4. SWOT analysis of Northeastern region's agriculture research and extension system in changing climate scenario (Time : 30 Mins)

Strengths *(Internal)*	Weaknesses *(Internal)*
S.1) …… **S.2)** …… **S.3)** …… **S.4)** …… **S.5)** …… **S.6)** …… **S.7)** …… **S.8)** …… **S.9)** …… **S.10)** …… **S.11)** …… **S.12)** ……	**W.1)** …… **W.2)** …… **W.3)** …… **W.4)** …… **W.5)** …… **W.6)** …… **W.7)** …… **W.8)** …… **W.9)** …… **W.10)** …… **W.11)** …… **W.12)** ……
Opportunities *(External)*	**Threats** *(External)*
O.1) …… **O.2)** …… **O.3)** …… **O.4)** …… **O.5)** …… **O.6)** …… **O.7)** …… **O.8)** …… **O.9)** …… **O.10)** …… **O.11)** …… **O.12)** ……	**T.1)** …… **T.2)** …… **T.3)** …… **T.4)** …… **T.5)** …… **T.6)** …… **T.7)** …… **T.8)** …… **T.9)** …… **T.10)** …… **T.11)** …… **T.12)** ……

5. EXTERNAL FACTOR EVALUATION MATRIX: **(Time : 15 Mins)**

	EXTERNAL FACTOR	WEIGHT*	RATING**	WEIGHTED SCORE
OPPORTUNITIES (Ratings are in between 3 - 4)	O.1			
	O.2			
	O.3			
	O.4			
	O.5			
	O.6			
	O.7			
	O.8			
	O.9			
	O.10			
	O.11			
	Sub Total			
THREATS (Ratings are in between 1 - 2)	T.1			
	T.2			
	T.3			
	T.4			
	T.5			
	T.6			
	T.7			
	T.8			
	T.9			
	T.10			
	T.11			
	Sub Total			
	TOTAL WEIGHTED SCORE	100		

***List all factors and weight them in between 10 and 100 in such way that total of column* is = 100**
(10 not important →→ 100 extremely important)

**** Assign each factor rating in between 1 to 4 to show whether a factor is opportunity or threat**
(Major threat = 1 →→ Minor threat = 2 →→ Minor opportunity = 3 →→ Major opportunity = 4)

6. INTERNAL FACTOR EVALUATION MATRIX: **(Time : 15 Mins)**

	INTERNAL FACTOR	WEIGHT*	RATING**	WEIGHTED SCORE
STRENGHTS (Ratings are in between 3 - 4)	S.1			
	S.2			
	S.3			
	S.4			
	S.5			
	S.6			
	S.7			
	S.8			
	S.9			
	S.10			
	S.11			
	Sub Total			
WEAKNESSES (Ratings are in between 1 - 2)	W.1			
	W.2			
	W.3			
	W.4			
	W.5			
	W.6			
	W.7			
	W.8			
	W.9			
	W.10			
	W.11			
	Sub Total			
	TOTAL WEIGHTED SCORE	100		

***List all factors and weight them in between 10 and 100 in such way that total of column* is = 100**
(10 not important →→ 100 extremely important)

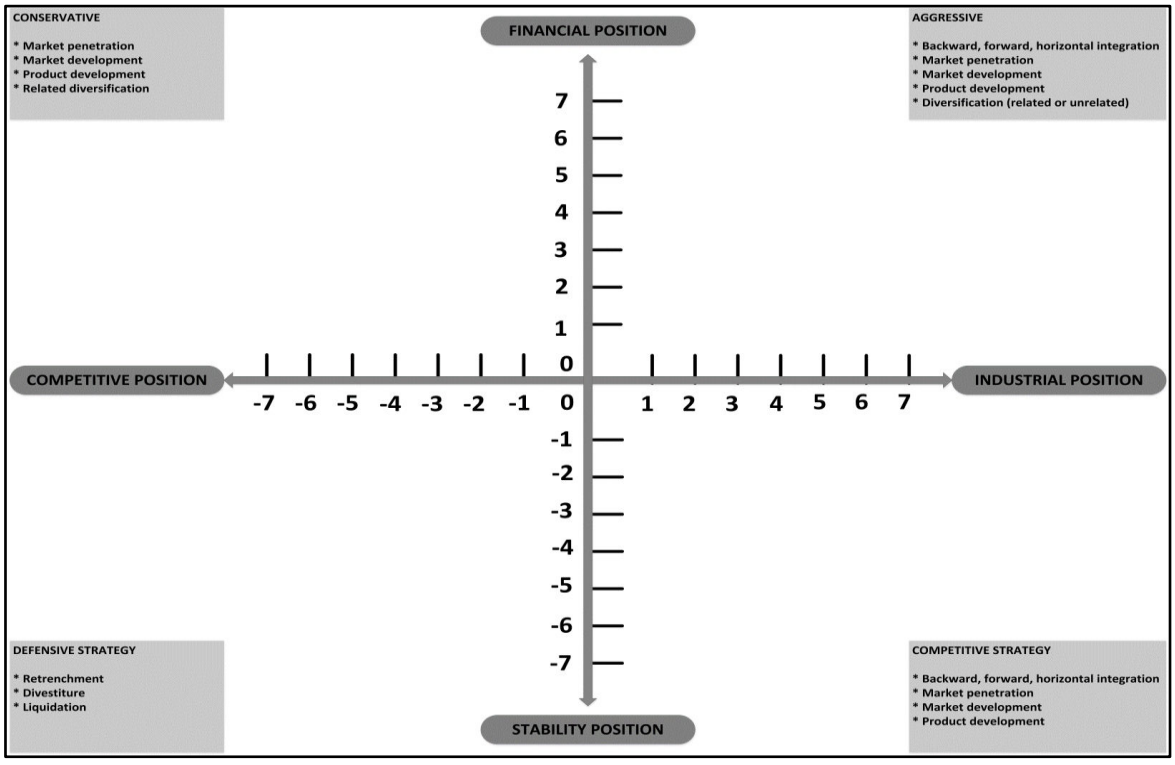
**** Assign each factor rating in between 1 to 4 to show whether a factor is strength or weakness**
(Major Weakness = 1 → Minor Weakness = 2 → Minor Strengths = 3 → Major Strengths = 4)

7. SPACE MATRIX for Agricultural research and extension system in Northeastern region

(Time: 25 Minutes)

Internal Strategic Position		External Strategic position	
Financial Position (FP)	**Competitive Position (CP)**	**Stability Position (SP)**	**Industry Position (IP)**
Return on investment	Market share	Technological changes	Growth potential
Leverage	Product quality	Rate of inflation	Profit potential
Liquidity	Product lifecycle	Demand variability	Financial stability
Working capital	Stakeholder loyalty	The price range of competing products	Extent leveraged
Cash flow	Capacity utilization	Barriers to entry in the market	Resource utilization
Inventory turnover	Technology know-how	Competitive pressure	Ease of entry into the market
Earnings per unit	Control over suppliers	Ease of exit from the market	Productivity
Price-earnings ratio	Control over distributors	Price of elasticity of demand	Capacity utilization
		The risk involved in business	

(Few more factors will be added or deleted as per the group consensus, Max 7 factors can be taken for each position)



The SPACE Matrix and its strategy quadrants (Only for understanding and ranking)

8. A space Matrix for Agricultural research and extension system in the Northeastern region

Sl. No.	Financial position (FP) variables	Rating (In between 1 – 7)*
FP.1		
FP.2		
FP.3		
FP.4		
FP.5		
FP.6		
FP.7		
	Subtotal of FP variable ratings	
Sl. No.	**Industry position (IP) variables**	**Rating (In between 1 – 7)***
IP.1		
IP.2		
IP.3		
IP.4		
IP.5		
IP.6		
IP.7		
	Subtotal of IP variable ratings	
Sl. No.	Stability position (SP) variables	Rating (In between -1 to -7)**
SP.1		
SP.2		
SP.3		
SP.4		
SP.5		
SP.6		
SP.7		
	Subtotal of SP variable ratings	
Sl. No.	**Competitive position (CP) variables**	**Rating (In between -1 to -7)****
CP.1		
CP.2		
CP.3		
CP.4		
CP.5		
CP.6		
CP.7		
	Subtotal of CP variable ratings	

*** Assign a numerical value ranging from +1 (worst) to +7 (best) to each of the variables for FP and IP dimensions.**
**** Assign a numerical value ranging from -1 (best) to -7 (worst) to each of the variables for SP and CP dimensions.**

FP average : (Subtotal of FP variable ratings) ÷ (Number of FP variables)	**( ) ÷( ) =**
IP average : (Subtotal of IP variable ratings) ÷ (Number of IP variables)	( ) ÷( ) =
SP average : (Subtotal of SP variable ratings) ÷ (Number of SP variables)	( ) ÷( ) =
CP average : (Subtotal of CP variable ratings) ÷ (Number of CP variables)	( ) ÷( ) =
Directional Vector Coordinates: X-axis = IP average + CP average	( ) + ( ) =
Directional Vector Coordinates: Y-axis = FP average + SP average	( ) + ( ) =

Draw a directional vector from the origin of the SPACE Matrix through the new intersection point, which reveals the type of strategy recommended for Agriculture research and extension system in the Northeastern region

CONCLUSION:

_____

(Time: 40 Minutes)

9. Policy recommendations/strategies for agricultural research and extension system

	INTERNAL STRENGTHS	INTERNAL WEAKNESSES
EXTERNAL OPPORTUNITIES	MAXI-MAXI (SO) = Aggressive	MINI-MAXI (WO) = Competitive
EXTERNAL THREATS	MAXI-MINI (ST) = Conservative	MINI-MINI (WT) = Defensive

MAXI-MAXI (SO)

Aggressive strategies	Ranking
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

MINI-MAXI (WO)

Competitive strategies	Ranking
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

MAXI-MINI (ST)

Conservative strategies	Ranking
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

MINI-MINI (WT)

Defensive strategies	Ranking
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	
11.	
12.	

(Priority ranking categories: 5=Very high, 4=High, 3=Medium, 2=Low, 1=Very low)

Guiding questions for framing alternative strategies based on the matching of SWOT quadrants	
9.1. Strategies for sustainable farming?	9.2. Strategies for boosting farmers' income?
9.3. Recommendations for future research	9.4. Recommendations for future extension programmes?

Appendix C. Delphi research pre-testing questionnaire

Subject: Pre-testing of Delphi questionnaire for strategy formulation study

Date <.....>

Dear <.....>,
Greetings from Hamburg, Germany....!!!

I am Amol Bhalerao, Scientist-AE (ICAR-ATARI, Umiam) and Ph.D. candidate of University of Hamburg, Germany. Presently, I am pursuing my doctoral degree research (Ph.D.) under the guidance of Professor Dr. Uwe Schneider, a renowned agricultural economist of the Center for Earth System Research and Sustainability (CEN). We are conducting multi-methodology research to explore and formulate "strategies to mitigate the socio-economic and environmental impacts of climate change," and research area is the Northeastern region of India. This research will tremendously contribute to our existing knowledge base, and it will provide a direction to formulate climate-resilient policies for the agricultural sector of the Northeastern region of India.

In this connection, I have purposefully selected you as an expert considering your expertise and vast work experience. We are anticipating your kind participation to make this study realistic and meaningful. You are at this moment requested to participate in this questionnaire pre-testing exercise. This questionnaire pre-testing round is designed to gather the ideas/views and expert suggestions to plan a novel strategy to minimize the impacts of climate change for the sustainability of Indian agriculture as well as it also provides an opportunity to evaluate the relevance of questions formulated by researchers. This pre-testing enables researchers to estimate the reliability, validity as well as the suitability of the questionnaire. We firmly believe that 'your response matters,' so please feel free to share your wisdom with us. Collected information will be used only for research purpose.

The pre-testing questionnaire is enclosed herewith (Or click here to fill online form). You are requested to answer the following questions based on your expertise and experiences. Additionally, please rank all the questions (question 1 to 11) according to their relevance for this study. Please rate each question on a scale of 1 to 5; where 1= least relevant, 3=mediocre relevance, and 5=most relevant. We are also looking for your suggestions to improve this study, so kindly share your suggestions and criticism, if any.
I understand that you are occupied with a lot of research and teaching activities, but I also feel that this study is incomplete without your participation. Looking forward to receiving an encouraging response from your side. Thanking you in advance.

Best regards,
Amol K. Bhalerao
Ph.D. candidate
Research Unit Sustainability and Global change
Universität Hamburg, Hamburg, Germany
Grindelberg 5, 20146 Hamburg

Delphi pre-testing questionnaire

Serial No.	Questions	Your Responses /Answer **(You may answer in bulleted points)**	**Relevance** **1=Least; 5=Most** (tick √ at the appropriate response category)				
			①	②	③	④	⑤
1.	In the near future, what kind of challenges Indian agriculture will face due to climate change? (You may answer the question concerning your subject matter/ specialization)						
2.	According to you, what are the ways to ensure the livelihood security of poor farmers (i.e., small, marginal, tribal farmers) in changing climate scenario?						
3.	What do you think are the innovative ideas/suggestions to formulate the sustainable and climate-resilient policy for Indian agriculture? (What needs to be incorporated in the futuristic policy?)						
4.	What should be the pioneering strategy to mitigate the "socio-economic" impacts of climate change in India?						
5.	What should be the advanced approach to mitigate the "environmental" impacts of climate change in India?						
6.	Which technologies will provide us with substantial						

	resilience against climate change? (Please provide inputs from your subject matter/area of expertise)						
7.	As per your experience, what are the probable areas of investment to secure a sustainable future? (Where we should invest more for assured results?)						
8.	Which skills/competencies are essentially required among “change agents” to fight against the changing climate? (Change agents = scientists, bureaucrats, professionals etc.)						
9.	Which skills/competencies are crucially desired among “farmers” to combat the impacts of changing the climate?						
10.	What are the barriers to attain the previously mentioned goals of sustainability?						
11.	Which are the ways/methods for overcoming these barriers?						

Appendix D. Delphi research invitation and first-round questionnaire

Subject: Participation in the first Delphi round

Date <.....>

Dear <.....>,
Greetings from Hamburg, Germany....!!!

This is the first round of Delphi method of data collection, which is administered by Mr. Amol K. Bhalerao (Scientist-AE) ICAR-ATARI, Umiam and Ph.D. candidate of University of Hamburg, Germany. Presently, I am pursuing my doctoral degree research (Ph.D.) under the guidance of Professor Dr. Uwe Schneider, a renowned agricultural economist of the Center for Earth System Research and Sustainability (CEN). We are conducting multi-methodology research to explore and formulate "strategies to mitigate the socio-economic and environmental impacts of climate change," and research area is the Northeastern region of India. This research will tremendously contribute to our existing knowledge base, and it will provide a direction to formulate resilient climate policies for the agricultural sector of the Northeastern region of India.

In this connection, I have purposefully identified you as a potential expert by considering your expertise and vast work experience in the Northeastern region of India. We are anticipating your kind participation to make this study realistic and meaningful. You are hereby requested to participate in the first Delphi survey round. This round is intended to gather the ideas/views and expert suggestions to plan novel strategies to minimize the impacts of climate change. Moreover, it also provides an opportunity to incorporate the views and concerns of farming-related professionals active in the Northeastern region of India. We firmly believe that 'your response matters,' so please feel free to share your wisdom with us.
Collected information will be used only for research purpose.

The First round survey questionnaire is enclosed herewith (Or click here to fill online form) to record your response. You are requested to answer the following questions based on your expertise and experiences. We are also looking for your suggestions to improve this study, so kindly share your suggestions and criticism, if any.

I understand that you are occupied with a lot of research and teaching activities, but I also feel that this study is incomplete without your participation. Looking forward to receiving an encouraging response from your side. In case you need any help or detailed information, please feel free to contact me by email (amolbhalerao.ars@gmail.com)
Thanking you in advance.

Best regards,
Amol K. Bhalerao, Ph.D. candidate
Research Unit Sustainability and Global Change
Universität Hamburg, Hamburg, Germany
Grindelberg 5, 20146 Hamburg

First Delphi round Questionnaire

Serial No.	Questions	Your responses /answer (you may answer in bulleted points)
1.	Name of respondent	
2.	Designation	
3.	Area/discipline of expertise	
4.	Years of experience (Of serving agriculture (and allied sciences) sector in Northeastern region of India)	
5.	In your view, which are the pressing challenges for Indian agriculture? (You may answer the question concerning your subject matter/ specialization)	
6.	Do you think climate change is also a challenge for Indian agriculture? (Please answer this question by rating the appropriate value 1= Not at all a threat, 3=Mediocre threat, 5=Most severe threat)	① ② ③ ④ ⑤
7.	According to you, what are the ways to ensure the livelihood security of poor farmers (i.e., small, marginal, tribal farmers) in changing future conditions?	
8.	What do you think are the innovative ideas /suggestions to formulate the sustainable and climate-resilient policy for Indian agriculture? (What needs to be incorporated in the futuristic climate resilient agriculture policy?)	
9.	What should be the pioneering strategy to mitigate the "SOCIO-ECONOMIC" impacts of climate change in India? (To safeguard societies, farming communities, etc. and their earnings)	

10.	What should be the advanced approach to mitigate the "ENVIRONMENTAL" impacts of climate change in India?	
11.	Which technologies will provide us with substantial resilience against climate change? (Please provide inputs/response from your subject matter/area of expertise)	
12.	As per your experience, what are the probable areas of investment to secure a sustainable future? (Where we should invest more for assured results?)	
13.	Which skills/competencies are essentially required among "CHANGE AGENTS" to fight against the changing climate? (Change agents = scientists, bureaucrats, professionals etc.)	
14.	Which skills/competencies are crucially desired among "FARMERS" to combat the impacts of changing the climate?	
15.	What are the barriers to attain sustainable farming?	
16.	Which are the ways for overcoming these barriers?	

Appendix E. Second round questionnaire of Delphi research

Dear expert of Delphi survey,
Greetings from Hamburg, Germany....!!

First of all, I thank you for your time and inputs in the round-1 questionnaire. Your inputs in the form of answers of the round-1 questionnaire are well received. Qualitative data generated in the first Delphi round is analyzed, and now we are headed for the second round of this Delphi exercise.

As you already know this exercise is aimed at novel strategy formulation to minimize the impacts of climate change in Northeastern India's agriculture. Moreover, this second round is a transition from open-ended textual response to rank order type of questions. Hence, in this second round, you have to rank certain questions in order to refine, categories and priorities the lists of policy components which are generated from the analysis of round-1. Kindly rank all of the policy options. You are allowed to add any additional information or policy component for each category in case you feel if relevant for this study. To facilitate your participation, every section will guide you with appropriate instructions.

However, in the last phase of this round-2 questionnaire (i.e., section-G), you can also rank the priority of action of various institutional players to shape up the climate change impact mitigation strategy in northeastern India. It will provide a much better overview of responsibility sharing and action priority among institutions.

Once again I assure that your responses will be used only for research purpose with due confidentiality. So please feel free to provide your ratings. Kindly fill the appropriate responses and at the end of this document click the “submit” button to send your responses. In case, you are not able to participate online then please inform me. I can mail you MS-word file to submit your responses.

I understand that you are already occupied with a lot of official activities thus please take your time to fill this form. I would appreciate your response up to XXXXX of 2017, which enables me for the timely analysis of this round.

I am looking forward to learning from your enriched experiences and wisdom.

Your sincerely,
Amol K. Bhalerao
Ph.D. candidate
Research Unit Sustainability and Global change
Universität Hamburg, Hamburg, Germany
Grindelberg 5, 20146 Hamburg

Section 1: Challenges to be addressed in the Northeastern region

This section is aimed at creating consensus about which challenges must be addressed on priority by the **climate change impact mitigation strategy** in northeastern India. The list of major challenges is derived from the content analysis of question 5 and question 15 of the round-1 questionnaire.

Instructions:

i. Kindly prioritize following challenges by rating. 10=very high and 1= very low

ii. Tick NA = in case you feel challenge statement is not applicable in policy

iii. Please give ratings for all listed components

No.	List of major challenges	Level of impact on farming **Very high → → → Very low**							NA
1.	Low climate change awareness and knowledge gaps	7	6	5	4	3	2	1	
2.	Policy apathy and low scheme penetration	7	6	5	4	3	2	1	
3.	Low societal resilience and poor farm insurance	7	6	5	4	3	2	1	
4.	Technology complex and unsustainable, less generation	7	6	5	4	3	2	1	
5.	Crop and livestock damage due to weather extremities	7	6	5	4	3	2	1	
6.	Drought management	7	6	5	4	3	2	1	
7.	Temperature increase and warming	7	6	5	4	3	2	1	
8.	Floods and high intensity Rainfall	7	6	5	4	3	2	1	
9.	Changes in season pattern	7	6	5	4	3	2	1	
10.	Rainfall dependency of farming	7	6	5	4	3	2	1	
11.	Land fragmentation	7	6	5	4	3	2	1	
12.	Increasing population and decreasing productivity	7	6	5	4	3	2	1	
13.	Generalized Extension + inadequate demonstrations	7	6	5	4	3	2	1	
14.	High labor cost and energy shortages	7	6	5	4	3	2	1	
15.	Poor Institutional access	7	6	5	4	3	2	1	
16.	Poverty and illiteracy among farmers, negative attitude	7	6	5	4	3	2	1	
17.	Meager Credit and subsidy for farming	7	6	5	4	3	2	1	
18.	Unscientific and exploitative Farming	7	6	5	4	3	2	1	
19.	Fertilizer inadequate but excessively used by many	7	6	5	4	3	2	1	
20.	Inputs costly and unavailable when needed	7	6	5	4	3	2	1	
21.	Unsustainable urbanization and industrialization	7	6	5	4	3	2	1	
22.	Trivial farm income	7	6	5	4	3	2	1	
23.	Higher Pollution due to fuel and biomass burning	7	6	5	4	3	2	1	
24.	Excess use of Pesticides	7	6	5	4	3	2	1	
25.	Farm mechanization less, few storage facility	7	6	5	4	3	2	1	
26.	Unscientific and resource poor Livestock farming	7	6	5	4	3	2	1	
27.	Inadequate and poor quality Seeds	7	6	5	4	3	2	1	
28.	Enormous Biodiversity loss	7	6	5	4	3	2	1	
29.	Weak and unstable Marketing network	7	6	5	4	3	2	1	
30.	Low Processing and value addition	7	6	5	4	3	2	1	
31.	Less Integrated and organic farming	7	6	5	4	3	2	1	

(Any other comments)

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Section 2: Socio-economic components of the policy

This section aims to create consensus about strategy aspects for maximizing the positive impact of sustainable climate resilient policy. You have to choose the strategy options, which will enhance the socio-economic stability in Northeastern India. These strategy options are derived from the content analysis of question 7 and question 9 of the round-1 questionnaire.

Instructions:

- ***i. Kindly prioritize following aspects by rating. 10=very high and 1= very low;***
- ***ii. Tick NA = in case you feel aspect is not applicable in policy***
- ***iii. Please answer all the listed components***

No.	Socio-economic strategy aspects for stability enhancement	Level of impact on socio-economic stability **Very high → → → Very low**							NA
1.	Integrated farming system	7	6	5	4	3	2	1	
2.	Scientific crop and livestock farming	7	6	5	4	3	2	1	
3.	Storage facilities and cold storage	7	6	5	4	3	2	1	
4.	Soil, water and resource conservation, watershed	7	6	5	4	3	2	1	
5.	Community approach for farming and awareness creation	7	6	5	4	3	2	1	
6.	Co-operative marketing , e-marketing	7	6	5	4	3	2	1	
7.	Crop and farming diversification	7	6	5	4	3	2	1	
8.	Timely and quality input supply	7	6	5	4	3	2	1	
9.	Price assurance and appropriation	7	6	5	4	3	2	1	
10.	Biodiversity and forest conservation	7	6	5	4	3	2	1	
11.	Post-harvest management and value addition	7	6	5	4	3	2	1	
12.	Organic farming	7	6	5	4	3	2	1	
13.	Insurance and credit for farming	7	6	5	4	3	2	1	
14.	Formulation and execution of national climate plan	7	6	5	4	3	2	1	
15.	Use of indigenous traditional knowledge and resources	7	6	5	4	3	2	1	
16.	Use of multi-stress tolerant breeds and varieties	7	6	5	4	3	2	1	
17.	Socially acceptable and efficient technologies	7	6	5	4	3	2	1	
18.	Weather based advisory and ICT use	7	6	5	4	3	2	1	
19.	Selective and planned industrialization	7	6	5	4	3	2	1	
20.	Revamping extension and advisory services	7	6	5	4	3	2	1	

(Any other comments)

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Section 3: Priority investment for resilient technologies

Through this section, we attempt to prioritize the investment in climate-resilient technologies in order to bring a highest possible degree of sustainability to Indian farming. The list of resilient technologies is derived from the qualitative analysis of question 11 and question 12 of the round-1 questionnaire.

Instructions:

i. ***Kindly prioritize following investment statements by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel investment category is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of technologies for priority investment	Priority of investment Very high → → → Very low							NA
1.	Organic and conservation farming	7	6	5	4	3	2	1	
2.	Efficient natural resource management and utilization	7	6	5	4	3	2	1	
3.	Multi stress tolerant varieties and breeds	7	6	5	4	3	2	1	
4.	Integrated farming system	7	6	5	4	3	2	1	
5.	Adaptive capacity development among farmers	7	6	5	4	3	2	1	
6.	Awareness and trainings for enhancing resilience	7	6	5	4	3	2	1	
7.	Rural infrastructure development	7	6	5	4	3	2	1	
8.	Solar energy infrastructure development	7	6	5	4	3	2	1	
9.	Accurate forecasting and preparedness by institutional linking (convergence)	7	6	5	4	3	2	1	
10.	Germplasm conservation and improvement using traditional knowledge	7	6	5	4	3	2	1	
11.	Crop diversification	7	6	5	4	3	2	1	
12.	Research for climate resilient policy	7	6	5	4	3	2	1	
13.	Intelligence based market reforms for stability	7	6	5	4	3	2	1	
14.	Credit and insurance provision	7	6	5	4	3	2	1	
15.	Community seed banks and nurseries	7	6	5	4	3	2	1	
16.	Post-harvest processing and value addition	7	6	5	4	3	2	1	
17.	Efficient energy utilization	7	6	5	4	3	2	1	
18.	Nutritive feeding to livestock	7	6	5	4	3	2	1	
19.	Housing climate resilient for livestock	7	6	5	4	3	2	1	
20.	Low carbon farming and carbon sequestration	7	6	5	4	3	2	1	
21.	Precision farming	7	6	5	4	3	2	1	

(Any other comments)

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Section 4: Policy components to safeguard the environment

This section is aimed to answer a question - Which of the following will be the environment-friendly and safer strategy components most suited for the northeastern region?
The list of strategy aspects to safeguard environment is acquired from the content analysis of question 8, question 10 and question 16 of the round-1 questionnaire.

Instructions:

i. ***Kindly prioritize following strategy aspects by rating. 10=very high and 1= very low***
ii. ***tick NA = in case you feel strategy aspect is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of strategy aspects to safeguard the environment	Level of impact on safeguarding environment Very high → → → Very low							NA
1.	Scientific farm and livestock production with diversification	7	6	5	4	3	2	1	
2.	Adoption of multi stress tolerant breeds and varieties	7	6	5	4	3	2	1	
3.	Efficient energy utilization (focus on use of renewable energy)	7	6	5	4	3	2	1	
4.	Demonstrations and trainings for awareness creation	7	6	5	4	3	2	1	
5.	Subsidy support for technology adoption	7	6	5	4	3	2	1	
6.	Price assurance with cheap credit and insurance	7	6	5	4	3	2	1	
7.	Efficient resource utilization and GHG emission reduction	7	6	5	4	3	2	1	
8.	Organic + sustainable farming	7	6	5	4	3	2	1	
9.	Community and cooperative farming	7	6	5	4	3	2	1	
10.	Germplasm and biodiversity conservation	7	6	5	4	3	2	1	
11.	Technology enhancement research using traditional knowledge	7	6	5	4	3	2	1	
12.	Farmer centric extension and skill development	7	6	5	4	3	2	1	
13.	Planning on the basis of regional modeling	7	6	5	4	3	2	1	
14.	Enhancement of irrigation efficiency and rainwater harvesting	7	6	5	4	3	2	1	
15.	Community afforestation and agro forestry	7	6	5	4	3	2	1	
16.	Integrated farming system approach	7	6	5	4	3	2	1	
17.	Access to low cost, timely and efficient inputs	7	6	5	4	3	2	1	
18.	Planned land use pattern change	7	6	5	4	3	2	1	
19.	Watershed conservation management	7	6	5	4	3	2	1	
20.	Soil conservation for organic carbon enhancement	7	6	5	4	3	2	1	
21.	Market linking and export promotion	7	6	5	4	3	2	1	
22.	Contingency planning with real time monitoring	7	6	5	4	3	2	1	
23.	Waste reduction and management	7	6	5	4	3	2	1	
24.	Carbon management, sequestration, trading	7	6	5	4	3	2	1	
25.	Precision farming	7	6	5	4	3	2	1	
26.	Infrastructure development (storage, transport, custom hiring)	7	6	5	4	3	2	1	
27.	Population control	7	6	5	4	3	2	1	

(Any other comments)

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Section 5: Crucial competencies for change agents

This section of the questionnaire is designed to create consensus about most desired and essential competencies among **change agents** to ensure sustainable climate resilient policy formulation as well as execution in the Northeastern region of India. The list of competencies for change agents is a result of qualitative analysis of question 13 from the round-1 questionnaire.

i. ***Instructions: Kindly prioritize following competencies by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel competency statement is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of competencies for change agents	Level of impact on policy formulation and implementation Very high → → → Very low							NA
1.	Research for tolerant technology generation	7	6	5	4	3	2	1	
2.	Vision and problem understanding skills	7	6	5	4	3	2	1	
3.	Integrated approach for policy formulation, program and contingency planning	7	6	5	4	3	2	1	
4.	Subject matter competence with innovativeness and fieldwork experience	7	6	5	4	3	2	1	
5.	Effective trainer, motivator, capacity builder	7	6	5	4	3	2	1	
6.	Holistic farming with environmental concerns	7	6	5	4	3	2	1	
7.	Trained in impact management	7	6	5	4	3	2	1	
8.	Real-time and efficient information dissemination using ICT	7	6	5	4	3	2	1	
9.	Computing, modeling, GIS, programing skills	7	6	5	4	3	2	1	
10.	Knowledge of efficient input use	7	6	5	4	3	2	1	
11.	Effective team work and problem solver	7	6	5	4	3	2	1	
12.	Environmental assessment competence	7	6	5	4	3	2	1	
13.	Natural resource management skills for sustainable development	7	6	5	4	3	2	1	
14.	Data management and interpretation skills	7	6	5	4	3	2	1	
15.	Convincing awareness creation	7	6	5	4	3	2	1	
16.	Efficient scheme implementation	7	6	5	4	3	2	1	
17.	Quick and dynamic decision making	7	6	5	4	3	2	1	
18.	Open minded attitude	7	6	5	4	3	2	1	
19.	Professional soft skills competence								
20.	Knowledge of an efficient water use	7	6	5	4	3	2	1	
21.	Credible demonstrator with strong farmer linkages	7	6	5	4	3	2	1	
22.	Robotics and nano-technology vision	7	6	5	4	3	2	1	
23.	Performer and quick learner	7	6	5	4	3	2	1	
24.	Market linking and processing competence	7	6	5	4	3	2	1	

(Any other comments)

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Section 6: Essential competencies for Farmers

This section of the questionnaire is attempting to create consensus about essential competencies desired among **farmers** to successfully implement sustainable climate resilient policy in the Northeastern region of India. The list of competencies for tribal farmers is a result of qualitative analysis of question 14 from the round-1 questionnaire.

i. ***Instructions: Kindly prioritize following competencies by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel competency statement is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of essential competencies desired among farmers of Northeastern India	Level of impact on policy implementation Very high → → → Very low							NA
1.	Positive consideration for technology use	7	6	5	4	3	2	1	
2.	Farm management competency	7	6	5	4	3	2	1	
3.	Knowledge and awareness of climate resilience	7	6	5	4	3	2	1	
4.	Resource smart farming	7	6	5	4	3	2	1	
5.	Biodiversity conservation	7	6	5	4	3	2	1	
6.	Eco-friendly farming skills	7	6	5	4	3	2	1	
7.	Working in community with a cooperative spirit (ex. Community marketing, seed banks)	7	6	5	4	3	2	1	
8.	Thorough Market understanding	7	6	5	4	3	2	1	
9.	Strong Will power and patience	7	6	5	4	3	2	1	
10.	Water harvesting knowledge and skills	7	6	5	4	3	2	1	
11.	Knowledge and resource sharing	7	6	5	4	3	2	1	
12.	Problem solving attitude	7	6	5	4	3	2	1	
13.	Information (internet) access skills	7	6	5	4	3	2	1	
14.	Integrated management farming skills	7	6	5	4	3	2	1	

(Any other comments)

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Section 7: Responsible action and priority level

This section is aimed to create consensus about action and responsibility sharing by various institutional stakeholders towards formulating the "climate change impact mitigation strategy" in northeastern India. You are requested to rate the priority level of responsible action for following institutional stakeholders.

Instructions:

i. ***Kindly prioritize level of action by rating. 1= No priority at all and 10 = Very High priority for action.***
ii. ***In case you wish to add any other institutions please add them as comment or suggestion***
iii. ***Please rate action priority for all stakeholders***

Sl. No.	List of institutional stakeholders	Priority for responsible action No priority at all → → → Very High priority
1.	Interventions by international organizations / institutions	①②③④⑤⑥⑦
2.	National level plans and programs	①②③④⑤⑥⑦
3.	Ministry level schemes and initiatives (Ex. Ministry of agriculture and farmers' welfare)	①②③④⑤⑥⑦
4.	Organization level efforts and initiatives (Ex. ICAR)	①②③④⑤⑥⑦
5.	Zonal / Regional level interventions (Center + State government)	①②③④⑤⑥⑦
6.	State level programs and schemes	①②③④⑤⑥⑦
7.	Initiatives of State Agricultural Universities' (SAUs/CAUs)	①②③④⑤⑥⑦
8.	District level management approaches (Administration, ATMA)	①②③④⑤⑥⑦
9.	*Krishi Vigyan Kendras* (farm science centers)	①②③④⑤⑥⑦
10.	Farmers co-operatives, community-level efforts	①②③④⑤⑥⑦
11.	NGOs / Self Help Groups' intervention in rural areas	①②③④⑤⑥⑦
12.	Village level activities / initiatives	①②③④⑤⑥⑦
13.	Individual farmers/farm family level actions	①②③④⑤⑥⑦
14.		①②③④⑤⑥⑦
15.		①②③④⑤⑥⑦

(Any other comments)

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Appendix F. Third round questionnaire of Delphi research

Dear expert of Delphi survey,

Greetings from Hamburg, Germany....!!

First of all, I thank you for your time and inputs in the round-2 questionnaire. Your inputs in the form of answers of the round-2 questionnaire are well received. The quantitative data generated from the ratings given by you were analyzed accordingly to get the mean value (average position) for each item.

As you already know this exercise is aimed at forming a consensus concerning novel strategy formulation to minimize the impacts of climate change in Northeastern India's agriculture. Moreover, this third (and last) round allows you to see the mean position of rating for each item, that is written in front of every item for rating (see value in the bracket). Also, it provides unique opportunity to see what other experts are thinking about particular policy option. However, you also get a chance to review your rating for each item, in case you want to. You may agree or disagree with the group thinking, which is a normal process. Moreover, you can once again vote for all options in a questionnaire with refined perspective.

Once again I assure that your responses will be used only for research purpose with due confidentiality. So please feel free to provide your ratings. Kindly fill the appropriate responses and at the end of this document click the “submit” button to send your responses. In case, you are not able to participate online then please inform me. I will mail you MS-word file to submit your responses.

I understand that you are already occupied with a lot of official activities so please take your time to fill this form. I would appreciate your response up to XXXXX of 2018, which enables me for the timely analysis of this round.

I am looking forward to learning from your enriched experiences and wisdom.

Your sincerely,
Amol K. Bhalerao
Ph.D. candidate
Research Unit Sustainability and Global change
Universität Hamburg, Hamburg, Germany
Grindelberg 5, 20146 Hamburg

Section 1: Challenges to be addressed in the Northeastern region

This section is aimed at creating consensus about which challenges must be addressed on priority by the **climate change impact mitigation strategy** in northeastern India. The list of major challenges is derived from the content analysis of question 5 and question 15 of the round-1 questionnaire.

Instructions:

i. Kindly prioritize following challenges by rating. 10=very high and 1= very low
ii. Tick NA = in case you feel challenge statement is not applicable in policy
iii. Please give ratings for all listed components

No.	List of major challenges	Level of impact on farming **Very high → → Very low**							Expert's average
1.	Low climate change awareness and knowledge gaps	7	6	5	4	3	2	1	5.3
2.	Policy apathy and low scheme penetration	7	6	5	4	3	2	1	5.5
3.	Low societal resilience and poor farm insurance	7	6	5	4	3	2	1	6.0
4.	Technology complex and unsustainable, less generation	7	6	5	4	3	2	1	5.5
5.	Crop and livestock damage due to weather extremities	7	6	5	4	3	2	1	6.0
6.	Drought management	7	6	5	4	3	2	1	5.7
7.	Temperature increase and warming	7	6	5	4	3	2	1	5.5
8.	Floods and high intensity Rainfall	7	6	5	4	3	2	1	6.2
9.	Changes in season pattern	7	6	5	4	3	2	1	5.5
10.	Rainfall dependency of farming	7	6	5	4	3	2	1	6.5
11.	Land fragmentation	7	6	5	4	3	2	1	5.1
12.	Increasing population and decreasing productivity	7	6	5	4	3	2	1	5.6
13.	Generalized Extension + inadequate demonstrations	7	6	5	4	3	2	1	5.3
14.	High labor cost and energy shortages	7	6	5	4	3	2	1	6.0
15.	Poor Institutional access	7	6	5	4	3	2	1	5.1
16.	Poverty and illiteracy among farmers, negative attitude	7	6	5	4	3	2	1	5.1
17.	Meager Credit and subsidy for farming	7	6	5	4	3	2	1	5.0
18.	Unscientific and exploitative Farming	7	6	5	4	3	2	1	5.7
19.	Fertilizer inadequate but excessively used by many	7	6	5	4	3	2	1	4.8
20.	Inputs costly and unavailable when needed	7	6	5	4	3	2	1	5.6
21.	Unsustainable urbanization and industrialization	7	6	5	4	3	2	1	5.0
22.	Trivial farm income	7	6	5	4	3	2	1	5.7
23.	Higher Pollution due to fuel and biomass burning	7	6	5	4	3	2	1	5.0
24.	Excess use of Pesticides	7	6	5	4	3	2	1	4.7
25.	Farm mechanization less, few storage facility	7	6	5	4	3	2	1	5.4
26.	Unscientific and resource poor Livestock farming	7	6	5	4	3	2	1	5.7
27.	Inadequate and poor quality Seeds	7	6	5	4	3	2	1	5.8
28.	Enormous Biodiversity loss	7	6	5	4	3	2	1	5.5
29.	Weak and unstable Marketing network	7	6	5	4	3	2	1	6.2
30.	Low Processing and value addition	7	6	5	4	3	2	1	5.9
31.	Less Integrated and organic farming	7	6	5	4	3	2	1	5.7

(Any other comments)

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Section 2: Socio-economic components of the policy

This section aims to create consensus about strategy aspects for maximizing the positive impact of sustainable climate resilient policy. You have to choose the strategy options, which will enhance the socio-economic stability in Northeastern India. These strategy options are derived from the content analysis of question 7 and question 9 of the round-1 questionnaire.

Instructions:

i. ***Kindly prioritize following aspects by rating. 10=very high and 1= very low;***
ii. ***Tick NA = in case you feel aspect is not applicable in policy***
iii. ***Please answer all the listed components***

No.	Socio-economic strategy aspects for stability enhancement	Level of impact on socio-economic stability **Very high → → Very low**							Expert's average
1.	Integrated farming system	7	6	5	4	3	2	1	6.1
2.	Scientific crop and livestock farming	7	6	5	4	3	2	1	5.7
3.	Storage facilities and cold storage	7	6	5	4	3	2	1	5.6
4.	Soil, water and resource conservation, watershed	7	6	5	4	3	2	1	5.9
5.	Community approach for farming and awareness creation	7	6	5	4	3	2	1	5.7
6.	Co-operative marketing , e-marketing	7	6	5	4	3	2	1	6.1
7.	Crop and farming diversification	7	6	5	4	3	2	1	5.9
8.	Timely and quality input supply	7	6	5	4	3	2	1	6.1
9.	Price assurance and appropriation	7	6	5	4	3	2	1	6.2
10.	Biodiversity and forest conservation	7	6	5	4	3	2	1	5.9
11.	Post-harvest management and value addition	7	6	5	4	3	2	1	6.1
12.	Organic farming	7	6	5	4	3	2	1	5.9
13.	Insurance and credit for farming	7	6	5	4	3	2	1	5.7
14.	Formulation and execution of national climate plan	7	6	5	4	3	2	1	5.6
15.	Use of indigenous traditional knowledge and resources	7	6	5	4	3	2	1	5.6
16.	Use of multi-stress tolerant breeds and varieties	7	6	5	4	3	2	1	5.5
17.	Socially acceptable and efficient technologies	7	6	5	4	3	2	1	5.7
18.	Weather based advisory and ICT use	7	6	5	4	3	2	1	5.7
19.	Selective and planned industrialization	7	6	5	4	3	2	1	5.1
20.	Revamping extension and advisory services	7	6	5	4	3	2	1	5.7

(Any other comments)

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Section 3: Priority investment for resilient technologies

Through this section, we attempt to prioritize the investment in climate-resilient technologies in order to bring a highest possible degree of sustainability to Indian farming. The list of resilient technologies is derived from the qualitative analysis of question 11 and question 12 of the round-1 questionnaire.

Instructions:

i. ***Kindly prioritize following investment statements by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel investment category is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of technologies for priority investment	Priority of investment Very high → → Very low							Expert's average
1.	Organic and conservation farming	7	6	5	4	3	2	1	5.9
2.	Efficient natural resource management and utilization	7	6	5	4	3	2	1	5.7
3.	Multi stress tolerant varieties and breeds	7	6	5	4	3	2	1	5.6
4.	Integrated farming system	7	6	5	4	3	2	1	5.9
5.	Adaptive capacity development among farmers	7	6	5	4	3	2	1	5.9
6.	Awareness and trainings for enhancing resilience	7	6	5	4	3	2	1	5.9
7.	Rural infrastructure development	7	6	5	4	3	2	1	5.5
8.	Solar energy infrastructure development	7	6	5	4	3	2	1	6.0
9.	Accurate forecasting and preparedness by institutional linking (convergence)	7	6	5	4	3	2	1	5.8
10.	Germplasm conservation and improvement using traditional knowledge	7	6	5	4	3	2	1	5.6
11.	Crop diversification	7	6	5	4	3	2	1	5.6
12.	Research for climate resilient policy	7	6	5	4	3	2	1	5.9
13.	Intelligence based market reforms for stability	7	6	5	4	3	2	1	6.0
14.	Credit and insurance provision	7	6	5	4	3	2	1	5.6
15.	Community seed banks and nurseries	7	6	5	4	3	2	1	5.7
16.	Post-harvest processing and value addition	7	6	5	4	3	2	1	5.9
17.	Efficient energy utilization	7	6	5	4	3	2	1	5.6
18.	Nutritive feeding to livestock	7	6	5	4	3	2	1	5.5
19.	Housing climate resilient for livestock	7	6	5	4	3	2	1	5.7
20.	Low carbon farming and carbon sequestration	7	6	5	4	3	2	1	5.5
21.	Precision farming	7	6	5	4	3	2	1	5.0

(Any other comments)

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Section 4: Policy components to safeguard the environment

This section is aimed to answer a question - Which of the following will be the environment-friendly and safer strategy components most suited for the northeastern region?
The list of strategy aspects to safeguard environment is acquired from the content analysis of question 8, question 10 and question 16 of the round-1 questionnaire.

Instructions:

i. ***Kindly prioritize following strategy aspects by rating. 10=very high and 1= very low***
ii. ***tick NA = in case you feel strategy aspect is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of strategy aspects to safeguard the environment	Level of impact Very high → → Very low							Expert's average
1.	Scientific farm and livestock production with diversification	7	6	5	4	3	2	1	5.8
2.	Adoption of multi stress tolerant breeds and varieties	7	6	5	4	3	2	1	5.8
3.	Efficient energy utilization (focus on use of renewable energy)	7	6	5	4	3	2	1	5.9
4.	Demonstrations and trainings for awareness creation	7	6	5	4	3	2	1	5.7
5.	Subsidy support for technology adoption	7	6	5	4	3	2	1	5.1
6.	Price assurance with cheap credit and insurance	7	6	5	4	3	2	1	5.8
7.	Efficient resource utilization and GHG emission reduction	7	6	5	4	3	2	1	5.9
8.	Organic + sustainable farming	7	6	5	4	3	2	1	6.1
9.	Community and cooperative farming	7	6	5	4	3	2	1	5.6
10.	Germplasm and biodiversity conservation	7	6	5	4	3	2	1	5.8
11.	Technology enhancement using traditional knowledge	7	6	5	4	3	2	1	5.5
12.	Farmer centric extension and skill development	7	6	5	4	3	2	1	5.6
13.	Planning on the basis of regional modeling	7	6	5	4	3	2	1	5.7
14.	Enhancement of irrigation efficiency and rainwater harvesting	7	6	5	4	3	2	1	6.3
15.	Community afforestation and agro forestry	7	6	5	4	3	2	1	6.2
16.	Integrated farming system approach	7	6	5	4	3	2	1	6.0
17.	Access to low cost, timely and efficient inputs	7	6	5	4	3	2	1	5.6
18.	Planned land use pattern change	7	6	5	4	3	2	1	5.8
19.	Watershed conservation management	7	6	5	4	3	2	1	6.0
20.	Soil conservation for organic carbon enhancement	7	6	5	4	3	2	1	5.8
21.	Market linking and export promotion	7	6	5	4	3	2	1	6.0
22.	Contingency planning and real time monitoring	7	6	5	4	3	2	1	6.1
23.	Waste reduction and management	7	6	5	4	3	2	1	5.7
24.	Carbon management, sequestration, trading	7	6	5	4	3	2	1	6.0
25.	Precision farming	7	6	5	4	3	2	1	5.2
26.	Infrastructure development (storage, transport, custom hiring)	7	6	5	4	3	2	1	5.9
27.	Population control	7	6	5	4	3	2	1	6.2

(Any other comments)

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Section 5: crucial competencies for change agents

This section of the questionnaire is designed to create consensus about most desired and crucial competencies among **change agents** to ensure sustainable climate resilient policy formulation as well as execution in the Northeastern region of India. The list of competencies for change agents is a result of qualitative analysis of question 13 from the round-1 questionnaire.

i. ***Instructions: Kindly prioritize following competencies by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel competency statement is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of competencies for change agents	Level of impact on policy formulation and implementation Very high → → Very low							Expert's average
1.	Research for tolerant technology generation	7	6	5	4	3	2	1	5.6
2.	Vision and problem understanding skills	7	6	5	4	3	2	1	5.7
3.	Integrated approach for policy formulation, program and contingency planning	7	6	5	4	3	2	1	5.9
4.	Subject matter competence with innovativeness and field work experience	7	6	5	4	3	2	1	5.8
5.	Effective trainer, motivator, capacity builder	7	6	5	4	3	2	1	5.8
6.	Holistic farming with environmental concerns	7	6	5	4	3	2	1	5.7
7.	Trained in impact management	7	6	5	4	3	2	1	5.4
8.	Real-time and efficient information dissemination using ICT	7	6	5	4	3	2	1	5.8
9.	Computing, modeling, GIS, programing skills	7	6	5	4	3	2	1	5.1
10.	Knowledge of efficient input use	7	6	5	4	3	2	1	5.5
11.	Effective team work and problem solver	7	6	5	4	3	2	1	5.8
12.	Environmental assessment competence	7	6	5	4	3	2	1	5.7
13.	Natural resource management skills for sustainable development	7	6	5	4	3	2	1	5.8
14.	Data management and interpretation skills	7	6	5	4	3	2	1	5.6
15.	Convincing awareness creation	7	6	5	4	3	2	1	5.8
16.	Efficient scheme implementation	7	6	5	4	3	2	1	5.8
17.	Quick and dynamic decision making	7	6	5	4	3	2	1	5.9
18.	Open minded attitude	7	6	5	4	3	2	1	6.0
19.	Professional soft skills competence								5.8
20.	Knowledge of an efficient water use	7	6	5	4	3	2	1	6.0
21.	Credible demonstrator with strong farmer linkages	7	6	5	4	3	2	1	6.0
22.	Robotics and nano-technology vision	7	6	5	4	3	2	1	4.5
23.	Performer and quick learner	7	6	5	4	3	2	1	5.4
24.	Market linking and processing competence	7	6	5	4	3	2	1	6.0

(Any other comments)

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Section 6: Essential competencies for Farmers

This section of the questionnaire is attempting to create consensus about essential competencies desired among **farmers** to successfully implement sustainable climate resilient policy in the Northeastern region of India. The list of competencies for tribal farmers is a result of qualitative analysis of question 14 from the round-1 questionnaire.

i. ***Instructions: Kindly prioritize following competencies by rating. 10=very high and 1= very low***
ii. ***Tick NA = in case you feel competency statement is not applicable in policy***
iii. ***Please answer all the listed components***

No.	List of essential competencies desired among farmers of Northeastern India	Level of impact on policy implementation Very high → → Very low							Expert's average
1.	Positive consideration for technology use	7	6	5	4	3	2	1	5.6
2.	Farm management competency	7	6	5	4	3	2	1	5.7
3.	Knowledge and awareness of climate resilience	7	6	5	4	3	2	1	5.9
4.	Resource smart farming	7	6	5	4	3	2	1	5.8
5.	Biodiversity conservation	7	6	5	4	3	2	1	5.9
6.	Eco-friendly farming skills	7	6	5	4	3	2	1	6.1
7.	Working in community with cooperative spirit (ex. Community marketing, seed banks)	7	6	5	4	3	2	1	5.9
8.	Thorough Market understanding	7	6	5	4	3	2	1	5.5
9.	Strong Will power and patience	7	6	5	4	3	2	1	6.0
10.	Water harvesting knowledge and skills	7	6	5	4	3	2	1	6.0
11.	Knowledge and resource sharing	7	6	5	4	3	2	1	5.6
12.	Problem solving attitude	7	6	5	4	3	2	1	6.1
13.	Information (internet) access skills	7	6	5	4	3	2	1	5.3
14.	Integrated management farming skills	7	6	5	4	3	2	1	6.0

(Any other comments)

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Section 7: Responsible action and priority level

This section is aimed to create consensus about action and responsibility sharing by various institutional stakeholders towards formulating the "climate change impact mitigation strategy" in northeastern India. You are requested to rate the priority level of responsible action for following institutional stakeholders.

Instructions:

1. *Kindly prioritize level of action by rating. 1= No priority at all and 10 = Very High priority for action.*
2. *In case you wish to add any other institutions please add them as comment or suggestion*
3. *Please rate action priority for all stakeholders*

Sl. No.	List of institutional stakeholders	Priority for responsible action No priority at all → → Very High priority	Expert's average
	Interventions by international organizations / institutions	①②③④⑤⑥⑦	5.1
	National level plans and programs	①②③④⑤⑥⑦	6.0
	Ministry level schemes and initiatives (Ex. Ministry of agriculture and farmers' welfare)	①②③④⑤⑥⑦	6.1
	Organization level efforts and initiatives (Ex. ICAR)	①②③④⑤⑥⑦	5.8
	Zonal / Regional level interventions (Center + State government)	①②③④⑤⑥⑦	5.9
	State level programs and schemes	①②③④⑤⑥⑦	6.2
	Initiatives of State Agricultural Universities' (SAUs/CAUs)	①②③④⑤⑥⑦	5.7
	District level management approaches (Administration, ATMA)	①②③④⑤⑥⑦	5.5
	Krishi Vigyan Kendras (farm science centers)	①②③④⑤⑥⑦	6.3
	Farmers co-operatives, community-level efforts	①②③④⑤⑥⑦	6.3
	NGOs / Self Help Groups' intervention in rural areas	①②③④⑤⑥⑦	6.2
	Village level activities / initiatives	①②③④⑤⑥⑦	6.2
	Individual farmers/farm family level actions	①②③④⑤⑥⑦	6.2

(Any other comments)

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Appendix G. District wise strengths reported from the sampled districts of NER

Strength description	Reporting frequency	District codes with reported strengths																			
		LD	ES	PP	LS	CH	DB	KK	LK	BG	DH	DG	AZ	LG	SC	SP	TB	JH	WK	SS	NS	NT
Institutional linkages and collaborations	20	1	1	1	1	1	1	1	1	1	1	2	1	2	0	1	1	1	1	0	0	1
Rich biodiversity and agricultural germplasm*	15	1	1	0	1	0	0	0	0	0	0	0	1	1	1	1	0	0	3	2	2	1
Use of social media and ICTs for extension	13	0	1	1	1	1	2	0	1	1	1	0	1	0	0	0	1	1	0	0	0	1
Technology refinement and customization	12	1	0	1	1	1	1	1	1	0	0	0	1	0	0	1	1	1	0	0	0	1
Abundant natural resources for diversification*	11	1	0	1	0	0	0	0	1	0	1	0	0	1	2	0	0	0	1	0	2	1
Farmer friendly approach and dedication	11	1	1	1	2	0	0	1	0	2	0	1	0	0	0	0	0	2	0	0	0	0
Technical knowledge credibility	11	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	1	0	0	0	0	1
Cooperative farmers (stakeholders)*	10	0	2	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	1	2	1	0
Favorable climatic conditions for farming*	10	1	0	0	0	0	0	0	0	0	0	0	1	1	2	1	1	1	1	1	0	0
Energetic extension professionals	9	0	0	0	0	1	0	3	1	1	1	0	0	0	0	0	0	0	0	0	1	1
Creative and efficient use of local resources	8	1	0	1	0	1	0	1	0	1	0	0	1	0	0	0	0	0	1	0	1	0
Traditional knowledge and expertise of farmers*	7	0	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	1	0
Digital documentation and publication	6	1	0	0	0	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	1
Fertile soils, less polluted*	6	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	1	0	0
Huge potential for organic farming*	6	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0
Participatory Technology Development (PTD)	6	0	0	0	1	0	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	1
Capacity building initiatives	5	0	0	0	0	0	0	0	1	1	0	0	1	0	1	0	1	0	0	0	0	0
Need based research and extension	5	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	1
Productive and efficient teamwork (coordination)	5	0	0	0	1	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Adequate water resources for farming/fishing*	4	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	0
Good infrastructure for research and extension	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0
Objective oriented leadership	4	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0

Social cohesion of farming communities*	4	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0
Competitive mindset for excellence	3	0	0	0	0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Efficient human resources in TOT	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	1
Energetic youth in Research and Extension	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Government support	3	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Human relation approach of leaders	3	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
regular and efficient monitoring	3	0	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0
Climate sensitive research and extension	2	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Skillful design and implementation of technology	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Agriculture-centric state economy*	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Community approaches for farm mechanization	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Efficient financial managements	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Empowered women	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Entrepreneurial promotion	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Good quality of inputs and service	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Improved *Jhum* farming	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Fewer insect pest and disease attacks	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Motivating work culture	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Secondary agricultural scope	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0

(See Table 13 for details of district codes)

Appendix H. District wise weaknesses reported from the sampled districts of NER

Weakness description	Reporting frequency	District codes with reported weaknesses																				
		LD	ES	PP	LS	CH	DB	KK	LK	BG	DH	DG	AZ	LG	SC	SP	TB	JH	WK	SS	NS	NT
Inadequate staff for research and extension	25	1	1	1	1	3	1	2	1	1	1	2	1	0	1	1	1	1	1	1	1	2
Shortage of climate and farmer sensitive policy	21	2	1	1	4	1	1	1	0	1	1	1	0	0	0	0	2	1	3	0	1	0
Untimely and inadequate funding, complex procedures	21	0	1	1	2	0	2	1	2	1	1	2	1	1	1	1	1	2	0	0	0	1
Lack of location specific technology	20	1	1	1	1	2	2	2	1	2	1	1	1	0	0	2	0	1	0	0	0	1
Poor logistic support for research and extension	19	2	1	1	1	2	2	2	1	2	1	1	0	0	0	2	0	0	0	0	0	1
Inappropriate and demotivating human resource policies	16	0	0	1	1	2	3	0	2	1	0	1	0	0	0	0	1	0	1	0	1	2
Inadequate and poor infrastructure	15	1	0	1	1	1	1	2	0	1	1	0	1	0	1	0	0	1	1	0	1	1
Inadequate, costly and untimely input supply	14	0	0	1	1	0	1	1	1	0	0	1	0	0	1	0	3	1	1	1	0	1
Excessive reporting and less time for scientific work	12	0	0	1	1	0	1	1	1	1	1	0	1	0	1	0	1	0	1	0	0	1
Overburdened by non-mandate activities	11	0	1	0	0	2	1	0	1	1	1	1	0	0	0	2	0	1	0	0	0	0
Inappropriate and inconsistent work distribution	10	0	0	0	1	2	0	0	1	2	1	0	0	0	0	0	1	0	0	0	2	0
Poor coordination with other departments	9	0	0	0	2	0	1	0	1	0	0	1	0	0	1	1	0	0	0	2	0	0
Little research on bio-inputs for organic farming	8	1	1	0	0	0	2	0	0	0	0	0	0	1	0	0	0	0	0	2	1	0
Inappropriate beneficiary targeting	7	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	2	1	0	0
Inadequate research and extension for irrigation	7	1	0	0	0	0	0	1	0	0	0	0	0	1	1	0	2	0	0	0	0	1
Multiple bossing	7	0	0	1	1	1	0	0	0	0	0	1	1	0	0	0	0	0	1	0	0	1
Unscientific HRD programs without need assessment	7	0	0	0	0	0	3	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1
Lengthy, bureaucratic hierarchy	6	0	0	0	1	0	0	1	2	1	0	0	1	0	0	0	0	0	0	0	0	0

Absence of market research and poor reforms	6	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0
Transport connectivity and accessibility	5	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2	1	0
Less efforts to produce quality seed	4	0	0	0	0	0	1	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0
No scope for creativity and monotony of work	4	0	0	0	0	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
Political interference in science	4	0	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Lack of scientific and authenticate data	3	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0
Inadequate post-harvest technologies	3	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0
Poor networking and communication (organizational)	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1
Poor state of policy implementation	3	0	0	0	0	0	0	0	1	0	0	1	0	1	0	0	0	0	0	0	0	0
Miserable state of germplasm conservation	3	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Inadequate soft skill development trainings	2	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Inadequate R & D vaccines and medicines for livestock	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Insufficient and miserable state of post-harvest research	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
Too much dependency on government	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Financial mismanagement	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Inadequate extension services	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Insufficient technological customization	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Deficiency of (timely) weather information	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
No recognition for hard work	2	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0
Miserable documentation and publications	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Trifling validation of indigenous traditional knowledge	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Monsoon dependent Research and extension	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Shifting cultivation	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Social instability and inequality	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

(See Table 13 *for details of district codes*)

Appendix I. District wise opportunities reported from the sampled districts of NER

Opportunity description	Reporting frequency	District codes with reported weaknesses																				
		LD	ES	PP	LS	CH	DB	KK	LK	BG	DH	DG	AZ	LG	SC	SP	TB	JH	WK	SS	NS	NT
Promotion of indigenous high value crops	29	1	0	0	3	2	2	2	1	3	2	2	0	1	1	1	3	1	2	1	0	1
Germplasm conservation and upgrading	22	1	0	1	2	1	1	2	0	1	1	2	1	2	1	1	1	2	1	0	0	1
Promotion and export of high value agricultural products	20	1	2	0	2	2	2	1	0	0	1	2	1	0	0	0	2	2	1	0	0	1
Scientific meat, pork, fish and milk production	19	1	0	1	2	2	2	1	1	1	1	2	0	0	1	0	0	2	0	0	0	2
Value addition and processing of local fruits for export	18	1	1	0	4	0	1	1	1	1	1	2	0	0	0	0	0	0	2	2	0	1
Indigenous traditional knowledge	18	1	0	0	2	1	1	2	0	2	1	1	0	0	1	1	2	1	1	0	1	0
Promotion of ornamental fishery, birds and hatchery	15	1	0	2	0	0	1	2	2	2	1	0	0	0	0	0	1	2	0	0	0	1
Organic farming promotion	14	1	0	0	0	1	0	1	1	1	0	1	1	0	1	1	1	1	0	1	2	0
Export of medicinal and aromatic plants (and products)	12	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	2	1	1	0	1
Scope for Bio-inputs, insecticides, fertilizer production	11	1	1	1	0	0	0	0	1	0	1	0	1	0	1	0	1	0	1	2	0	0
Orchids farming, protected floriculture	11	1	1	0	1	0	1	0	1	2	0	1	0	0	0	2	0	0	0	0	0	1
Export promotion of ginger, spices and orange	10	0	1	2	4	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Tapping export potential of black scented rice	8	0	0	1	0	0	0	1	1	0	1	1	0	0	0	1	1	0	0	0	0	1
Promotion of integrated farming systems	8	0	0	0	1	0	1	0	0	2	0	0	0	0	1	0	1	0	1	1	0	0
Tapping export potential of bamboo processing and export	8	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	1	0	1
Promotion of resilient cropping and agroforestry	7	0	0	0	2	0	1	0	0	2	0	0	0	0	1	0	1	0	0	0	0	0
Rich biodiversity, rainfall adequacy and healthy climate	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	3	0
Diversification of protected farming	6	0	0	0	0	0	1	0	1	0	0	1	1	0	0	0	0	0	1	0	1	0
Introduction of dual purpose breeds of livestock	6	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	2	0	0	0
Livestock breeding and bird hatchery for diversification	5	0	2	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oilseeds and pulses production in winter season	5	0	1	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Sericulture, lac farming, apiculture for diversification	5	0	0	0	0	1	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0

pulses and oilseeds processing	4	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	1
Low cost livestock feed production	4	0	1	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0
Promotion of terrace cultivation	4	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0
Efficient irrigation system development	4	0	1	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0
Farm mechanization	4	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	1	0	0
Kiwi production and export	4	0	0	1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0
Mushroom farming and export	4	1	0	0	0	0	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0
High potential of agro eco-tourism	3	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	0	0	0
Tapping potential of hydroponics (aquaculture)	3	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0
Bee keeping	3	0	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
Drudgery reduction inputs	3	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Integrated insect, pest, disease and nutrient management	3	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0	0
Rainwater harvesting	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0	0
Development of small and marginal enterprises	2	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Credit linkage development	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Exploration of positive impacts of climate change	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Promotion of high-value tuber crops	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

(See Table 13 for details of district codes)

Appendix J. District wise threats reported from the sampled districts of NER

Threats description	Reporting frequency	District codes with reported weaknesses																				
		LD	ES	PP	LS	CH	DB	KK	LK	BG	DH	DG	AZ	LG	SC	SP	TB	JH	WK	SS	NS	NT
Erratic and untimely rains	22	1	2	1	1	2	1	2	1	1	1	0	1	1	1	0	1	1	0	0	1	3
Erratic weather aberrations (hailstorms)	18	0	2	2	0	1	0	2	1	0	0	2	0	1	0	0	2	1	1	0	1	2
Indiscriminate and unscientific use of agro-chemicals	16	1	1	0	1	1	2	1	1	1	1	1	1	0	2	0	1	0	0	0	0	1
Insect, pest and disease outbreaks	16	0	1	0	2	1	2	2	1	3	1	0	0	0	0	0	1	0	1	0	1	0
Middleman dominance and illegal trade	15	0	1	1	1	1	2	0	2	1	0	0	1	0	1	1	1	2	0	0	0	0
Corruption and malpractices	13	1	2	0	0	1	2	1	1	0	0	0	0	0	0	0	2	2	0	0	0	1
Farmers leaving agriculture (job shift)	11	0	0	1	0	1	2	0	1	1	1	0	0	0	0	0	0	1	1	0	1	1
Illegal and rampant deforestation	11	1	2	1	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0
Massive and recurrent floods	11	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1
Transboundary diseases (livestock)	10	0	0	0	0	1	1	1	0	0	1	0	1	0	1	1	1	1	0	0	1	0
No research and development on market reforms	9	0	0	1	1	0	2	1	1	1	0	0	1	0	0	0	0	0	0	0	0	1
Climate change impacts (global warming)	8	0	0	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1
Illegal natural resource exploitation	8	1	0	1	0	0	1	0	0	0	0	1	0	0	0	1	0	2	0	1	0	0
Natural calamities (earthquake)	8	1	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	0	1	1	1	0
No germplasm (biodiversity) conservation	8	0	0	1	0	0	0	1	0	2	0	1	0	0	0	0	0	1	0	1	1	0
Illegal hunting and poaching	7	1	1	1	0	0	0	1	0	0	0	0	0	1	0	2	0	0	0	0	0	0
Slash and burn cultivation	7	1	1	0	1	0	0	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0
Unplanned urbanization	7	0	1	1	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	1
Illegal and inappropriate fishing	6	1	1	1	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Illegal migration (illegal immigrants)	6	0	0	0	0	1	1	0	1	0	0	0	0	1	0	0	1	1	0	0	0	0
Illegal mining in hills and rivers (coal mining)	6	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0
Changes in seasonal pattern (monsoon fluctuations)	5	0	0	1	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	1
Land fragmentation	5	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	1
Soil erosion and degradation due to landslides	5	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0	0
Social instabilities and insurgency (extremism)	5	0	0	0	0	1	0	0	1	0	0	0	0	0	0	1	1	0	0	0	0	1
Futile (zero) quarantine measures on border areas	5	0	0	0	0	1	0	0	0	0	1	0	0	0	1	1	1	0	0	0	0	0
Intensive cash cropping (ex. Rubber)	4	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1
Political interference in science	4	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	1
Epidemics in livestock sector (bird flu, swine flu)	3	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0

Higher temperature in winter season	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Policy apathy towards farmers and agriculture	3	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Unscientific and unhygienic meat production	3	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
Drug addiction	2	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Inappropriate talent retention policies	2	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0
Lack of scientific information among farmers	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pollution and garbage (inadequate waste management)	2	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rodent outbreak during bamboo flowering	2	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0
Unethical and exploitative mindset	2	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0
Wildlife conflict (increasing attacks)	2	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0
Cellphone radiation from towers	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Drying of streams and rivers	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ground water table depletion	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Hydro power projects	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Indiscriminate use of artificial insemination (in livestock)	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Indiscriminate and unscientific use of plastic	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor shortages for farming	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Inadequate research and development on effective irrigation	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Less research and development on water harvesting	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Natural enemies of insects (beneficial insects) are vanishing	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
No or inadequate bio-input support for farmers	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Open grazing of livestock (during winter and summer)	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Poor nutrition management of infants (livestock)	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Population explosion	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Wildlife outbreak (Rodents)	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0

(See Table 13 for details of district codes)

Appendix K. Trainings imparted to the farmers of NER by the Farm Science Centers during 2011-2017

The thematic area of training	2016-17		2015-16		2014-15		2013-14		2012-13		2011-12		2010-11		Total Courses	Total Participants
	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants		
Crop Production	654	18719	472	12991	403	10665	656	20539	749	21331	611	16302	565	14859	4110	115406
Horticulture	697	35438	515	16268	422	11345	575	20288	711	18848	561	14327	474	12885	3955	129399
Soil Health and Fertility Management/INM	417	11343	325	9419	191	4912	285	8522	373	9177	336	8559	243	6693	2170	58625
Fisheries	328	10211	206	6758	203	5223	203	5293	227	5669	209	5162	176	4360	1552	42676
Home Science/Women empowerment	204	5409	78	970	212	5144	299	7284	351	7897	300	7105	325	8469	1769	42278
Agril. Engineering	107	2246	74	1891	32	848	67	1972	98	2638	55	1228	49	1258	482	12081
Integrated Pests Management	299	8805	299	6491	0	0	0	0	0	0	0	0	0	0	598	15296
Integrated Disease Management	153	4570	118	2556	0	0	0	0	0	0	0	0	0	0	271	7126
Integrated Crop Management	161	4593	27	522	0	0	0	0	0	0	0	0	0	0	188	5115
Integrated Farming System	23	515	34	509	0	0	0	0	0	0	0	0	0	0	57	1024
Production of seeds/planting materials	84	2636	51	892	19	559	0	0	0	0	0	0	0	0	154	4087
Capacity Building and Group Dynamics	254	7128	158	5128	127	3601	242	8182	257	6766	176	5233	153	3782	1367	39820

Agro forestry	33	971	24	1001	21	584	42	1011	33	782	38	1007	26	695	217	6051
Post-harvest Technology	11	389	12	222	5	123	0	0	0	0	0	0	0	0	28	734
Resource Conservation Technology	60	1554	8	166	12	336	0	0	0	0	0	0	0	0	80	2056
Value addition	149	3691	74	1638	44	1410	0	0	0	0	0	0	0	0	267	6739
Integrated Water management	33	802	2	49	11	223	0	0	0	0	0	0	0	0	46	1074
Mushroom cultivation	25	595	27	725	17	324	0	0	0	0	0	0	0	0	69	1644
Bee Keeping	2	60	10	268	3	66	0	0	0	0	0	0	0	0	15	394
Plant Protection	121	3075	0	0	329	8843	475	16096	519	13071	472	13276	523	14175	2439	68536
Production of Inputs at site	37	958	0	0	0	0	50	1780	44	1286	60	1425	34	750	225	6199
Livestock production and management	0	0	0	0	215	5310	441	12965	480	13224	370	11085	411	11122	1917	53706
management of problematic soil	0	0	0	0	2	32	0	0	0	0	0	0	0	0	2	32
Bio-control and bio-pesticide	0	0	0	0	6	184	0	0	0	0	0	0	0	0	6	184
Fodder conservation	0	0	0	0	5	120	0	0	0	0	0	0	0	0	5	120
Any other	0	0	37	319	40	1300	0	0	0	0	30	736	0	0	107	2355
Total	3852	123708	2514	68464	2279	59852	3335	103932	3842	100689	3188	84709	2979	79048	22096	622757

(Source: Annual reports of ICAR-Agricultural Technology Application Research Institute, Umiam (Barapani), Meghalaya.)

Appendix L. Trainings imparted to the rural youth of NER by the Farm Science Centers during 2011-2017

The thematic area of training	2016-17		2015-16		2014-15		2013-14		2012-13		2011-12		2010-11		Total Courses	Total Participants
	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants		
Crop Production	32	704	82	2297	42	1369	115	2590	15	380	3	86	53	1601	342	9027
Horticulture	178	4234	129	3026	52	1518	34	875	128	2895	111	2123	163	3627	795	18298
Soil Health and Fertility Management/INM	21	558	100	1396	24	445	1	28	12	330	14	372	24	729	196	3858
Livestock Production and Management	122	3122	138	3648	47	1063	221	5579	129	3177	127	3649	150	3888	934	24126
Fisheries	72	1912	48	1277	79	2209	37	669	42	1039	56	1286	4	1029	338	9421
Home Science/Women empowerment	43	1029	55	1133	38	928	34	754	44	914	106	2342	144	3625	464	10725
Agricultural Engineering	15	383	14	459	7	141	9	189	2	28	0	0	0	0	47	1200
Insect Pest Management	2	35	45	1191	83	2209	8	206	6	149	18	405	14	374	176	4569
Integrated crop management	4	98	21	164	0	0	1	24	4	113	39	960	15	356	84	1715
Integrated Farming System	83	1792	11	341	8	193	31	874	59	1538	0	0	22	656	214	5394
Planting material and seed production	62	1438	25	450	12	257	44	1119	36	774	33	731	48	1288	260	6057
Capacity Building and	58	1530	47	1448	28	645	0	0	18	285	32	798	46	1143	229	5849

Group Dynamics																
Post-Harvest Technology	16	377	31	712	5	93	10	228	10	208	0	0	0	0	72	1618
Resource conservation	5	66	3	67	2	33	0	0	2	47	0	0	3	74	15	287
Mushroom Cultivation	84	2050	49	1306	56	852	0	0	76	1884	31	704	0	0	296	6796
Bee Keeping	36	841	13	293	9	227	12	236	14	275	6	127	0	0	90	1999
Vermi-culture / compost making	40	842	0	0	6	130	30	715	38	842	11	199	0	0	125	2728
Value addition	46	980	30	766	13	266	67	1579	69	1459	5	106	0	0	230	5156
Small scale processing	13	279	0	0	0	0	0	0	0	0	0	0	0	0	13	279
Soil and Water Testing	8	203	2	20	0	0	0	0	0	0	0	0	0	0	10	223
Sericulture	2	51	13	332	0	0	1	30	4	111	7	176	7	163	34	863
Nutrition Garden	5	186	1	30	0	0	0	0	0	0	0	0	0	0	6	216
Marketing / Agril. economics	6	136	0	0	0	0	0	0	39	1009	7	161	0	0	52	1306
Agro-forestry	1	50	5	156	5	126	0	0	3	67	0	0	0	0	14	399
Rainwater harvesting / conservation	0	0	0	0	6	133	1	27	1	35	49	472	0	0	57	667
Production and use of organic products	0	0	0	0	9	212	10	295	35	798	5	125	0	0	59	1430
crop protection	0	0	0	0	0	0	16	354	5	129	0	0	0	0	21	483
Any Other	9	316	17	506	20	484	112	2956	6	144	14	346	95	2268	273	7020
Total	954	22896	862	20512	531	13049	682	16371	791	18486	660	14822	693	18553		

(Source: Annual reports of ICAR-Agricultural Technology Application Research Institute, Umiam (Barapani), Meghalaya.)

Appendix M. Trainings imparted to the extension personnel of NER by the Farm Science Centers during 2011-2017

The thematic area of training	2016-17		2015-16		2014-15		2013-14		2012-13		2011-12		2010-11		Total Courses	Total Participants
	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants	courses	participants		
Crop Production	84	1729	20	466	32	515	22	435	54	1160	47	882	30	750	289	5937
Horticulture	49	858	37	1002	32	542	1	21	17	343	38	853	28	826	202	4445
Soil Health and Fertility Management/INM	17	369	24	576	12	290	11	211	27	559	16	350	13	291	120	2646
Livestock Production and Management	106	1006	21	525	15	304	3	69	27	552	34	821	33	944	239	4221
Fisheries	10	212	9	211	24	302	1	15	3	59	12	249	5	94	64	1142
Integrated Farming System	1	42	2	42	13	149	2	51	7	163	3	68	0	0	28	515
Home Science/Women empowerment	32	767	20	441	14	365	6	143	43	806	21	477	28	787	164	3786
Agricultural Engineering	3	63	1	25	3	100	7	164	3	46	0	0	0	0	17	398
Integrated Pest Management	47	1050	40	665	29	396	28	530	39	800	19	326	39	853	241	4620
Integrated Disease management	3	69	3	80	5	67	0	0	0	0	0	0	14	268	25	484
Integrated Crop Management	2	50	3	62	2	66	10	154	2	92	2	68	4	75	25	567

Integrated Nutrient Management	13	244	0	0	0	0	18	262	0	0	15	280	23	1062	69	1848
Bio-control of pests / plant protection	4	83	0	0	12	255	0	0	0	0	32	643	0	0	48	981
Capacity Building and Group Dynamics	36	787	0	0	14	246	20	493	21	465	35	828	32	741	158	3560
Agro-forestry	3	46	1	27	4	75	0	0	1	15	0	0	0	0	9	163
Resource conservation	3	65	2	48	0	0	13	237	11	214	4	80	0	0	33	644
Mushroom Cultivation	4	97	1	30	6	124	1	18	2	49	0	0	0	0	14	318
Soil and water testing	1	22	0	0	0	0	0	0	0	0	0	0	0	0	1	22
Value addition	2	57	2	55	11	275	0	0	1	36	0	0	0	0	16	423
Marketing	1	30	0	0	0	0	0	0	0	0	0	0	0	0	1	30
Crop insurance	0	0	1	25	0	0	0	0	0	0	0	0	0	0	1	25
Integrated water management	0	0	0	0	2	60	0	0	1	10	2	38	1	32	6	140
Agril. Extension	0	0	0	0	0	0	15	333	0	0	0	0	0	0	15	333
Any Other	5	89	52	716	7	159	99	2041	7	169	33	751	25	454	228	4379
Total	421	7646	187	4280	230	4131	158	3136	259	5369	280	5963	250	6723	2013	41627

(Source: Annual reports of ICAR-Agricultural Technology Application Research Institute, Umiam (Barapani), Meghalaya.)

Appendix N: Some photographs showing glimpse of data collection activity from the farmers of Northeastern region of India, during November 2017 to January 2018

(Data collection with the farmers of the North Sikkim district, Sikkim state)

(Data collection with the farmers of the South Sikkim district, Sikkim state)

(Data collection with the farmers of the West Garo Hills district, Meghalaya state)

(Data collection with the farmers of the Churachandpur district, Manipur state)

(Data collection with the farmers of the Jaintia Hills district, Meghalaya state)

(Interaction with the farmers of the Senapati district, Manipur state)

Appendix O. Some photographs displaying the glimpse of Brainstorming Sessions conducted in various *Krishi Vigyan Kendras* of Northeastern region of India (November 2017 to January 2018)

(Brainstorming session held at *Krishi Vigyan Kendra* Aizawl, Mizoram state)

(Brainstorming session held at *Krishi Vigyan Kendra* Lower Dibang Valley, Arunachal Pradesh state)

(Brainstorming session held at *Krishi Vigyan Kendra* Serchhip, Mizoram state)

(Brainstorming session held at *Krishi Vigyan Kendra* North Tripura, Tripura state)

(Brainstorming session held at *Krishi Vigyan Kendra* Dhubri, Assam state)

(Brainstorming session held at *Krishi Vigyan Kendra* Lower Subansiri, Arunachal Pradesh state)

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Eidesstattliche versicherung

“Hiermit erkläre Ich, **Amol Kamalakar Bhalerao**, an Eides statt, dass ich die vorliegende Dissertation mit dem Titel: „**Strategies to Mitigate the Socio-Economic and Environmental Impacts of Climate Change: a Case of Northeastern India**“ selbstständig verfasst und keine anderen als die angegebenen Hilfsmittel – insbesondere keine im Quellenverzeichnis nicht benannten Internet-Quellen – benutzt habe. Alle Stellen, die wörtlich oder sinngemäß aus Veröffentlichungen entnommen wurden, sind als solche kenntlich gemacht. Ich versichere weiterhin, dass ich die Dissertation oder Teile davon vorher weder im In- noch im Ausland in einem anderen Prüfungsverfahren eingereicht habe und die eingereichte schriftliche Fassung der auf dem elektronischen Speichermedium entspricht.”

Declaration of oath

“I, **Amol Kamalakar Bhalerao**, do hereby assure on oath that I have written the present dissertation with the title: "**Strategies to Mitigate the Socio-Economic and Environmental Impacts of Climate Change: a Case of Northeastern India**" independently and have not used other than the cited resources. I further declare that I have not previously submitted the dissertation or parts of it in another examination procedure either in Germany or abroad and that the submitted written version corresponds to that on the electronic storage medium."

Place	**Date**	**Signature**
Hamburg	April, 2019	.....