Disaster Preparedness and capacity building for Resilience in Agriculture

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Abstract

Agriculture faces unprecedented challenges due to the increasing frequency and severity of natural disasters and extreme weather events. Agriculture sector needs resilience to support food production and livelihoods because it is susceptible to cyclones, floods, droughts, soil erosion, pests, and disease outbreaks. Geospatial technology plays a significant role in disaster management for agriculture, offering tools for preparedness, response, and recovery. This study explores the role of geospatial technology in early warning systems and risk assessment for different types of natural disasters that impact agriculture activity. Sustainable farming practices that are essential for resilience include crop diversity, climate-resilience varieties, and adaptation strategies. Capacity building and training are vital for effective geospatial technology utilization, especially in developing countries like India, where infrastructure and technology access may be limited. Tailored capacity-building programs are essential, emphasizing climate-smart practices, sustainable land management, and post-disaster recovery strategies. Access to financial services and insurance schemes enhances resilience by helping farmers cope with losses and recover from disasters. In order to improve resilience and sustainability in agriculture, geospatial decision support systems make it possible to evaluate alternative planning, optimise resource allocation, and implement adaptive management.

1. Introduction

Agriculture has faced unprecedented challenges due to the increasing frequency and severity of natural disasters and climate-related events. Agriculture is inherently vulnerable to a wide range of hazards, including floods, droughts, cyclones, soil erosion and degradation, and disease and pest outbreaks, which can cause devastating losses to crops, livestock, and infrastructure. Climate change has further worsened these risks, leading to unpredictable weather patterns, shifting growing seasons, and increased pest pressure. In this context, resilience – the ability of agricultural systems to absorb shocks, adapt to changing conditions, and recover swiftly, is essential for ensuring sustainable food production and livelihood security. In response, building resilience in agriculture has emerged as a critical imperative, requiring different measures to enhance readiness and capability to face the adversity. In an era marked by increasing frequency and intensity of natural and man-made hazards, the need for advanced tools to predict, monitor, and manage these events has never been more critical. Geospatial technology, encompassing a suite of tools such as Geographic Information Systems (GIS), remote sensing, and global positioning systems (GPS), has emerged as a pivotal component in the field of risk assessment and early warning systems. This technology enables the collection, integration, and analysis of spatial data, providing invaluable insights into the dynamics of hazards and their potential impacts. By enhancing our ability to visualize and interpret complex environmental data, geospatial technology not only improves our understanding of risks but also bolsters our preparedness and response capabilities.In the recent past, the exponential growth of satellite-based information plays vital in agriculture resource management. Remote sensing provides reliable and timely information that is essential for mapping and monitoring agricultural resources and GIS combines the tool for integration and establishment of relationships among the various variables. In determining proper agronomic and cultural practices one should consider appropriate strategies in accordance with the changing climatic conditions. Geospatial technology plays a significant role in agricultural disaster management by providing valuable tools and insights for preparedness, response, and recovery efforts. However, the effective deployment of these technologies requires a robust framework of knowledge and skills among farmers, agronomists, and policymakers. This is where capacity building becomes essential. By training programs, workshops, and educational initiatives, agricultural stakeholders can be fully equipped with the expertise needed to harness the full potential of geospatial technology. This empowerment not only aids in optimizing crop yields and improving land use but also enhances the ability of agricultural systems to withstand and adapt to challenges such as climate change, pest outbreaks, and resource constraints.

2. Role of Geospatial Technology in Risk Assessment and Early Warning Systems

Geospatial technology enables the development of early warning systems that utilize satellite imagery, weather data, and geographic information systems (GIS) to monitor weather patterns and predict potential disasters such as floods, droughts, and disease pest outbreaks, etc. Training farmers and agricultural stakeholders to interpret and utilize these early warning systems empowers them to take proactive measures to mitigate risks, such as adjusting planting schedules, implementing soil conservation measures, or relocating livestock to safer areas. Through the identification of potential disaster hazards, farmers and other agricultural stakeholders can promptly take measures to reduce risks and minimize losses. In India, Mahalanobis National Crop Forecast Centre (MNCFC) provides in-season crop forecasts and assessment of drought situation using state of the art techniques and methodologies developed by Indian Space Research Organization (ISRO). Similarly National Remote Sensing Centre (NRSC), ISRO has created a repository of large data pertaining to the floods & cyclones in different areas of the Country. These hazard maps, generated by NRSC/ISRO, are useful for identification of disaster affected areas (Babu et.al., 2023). Flooding often results in major damage and unrecoverable losses to the agricultural crop over various parts in India. Timely monitoring of flood based on various parameters such as flood inundation area and flood duration is essential for monitoring crop and its loss. Every year, in north eastern region (NER) of India during South West monsoon season, the river Brahmaputra, Barak and its tributaries of Assam has been causing floods leading to huge crop loss of cultivated areas. Crop phenological changes and damages have been observed in Assam for 2021 Kharif season using Sentinel 1A data at 12 days interval from the middle of June to first fortnight of December (Goswami, et. al. 2021). Crop damage areas were categorized into severe, moderate, low based on areas inundated continuously from September to October (Figure 1) and it is observed that in 2021, 1.9% of Kharif crop area in Assam, India was severely damaged due to flood.

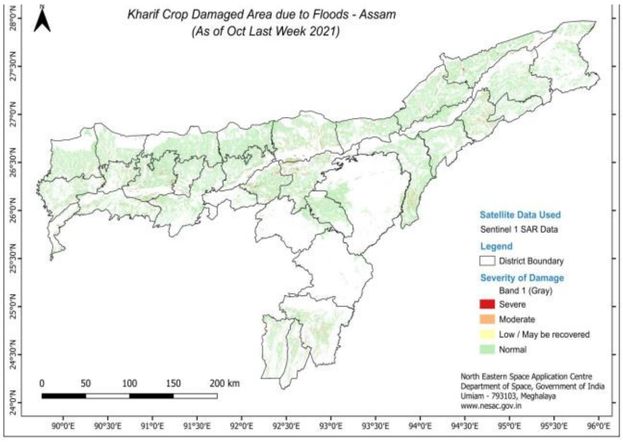

Figure 1. Kharif rice Crop damage area in Assam state

Similarly, Agricultural drought demotes to a condition where the soil moisture is no longer sufficient to meet the needs of growing crops in the field. Careful monitoring of signs of drought and early warning are important in successful management of the catastrophe. NER of India receives heavy rainfall during the monsoon months (June-September), which replenishes the rivers every year. However, the frequency of rainfall deficit years and their spatial extent have been increasing over the NER region of India particularly in Assam in the past decades. Increase in rainfall deficiency has lead to drought like scenario affecting the agricultural crops in the region. In view of that, seasonal agricultural drought hazard mapping has been done for the Rabi crop season over the Assam using time series geospatial data from different sources. Various meteorological indices, vegetation indices and Soil moisture for the past 20 years for the period of 2010 to 2022 were used to map the drought hazard and it was classified into very high, high, medium and low hazard (Figure 2). The district-wise analysis reveals significant variability in the extent of drought impacts. The five districts with the largest affected areas are Barpeta, Kamrup Rural, Udalguri, Darrang, and Bongaigaon, which together account for a substantial portion of the total affected area. Barpeta, district stands out as the most severely impacted, highlighting a critical need for targeted drought management strategies. The large-scale impact in these districts underscores the vulnerability of their agricultural sectors and the associated economic risks posed by crop failures. Effective interventions, such as improved irrigation infrastructure, drought-resistant crop varieties, and farmer support programs, are essential to mitigate these risks and enhance resilience. On the other hand, districts like N C Hills, Charaideo, Kamrup Metro, Jorhat, and Karbi Anglong Diphu have relatively minor affected areas. Despite their smaller scale, even these regions require attention to prevent potential disruptions to local agricultural practices. The cumulative effect of drought across Assam requires a comprehensive, state-wide approach to drought preparedness and response. By addressing both the heavily and lightly affected districts, Assam can safeguard its agricultural productivity and support the livelihoods of its farming communities.

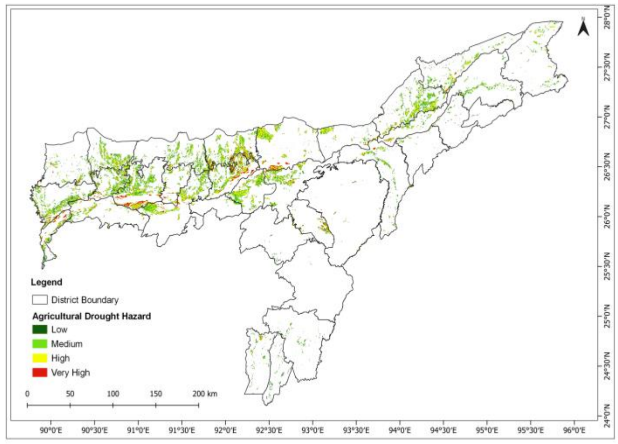

Figure 2. Agricultural Drought Hazard Map of Assam (Rabi Season)

The periodical information on extent of crop, pest and disease infestation and monitoring of the crops in inaccessible areas are difficult due to insufficient technical inputs, infrastructure bottlenecks and ineffective monitoring methods. Unmanned Aerial Vehicle (UAV) were implemented in agriculture for multiple tasks such as spraying pesticide, and monitoring crop and rapid assessment of the extent of crop damage due to massive pest and disease infestation (Handique and Goswami et.al.2016). Hyperspectral remote sensing offers significant potential for monitoring and assessing crop conditions at various scales, from individual fields to entire regions. Its detailed spectral information enables precise and timely interventions, ultimately contributing to more efficient and sustainable agricultural practices. UAV fitted along with multispectral hypespectral, thermal and RGB sensors can detect field areas inflicted by weeds, infections, and pests (Figure 3) . The high resolution imagery helps in getting accurate data to enable crop insurance companies and they are able to give proper compensation to affected farmers. Monitoring and assessment of crop conditions at different scales is therefore of paramount importance and timely dissemination of such assessment and alerting the appropriate authorities to prioritize resources, and develop targeted interventions to enhance resilience in vulnerable areas. Currently, many insurance agencies rely on a satellite based survey not only to determine the actual cultivable land, but also during the claims process to understand the extent of crop loss and the actual yield and compensate the farmers accordingly.

Figure 3. UAV survey for crop damage assessment due to Brown Plant Hopper infestation.

3. Sustainable farming practices and Resilience building

Climate change influences the geographic distribution of crops and shifts the suitability of different regions for agriculture. The exponential increase of CO_2 with concomitant rise of temperature in the atmosphere is an important climate change, which severely influences the productivity of crop plant (Rosenzweig and Hillel, 1995). Changes in temperature and precipitation regimes can impact the length of growing seasons, alter crop phenology, and affect the viability of traditional cropping systems. Farmers may need to adapt to new crop varieties, adjusting planting dates, and diversifying their agricultural practices to maintain productivity and resilience in changing climatic conditions (Fatima et. al. 2020). Promoting the cultivation of climate-resilient crop varieties and livestock breeds that are adapted to local agro-climatic conditions enhances the resilience of agricultural production systems. There have been changes in the climate and other natural resources in different parts of India to varying degrees. In order to address the agricultural issue, very few attempts have been undertaken in the North Eastern Region of India to identify the main agroclimatic zones with respect to climate, physiography, and soil. The Eastern Himalayan Region, Purvanchal Region, and Meghalaya-Mikir Region are the three major geographical zones that make up the North-Eastern Hill Region. The Purvanchal Zone includes Nagaland, Manipur, Tripura, Mizoram, and the Lohit district of Arunachal Pradesh; the Eastern Himalayan Region includes Sikkim, Arunachal Pradesh (excluding Tirap), and a portion of the Lohit District. The Meghalayan regions of Khasi, Jayantia, and Garo Hills make up the third zone of the Mikir Region. Due to variances in soil, topography, altitude, and other factors, the three main regions exhibit a wide range of climates, which contribute to the diversity of agricultural activities (ICAR, 1984) . The National Agricultural Research Project (NARP) has divided the North-Eastern Hill region into 6 agroclimatic zones essentially based on altitude, rainfall pattern, temperature variation, etc. A geographical area that meets the requirements of crops and their cultivars as well as having a major climate is known as an agro-climatic zone. An ecological region is an area of the earth's surface characterized by distinct ecological responses to macro-climate, as expressed by the landscape, soil orders, natural vegetation, flora & fauna, and aquatic systems (after FAO, 1996). Agro-ecological areas have been identified at the national level by the National Bureau of Soil Survey and Land Use Planning, based on factors such as soils, physiography, length of growing period (LGP), and bioclimate (Rao, etal. 2013)

Mizoram is one of the eight states in the North Eastern Region (NER) of India, a biodiversity hotspot where climate change adaptation is of critical importance for the largely rural population. Large areas of the state are warm to hot perhumid ecological sub region with very shallow to shallow sandy clay loam, clay loam, and loam soil texture, low to medium available water capacity (AWC) and 300 days length of growing period (LGP). With a hilly terrain, low population density, shallow soils and high rainfall, farmers have adopted a shifting cultivation system known as jhum. This largely self-sufficient system that adequately met the various needs of rural communities, including food, fibre and energy, but is now getting disrupted due to shortening of jhum cycles as a result of increasing population, focus on high value crops for cash income, soil fertility degradation and top soil erosion on account of decreased fallow cycles. However, agroclimatic characterization based on the various aspects of climate, topography, soil, etc., and delineation of agroclimatic zone specific land use planning at large scale has been attempted with view to tackling the problem of agriculture and production in this specific region (Table1).

Table 1 Agroclimatic characterization for Champhai district of Mizoram.

Zone	LULC	Texture	AWC	LGP	Elevation (m)
C,W	Forest (72%), Shifting cultivation (13%) Scrub land (12%) Agriculture (2%) Builtup & other (1%)	Sandy Clay Loam (39%) Light Clay (27%) Clay Loam (26%)	VH (37%) M (34%) H (23%)	300 (63%) 270 (37%)	800-1600 (51.64%), 400-800 (37.1%)
C, Ew	Forest (77%) Shifting cultivation (12%) Scrub land (7%) Agriculture (3%) Builtup & other (1%)	Sandy Clay Loam (41%) Light Clay (33%) Clay Loam (22%)	VH (40%) M (32%) H (22%),	300 (87%)	800-1600 (49%), 21600-2000 (33%), 400-800 (14%)
Md,M	Forest (68%) Shifting cultivation (19%) Scrub land (10%) Agriculture (1%) Builtup and other areas (1%)	Sandy Clay Loam (37%) Clay Loam (31%) Light Clay (24%)	VH (45%) M (28%) H (21%),	270 (100%)	400-800 (58%), 800-1600 (31%)
Md, W	Forest (77%), Shifting cultivation (13%) Scrub land (7%) Agriculture (2%) Builtup & other (1%)	Sandy Clay Loam (37%) Clay Loam (32%) Light Clay (26%)	VH (38.23%), M (34.81%), H (20.95%),	270 (46%), 300 (44%)	800-1600 (44%), 400-800 (43%)
Md, Ew	Forest (73%) Shifting cultivation (16%) Scrub land (8%) Agriculture (2%) Builtup & other (1%)	Sandy Clay Loam (35%) Clay Loam (32%) Light Clay (25%)	M (36%) VH (30%) H (24%)	300 (55%) 240 (25%) 270 (20%)	800-1600 (49%) 400-800 (35%) 1600-2000 (14%)

Agroclimatic zone has been delineated which has helped the farmers to comprehend the climatic variables for more productive planning. agroclimatic zone expresses the relationship between climate and agricultural production in quantitative terms. Specific agroclimatic group define the favourable climate for growth of specific crops. In determining proper agronomic and cultural practices one should consider strategies appropriate for each climatic zone. Thronthwaite moisture index not only delineates climate moisture gradient but also defines a single seasonality index responsive to mean seasonal variation in both thermal and moisture conditionsA thorough assessment of agroclimatic resources of Khawbung community and Rural Development (C&RD) Block of Champhai district of Mizoram has been done integrating information in GIS domain on updated Agro-climate zones, land use land cover, soil, available water capacity, length of growing period, slope and elevation for land suitability studies and land use planning by careful assessment of agro-climatic resources so that the farmers receives the maximum benefit from jhum and settled agriculture, horticulture, agroforestry, livestock, integrated farming, land-use planning, etc. The layers were given weights in a scale of 0 to 100 depending on their level of importance with respect to each suitable landuse and the attributes were given rank in the scale of 0 to 9; 0 for least suitable and 9 for most suitable. Integration of the above discussed layers and weighted overlay analysis operation for each criteria finally provide us with land suitability for Intensive Agriculture, Agriculture, Horticulture, Agro-Forestry, Afforestation, Recreational and No Change (Figure 4 a-f).

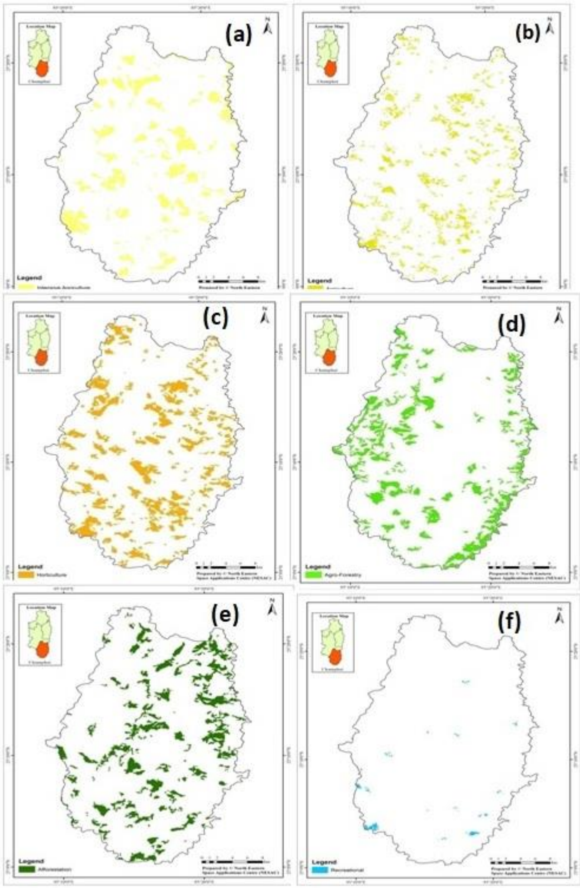

Figure 4. Land suitable for (a) Intensive agriculture (b) Agriculture (c) Horticulture, (d) Agro-Forestry, (e) Afforestation, and (f) Recreational in Khawbung in Khawbung

The individual layers of each suggested land use category and the overlay of each criterion provided the final land use plan map, depicted in Figure 5.The agro-climatic variation within the block provide sufficient environment for cultivation of horticultural crops and agro forestry. From the study it was evident that in Khawbung Block of Champhai District of Mizoram has the highest area under Cold Extremely Wet (CEw) agroclimatic zone followed by Mild Extremely Wet (Mew) and Mostly covered with evergreen forest and forest scrub land. But it was observed that within the Khawbung Block (Figure 6) about 11027 ha of area is suitable for expansion of horticulture (15%) followed by 9168 ha of area is suitable for agro-forestry and 9128 ha area for afforestation (12%). about 5211 ha of area is suitable for agriculture, 8051 ha for intensive agriculture (16%). Village-wise land use plan statistics are also presented in Table 2

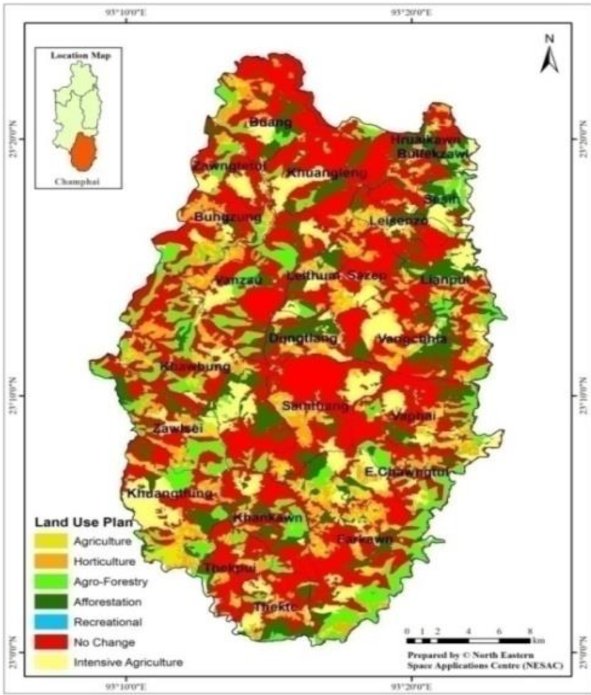

Figure 5: Land use plan for Khawbung Block of Champhai District of Mizoram

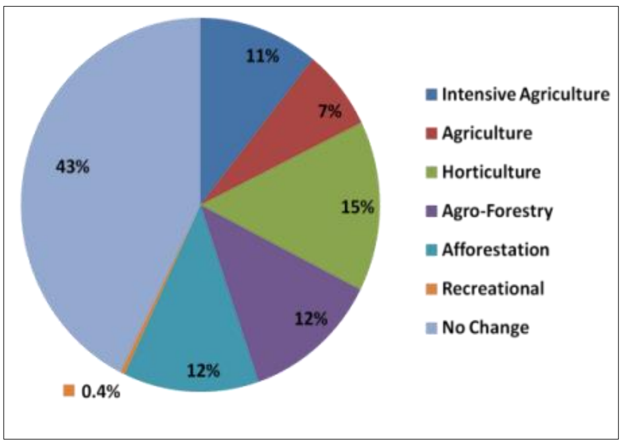

Figure 6: Pie chart showing percent area suitable for LUP in Khawbung Block of Champhai District of Mizoram

A training program was also organized for the officers of Government of Mizoram on the use of agro-climatic atlas with detailed information about the climate, soil characteristics, terrain, and other relevant factors influencing agricultural productivity in particular region. This involves matching the characteristics of the land (soil, climate, etc.) with the requirements of specific crops or agricultural practices. for land suitability studies and land use planning.

Table 2: Village-wise land use plan statistic

Village Names	Intensive Agriculture	Agriculture	Horticulture	Agro-Forestry	Afforest-tation	Recreation	No Change	**Total**
Buang	184	185	511	352	399	0	1722	**3355**
Bulfekzawl	73	6	11	133	153	0	115	**491**
Bungzung	171	296	701	457	112	0	1061	**2799**
Dilkawn	71	1	1	109	3	0	318	**502**
Dungtlang	256	108	296	0	499	11	430	**1600**
Chawngtui	133	76	193	647	87	8	873	**2017**
Farkawn	828	835	1661	1306	876	81	2624	**8211**
Hruaikawn	14	53	117	0	123	0	282	**590**
Khankawn	210	83	221	395	448	1	1387	**2746**
Khawbung	733	350	774	1422	790	16	3147	**7232**
Khuangleng	511	216	439	155	788	6	3088	**5203**
Khuangthing	836	520	940	511	503	156	1149	**4615**
Leisenzo	147	187	283	34	272	6	494	**1424**
Leithum	174	178	351	68	362	0	450	**1582**
Lianpui	295	227	444	342	716	12	1034	**3069**
Samthang	474	336	736	1	264	0	2398	**4209**
Sazep	158	232	448	18	42	0	902	**1800**
Sesih	260	42	94	266	329	0	420	**1412**
Thekpui	37	123	292	170	125	0	1160	**1907**
Thekte	286	165	370	151	363	4	807	**2147**
Tualte	0	0	0	1	5	0	9	**15**
Vanchhia	615	359	694	220	720	0	1776	**4384**
Vanzau	444	136	389	935	336	0	2302	**4543**
Vaphai	513	208	438	412	395	0	1789	**3757**
Zawlsei	230	235	489	802	358	4	1208	**3325**
Zagtetui	396	53	132	260	57	0	898	**1797**
Total	**8051**	**5211**	**11027**	**9169**	**9128**	**304**	**31842**	**74732**

4. Capacity Building and Training

Capacity building and training have emerged as important strategies for improving disaster preparedness and resilience in the agricultural sector in the context of rising environmental uncertainties and the growing impact of climate change. The goal of these initiatives is to provide communities, farmers, and agricultural stakeholders with the information, abilities, and resources they need to foresee, face, and recover from unfavourable events by implementing workshops, seminars, and online courses about potential risks and appropriate response strategies. Women, who constitute a significant portion of the agricultural workforce in many regions, are particularly vulnerable to impact of climate change. Therefore, it is imperative to empower women and communities with the knowledge and skills necessary for climate-resilient agriculture. Initiative has been taken to equip women and community members with the necessary tools such as satellite technology to mitigate and adapt to climate change impacts on agriculture. By focusing on targeted training, practical demonstrations, and active community engagement, the program aims not only to bolster agricultural productivity and food security but also to foster women's leadership and catalyze positive change within their communities. Emphasizing gender equality and inclusivity in climate adaptation efforts is crucial for building robust communities capable of overcoming climate challenges and advancing towards sustainable development goals.

Training on advanced agricultural practices that enhance productivity and resilience, such as climate-smart agriculture, sustainable farming practices, and disaster risk reduction techniques etc and demonstrating the use of technology in agriculture, including precision farming tools and remote sensing for better decision-making. Many developing countries like India, lack adequate infrastructure for geospatial data collection, processing, and analysis. Access to technology, such as satellite imagery, GPS devices, and GIS software, may be limited or expensive, inhibiting widespread adoption and skill development. Capacity building initiatives can be more responsive, relevant, and effective when approaches are tailored to local contexts and requirements with open source data and software which enable concerned individuals to fully utilise the potential of geospatial technology towards climate-smart practices, sustainable land management, crop diversification, and post-disaster recovery strategies. ISRO/DOS has launched many capacity building programme on Geospatial technology and applications in tandem with objectives of National Geospatial Policy -2022. Focuses has been given to tailor made courses based on user requirement for maximum utilization of geospatial inputs for planning and developmental activities.

The Outreach and Capacity Building Programme of North Eastern Space Applications Centre (NESAC) have significantly contributed to the empowerment of the northeastern states by enhancing their capabilities to use space technology for development planning and disaster management. These initiatives have facilitated better decision-making processes, improved resource management, and increased the overall resilience of the region to various challenges. NESAC's outreach and capacity-building programs are integral to its mission of promoting the use of space technology for the sustainable development of the North Eastern Region (Figure 7). By educating and training stakeholders, NESAC ensures that the benefits of space technology reach the grassroots level, fostering a culture of innovation and scientific temper in the region.

Figure 7: Remote Sensing &GIS lab facility at NESAC

In 2022 -23, a total of 635 participants from Water Resource Department, Department of Agriculture, Assam Survey & Settlement Training Centre, National Disaster Management Authority, and BSF has participated in 22 such training programme at NESAC. Additionally a training was also organized for registered farmers in collaboration with Assam Agricultural University on the use of interactive mobile app which was developed integrating spatial database on soil nutrient including weather forecast of India Meteorological Department and NESAC to strengthens the resilience of agricultural systems (Figure 8)

Figure 8: Hands on training on interactive mobile app for farmers .

Impact assessment of training program has been done by establishing mechanisms to monitor and evaluate the effectiveness of training programs and capacity-building initiatives of ISRO/DOS and NESAC . Training and capacity building creates a platform for knowledge exchange and sharing best practices among farmers, researchers, and policymakers. By examining the insights and experiences shared by participants, feedback analysis helps to evaluate the program's effectiveness, identify strengths and areas for improvement, and highlight the broader impacts on participants' preparedness and resilience in the face of climate-related challenges. Ultimately, it underscores the importance of continuous learning and adaptation in strengthening agricultural systems against the impacts of a changing climate.

5. Conclusion

Building agricultural resilience is becoming more important for sustainable development due to the growing challenges posed by climate change and disasters. Geospatial decision support systems (DSS) provide valuable tools for adaptive management and decision-making in agricultural disaster management. Training stakeholders in the use of DSS platforms allows for the integration of multi-dimensional data, scenario analysis, and spatial modelling to evaluate alternative planning, optimize resource allocation, and inform policy decisions aimed at enhancing resilience and sustainability in agriculture. In addition, facilitating access to financial services, microcredit, and insurance schemes helps farmers and rural households cope with agricultural losses and recover from disasters. Effective capacity building gives a holistic approach that includes education, technical training, resource management, institutional strengthening, and the use of technology. It encourages the documentation and dissemination of successful resilience-building initiatives and lessons learned. It helps to get feedback and data to continuously improve and adapt strategies to changing conditions and emerging risks. Together, these efforts ensure that agricultural communities are better equipped to face the challenges posed by a changing climate and an increasingly uncertain environment.

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