BHUTAN
CLEAR | Consolidated Livelihood Exercise for Analysing Resilience

IFAD
INTERNATIONAL FUND FOR AGRICULTURAL DEVELPMENT

WFP
World Food Programme

ABOUT THIS REPORT

This report aims to analyze the climate change impacts and climate resilience of smallholder farmers in Bhutan and provide actionable recommendations to enhance their livelihoods. It is part of the Building Resilient Commercial Smallholder Agriculture (BRECSA) Project with the World Food Programme (WFP), in partnership with the International Fund for Agricultural Development (IFAD) and Bhutan's Ministry of Agriculture and Livestock (MOAL), leading the technical part of this project and with the Global Agriculture and Food Security Program (GAFSP) and IFAD supporting it. BRECSA aims to increase resilient commercial agricultural production by 30% and improve food and nutrition security in the districts of Trongsa, Tsirang, Sarpang, and Zhemgang by 2030.

A key component of BRECSA is WFP's Consolidated Livelihood Exercise for Analyzing Resilience (CLEAR+), which examines how climate change affects livelihoods, nutrition, and food security in order to build climate resilience in vulnerable communities. CLEAR emphasizes robust climate analysis and the participatory approach of engaging communities directly through focus group discussions in 37 Gewogs across the target districts, drawing on local knowledge to develop effective Agricultural Resilience Plans (ARPs).

The report is divided into four main sections, that can be used as stand-alone products, i.e. livelihoods, climate resilience, value chains and climate analysis. Together, they will inform the development of ARPs for 37 Gewogs in Bhutan. Each section first gives an overview for the whole Bhutan and then focuses on the four BRECSA project's districts. Detailed methodology can be found in Annex I, while the reference maps are located in Annex V.

FIGURE 1. STEPS IN BHUTAN CLEAR+ APPROACH.

Acknowledgements

The report is made possible thanks to the financial support of GAFSP, IFAD, RGoB, beneficiary and financial institution. WFP created this document to build evidence of the impacts of climate change on smallholder farmers in Bhutan, to encourage adaptation actions and to provide a baseline for BRECSA project. This work was prepared by the core CLEAR+ Bhutan technical team: Irina Bird Reddiar (Climate Change Adaptation and Food Security Specialist, WFP Bhutan), Karma Penjore (Project Manager), Ugyen Lhendup (Community Consultation Specialist), SDI Consultancy (Value Chain Specialist) and the UK MET Office (Climate Analysis Specialist). From WFP, substantial support and guidance was received from Ana Aguilar at the regional level and at the country level from Binai Lama, Karma Yangden, Jigme Tenzin and Kinley Rinchen. Additional support was also provided by Rachel Allen, Nadezda Amaya, Shama Maqbool and Jothiganesh Sundaram from WFP. This work was made possible by the NSB in Bhutan, who helped obtain a lot of the data, and MoAL and FAO, who shared the previous experiences and helped review the information.

Map disclaimer: The boundaries and names shown on the maps in this report do not imply official endorsement or acceptance by United Nations.

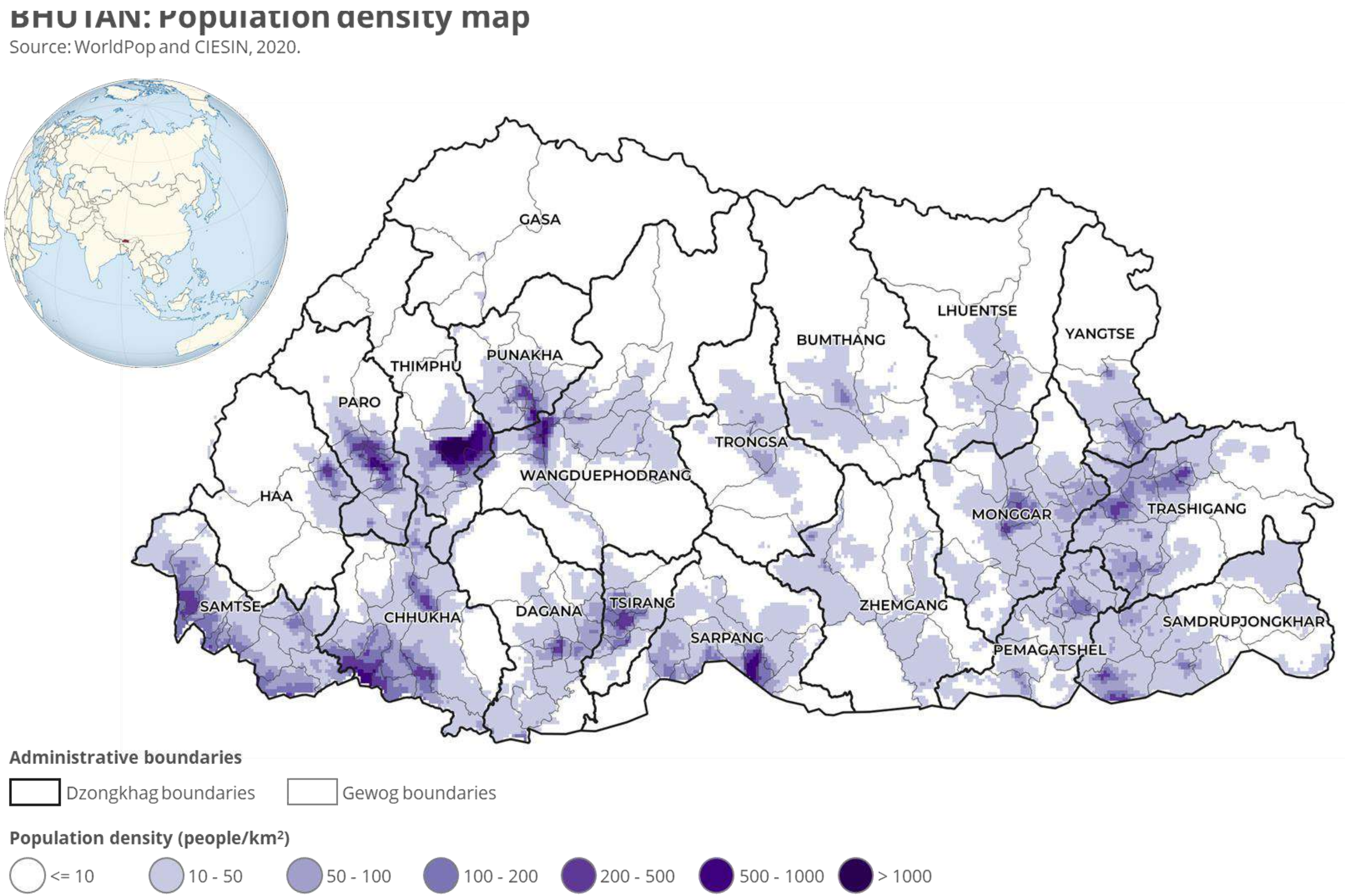


Figure 2. Bhutan population density map. Source: based on WorldPop and CIESIN, 2020.

CONTENT

KEY MESSAGES

Bhutan's agriculture is highly susceptible to climate change due to dependence on monsoon rains, short growing seasons, and challenging mountainous terrain. This vulnerability coupled with poverty, connectivity issues, and the predominance of subsistence farming, which collectively weaken the resilience of Bhutanese farmers to climate shocks. Bhutan's limited arable land (3%) exacerbates the challenges caused by climate change and population shifts. Small farm size (1.4 ha average) and limited access to resources like technology and credit further expose Bhutanese farmers to climate risks. Heavy dependence on agriculture and high sensitivity of this sector to climate threatens Bhutan's food security. Smallholder farmers are currently responsible for producing more than 50% of the country's food basket, contributing immensely to the national food security. However, erratic rainfall patterns and unpredictable monsoon seasons could substantially affect the cultivation of rice which is considered as the most important crop.

Bhutan's diverse geography supports over 20 unique livelihood groups. Interventions need to be tailored to these to increase the resilience of farmers in Bhutan. For example, the northern region where farmers predominantly rely on livestock could benefit in strategizing a yak value chain; however, using the same intervention would not be much help to the farmers of the southern part of the country where production of commercial crops such as mandarin, cardamom, and ginger are the main sources of income.

BHUTAN: Climate resilience

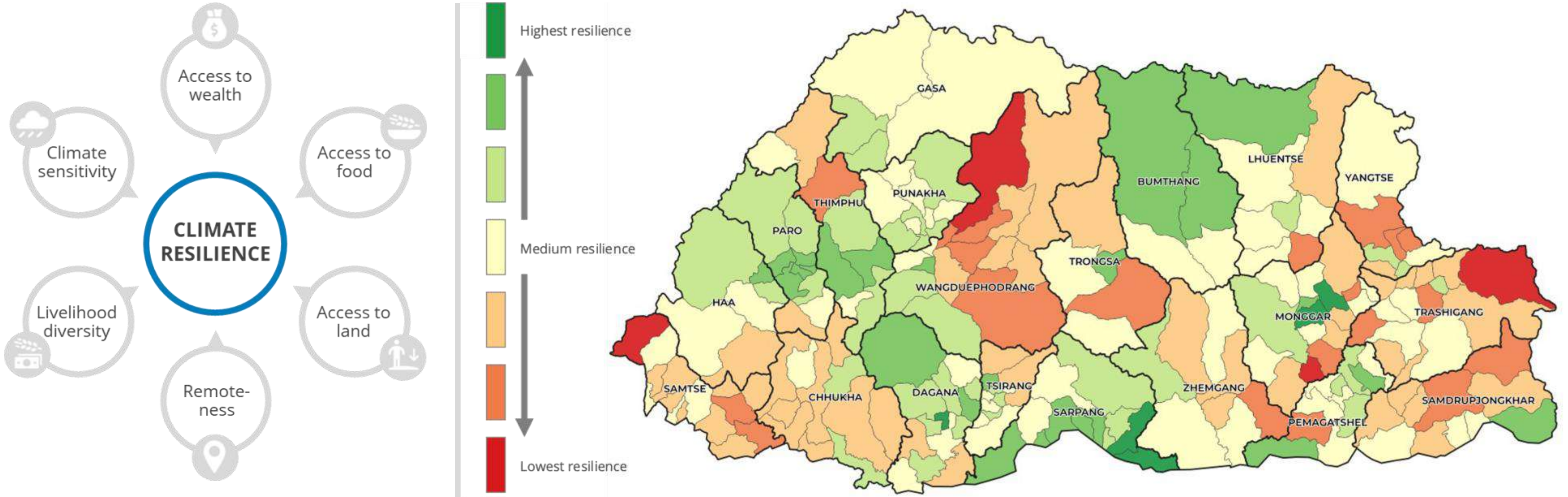


FIGURE 3. FACTORS CONTRIBUTING TO CLIMATE RESILIENCE OF RURAL COMMUNITIES IN BHUTAN AND THE OVERALL CLIMATE RESILIENCE MAP OF BHUTAN.

Climate change is one of the key challenges faced by rural communities in Bhutan. The following key climate trends have the potential to significantly affect livelihoods:

BHUTAN: Livelihood zones

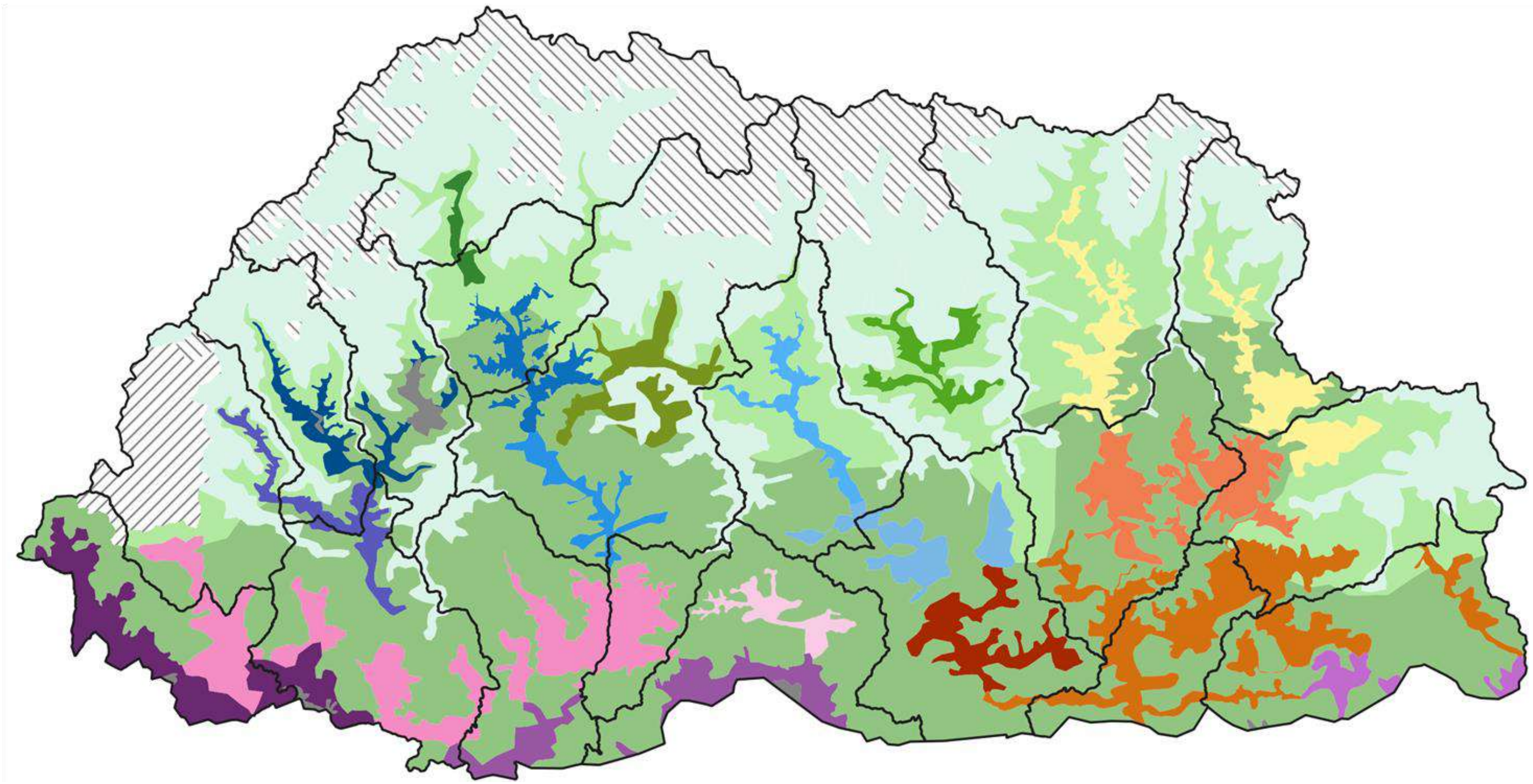


FIGURE 4. KEY CLIMATE TRENDS AFFECTING LIVELIHOODS IN BHUTAN.

LIVELIHOODS

Livelihood zones

Livelihoods in Bhutan are highly diverse due to the dramatic variations in elevation and the complex influence of the Asian monsoons. The agricultural sector (comprising of farming, livestock and forestry) is the cornerstone of rural livelihoods, employing roughly 43% of the working population and contributing almost 15% to the GDP (NSB, 2023). However, the steep terrain poses significant challenges for agriculture restricting agricultural land to 13.8% of its total area, of which less than 3% (1,138 km^2) is cultivated (NLCS DoSAM, 2023). Subsistence farming continues to be prevalent; however, there's a growing shift towards increased production and commercialization. However, the sector grapples with hurdles like climate change, small land size, limited infrastructure and market access, and a shrinking workforce due to rural-urban migration.

Most rural households depend on a mixed farming system of crops and livestock, as well as forest products for their livelihoods. Mostly they are smallholder subsistent farmers, with an average land holding of about 3.5 acres (1.4 ha) fragmented into smaller lands in different locations, and with 90% of them producing mostly or only for own consumption (NSB and MoAF, 2019). Only about 18% of the total area is irrigated, while the rest of the crops are grown under rain-fed conditions – this makes the sector particularly vulnerable to any changes in the precipitation. Farm mechanization is difficult due to the rugged landscape that renders farming extremely labour intensive, and farmers use limited chemical inputs (Tenzin et al., 2019). Women are crucial players in Bhutan's agriculture, constituting over 56% of the agricultural workforce, a trend that is growing as men are increasingly leaving farms in search of off-farm work (FAO, 2023). However, despite their significant contribution, they often face unequal access to resources like land, credit, and training opportunities, hindering their full potential for productivity and income generation (ibid.).

Maize and irrigated paddy are the two dominant crops accounting for 31% of the total agricultural land in Bhutan, followed by potato, vegetables and mandarin orange (NSB and MoAF, 2019). Out of the two cereals, rice is preferred for consumption while maize holds importance as livestock feed. Animal husbandry is closely integrated with crop production, providing draft power, manure, and additional income through eggs, dairy and meat products. In recent years, the government has prioritized initiatives to promote organic farming, high-value crops like apple and cardamom, and improved breeds of livestock to enhance productivity and incomes for rural communities.

Bhutan's climatic and altitudinal variability creates distinct livelihood zones with unique agricultural practices. The annual precipitation ranges widely in various parts of the country; however, in general Bhutan receives about 70% of the precipitation during monsoons from late June through late September, while pre-monsoon rainfall accounts for 20% (NEC, 2023). Due to this, livelihoods in Bhutan roughly follow the six agro-ecological zones: wet-subtropical, humid-subtropical, dry-subtropical, warm temperate, cool temperate, and alpine (Chhogyel and Kumar 2018).

High-altitude alpine zone, encompassing areas like northern Bumthang and upper reaches of Lhuntse, is characterized by harsh winters and short growing seasons that limit crop options. Here, communities practice agro-pastoralism, relying heavily on livestock rearing. Sheep, yaks, and cows are well-adapted to the cold climate, providing essential products like wool, milk, and meat. Gathering and sale of *Cordyceps sinensis* is one of the main sources of income for most highlanders.

Cool and warm temperate zones in the main central river valleys, which include regions like Wangdue Phodrang, Paro and Trongsa, are characterized by moderate rainfall and cool winters and hot summers. These zones offer a more favourable climate for a wider variety of crops. Here, farmers cultivate staple crops like rice, maize, buckwheat and barley alongside potatoes, vegetables and cash crops like apples. Animal husbandry remains important, with cattle providing draft power and additional income.

Bhutan's southern foothills and valleys constitute the wet-subtropical, humid-subtropical, and dry-subtropical zones, encompassing areas like Chukha and southern Sarpang. Subtropical areas are characterized by high humidity and heavy rainfall with very hot summers and warm winter. These zones boast the most fertile land and the longest growing season. Here, rice and maize cultivation dominates, with multiple cropping cycles possible in some areas. Cash crops like fruits, spices, and vegetables are also significant contributors to livelihoods. Given the warmer climate, livestock rearing focuses on cattle, pigs, and poultry.

Summary of methodology

The livelihood zones were developed to highlight areas that have relatively similar geography (agro-ecology and topography), main livelihood activities and infrastructure, including roads and access to markets. This analysis relied heavily on the expert knowledge and review of secondary data (such as land cover, agricultural censuses, agro-ecological zones, elevation, and satellite imagery). The zones were then further validated in the four districts (Sarpang, Trongsa, Tsirang, and Zhemgang) through field observations and community consultations. For more detailed description of methodology see Annex I.

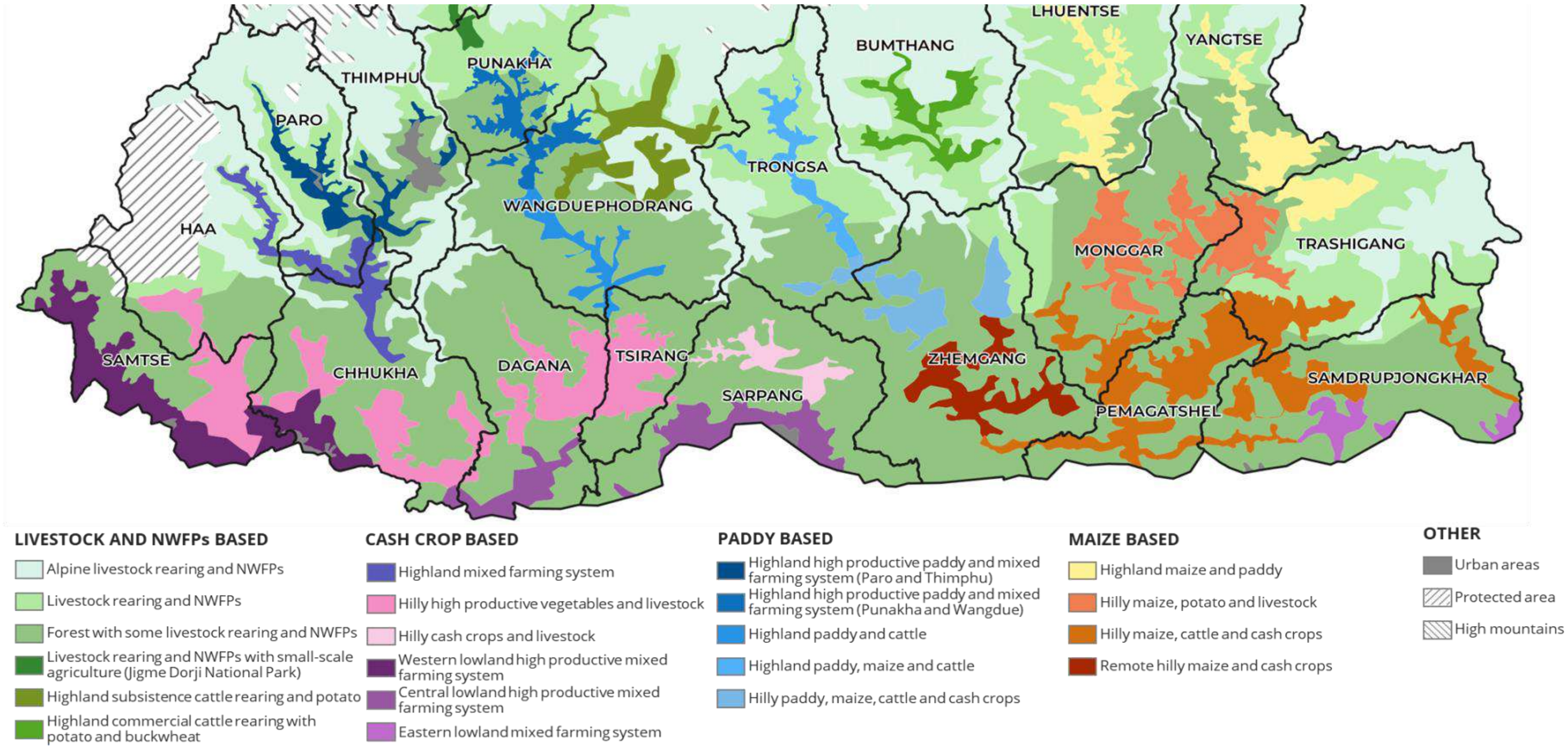


FIGURE 5. LIVELIHOOD ZONE MAP FOR BHUTAN HIGHLIGHTING MAIN LIVELIHOOD ACTIVITIES (FOR DETAILED DESCRIPTIONS OF LIVELIHOOD ZONE ACTIVITIES SEE ANNEX II).

CASE STUDIES: LIVELIHOODS IN SARPANG, TRONGSA, TSIRANG, AND ZHEMGANG

Trongsa, Zhemgang, Sarpang, and Tsirang are districts in central and southern Bhutan, each known for their unique geographical features, cultural heritage, and economic activities. Trongsa is historically significant with its majestic Trongsa Dzong, playing a vital role in Bhutan's monarchy. Zhemgang is rich in biodiversity, home to various wildlife and dense forests. Sarpang, with its fertile plains, serves as an agricultural hub and benefits from its strategic location near the Indian border, enhancing trade opportunities. Tsirang is renowned for its organic farming and horticulture, particularly its citrus fruits, contributing significantly to the local economy. The livelihoods of people in Trongsa, Zhemgang, Sarpang, and Tsirang districts in Bhutan are predominantly based on agriculture and livestock rearing. Trongsa's residents engage in farming, livestock rearing, and traditional handicrafts in small pockets. In Zhemgang, agriculture, forestry, and eco-tourism are the primary sources of livelihood, complemented by livestock rearing. Sarpang's fertile plains support extensive farming and horticulture, with trade and livestock rearing also playing significant roles. Tsirang is known for its organic farming and horticulture, particularly citrus fruits, along with dairy farming and small-scale agro-based industries. Each district's unique combination of these activities reflects their diverse landscapes and cultural practices.

FIGURE 6. CASE STUDIES: LIVELIHOOD ZONE MAP FOR SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

Main livelihood activities

In Sarpang Dzongkhag, the main livelihood activities are paddy, dairy, areca nuts, vegetables and oranges. Of these, areca nut contributes the most to household income, followed by dairy, orange and cardamom. When it comes to sale, the highest percentage of sold products are areca nut, dairy and orange. Paddy mainly cultivated to meet the food requirement of the household.

In Trongsa Dzongkhag, the primary sources of livelihood include paddy cultivation, dairy farming, maize farming, cardamom production, and vegetable cultivation. Dairy farming is the biggest contributor to household income followed by cardamom and Sichuan pepper. In terms of sales, dairy products, cardamom, and Sichuan pepper make up the highest percentage of products sold.

In Tsirang, a majority of the households are engaged in vegetable production, dairy farming, maize cultivation, paddy cultivation and poultry farming. Vegetable farming also contributes the most to household income and food, followed by paddy, dairy, orange and maize. Vegetables are also the most sold product of the Dzongkhag, along with oranges and dairy products.

In Zhemgang Dzongkhag, most households are into dairy farming, growing oranges and maize, and producing cardamom. Yet, when it comes to bringing household income, oranges lead the way, followed by dairy, maize, ginger, and cardamom. Oranges are the top-selling produce in Zhemgang, followed by cardamom, dairy, and ginger. The percentage of self-consumption for these products is very low.

Infrastructure and household assets

All gewogs in Sarpang are well-equipped with essential infrastructure including Renewable Natural Resources (RNR), farm roads, community centers, and dairy cooperatives. The dzongkhag also has an ice cream factory, Agriculture Research and Development Centre (ARDC), Farm Machinery Corporation Limited (FMCL), Army Welfare Project (AWP), and a feed production unit. On average, households own 3 to 4 acres of land and maintain 2 to 3 cows. The average literacy rate stands at 65 percent, and most gewogs have access to machinery such as power tillers, mini power tillers, rice mills, tractors, flour mills, grass cutters, and maize mills.

Trongsa Dzongkhag has facilities like RNR Centers, Gewog Centers, Community Centers, farm roads, vegetable cooperatives, and Milk processing units. Households have on average, 2 acres of land and own 3 to 4 cows. The literacy rate is 73 percent and a good portion of households have power tillers, rice mills, weed cutters, and power chains.

Most of the gewogs in Tsirang have RNR (Renewable Natural Resources) centers, Farm Roads, Community Centers, Gewog Offices, and Forest Offices. On average, households own 1 to 2 acres of land and maintain 3 to 4 cows. However, some households are landless, a situation where few cases are common across all the Dzongkhags. The average literacy rate stands at 65 percent. In terms of machinery, a significant number of households have access to power tillers, rice mills, mini power tillers, grass cutters, and paddy threshers.

Resources (RNR) centers, farm roads, Basic Health Units (BHUs), Community Centers, schools, Primary Health Centers (PHCs), and Early Childhood Care and Development (ECCD) centers. On average, households in the region own 2-3 acres of land and keep 3 to 4 cows. However, there are also some households that do not own any land.

The average literacy rate in Zhemgang is 69 percent, indicating a moderate level of education within the community. Some households in the gewogs have access to power tillers and mini power tillers, which assist in farming activities. However, in certain gewogs, the challenging terrain makes the use of machinery impractical, resulting in no households owning such equipment in those areas.

Main challenges

The primary challenges to livelihoods in the four dzongkhags stem from climate variability and climate change. Insufficient rainfall from February to May leads to water shortages during the cultivation of crops like paddy and maize, while excessive rain from August to October hinders crop harvest and spoils the yield, negatively impacting farmers' livelihoods. Prolonged dry seasons (February to May) also disrupt the production of cash crops such as vegetables, areca nuts, and oranges. Similarly, inadequate rainfall results in fodder shortages for dairy farming. Rising temperatures not only complicate crop cultivation but also limit farmers' ability to work during the day. Additionally, unpredictable windstorms damage crops, adding to the difficulties farmers face.

Another major concern is Human-Wildlife Conflict (HWC), which poses a persistent challenge throughout the year, unlike the seasonal impacts of climate change. HWC leads to significant crop damage, with losses ranging from 20 to 100 percent, and is a widespread issue across all four Dzongkhags. However, the problem is particularly severe in Trongsa and Zhemgang Dzongkhags.

Farmers also face significant challenges due to the prevalence of pests and diseases affecting both crops and livestock. The diverse climate and topography create conditions conducive to various pests and diseases threatening agricultural productivity. For crops, infestations such as armyworms (Maize and paddy), aphids, cutworms (in vegetables), and fungal diseases such as early blight (potato) severely reduce yields. These infestations are often exacerbated by changing weather patterns, which can create favorable environments for pests to thrive. On the livestock front, farmers grapple with diseases such as foot-and-mouth disease and lumpy skin disease in cattle, avian influenza in poultry, swine flu in pigs, and parasitic infections across various livestock species. These outbreaks not only lead to direct losses through mortality and reduced productivity but also increase the costs associated with disease management, such as veterinary care and preventive measures. Consequently, these challenges undermine food security and income stability for farmers, making it difficult for them to sustain their livelihoods.

Moreover, farmers are experiencing a shift in labor availability. Labor shortages during peak farming seasons are affecting all the Gewogs within the four Dzongkhags. This issue is further compounded by rising costs of labor and hiring machinery, making it increasingly challenging for poorer households to carry out essential farming tasks.

Moreover, most agricultural products are sold in raw form primarily due to limited processing infrastructure, financial constraints, and a lack of access to advanced technology. The rugged terrain and scattered rural communities make it challenging to establish and maintain processing facilities, which are often located far from farming areas. Smallholder farmers, typically lack the resources and technical knowledge required for value addition. This is compounded by insufficient market linkages and a lack of cold storage, packaging, and transportation facilities that are necessary to preserve and process agricultural produce. As a result, farmers tend to sell their products in raw form immediately after harvest to avoid spoilage and to meet immediate cash needs, missing out on the potential higher earnings that could be achieved through value-added products. However, in the case of milk, it is typically processed into cheese and butter, which are used both for sale and household consumption.

Many vegetable vendors in these dzongkhags also function as aggregators, connecting farmers directly to buyers and streamlining the agricultural supply chain. However, despite improving efficiency, farmers express dissatisfaction with the prices offered by these aggregators. Sarpang and Tsirang districts have a particularly high concentration of aggregators, primarily dealing in vegetables, poultry, and pork products. Compounding the challenges faced by farmers is the competition from imported goods, which negatively impacts their earnings.

<u>Main coping strategies</u>

Farmers across the four Dzongkhags are implementing a variety of strategies to cope with the challenges brought about by climate change. Given Bhutan's rugged terrain and heavy reliance on agriculture, these adaptive measures are essential for sustaining livelihoods. For example, in Tsirang and Sarpang, farmers plant pulses and summer vegetables when a lack of rainfall prevents paddy cultivation. Similarly, in certain gewogs of Zhemgang, farmers have begun cultivating Areca nuts as an alternative to citrus plants, which are reportedly declining due to rising temperatures. Though on a smaller scale, communities in Sarpang and Tsirang have also adopted several strategies to mitigate irrigation water shortages. These include protecting water sources, constructing water storage facilities to capture excess water during peak monsoon periods, and implementing rainwater harvesting techniques. Additionally, many gewogs have established irrigation channels to access more reliable water sources, and some farmers have adopted drip irrigation methods for vegetable cultivation to conserve water.

To enhance vegetable production, many households have adopted the use of poly-houses, which provide an effective way to cultivate vegetables, particularly during the summer. These poly-houses primarily serve as protection against excessive rainfall, allowing farmers to grow summer vegetables with greater success. Additionally, during times when farming is not feasible or during off-seasons, farmers in most gewogs turn to off-farm work, such as construction, masonry, or roadside labor, to supplement their income.

To tackle the challenge of labor shortages in the dzongkhags, farmers have embraced the practice of labor exchange. This system allows community members to assist each other with various agricultural tasks in exchange for labor, fostering cooperation and ensuring that necessary work is completed despite the limited workforce. The reduction in available labor has also led to a greater reliance on machinery, particularly for tasks like ploughing, which increases efficiency and compensates for the smaller workforce.

To mitigate Human-Wildlife Conflict, farmers employ a variety of tactics. These include installing electric fences, setting up bamboo barriers and green nets, erecting scarecrows, using dummy tigers, and night guarding their fields. However, these measures require considerable labor and tend to lose effectiveness over time. Many farmers believe that only chain-link fencing can effectively deter wildlife from encroaching on their fields, offering a more permanent solution to the problem.

Gender dynamics

The division of labor between men and women is traditionally defined but becoming increasingly adaptable. Men typically take on tasks that require high mobility and physical strength, such as plowing fields, operating farm machinery, performing off-farm work like construction, and herding livestock.. They also play a major role in transporting goods to distant markets and selling bulk products like potatoes, vegetables, and oranges. Another task typically carried out by men is night guarding of crops in the field from wild animals. As a result, households with fewer male members often face significant challenges, experiencing greater crop damage and losses due to wildlife, largely because they lack the manpower necessary to effectively protect their fields.

Women, on the other hand, are primarily responsible for tasks within and around the household and typically manage household chores, childcare, and agricultural activities like planting, weeding, and harvesting crops. They are also significantly involved in community-based tasks and small-scale businesses, such as selling vegetables and dairy products. However, with modernization and education, these roles are gradually evolving, with women increasingly participating in decision-making processes, economic activities, and leadership roles within their communities.

Moreover, the impacts of climate change disproportionately affect women, as they are tasked with maintaining hygiene and managing their household as well as carrying out a major portion of the farm work. Vulnerable groups, including households with elderly members and people with disabilities (PWDs), are particularly impacted as they are unable to participate in off-farm work to earn additional income or engage in labor exchange. Unlike younger and able-bodied individuals (male or female), they are often not accepted readily by other community members for labor exchange. Farmers who rely on a limited variety of crops, such as paddy, are particularly vulnerable during adverse conditions, as their entire livelihood depends on the success of these crops. This lack of diversification makes them more susceptible to significant losses in the face of changing climate and wildlife threats.

In terms of decision-making, spouses share a collaborative responsibility. Important decisions are typically made jointly by both partners. However, regarding income generation, men tend to contribute slightly more to household income as they are predominantly engaged in off-farm work.

Policies, projects, plans, and incentives

Bhutan has implemented several policies, projects, plans, and economic incentives aimed at addressing the needs and rights of youth, women, and individuals with special needs. The National Youth Policy (MoE, 2011), provides a framework for youth development, focusing on education, health, employment, social environment, civic participation and empowerment. The policy recommends unique and diverse interventions to be instituted for prioritized target groups, including out-of-school youths, unemployed youths, youths with disabilities, and uneducated young women in urban and rural areas. The National Gender Equality Policy (NCWC, 2020) is to promote gender equality and empower women by ensuring that they have equal access to resources, opportunities, and rights across all sectors of society. This policy aims to address and eliminate gender-based discrimination and disparities, enhancing the participation of women in social, economic, and political spheres. For individuals with special needs, Bhutan has established the National Policy for Persons with Disabilities, 2019, which aims to create an inclusive society by improving accessibility, education, and employment opportunities.

Additionally, various economic incentives and projects, such as the Priority Sector Lending Scheme, support entrepreneurship and skill development among farmers and young entrepreneurs. However, at the local agency level, there is a lack of awareness regarding the implementation of these policies, which affects the overall well-being of youth, women, and individuals with special needs. Most of the priorities and strategies at Dzongkhag or Gewog level, emphasize enhancing food security and diversifying agricultural practices to increase income. Nonetheless, there are no specific plans or frameworks implemented by any agencies, specifically designed for youths, women, and PWD. Many sector heads and Gup have reported that while they give higher priority to youths and women who come forward with ideas and proposals, there are still gaps in targeted support and structured initiatives for these groups. In general, the projects and activities in a given Dzongkhag or Gewog are primarily determined by the approved 5-year plan.

VALUE CHAINS

Bhutan's agricultural sector is critical for rural livelihoods, and based on the studies carried out by the Ministry of Agriculture and Livestock, of recent it has been identified that the sector employs 86,000 of the rural population, a decrease from 54% in 2018 to 43.5% in 2023. Despite the decrease in rural employment by 19 % over 5 years, yet it still is the key sector that employs the rural sector. In total of the 86000 persons employed, 57.8% are women and 41.3% are men indicating that the agriculture and the livestock sector are heavily dominated by women.
The key value chains include:

Key value chains	Value chain analysis	Community consultations
Crops	Potatoes, vegetables, fruits (mandarin), cardamom, rice and maize.	Paddy, maize, vegetables, potatoes, mandarin oranges, areca nut, cardamom
Livestock	Dairy products (milk butter, cheese), pork, chicken, eggs	Dairy farming, poultry, piggery

Source	Challenges	Opportunities	Main markets & market access

Value chain analysis	• Rural-Urban Migration: Decrease in rural workforce. • Climate Change: Erratic weather patterns affecting crop yields. • Human-Wildlife Conflict: Damage to crops and livestock by wildlife. • Lack of Investment: Insufficient government outlays for agriculture and livestock development. • Infrastructure: Poor irrigation systems and inadequate storage facilities.	• Winter Vegetable Production: Potential due to climate suitability and market demand. • Bulk Market Access: Institutional buyers such as schools and hospitals. • Agri-tourism: Leveraging Bhutan's pristine environment for tourism-related agricultural activities. • Value Addition: Processing agricultural produce to enhance market value.	• Domestic Markets: Bulk consumers within Dzongkhags, centenary farmers markets. • Export Markets: India for crops like potatoes, spices, and fruits. • Challenges: Transportation costs, illegal trade across borders, and market competition.
Community consultations	• Climate Change: Unpredictable rainfall and increasing temperatures impact crop yields and livestock productivity. • Infrastructure: Limited road access in remote areas, hindering market access. • Human-Wildlife Conflict: Significant crop and livestock losses. • Labor Shortage: Younger workforce migrating to urban areas, leading to labor scarcity in farming communities, increasing labor costs and reliance on mechanization. • Market Access: Limited knowledge about markets and value addition, and competition with imported products. • Water Scarcity: Inadequate irrigation infrastructure makes agriculture vulnerable to changes in precipitation.	• Diversification: Encouraging farmers to engage in a variety of livelihood activities to spread risk. Such as introducing high-value crops like cardamom and organic farming practices can increase income and sustainability. • Infrastructure Development: Improving roads and market access can enhance the profitability of agricultural products • Irrigation and Water Management: Investment in irrigation infrastructure to cope with water scarcity. • Climate-Resilient Crops: Promoting crops that are less sensitive to climatic variations. • Capacity Building: Training farmers in modern agricultural techniques and climate-resilient practices can improve productivity.	• The primary markets are local and regional, with produce often sold in nearby towns and urban centers. • Access to markets is influenced by road connectivity, with better-connected regions like southern Bhutan having more efficient market access compared to remote and mountainous areas.

CASE STUDIES: VALUE CHAINS IN SARPANG, TRONGSA, TSIRANG, AND ZHEMGANG

Figure 7. Case studies: Livelihood zone map for Sarpang, Trongs, Tsirang and Zhmegang in Bhutan.

Of the several cereals, vegetables, dairy, poultry, and meat products produced by the project landscape Dzongkhags, the key staple food source for the households are Maize and Paddy. Of the varieties of vegetables that are grown in the Dzongkhags, the household engagement in the production of native vegetables such as potatoes, chilly, beans, and radish is the highest. New vegetables such as the Cole crops, tomato, onion, and asparagus cultivation are also picking up amongst the households in the Dzongkhags. In the project landscape Dzongkhags, the fast-moving cash crops identified are, milk, cheese, butter, and eggs, followed by vegetables and annual seasonal cash crops such as mandarin, cardamom, ginger, turmeric, potato, avocado, and areca nut.

Cereal crops are cultivated mainly for household consumption and vegetables are grown for mixed purposes for household consumption and sale in the event of generation of any marketable surpluses. For the seasonal cash crops, the sole purpose of cultivation is targeting the export market via the Food Corporation of Bhutan Ltd.'s auctioning process.

For the seasonal cash crops the value chains are in perfect fit with the Auction yards acting as market intermediaries for the export market and for the fast-moving cash crops such as milk and vegetables the key constraint is the lack of consistent demand entry points except for a few milk processing units and few school feeding program engagements. For meat products, owing to the production being concentrated in only select Dzongkhags of Sarpang and Tsirang, there is no dearth of demand points for the meat products.

Trongsa	Vegetables	Household producers, consumers, vegetable ve	• Agro-ecological advantage, Market access	• Limited market information • Weak bargaining power • Limited value addition	• Farmer group formation/Strengthening: • Direct linking with vendors: • Youth led enterprises	Associated market risk for the producer

				• Lack of access to assured market		
Trongsa	Dairy	Household producers, milk processing units, consumers	• Fast moving cash generation • Production of Diverse products • Existing Infrastructure (Milk Processing Units & Milk Collection Centers)	• Lack of practice of pricing strategy • Conventional method of livestock farming • Limited value addition	• Strengthening of the milk processing units • Extension of milk collection centers to community households • Dairy rural enterprise establishment	Associated market risk for the milk processing units
Zhemgang	Vegetables	Household producers, consumers	• Agro-ecological advantage • Circular Community Economy	• Limited knowledge and skills to identify potential consumers • Individual production & sale • Limited value addition: Lack of access to assured market	• Farmer group formation/Strengthening:	Human wild life conflict
Zhemgang	Turmeric	Household producers, turmeric processing units	• Suitable agro ecological conditions • Predator resilient crop production • Existing Infrastructure (Turmeric Processing Unit)	• Lack of knowledge and skills on value addition	• Scaling up the production volume	Associated market risk and export market price fluctuations
Sarpang	Dairy	Household producers, Milk processing units, consumers	• Ready availability of infrastructure • Adequate milk production	• Lack of enthusiasm to market collectively • Limited value addition:	• Insertion of milk aggregators • Use of already existing facility	Disease outbreaks

Sarpang	Eggs	Producers, aggregators, retailers, consumers	• Protected and precision production • Technical backstopping by the Government	• Locational disadvantage	• Formation of egg Marketing cooperative	Disease outbreaks
Tsirang	Eggs	Small holder producers, consumers, aggregators	• Protected and precision production • Technical backstopping by the Government	• Small holder producers	• Formation of egg Marketing group/cooperative	Disease outbreaks
Tsirang	Meat	Producers, meat vendors, consumers	• Knowhow in the production of meat • Adequate meat production	• Lack of storage during lean months • Limited value addition:	• Intervention of establishing a storage and meat processing unit	Disease outbreaks

The findings from the community consultations reveal the following main value chains and some of the main opportunities and challenges faced are listed.

Dzongkhag	Source	Main value chains	Challenges	Opportunities
Sarpang	Value chain analysis	Chicken, eggs, pork, milk, rice, ginger, areca nut, chili, potato	Long monsoon season, human-wildlife conflict, porous border with Assam, water scarcity	Winter vegetable production, access to bulk markets
	Community consultations	Paddy, dairy, areca nut, vegetables, orange	Water scarcity, climate impacts on crop yield, labor shortage, market access & competition	Diversification into high-value crops (areca nut and ginger), improving irrigation (drip irrigation methods for vegetables) and market infrastructure
Tsirang	Value chain analysis	Chicken, eggs, pork, milk, rice, vegetables, ginger, areca nut, chili, potato	Climate vulnerability, biosecurity issues, market access for surplus production	Vegetable and sugarcane production, avocado plantation, value addition in dairy products
	Community consultations	Paddy, dairy, vegetables, maize, poultry	Unpredictable rainfall, temperature rise, pests, diseases in poultry and pigs, labor shortages, competition with imported products	Enhancing irrigation, promoting greenhouse farming, and developing value-added products (diversification into dairy and piggery)
Trongsa	Value chain analysis	Dairy products, milk, potato, rice, vegetables, barley, chili, maize, cardamom, ginger	Human-wildlife conflict, climatic conditions affecting crops, market access for potatoes	Branding and marketing dairy products, vegetable production linked to bulk consumers

	Community consultations	Paddy, dairy, maize, cardamom, vegetables	Human-wildlife conflict, climate variability, limited mechanization, climate change, particularly affecting paddy and cardamom	Introducing alternative and high-value crops, enhancing irrigation systems, developing community-based wildlife management, and mechanization
Zhemgang	Value chain analysis	Rice, maize, potato, vegetables, chili, dairy products, milk, cardamom, ginger, pork	Isolation due to protected areas, long distance to markets, human-wildlife conflict	Eco-tourism, coffee cultivation, ginger and turmeric production, centralized milk processing
	Community consultations	Dairy, orange, maize, cardamom, ginger	Fodder shortages, pest and disease outbreaks, infrastructural deficiencies, market access due to terrain, climate impacts on oranges and cardamom	Strengthening dairy cooperatives, introducing pest-resistant crop varieties, improving infrastructure, diversifying livelihoods with bamboo and cane crafts, greenhouse farming.

RESILIENCE

CLIMATE RESILIENCE PROFILE

Climate resilience refers to the ability of livelihood groups, households, communities and individuals to manage climate-related stressors and shocks with no long-lasting adverse effects on development – i.e. the factors that help smallholder farmers bounce back faster and build back better after a climate-related shock. From a rural livelihoods perspective in Bhutan, the following six important factors contribute to climate resilience outcomes.

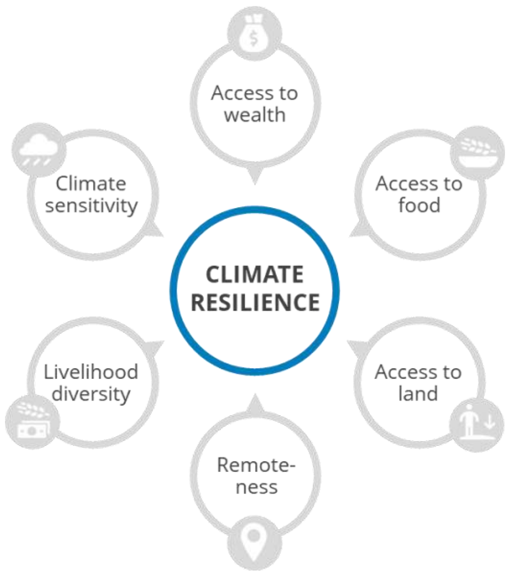


FIGURE 7. FACTORS CONTRIBUTING TO CLIMATE RESILIENCE OF RURAL COMMUNITIES IN BHUTAN.

Access to wealth: Poverty is widely used for determining resilience. Poverty traps smallholder farmers in a cycle of vulnerability. Limited resources make it difficult for them to invest in climate-resilient practices, leaving them exposed to changing weather patterns and declining crop yields.

Remoteness: Road connectivity and distance to services (including markets) greatly influences households' livelihood options and income in Bhutan. Among other, long travel times to markets and other services limits their ability to sell surplus produce or access climate-resilient seeds, technologies and trainings.

Access to food: The existing food sufficiency status of rural households provides an indication of the concurrent vulnerabilities to future food insecurity in the event of a shock. Households that are already lacking sufficient food are more likely to be severely affected by even low-impact climatic shocks or stressors and may be more likely to experience repeating seasonal food insecurity.

Access to land: Land size and its usability are an important factor determining livelihood options and income. Small plots in Bhutan's steep terrain limit farmers' ability to produce sufficient food, diversify crops, use farm mechanization and implement soil conservation practices, hindering their resilience to climate shocks.

Livelihood diversity: Farmers that depend on one major activity throughout the year may be unable to meet their livelihood needs when a significant climatic stressor or shock damages their primary activity. In contrast, those farmers that have a diverse range of activities are better able to withstand the impact of certain climatic shocks. To illustrate, paddy farmers who engage solely in rainfed agriculture would experience significant losses from a drought and may be unable to obtain sufficient income or food. Other households who engage in a number of activities may be able to invest more time in a different task – such as petty trade – during this period to better manage climate risk.

Climate sensitivity of income: Reliance on climate-sensitive agricultural systems renders households less resilient to climate variability. Income from rain-fed agriculture and livestock rearing is particularly climate-sensitive. Climate sensitivity of income sources becomes a particular challenge in areas located at the margin of key agro-climatic zones where shocks are more unpredictable and can lead to lower resilience capacity. This becomes ever more important in the context of climate change.

Resilience patterns for Bhutan can be mapped by aggregating the above indicators at Gewog level, which allows for the development of targeted interventions that strengthen smallholder farmers' ability to withstand and recover faster after climate shocks thus ensuring long-term food security.

Summary of methodology

During the consultations, communities and BRECSA stakeholders themselves identified factors that make smallholder farmers more resilient to climate shocks. Each of the identified factors was then matched with the available Gewog-level national secondary data sources. For the four Dzongkhags (Sarpang, Trongsa, Tsirang, and Zhemgang), this information was further complemented with the primary data collected through consultations. For more detailed description of methodology see Annex I. For a comparison with the vulnerability analysis see Annex IV.

BHUTAN: Climate resilience

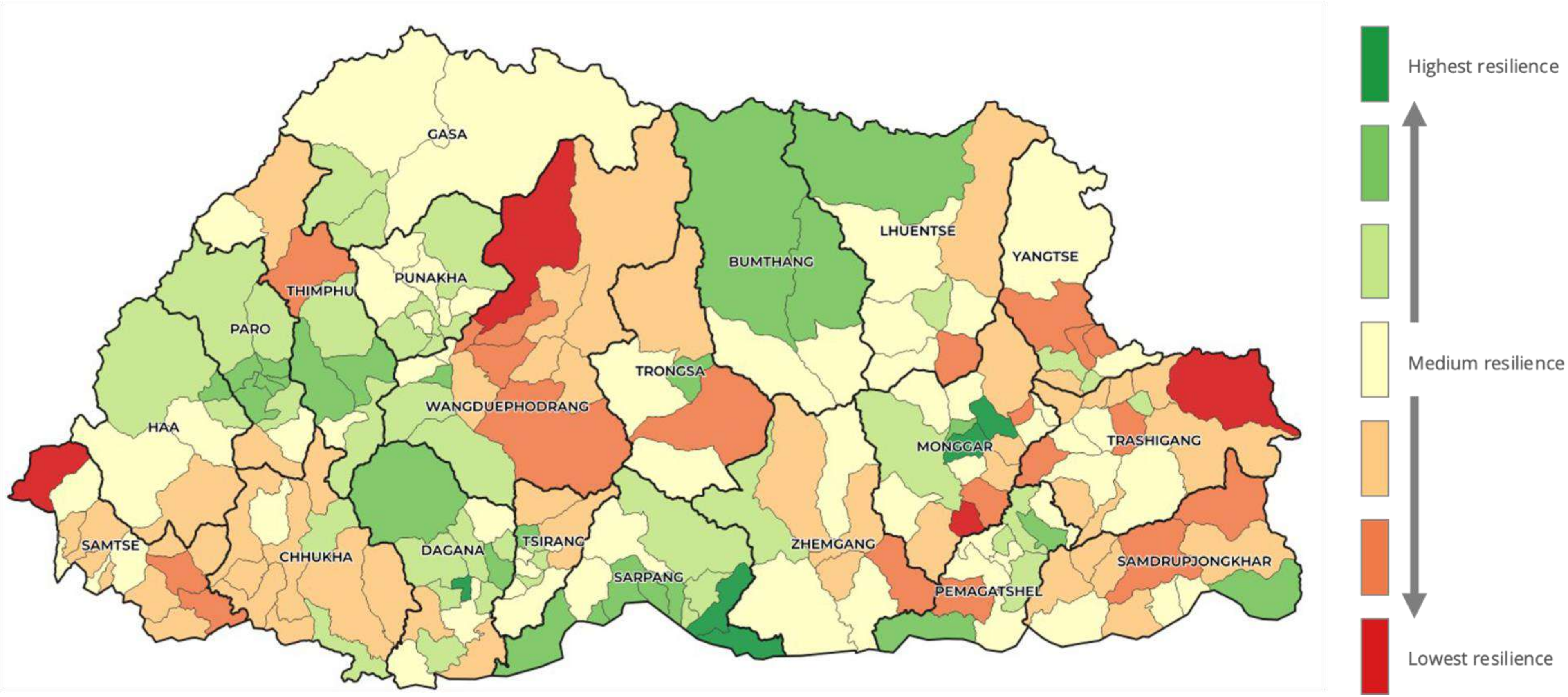


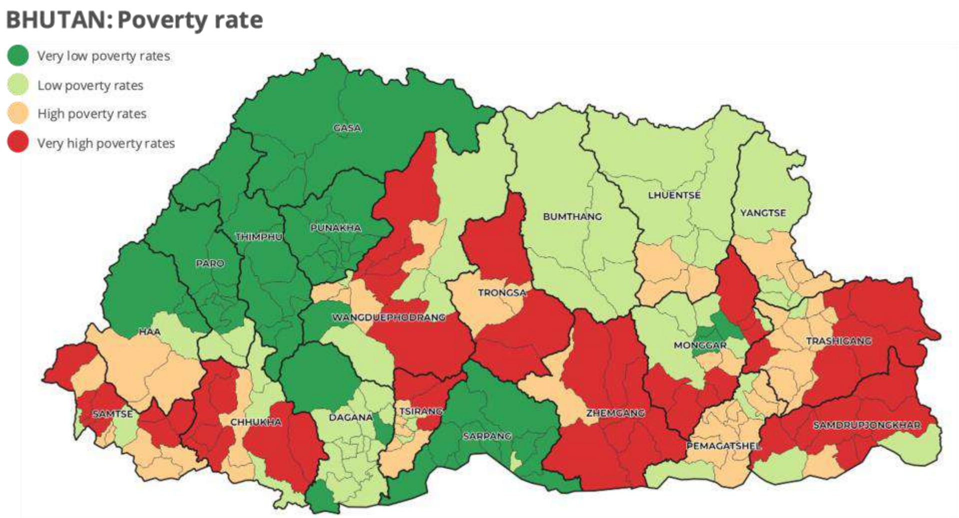
FIGURE 8. BHUTAN'S CLIMATE RESILIENCE BY GEWOG. BASED ON ACCESS TO WEALTH, ACCESS TO FOOD, ACCESS TO LAND, REMOTENESS, LIVELIHOOD DIVERSITY AND CLIMATE SENSITIVITY. INDIVIDUAL MAPS ARE PRESENTED IN SUBSEQUENT CHAPTERS.

Access to wealth and remoteness

Wealth is an important factor influencing climate resilience levels. Availability of financial capital determines the ability of households to invest in different assets and withstand climate-related shocks. Bhutan has made significant strides in reducing poverty in recent decades. The national poverty rate dropped from 23.2% in 2007 to 12.4% in 2022 (NSB and WB, 2023). This progress is largely attributed to government initiatives focused on poverty reduction and economic growth averaging 7.5% over the past 30 years (FAO, 2023).

However, significant disparities and challenges remain. Poverty is much higher in rural areas (17.5%) compared to urban areas (4.2%) – or in other words, 87% of all poor individuals in Bhutan reside in rural areas (NSB and WB, 2023). High poverty rates in rural areas are primarily due to dependence on subsistence agriculture in mountainous regions with limited land, infrastructure and irrigation. Working in agriculture is highly correlated with being poor in Bhutan (NSB, 2022d). Farmers often don't own enough productive land and livestock to gain financial security. Opportunities to generate cash income outside of agriculture are very limited in rural areas, making majority of farmers exclusively dependent on the success of their crops. To some extent, engaging in cash crops increases wealth as can be seen by the low poverty rates in commercial agriculture area in Sarpang. Poverty rates vary across districts, with Zhemgang, Samdrup Jongkhar, Samtse, and Trongsa having the highest rates (NSB and WB, 2023).

Bhutan's challenging geography plays a major role in poverty levels. Limited road access in remote rural areas hinders access to markets, education, and healthcare, perpetuating a cycle of poverty. Communities that are well connected to major towns and to the Indian border in the south of Bhutan fare better than those in mountainous central and eastern areas. Despite huge investments in road construction in Bhutan, in six districts, more than 15% of the population still lives at least 30 minutes away from access to any main roads (FAO, 2023). Additionally, natural hazards are another important driver of poverty in Bhutan, further threatening agricultural productivity and food security, potentially pushing more people into poverty.



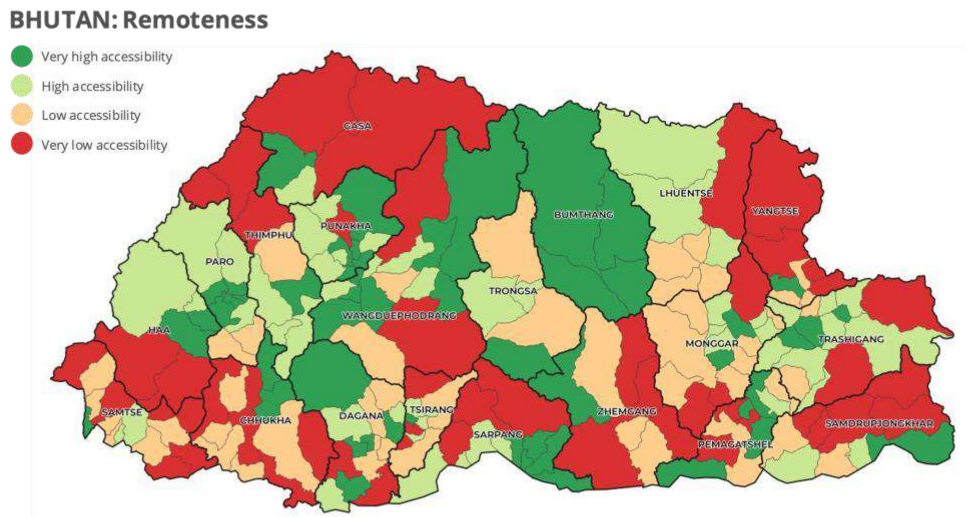


FIGURE 9. (LEFT) POVERTY RATE MAP OF BHUTAN (THE PROPORTION OF THE POPULATION LIVING IN HOUSEHOLDS WHOSE PER CAPITA EXPENDITURE IS BELOW THE POVERTY LINE). SOURCE: BASED ON NSB AND THE WORLD BANK, 2023. (RIGHT) REMOTENESS MAP OF BHUTAN (THE PROPORTION OF HOUSEHOLDS MORE THAN 30 MINUTES AWAY FROM THE NEAREST MOTORABLE ROAD HEAD). SOURCE: BASED ON NSB, 2017.

CASE STUDIES: ACCESS TO WEALTH IN SARPANG, TRONGSA, TSIRANG, AND ZHEMGANG

FIGURE 10. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

Through community consultations, participants highlighted several factors driving poverty, such as land ownership, literacy rates, family size, inadequate rural infrastructure, and reliance on agriculture. Across the project landscape, excluding Sarpang Dzongkhag, the Dzongkhags of Tsirang, Trongsa, and Zhemgang exhibit notably high poverty rates. Among these, Zhemgang has the highest poverty rate at 41.4% (NSB, 2022c). To delineate the disparities in poverty and their underlying causes, it is necessary to analyze the relationship between poverty and developmental indicators such as infrastructures, market access, exposure to natural hazards, climate change vulnerability, and agricultural production.

Infrastructure and connectivity

At the heart of poverty in Bhutan lies its challenging rugged terrain, leading to geographical isolation and depriving communities of essential access to social services, healthcare, education, and markets. Due to the rugged terrain, there is a lack of accessible and high-quality land, posing challenges for agricultural activities. This rugged terrain makes it challenging to construct essential resources like irrigation channels and farm roads, as well as hinder farm mechanization, thereby further impeding agricultural productivity and efficiency in the region. According to the Asian Development Bank's (2013) country diagnostic study, poor connectivity in rural areas is one of the critical obstacles to reducing poverty and inequality.

Geographical remoteness is a major factor influencing the poverty situation in Zhemgang Dzongkhag. Most district Gewogs face significant challenges in accessing essential resources, services, and economic opportunities. The main reason for these challenges is the underdeveloped road infrastructure, which is primarily due to the difficult terrain in the area and the considerable distance of these Gewogs from the Dzongkhag center and major markets. As a result, communities in these remote areas encounter obstacles in engaging with economic activities, receiving necessary services, and accessing markets for their goods and services, which contributes to the persistence of poverty in the region.

For a landlocked country like Bhutan, having an efficient and reliable road network is crucial for socioeconomic development. Roads facilitate the movement of goods and services, and people and communities situated far away from the road network face greater economic disadvantages. It is worth noting that Gewogs such as Shingkhar and Bardo of

Zhemgang Dzongkhag are particularly isolated. Located 120 km and 133 km away from the district headquarters, respectively, and about 220 km from Gelephu, the main market, these Gewogs face significant challenges and are witnessing exceptionally high poverty rates. Similarly, Gewogs such as Phangkhar, Goshing, Bjoka, and Ngala also exhibit elevated poverty rates because of remoteness from the market. The nearest market for them is Nanglam which is about 88 km away

Poverty disparities among various Gewogs within a Dzongkhag are also apparent and stem from a variety of interconnected factors. However, remoteness emerges as a key factor contributing to higher poverty rates, as exemplified by Gewogs such as Chudzom in Sarpang, Nubi in Trongsa, and Sergithang and Phuentenchhu Gewogs in Tsirang, which notably exhibit higher poverty rates.

Many communities also pointed out that insufficient rural infrastructure especially the roads and economic reliance on agriculture serve as a significant contributor to poverty. While Gewog Centre Road, which serves as the primary transportation route, connects all 37 Gewogs and there are farm roads connecting all the Chiwogs, the road quality varies significantly across different Gewogs. While some roads are well maintained and in good condition, those roads connecting to remote Gewogs such as Shingkhar and Bardo are exceptionally lengthy and in poor condition. These rough and long roads escalate the cost of transportation, consequently driving up the cost of living in these isolated areas. Similarly, several Gewogs such as Chudzom, Sergithang, Puentenchu, and Tsirang Toed, characterized by poor road connections, exhibit higher poverty rates.

Income

Income emerges as another factor with many community members highlighting its direct correlation with poverty. Income levels dictate if households can afford food, good houses, farm machinery, and education for children and are influenced by the accessibility of the market. Dzongkhags and Gewogs endowed with better access to markets such as those of Sarpang and Tsirang tend to have higher incomes and are better equipped to afford necessities and amenities. Conversely, Gewogs in Zhemgang and Trongsa, with less market accessibility, experience lower income levels and higher poverty rates.

Apart from market accessibility, the choice of livelihood pursued by residents within a Gewog significantly influences their economic well-being. Livelihoods focused on maize and paddy cultivation are primarily for the fulfillment of the food needs of the household rather than being sold for profit. In contrast, farmers producing cardamom, areca nuts, oranges, poultry, or piggery have better opportunities for increased income and experience greater prosperity compared to subsistence paddy or maize growers. The sale of these products represents key revenue streams for many households as confirmed by participants, while off-farm work is also an important source of income and employment for many households such as the ones in Samtenling Gewog. As a consequence of these differing livelihood patterns, regions where residents engage in more cash crop livelihood activities, such as Sarpang and Tsirang Dzongkhag, tend to have lower poverty rates compared to areas where subsistence maize and paddy farming is more prevalent, such as Zhemgang or Trongsa.

While agriculture provides a steady income, it is often susceptible to various risks such as climate change, pests, wildlife and market instability. Moreover, the subsistence farming practice with limited access to inputs and lack of market linkages is further constraining the agricultural productivity and income generation in the villages.

Land ownership

Land ownership also stands out as a key livelihood asset, often seen as a symbol of wealth, given its role in income generation and eligibility for bank loans within many communities. Land location and distribution are two factors that determine the productivity of land. In general residents of Dzongkhags or Gewogs with rugged terrain tend to have less productive lands.

Education

Education and skill are also key factors in determining an individual's earning potential and overall household prosperity. An educated person with specialized skills is often seen as a mark of a prosperous household in a community. The presence of capable manpower within a household significantly impacts its income stability and overall wealth. Numerous communities observe that households possessing a younger and more capable workforce tend to enjoy greater prosperity compared to those with fewer able-bodied individuals.

Gender

Gender disparities are evident in all four Dzongkhags and are intrinsically linked to poverty due to cultural norms. Women are significantly underrepresented in leadership positions within local government, with a notable lack of female participation in the consultation meetings at the gewogs, which men mainly attended. Women are mainly occupied with fieldwork or household chores, and social norms place a heavy burden of unpaid domestic and care work on them. This imbalance restricts women's time and opportunity for engaging in income-generating activities, thereby perpetuating poverty. Significant disparities are also observed in education and labor force participation, particularly in off-farm work, which is dominated by men. Additionally, the matrilineal inheritance system further limits women's socio-economic choices, often binding them to the land and restricting their opportunities beyond their villages.

Access to food

National statistics suggest near-universal food sufficiency in Bhutan (in 2022, 1.5% and in 2017, 6.2% of households reported insufficient food (NSB, 2022d, 2017)); however, its mountainous terrain, climate vulnerability, and limitations of smallholder agriculture pose significant challenges, particularly for food access and nutrition. The four pillars of food security – availability, access, stability, and utilization – provide an understanding of the current situation and the drivers of food insecurity in Bhutan.

Availability

Bhutan's mountainous terrain restricts cultivable land to just 3%, forcing the country to import nearly 50% of its food needs, primarily from India (WFP, 2021). This dependence leaves Bhutan susceptible to external factors like trade disruptions and price fluctuations. For the main staple foods, the self-sufficiency in Bhutan was 46.7% for rice and 86% for maize and vegetables (GNHC, 2019). Purchased food items (both domestically produced and imported products), account for 43.4% of the total consumption expenditure of households. On average, the households spend 15.3% of their food budget on dairy products, 14.3% on vegetables, 11.1% on other cereals and pulses, and 10.4% on meats (NSB, 2022d).

Access

Despite sufficient national availability, food access issues persist particularly in rural areas, where 1.6% and 8.1% of the households indicated insufficient food in 2022 and 2017 respectively, compared to 1.2% and 2.9% for urban areas (NSB, 2022d, 2017). Poorer households and those headed by single women face greater challenges in accessing nutritious food (NSB, 2022d), particularly during lean season between the months of April to July (Tenzin et al., 2019).

Stability

Bhutan's agriculture sector, the backbone of food security supplying over 50% of country's food basket and employing roughly 43% of the population (NSB, 2023), is dominated by smallholders with an average land size of just 1.4 ha – significantly lower than the global average (NSB and MoAF, 2019). These farmers face a multitude of challenges:

unpredictable rainfall patterns and extreme weather events that threaten crop yields, particularly of water-intensive rice, the main staple; low inherent soil fertility further restricts productivity; fragmented landholdings and remoteness hinder access to essential inputs and services; increasing human-wildlife conflict reduces yields; and rural-urban migration depletes the agricultural workforce, driving up farm costs (FAO, 2023; Chhogyel et al., 2020). All these challenges jeopardize for production stability by significantly disrupting agricultural production and leading to price fluctuations.

Utilization

While overall food scarcity is low, hidden hunger due to malnutrition, particularly among children under five, remains a concern. Stunting (low height for age) affects 21.2% of children under five, concentrated in poor and rural households and in eastern part of the country (FAO, 2023; WB and ADB, 2021). Nearly half of children under five and over a third of reproductive-age women suffer from iron deficient anaemia (Tenzin et al., 2019). Similarly, 22% of pre-school children and 17% pregnant women are vitamin A deficient (FAO, 2023).

Women and food security

Women constitute a significant portion (56.3%) of the agricultural workforce and manage homestead gardens that contribute substantially to household diets (FAO, 2023). However, they often lack access to information, resources, and decision-making power, hindering their full potential to contribute to food security and nutrition. Reaching women farmers with information and resources is crucial for ensuring food and nutrition security.

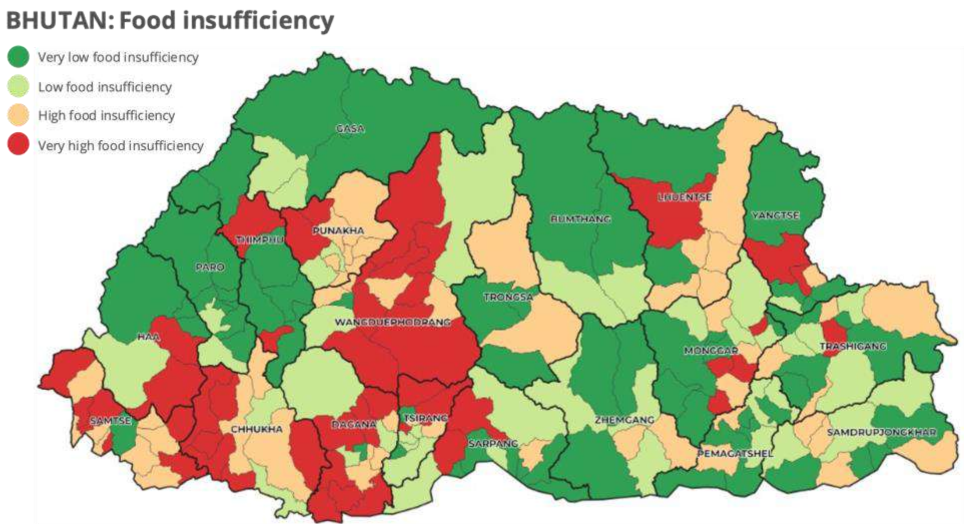


FIGURE 11. FOOD INSUFFICIENCY MAP OF BHUTAN (THE PROPORTION OF HOUSEHOLDS THAT FACED A SITUATION IN THE PREVIOUS 12 MONTHS WHEN THERE WAS NOT ENOUGH FOOD TO FEED ALL MEMBERS OF THE HOUSEHOLD). DATA LIMITATIONS: PRESENT DATA SHOWS FOOD INSUFFICIENCY JUST FOR THE 12 MONTHS PRIOR TO THE PHCB SURVEY IN 2017, WHICH COULD BE INFLUENCED BY INTENSE FLOODS THAT AFFECTED WESTERN AND CENTRAL BHUTAN DURING 2017. SOURCE: BASED ON NSB, 2017.

CASE STUDIES: ACCESS TO FOOD IN SARPANG, TRONGSA, TSIRANG AND ZHEMGANG

FIGURE 12. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

Although there is no direct measure of food insecurity, we can examine the relationship between the drivers and food insecurity from the community consultation within the four Dzongkhags:

Limited productive land

To begin with, farmers have limited land to grow enough food to sustain themselves with enough to eat year-round. Moreover, many communities are experiencing a shortage of labour which limits the full utilization of their land often resulting in fallow land. This limited cultivation performed by the farmers is vulnerable to depredation by wild animals, pests, and disease leading to significant losses of up to 50% of their yield by the end of the season. Consequently, in most communities, this reduced production can meet only a certain portion of their food requirement, compelling them to buy the remaining portion from the grocery stores. Community consultations reveal that the sufficiency rate of grains produced through local farming ranges from 20% in Patshaling Gewog to 90% in Phangkhar Gewog. The limited land cultivated by households leads to a lack of economies of scale in production, resulting in low-income generation when sold. For some households, this means they are unable to buy additional food once their supply is depleted and hence have to seek off-farm employment for extra money to meet their food needs.

Wildlife crop damage

Crop losses due to wild animals are one of the main constraints to alleviating poverty and increasing food security in the country. A range of wildlife species are responsible for crop damage across the four Dzongkhags. The main vertebrate pests include deer, sambar deer, porcupine, bears, monkeys, peacocks, elephants, and wild boar. Wild boars are the single biggest problem species, causing substantial losses to maize, potatoes, and paddy at mid-altitudes across the country. The estimated cost of maize and paddy losses due to wildlife, primarily wild boar, is in the order of USD 4-5 million per year (NPPC, 2024). Therefore, certain Gewogs in the mid-latitudes, where primary livelihoods rely heavily on cereal crops such as paddy and maize, experience greater food insecurity due to wild animal incursions. This issue affects all the Gewogs in Trongsa, Zhemgang, Tsirang, and a few specific Gewogs of Sarpang Dzongkhag including Chudzom, Jigmecchling, and Gakidling Gewogs. The situation is particularly critical in the case of Langthel and Dragten Gewogs where numerous issues compound the impact of wild animal damage on crops. These include shortage of irrigation water, limited land, outbreak of armyworm, and occurrence of windstorms all of which further challenge paddy and maize cultivation and ultimately impact food security.

Climate change

Climate change also presents a significant challenge that undermines food and water security in many Gewogs. Shifts in rainfall patterns and increasing temperatures are known to restrict the timing of cultivation, extent of cultivation, and food distribution. These changes are also directly linked to the decreased availability of fodder for animals by most communities consulted. For example, the lack of rainfall in February and March prevents farmers in the Gewogs of Senggyee, Gakidling, Shompangkha, Chudzom, Gelephu, and Jigmechholing in Sarpang from sowing maize seeds on time. In some cases, this delay forces them to forgo planting maize altogether. This situation disrupts the agricultural calendar, reduces crop yields, and contributes to food insecurity in these areas. The same challenge is faced by farmers of Shinkhar, Bardo, Phangkhar, Ngala, Goshing, and Bjoka Gewogs of Zhemgang who also rely on maize cultivation.

Delayed rainfall in June and July affects paddy cultivation across all Gewogs within the project area. Even when irrigation systems are in place, their effectiveness depends on sufficient rainfall to maintain stream flow. Without sufficient rain, the stream flow in these channels is inadequate, causing delays in planting paddy which results in reduced crop yields. In Gewogs like Drakten and Langthel in Trongsa, where paddy is the main livelihood, irrigation water shortage causes serious food insecurity. Similarly, Gewogs such as Sergithang, Puenthenchu, Tsirang Toed, and Shemjong in Tsirang face acute water shortages due to erratic rainfall patterns. In these Gewogs, delayed rainfall in June and July forces farmers to forgo paddy planting and switch to other crops, such as summer vegetables. Some communities, such as those in Sergithang, have resorted to pulse production due to severe water shortages. Similarly, various Chiwogs in Goshing Gewog face severe water shortages as water sources are drying up. In these places, especially in winter, they do not have enough water even for drinking.

Besides affecting production, climate hazards also impact food distribution in several ways. Extreme weather events such as heavy rainfall cause landslides to disrupt transportation networks. For instance, communities in Shingkhar, Bardo, Bjoika and Phankhar Gewog in Zhemgang, as well as Chudzom and some Chiwogs of Gakidling Gewog occasionally get cut off due to roadblocks caused by landslides. Hence, these community members must ensure that they stock up on enough supplies before the onset of the monsoon season to avoid shortages during periods of isolation.

Seasonality

The cyclical period of food insecurity is normally between April to July, a period in which the food from the previous harvest runs out and the current production is yet to be harvested. However, there was no mention of households or families who had to cut back on meals. During these periods, most communities in Zhemgang also rely on a variety of NWFPs to alleviate food shortages. It is reported that around 8 different varieties of yam can be harvested from the forests and consumed as a staple during times of scarcity.

ACCESS TO LAND

Availability of land determines the ability of households to produce sufficient food for home consumption as well as surplus for sale in markets. Availability of land and wealth can be interlinked as rural communities with larger cultivated landholdings are able to produce crops commercially for profits. Bhutan's mountainous terrain significantly limits available agricultural land. With only 2.93% of the total land area suitable for cultivation (NLCS DoSAM, 2023), competition for this limited resource is high.

Currently, 61% of the population resides in rural areas and 82.2% of rural households own land (NSB, 2022d). A majority of the farming households depend on integrated small-scaled subsistence farming. The average household landholding is a mere 1.4 ha (NSB and MoAF, 2019), hindering agricultural commercialization and financial security for farmers.

However, larger landholding sizes are often not linked to higher crop productivity in Bhutan. The steep slopes of much of Bhutan's agricultural land (over 30% exceeding 50 degrees) make mechanization difficult and contribute to soil erosion, further diminishing productivity (FAO, 2023; Tenzin et al., 2019). This and factors like lack of irrigation, wildlife conflicts, low soil fertility, and rural-urban migration result in almost 26% of cultivable land being left fallow (NSB and MoAF, 2019). This reduces the already limited land available for food production.

Land inheritance practices, traditionally favouring daughters in most of the country (with the exception of the southern region where a patriarchal system is followed), have resulted in women owning 46% of land compared to 54% for men (Verma and Ura, 2021). However, decision-making power over land use often remains with men or the decisions are taken jointly, limiting women's full agency in agricultural activities (FAO, 2023).

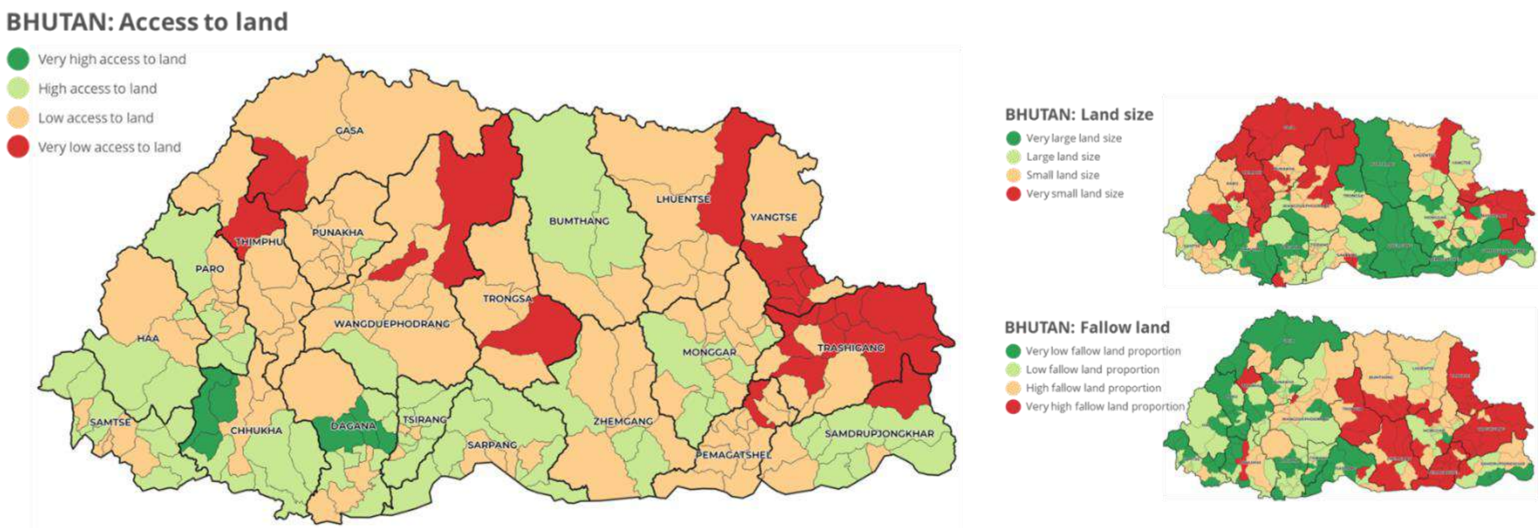


FIGURE 13. ACCESS TO LAND MAP OF BHUTAN (THE AVERAGE VALUE OF THE AVERAGE LAND SIZE OWNED BY FARMING HOUSEHOLDS AND THE AVERAGE PROPORTION OF THE LAND OWNED BY FARMING HOUSEHOLDS THAT IS LEFT FALLOW). SOURCE: BASED ON NSB AND MOAF, 2019.

CASE STUDIES: ACCESS TO LAND IN SARPANG, TRONGS, TSIRANG AND ZHEMGANG

FIGURE 14. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG, AND ZHMEGANG IN BHUTAN.

Land availability and utilization among farmers in the four Dzongkhags vary significantly, ranging from complete landlessness to holdings of up to approximately 30 acres. On average, farmers typically possess land holdings ranging from 1 to 7 acres, serving as a fundamental resource for agricultural activities. Land is a key asset in rural areas; besides being the primary resource for farming, it also plays a crucial role in serving as collateral for securing loans for a farmer that can be used for consumption or investment purposes. Among the two land types “Chushing” is considered particularly valuable as it allows for the cultivation of water-intensive crops such as paddy through irrigation. Ownership of such land is considered a good indicator of food sufficiency.

According to the Land Act of Bhutan, 2007, the land ceiling for a family, is set at 25 acres regardless of the type of land it includes. While the ceiling seeks to limit excessive land accumulation, it fails to consider the diverse needs and circumstances of different families, as well as the requirements of large-scale agricultural operations that need more land to function effectively. Extensification of agriculture, to offset the deficit in food requirement, faces serious constraints because expansion of arable land is not possible firstly due to the rugged terrain and secondly due to the land ceiling. Leasing of state land is an option, to encourage interested individuals to undertake commercial agriculture. However, the bureaucratic process for leasing state land is lengthy and time-consuming.

In instances where households have limited or no land ownership, they must enter into sharecropping agreements with landowners to secure an income and food supply. For example, in Dragten and Langthel Gewogs under Trongsa Dzongkhag, numerous households cultivate paddy fields belonging to the Central Monastic Body or individuals from Bumthang, underscoring the region's diverse dynamics of land utilization. However, because these families do not own the land they work on, they lack the motivation to invest in long-term improvements or enhancements of the land. Such households do not invest in infrastructure, soil fertility or other agricultural innovations that could potentially increase the yield or use it as collateral for any credit.

It is also evident that agricultural land is facing challenges such as land fragmentation because of inheritance which results in competition for resources which affects productivity and sustainability. There are two patterns of land inheritance, patrilineal inheritance which is commonly followed by Bhutanese of Nepali origin, and matrilineal which is followed by rest. In Trongsa and Zhemgang Dzongkhags, matrilineal inheritance is predominantly practiced, whereas in Tsirang and Sarpang Dzongkhags, a mixed mode of inheritance is followed, varying according to the household's ethnicity. While the matrilineal inheritance practice offers economic opportunities for Bhutanese women and contributes to their relatively equal status with men (NCWC et al., 2013), it can potentially tether women to their villages, potentially limiting their mobility and economic opportunities elsewhere. It also restricts the personal and professional growth of women in many parts of Bhutan. Therefore, despite women having equal legal status, they are less mobile than men and less active in social and economic life outside of their villages.

Despite possessing land, many farmers struggle to harness the potential due to various challenges such as wildlife, water shortages, and threats from pests and diseases making it challenging to sustain livelihoods solely through farming. Consequently, there is a pressing need for comprehensive strategies that not only address land distribution but also mitigate the impacts of wildlife intrusion, pest infestations, and climate vulnerabilities.

LIVELIHOOD DIVERSITY

Diversification of livelihood activities helps to enhance climate resilience — farming households with diverse livelihood profiles are more capable of responding to climate shocks in case one activity or crop is affected. For example, a failed harvest of rice due to unfavourable weather can be offset by an alternative crop or by income from livestock. Diversification is important as it allows households not only to reduce risks but also to improve nutrition by increasing dietary diversity and to potentially increase the number of income sources.

Many Bhutanese farmers already practice a diversified system that in general integrates rice- (34%), maize- (59%) or potato-based (51%) farming system with livestock (79%), vegetables (81%) and NWFPs (86% of all farming households; NSB, 2022a; Chhogyel and Kumar, 2018). Subsistence farming is still predominant. However, in recent years, an increasing number of farmers are also engaging in production of commercial and cash crops such as mandarin (37%), cardamom (24%), ginger (24%) and areca nut (18% of all farming households; NSB, 2022a). This provides an important additional livelihood activity which strengthens the resilience of households. While this diversity of agricultural activities acts as a buffer against crop failures due to extreme weather events, there is a worrying decline in on-farm agro-biodiversity in Bhutan (a study by Katwal et al. (2015) highlighted an almost 30% loss of traditional crop varieties in two decades).

Livelihood diversification goes beyond just diversity of agricultural activities. By encouraging rural farming households to engage in income-generating activities beyond agriculture, such as handicrafts, tourism, or small-scale businesses, communities spread their risk and become less vulnerable to climate-induced disruptions in agricultural productivity. This is extremely important in Bhutan as limited productive land, coupled with challenging terrain and dependence on rain-fed agriculture, leaves farmers vulnerable to weather fluctuations and other shocks. However, opportunities to generate cash income outside of agriculture (off-farm activities) are extremely limited in rural Bhutan (NSB, 2019), making farmers almost exclusively dependent on the success of their crops and livestock (for example, 19% of farming households engage in handicrafts while other non-farming activities are rare; NSB, 2019; Chhogyel and Kumar, 2018). When possible, around a third of households try to complement their income from crops and livestock with off-farm employment, particularly of men, during the winter months (community consultations).

Livelihood diversification is uneven across Bhutan. Mountainous regions with limited arable land and harsh climatic conditions often have fewer options for diversification. Conversely, areas with lower elevation, better infrastructure and access to markets might allow for a wider range of income-generating activities. On the other hand, greater focus on one or two cash crops might lead to reduced diversification in those areas. Gender roles also play a part, with men typically engaging more in cash crops and off-farm activities while women focus on subsistence farming (community consultation; FAO, 2023).

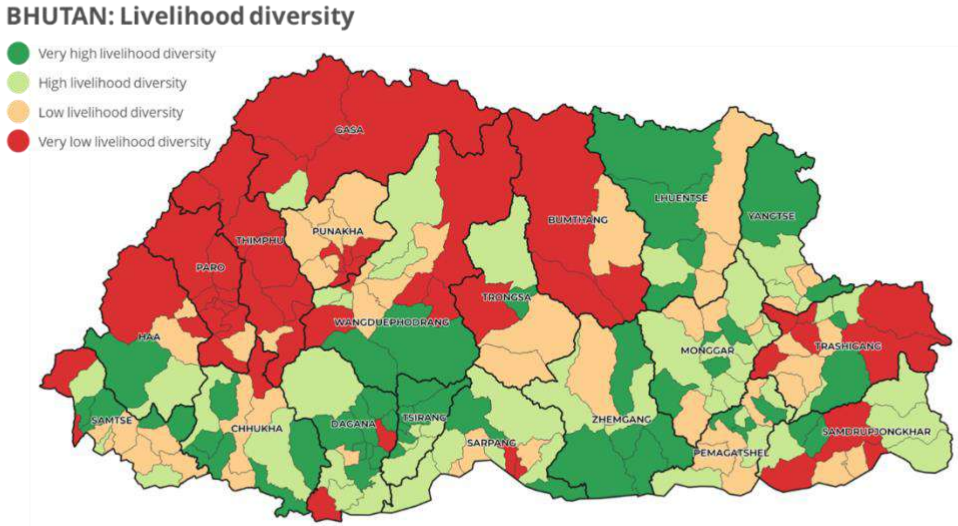


FIGURE 15. LIVELIHOOD DIVERSITY MAP OF BHUTAN (THE AVERAGE NUMBER OF LIVELIHOOD ACTIVITIES CARRIED OUT BY FARMING HOUSEHOLDS). SOURCE: BASED ON NSB AND MOAF, 2019.

CASE STUDIES: LIVELIHOOD DIVERSITY IN SARPANG, TRONGSA, TSIRANG AND ZHEMGANG

FIGURE 16. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

Farmers across the four Dzongkhags of Tsirang, Sarpang, Zhemgang, and Trongsa showcase a remarkable diversity in their livelihood pursuits, reflecting the region's varied agroecological zones and cultural practices. While crop cultivation is the main livelihood, with rice, and maize being staple crops, farmers also partake in livestock rearing and are increasingly engaged in cash crop cultivation like areca nuts and cardamom. In general, the communities within the four Dzongkhags integrate crop cultivation with animal husbandry to optimize land use and diversify income sources. Women are often responsible for most of the work in crop cultivation, managing livestock rearing, and handling household chores. They also play a crucial role in processing and post-harvest activities. Men predominantly perform the physically demanding works such as ploughing, digging, carrying etc. and the off-farm works such as transportation, construction, masonry and carpentry. Hence, men often move out of their villages in search of employment which allows them to bring more income for their households.

While staple crop cultivation is widespread among all the communities, it is important to acknowledge subtle differences in poultry and piggery livelihoods. These activities are predominantly pursued by Nepali ethnic groups, who do not attach any stigma to the slaughter of animals, unlike their Buddhist counterparts. Therefore, upon closer examination of livelihoods, it becomes apparent that residents of Zhemgang and Trongsa primarily rely on crop cultivation and dairy farming. In contrast, the communities of Shompangkha, Gakidling, Dekiling in Sarpang and of Sergithang, Puentenchu, Shemjong in Tsirang exhibit greater diversity in livelihoods, engaging in crop cultivation, dairy farming, poultry, piggery and fishery. This higher livelihood diversity not only enhances resilience to climate and economic shocks but also contributes to the overall stability of communities. While crop and livestock are the main livelihoods pursued across the four Dzongkhags, unexpectedly, the communities of Bjoka in Zhemgang Dzongkhag, depend on bamboo crafts as their main livelihood. The forest within this Gewog has various types of bamboo and canes from which they prepare the bamboo crafts. It also has the “Yula” bamboo from which the “Bangchung”, the traditional food basket, is prepared.

Climate sensitivity of income sources

Changes in climatic patterns, both long-term and seasonal, have a detrimental effect on livelihoods that depend on climate-sensitive income such as agriculture and livestock. Generally, rural livelihoods in Bhutan are highly sensitive to climate, owing to reliance on monsoon rains, shorter growing periods and about 65% of all rural households engaging in agriculture (NSB and MoAF, 2019; NSB, 2018). This dependence on a climate-sensitive sector makes Bhutan highly vulnerable to the impacts of climate change, which are already being felt through the delays in the onset of rainy season, erratic rainfall patterns, increasing extreme events, rising temperatures, and glacial melt.

Within agriculture, the degree of climate sensitivity varies between different types of farming techniques, such as the use of irrigation and the crop cover. Farmers in Bhutan largely rely on rain-fed agriculture with only about 20% of the total cultivated area under irrigation (and with only 48% of farming households irrigating part of their land; NSB and MoAF, 2019; Tenzin et al., 2019). In addition, the main type of irrigation is surface irrigation using surface water (84%) where any delays or changes in precipitation can significantly affect the flow and consequently availability and amount (ibid.). Limited access to irrigation means that farming households in Bhutan are generally quite sensitive to the effects of rainfall variability: delays in the onset of the rainy season can have severe effects on planting and other agricultural activities and can have negative effects on crop yields, leading to substantial food and income losses. Furthermore, the use of crop cover such as plastic or glass greenhouses and shade nets can enhance production and safeguard crops from climate hazards such as hail, excessive rain or sunlight and changing temperatures; however, only about 5% of farming households in Bhutan use protective cover for their crops (over only 220 acres of land; ibid.). Crops protected by plastic cover for example tend to be less climate-sensitive.

Climate sensitivity in agriculture also varies between different types of crops and agricultural activities. Income is particularly sensitive for farmers dependent on labour- and water-intensive paddy, which requires regular rainfall and/or irrigation in order to grow. Maize and potato crops are more tolerant to irregular rainfall but are still affected by low rainfall, particularly during the planting. Diversification towards less water- and temperature-sensitive crops with shorter growing period will reduce climate sensitivity of agricultural sector in Bhutan. Livestock rearing in Bhutan is also very sensitive to climate as climate shocks and climate change can disrupt grazing patterns, fodder availability and cause heat stress, resulting in reduced milk production and meat quality. On the other hand, farming households that engage in activities that do not depend directly on rainfall patterns—such as construction, urban activities, harvesting of wood and NWFPs, and tourism—are less climate-sensitive and are therefore less affected by climate variability. For these households, other shocks such as price volatility, may be more significant threats to overall resilience.

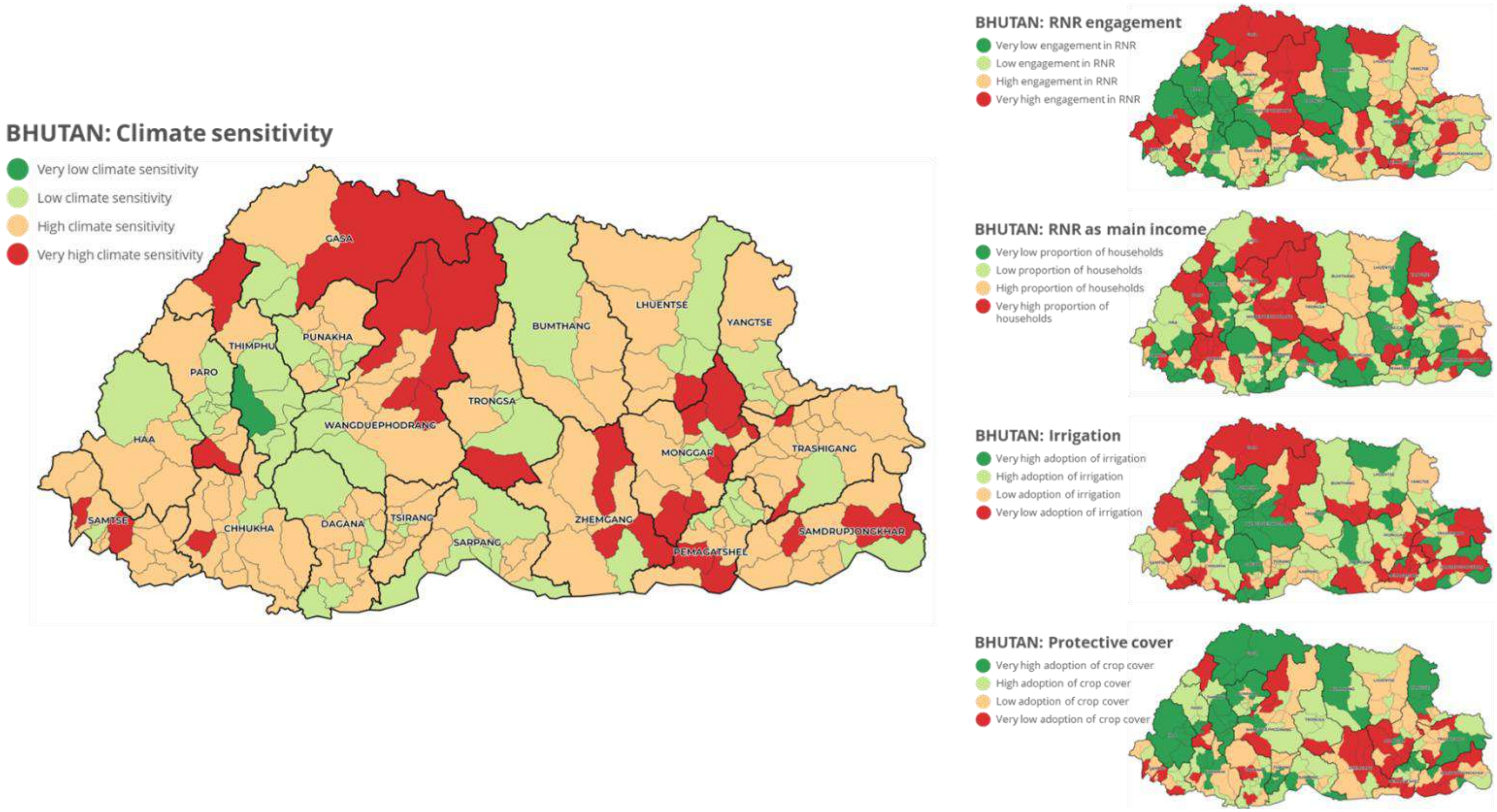


FIGURE 17. CLIMATE SENSITIVITY OF INCOME SOURCES MAP OF BHUTAN (THE AVERAGE VALUE OF THE PROPORTION OF INDIVIDUALS OVER 14 YEARS OLD WHOSE MAIN ACTIVITY IS RNR, THE PROPORTION OF FARMING HOUSEHOLDS THAT DERIVE MOST OF THEIR INCOME (>51%) FROM RNR ACTIVITIES, THE PROPORTION OF FARMING HOUSEHOLDS WITHOUT ANY IRRIGATION AND THE PROPORTION OF FARMING HOUSEHOLDS THAT DO NOT USE ANY PROTECTIVE COVER FOR THEIR CROPS/LAND). SOURCE: BASED ON NSB, 2017; NSB AND MOAF, 2019.

CASE STUDIES: CLIMATE SENSITIVITY OF MAIN LIVELIHOOD ACTIVITIES IN SARPANG, TRONGSA, TSIRANG, AND ZHEMGANG

FIGURE 18. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

The primary livelihood practiced by farmers in the four dzongkhags encompasses sixteen main activities (listed in the order of importance the number of Gewogs that highlighted the activity during the community consultation): paddy, orange, maize, ginger, dairy, cardamom, poultry, Arecanut, Vegetables, wheat, buckwheat, cane and bamboo crafts, green gram, potato, piggery and Sichuan pepper. The success and productivity of these livelihood activities are subject to various climatic factors which manifest in several ways. Recent climatic trends in Bhutan, show rising temperatures and declining rainfall (Wangmo et al, 2023). This shift has been noticed by farmers from the four districts who are experiencing changes in rainfall patterns, rise in temperature, and extreme weather impacting water sources and crop yields. While the effect of climate change on rural livelihoods and how the communities adapt to these changes are widely acknowledged, there hasn't been a comprehensive formal study conducted on this topic. As a result, there is no clear picture of how rural populations are being affected by climate change or how effectively they are adapting to these changes. Therefore, it is challenging to quantify yield reduction in various livelihood activities or classify and prioritize the vulnerability level of farming communities.

One significant climate change concern raised in all community consultations was the unpredictable nature of rainfall. The heavy reliance of current agricultural practices on monsoon rains renders them particularly susceptible to the impacts of climate change (Chhogyel and Kumar, 2018). Variations in rainfall, including the amount of rainfall, the timing of its onset, and cessation play a crucial role in the production of major livelihood crops. Amongst them, rice stands out as a major livelihood crop that is impacted by erratic rainfall patterns. Rice cultivation demands more water than any other crop, rendering it highly vulnerable and highly dependent on climatic parameters, such as monsoon rains. The shortage of rainfall during the peak paddy transplantation seems to be an annual occurrence in the four Dzongkhags as reported by the participants. The situation is especially severe in the case of Sergithang, Phuentenchu, Tsirang Toed and Shemjong Gewogs in Tsirang; Gelephu and Gakidling Gewogs in Sarpang, and Dragten and Langthel Gewogs in Trongsa Dzongkhag. These areas are particularly affected, facing significant challenges in their agricultural activities due to the unreliable and insufficient rainfall, which is crucial for successful paddy transplantation. If farmers are unable to complete their paddy transplantation by the end of July, they abandon the activity for the year and instead resort to cultivating alternative crops such as vegetables or pulses. This is a common practice in Sergithang, Puentenchu, Tsirang Toed and Gelephu Gewogs. Some farmers in Jigmechholing Gewog even started using paddy areas for cultivating crops such as cardamom, which comparatively required less water than paddy, as a coping mechanism. Similarly, the scarcity of rainfall during the initial months of the year impacts various livelihoods, as illustrated in Table 1.

While the precipitation in the early months of the year has decreased, participants have noted heavy and prolonged rainfall towards the end of the rainy season. This change in rainfall pattern is particularly destructive as it leads to damage to infrastructure such as irrigation channels, farm roads, and bridges, and also causes delays in paddy harvesting as the fields become waterlogged or damages paddy that has already been harvested either by causing the grains to rot in the field or washing it away in floods. Overall, this shift in rainfall distribution poses a significant risk to agricultural productivity and rural livelihoods in all four Dzongkhags.

The increasing temperature poses a complex challenge, affecting both farmers and their livelihood activities. Many respondents across the 37 Gewogs in the four dzongkhags associate rising temperatures with warmer winter seasons or the absence of frost in higher altitude areas, as well as the lack of dew drops in certain locations. The temperature rise is frequently observed from April to June, resulting in heat stress for farmers and adversely affecting their health and productivity. Heat stress among individuals occurs when daytime temperatures exceed 32°C (AAA and CGIAR, 2024). This effect is particularly pronounced in the subtropical regions of Sarpang where people avoid working in the heat of the day, and practice working in the cooler mornings and evenings. Moreover, the higher temperatures have led to an increased demand for water, reduced soil moisture levels, and water and heat stress in many crops such as oranges, Areca nuts, and cardamoms.

The sensitivity of crops to rise in temperature is understood in various ways by the farmers. For instance, they recognize that orange plants are highly susceptible to the effects of hot and dry weather conditions, especially in February and March, leading to tree mortality in low-elevation places. Hence, in some parts of Zhemgang, some households have started planting areca nuts as a coping strategy. However, it needs to be investigated whether the trees are perishing due to heat stress or if the decline and mortality of the citrus plants are caused by citrus greening disease. Additionally, farmers attribute drying up cardamom plants and the outbreak of lumpy skin diseases (LSD) in cattle to the rise in temperature.

Heat stress is also a widespread phenomenon for poultry birds and pigs in regions of Tsirang and Sarpang Dzongkhags. It is known to reduce feed intake and retard growth in animals.

The division of labor in agriculture is gender-specific, with men and women facing distinct challenges and risks as climate patterns shift. Men are often involved in cash crop cultivation and off-farm work, which subjects them to different impacts of climate change. Cash crops such as oranges, cardamom, and ginger are particularly sensitive to climatic variations like rising temperatures and erratic rainfall. For instance, orange plants are especially vulnerable to hot and dry conditions, which have become increasingly common in lower-elevation areas.

Conversely, women are primarily engaged in subsistence farming, focusing on crops like paddy, maize, and vegetables. These activities are highly susceptible to changes in rainfall patterns and temperature fluctuations. For example, paddy cultivation, a crucial aspect of subsistence farming, requires a consistent and adequate water supply during transplantation. In the four Dzongkhags—Sarpang, Tsirang, Zhemgang, and Trongsa—unpredictable and insufficient rainfall during the paddy transplanting season has often forced women to abandon paddy cultivation or switch to alternative crops like vegetables or pulses, which are less water-dependent. This shift not only impacts household food security but also increases the labor demands on women, who must adapt to new crops and cultivation techniques.

TABLE 1. CLIMATE SENSITIVITY AND COPING STRATEGIES FOR THE MAIN LIVELIHOOD ACTIVITIES IN SARPANG, TRONGSA, TSIRANG AND ZHEMGANG.

Livelihood	Description	Main areas of production	Observed climate change	Observed climate-related impact	Current coping strategies
CEREAL CROP PRODUCTION	Paddy	• Sarpang (Samtenling, Chuzanggang, Tareythang Umling, Gakiling, Senggey, Jigmechholing, Sherzhong, Dekiling, Chudzom, Shompangkha, Gelephu). • Trongsa (Drakten, Langthil, Nubi, Tangsibji, Korphu) • Tsirang (Kikorthang, Gosarling, Phuentenchu, Shemjong, Tsirang Toed, Dunglegang, • Zhemgang (Nangkor, Shingkhar, Trong)	**Change in precipitation pattern** • Shortage of rain / delayed rains during transplantation (June to July) • Excess rain during the crop maturity or harvesting time in October to November	• Delayed transplantation in June to July and reduced yield as plants do not mature in October and November • Delayed harvesting and reduced yield due to excess rainfall in October and November • Reduced yield due to wildlife damage (the communities believe that due to rainfall changes wildlife does not have enough natural foos source and turns to crops)	• When paddy transplantation is delayed due to a lack of rainfall, farmers switch to growing pulses, summer vegetables, or convert their paddy fields into cardamom fields. • Drawing irrigation water from other water sources
	Maize	• Sarpang (Gelephu, Sherzhong, Chuzanggang) • Trongsa (Dragteng, Nubi, Langthil, Tangsibji) • Tsirang (Shemjong, Tsirang Toed, Barzhong, Rangthaling, Mendrelgang, Phuentenchu,) • Zhemgang (Shingkhar, Bjoka, Bardo, Nangkor, Phangkhar,)	• Shortage of rain during sowing (February to March) • Increased frequency and intensity of hailstorms • Increased frequency and intensity of windstorms	• Delayed sowing in February and March affects germination and reduces yield • Outbreak of army worm (sometimes they have to re-sow the seeds as the insect damages 100% of crop) • Damaged crop and reduced yield (up to 100%)	• Unaware of any coping mechanisms since maize is primarily grown on dryland. • Similarly farmers do not have any coping measures for hailstones and windstorms

	Wheat	• Trongsa (Dragteng) • Zhemgang (Shingkhar)	• Rainfall during harvest stages	• Shattering losses	• Not aware of any coping mechanism
	Buckwheat	• Trongsa (Langthil)	• Windstorms	• Causes the buckwheat plants to lodge making it diccicult to harvest	• Not aware of any coping mechanism
FRUIT PRODUCTION	Areca nut	• Sarpang (Samtenling, Chuzanggang, Tareythang, Umling, Senggey, Sherzhong, Dekiling, Shompangkha, Gelephu) • Zhemgang (Ngangla)	• Shortage of rain (February to March) • Rise in temperatures (May to July) • Increased frequency and intensity of windstorms	• Hot dry conditions affects fruit maturation, flowering and causes biennial bearing • Wind storm snaps the Areca nut stem or shred the leaves.	• Provide supplemental irrigation where irrigation source is available
	Orange	• Sarpang (Jigmechholing, Shompangkha, Senggye, Gakiling) • Trongsa (Korphu) • Tsirang (Barzhong, Gosarling, Dunglegang, Tsholingkhor Kikorthang, Sergithang,) • Zhemgang (Ngangla, Phangkhar, Bardo, Nangkor, Trong, Bjoka, Goshing)	• Shortage of rain (February to March) • Hot and dry conditions (March to June), particularly in lower elevations	• Affects flowering • Causes tree mortality due to hot and dry conditions • Outbreak of pest and diseases (citrus greening and citrus fruit flies; results in about 50% fruit drop due to fruit flies) • Reduced yield	• Provide supplemental irrigation where irrigation source is available • People are planting Areca nut where orange tree are declining.
SPICE PRODUCTION	Cardamom	• Sarpang (Chhudzom, Jigmichhoeling) • Trongsa (Langthil, Korphu) • Tsirang (Dunglegang, Tsholingkhor) • Zhemgang (Phangkhar, Bardo Goshing, Trong)	• Shortage of rain (February to March) • Hot and dry conditions (March to June)	• Affects flowering • Causes mortality of plants • Reduced yield formation	• Some farmers use improvised sprinklers where there is water.

	Ginger	• Sarpang (Umling, Taraythang, Chuzarggang) • Tsirang (Mendrelgang • Zhemgang (Gozhing, Pangkhar, Ngangla)	• Shortage of rain (February to March)	• Delayed planting and reduced yield	• No coping mechanism
	Sichuan pepper	• Trongsa (Nubi)	•	•	• Not aware of any coping mechanism
VEGETABLES PRODUCTION	Winter vegetables	• Sarpang (Chudzom, Gakiling, Samtenling, Tareythang, Umling, Senggye) • Tsirang (Barzhong, Patshaling, Kikorthang, Mendrelgang, Rangthaling, Dunglegang, Gosarling, Sergithang, Phuentenchu, Shemjong, Tsirang Toed, Tsholingkhor)	• Shortage of rain (February to April) • Excessive rainfall from August till october	• Delayed planting and reduced yield • Water and nutrient stress to crops • Higher irrigation demand	• Most farmers have to give supplemental irrigation • Some faremers use drips irrigation to optimize water use. • Some farmers use poly-tunnle houses as rain protection for summer vegetable cultivation.
TUBER PRODUCTION	Potato	• Trongsa (Tangsibji)	• Shortage of rainfall in march and April months.	• Water stress in potato plants • Reduced yield • Poor tuber quality • Outbreak of diseases	• Potatoes planted in terraced fields are given irrigation. • Those on the non-terraced fields rely solely on natural rainfall.
LIVESTOCK FARMING	Dairy	• Sarpang (Gakiling, Gelephu, Samtenling, Dekiling, Chudzom, Chuzanggang, Jigmechholing, Serzhing, Shompangkha) • Trongsa (Dragteng, Nubi, Langthil, Korphu) • Tsirang (Barzhong, Patshaling, Kikorthang, Mendrelgang, Rangthaling, Gosarling,	• Shortage of rain (February to April) • Rise in temperature (April to June)	• Reduced fodder availability • Reduced milk production • Poor animal health • Farmers are unable to expand their herd size.	• Supplement with feeds and concentrates • Feed animals with crop residues and straw

		Sergithang, Phuentenchu, Tsholingkhor) • Zhemgang (Ngangla, Phangkhar, Bardo, Nangkor, Trong, Bjoka, Goshing)		• Heat stress to animals (especially in tropical regions of Sarpanf and Tsirang)	
	Poultry	• Sarpang (Dekiling) • Tsirang (Rangthangling)	• Hot and dry conditions (March to June)	• Heat stress in animals • Reduced growth and egg production • Animal death	• Use straw to insulate the chicken coop • Hanging wet burlap around the chicken coop to create a more comfortable environment thorugh evaporative cooling.
	Piggery	• Tsirang (Sergithang, Shemjong, Patshaling)	• Hot and dry conditions (March to June)	• Heat stress in animals • Reduced growth • Increased disease instances	• Use straw to insulate the pig sty. • Sprinkling water on pigs during hattest part of the day.

CASE STUDIES: CLIMATE SENSITIVITY OF MAIN VALUE CHAINS IN SARPANG, TRONGSA, TSIRANG, AND ZHEMGANG

FIGURE 19. CASE STUDIES: LOCATION OF SARPANG, TRONGS, TSIRANG AND ZHMEGANG IN BHUTAN.

Table 2. Climate sensitivity and coping strategies for the main value chains in Sarpang, Trongsa, Tsirang and Zhemgang.

Value chain	Description	Main areas	Observed climate change (and when)	Observed climate-related impact (who/what part of VC is affected and why)	Current coping strategies
Vegetables	Grown mostly in the open fields		1. Water stress 2. Outbreak of pest and diseases 3. Erratic weather conditions during flowering and harvest time	Household growers are affected the most with the decrease in the yield.	Cultivation of native crops such as radish and turnip to be used as cattle fodder.
Dairy	Traditional livestock farming with indigenous breeds		1. Shortage of fodder 2. Outbreak of pest and disease	Households are affected the most having to invest in alternate fodder to feed the cattle.	Investment into alternate fodder such as cultivation of radish, purchase of hay and other processed feeds.
Turmeric	Grown as a trial crop		1. Shortage of rainfall (Feb-April)	Households are affected with yield decrease and the yield not covering the opportunity cost of using the land for turmeric plantation.	Plant alternate crops such as ginger when the yield during the previous year is not satisfactory.
Meat	Produced for supply to non meat producing Dzongkhags and farms are established on a commercial enterprise model		1. Outbreak of diseases heat stress	Farm owners are affected with Zero production having to curl the animals during the disease out breaks.	Strict adherence to bio security measure by fencing the farms and restricting access to other stray animals by building secure stall and sheds.
Eggs	Farms are established on a commercial enterprise model as a source of livelihood		1. Heat stress (March-May) 2. Out-break of diseases	Farm owners are affected with decrease in the yield during the heat stress and zero returns during the disease outbreaks.	Use of ingenious methods of covering the roof with gunny bags and keeping the gunny bags moist by using water to keep the temperatures of the roof low and at occasions use of table fans in the sheds.

Dzongkhag	Value chain	Description	Observed climate-related impact & when	Who/What is more affected? Why?
Trongsa	Vegetables	Open field vegetable cultivation	1. Water stress 2. Outbreak of pest and diseases 3. Erratic weather conditions during flowering and harvest time	Yield reduction of the crops and households growers are affected the most for the investment of time, inputs made in growing the crop. The cause of the effect is beyond the adaptation limits of the household growers.

	Dairy	Milk and dairy products	1. Shortage of fodder 2. Outbreak of pest and disease	Cattle productivity decreases producing less milk and households are affected since the cost of maintaining the heard increases having to invest in supplement fodders such as purchase of hay and other processed animal feeds. The cause of the the impact again is external beyond the adaptive measures of the households.
Zhemgang	Vegetables	Open field vegetable cultivation	1. Water stress 2. Erratic weather conditions during flowering and harvest time	Yield reduction of the crops and households growers are affected the most for the investment of time, inputs made in growing the crop. The cause of the effect is beyond the adaptation limits of the household growers.
	Turmeric	Cultivation on trial basis and grown with the natural conditions	1. Shortage of rainfall (Feb-April)	Yield reduction and household growers are caused the loss because the opportunity cost of growing the crop is high. Household growers could have used the land in growing their native crops such as native vegetables such as chilly and beans.
Sarpang	Poultry	egg	1. Heat stress (March-May) 2. Out-break of diseases	Poultry farmers due to increased vulnerability to diseases and reduced productivity during hot and dry weather conditions. The poultry farmers are affected the most for their return on investment is less than the cost of borrowing since most of the farmers establish the farms through financial institution financing.
	Dairy	Milk and dairy products	1. Shortage of fodder (Jan – Mar) 2. Heat stress (Mar-May) 3. Outbreak of diseases	Cattle productivity decreases producing less milk and households are affected since the cost of maintaining the heard increases having to invest in supplement fodders such as purchase of hay and other processed animal feeds. The cause of the the impact again is external beyond the adaptive measures of the households.
Tsirang	Poultry	Egg	1. Heat stress (March-May) 2. Out-break of diseases	Poultry farmers due to increased vulnerability to diseases and reduced productivity during hot and dry weather conditions. The poultry farmers are affected the most for their return on investment is less than the cost of borrowing since most of the farmers establish the farms through financial institution financing.
	Livestock	chicken and pork	1. Outbreak of diseases heat stress	Farm owners are affected the most since the products cannot be sold and has to be curled. The farms are established on a commercial scale with financing from the financial institutions and with zero returns farms enter into debt traps.

CURRENT CLIMATE

Baseline climate overview and recent trends

The country of Bhutan is located in South Asia, bordering India and China. Bhutan is situated in the southern slopes of the eastern Himalayan range and has altitudes varying from less than 100 meters in the south to over 7500 meters in the north. About 70 per cent of the country's land area is under forest cover. The country has three distinct climatic zones: subtropical, alpine tundra, and temperate, which encompass numerous micro-climates due to dramatic variations in elevation and topography (Dorji and Tamang, 2019).

Bhutan experiences daily mean temperatures typically ranging from 12°C to 28°C through the year, with daily maximum temperatures sometimes exceeding 30°C during the hottest months (April to June). Temperature varies with topography across Bhutan with colder temperatures at high elevations. The warmest time of year is pre-monsoon (March to May), when the southernmost areas of the country can be affected by severe thunderstorms (Dorji and Tamang, 2019).

This region of South Asia receives around 400 to 500mm of precipitation per month between June to September with relatively lower amounts during the coldest months. Precipitation is controlled primarily by the Southwest Monsoon.

The very high Himalaya mountains in the northern parts of the country experience an alpine tundra climate. Temperatures are low throughout the year and precipitation is low with a small peak June to September.

Regional climate drivers

- The precipitation patterns in South Asia, including over Bhutan, are controlled mainly by the Southwest Monsoon circulation. The Southwest Monsoon is a seasonal pattern of winds from the south west which brings heavy rain in the months of June to September over most of the country, with southern and eastern parts experiencing the highest rainfall totals due to their proximity to the Bay of Bengal. The variability of monsoon rainfall can lead to dry spells and drought over much of the country.
- During the winter months, the climate of Bhutan is influenced by small weather systems known as the "Western Disturbances" (WDs). WDs originate over the Atlantic Ocean and bring moisture to the region. The interaction between WDs and the Himalayas causes precipitation over northern and western parts of South Asia in the otherwise dry winters, which is crucial for the glacier mass balance in the area.
- Tropical cyclone systems can sometimes travel from the Bay of Bengal to Bhutan and cause heavy rainfall events, particularly in eastern regions. The occurrence of tropical cyclones in the region peaks in October and November.
- The El Nino Southern Oscillation (ENSO) can influence interannual temperature variability with warmer conditions occurring during positive El Nino phases.

Observed trends in regional climate

A long-term warming trend in annual mean surface temperature has been observed across the whole of Asia during 1960–2015, and the warming accelerated after the 1970s. In the South Asian region, including Bhutan, observational records show an increase in average annual surface temperatures of between 0.1–0.2 °C of warming per decade during 1980-2015. Minimum temperatures have increased at a slower rate than maximum temperatures (Shaw et al., 2022; Zhang et al., 2019; Naveendrakumar et al., 2019). General warming has resulted in more frequent warm days and nights, and less frequent cold days and nights (Shaw et al., 2022). There are more frequent heat extremes in the recent decades driven by anthropogenic (human-induced) global warming, El Niño and urbanization (Castellanos et al., 2022).

Changes in the South Asian monsoon have caused contrasts in precipitation trends across the region, with some areas experiencing a wetting trend and some a drying trend. The Southwest Monsoon has weakened in the second half of the 20th century.
In the Himalayan mountains temperatures have warmed by 0.1°C–0.2 °C per decade over the period 1980-2015. There has been increased winter precipitation, and the proportion of precipitation falling as rain, rather than snow, has increased in these regions (IPCC, 2021). There has been an observed downward trend in snow cover, glacier, and ice sheets, as well as in permafrost and lake, river and sea ice (Gutiérrez et al., 2021).

Baseline observations of seasonal precipitation and temperature

The baseline climate of Bhutan is characterised here using two different datasets: BhutanClim (Lehner & Formayer, 2023), and ERA5 (Hersbach et al., 2020). The data from both sources is averaged over the time period 1996-2019 to provide a climatological average for the present-day climate.
Figures 21-23 show seasonally averaged minimum and maximum temperatures, and total precipitation for Bhutan over the baseline period (1996-2019) from the ERA5 reanalysis and the BhutanClim dataset. The four seasons presented here are as recommended by the Royal Government of Bhutan's National Centre for Hydrology and Meteorology (NCHM)): the winter season from December to February, DJF; spring (pre-monsoon) season from March to May, MAM; summer (monsoon) season from June to September, JJAS; and the autumn (post-monsoon) season of October and November, ON (Dorji and Tamang, 2019). It should be noted that this results in uneven season lengths, with the monsoon season having 4 months, and the autumn season only two.
Figure 24 shows averaged annual cycles of minimum and maximum temperatures, and total precipitation for Bhutan over the baseline period (1996-2019) from the ERA5 reanalysis and the BhutanClim dataset. The maximum and minimum values over the baseline are shown by shading in these plots.

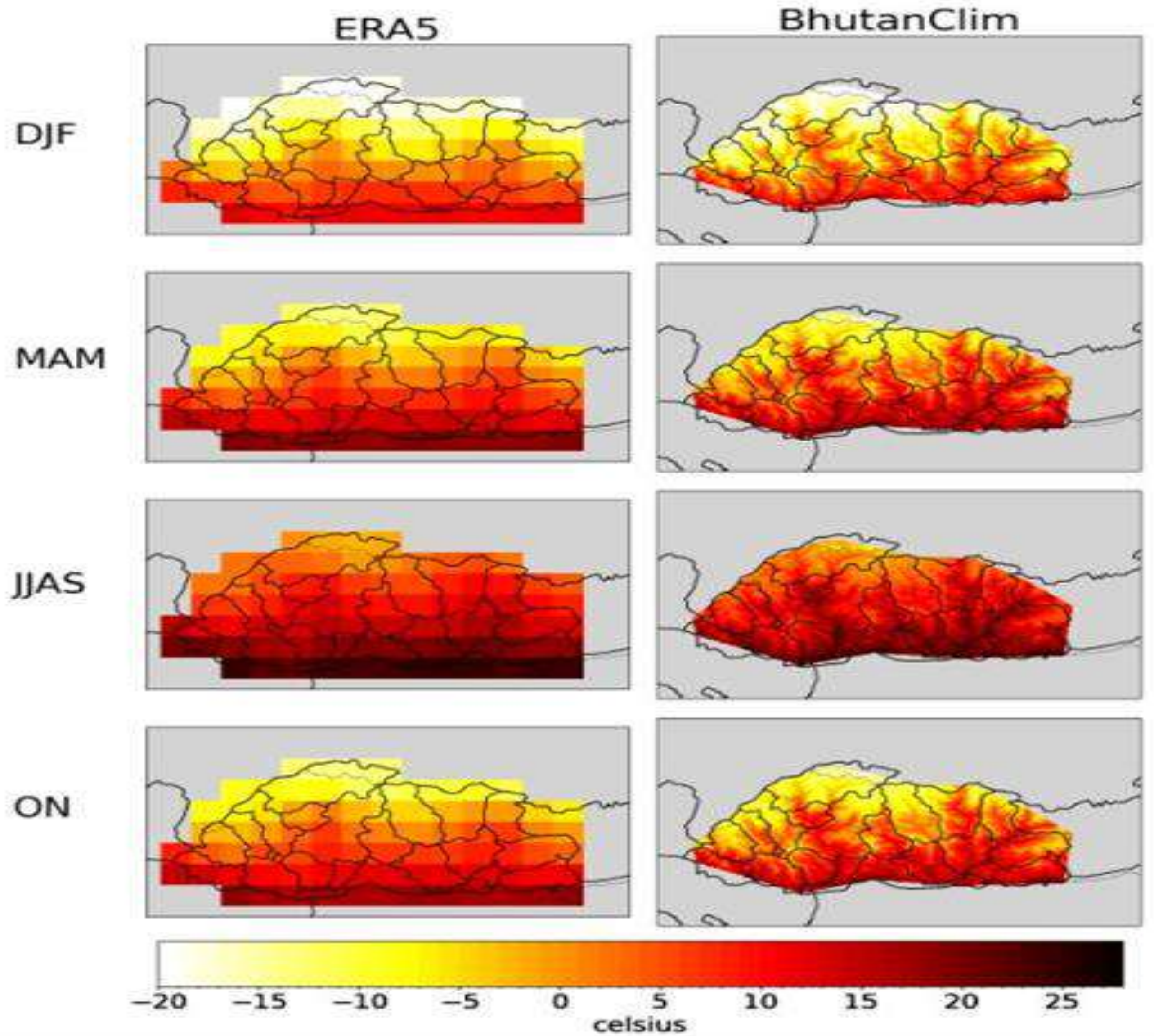


FIGURE 21: SEASONALLY AVERAGED MINIMUM TEMPERATURE (°C) FOR BHUTAN OVER THE BASELINE PERIOD (1996-2019) FROM ERA5 (LEFT) AND BHUTANCLIM (RIGHT).

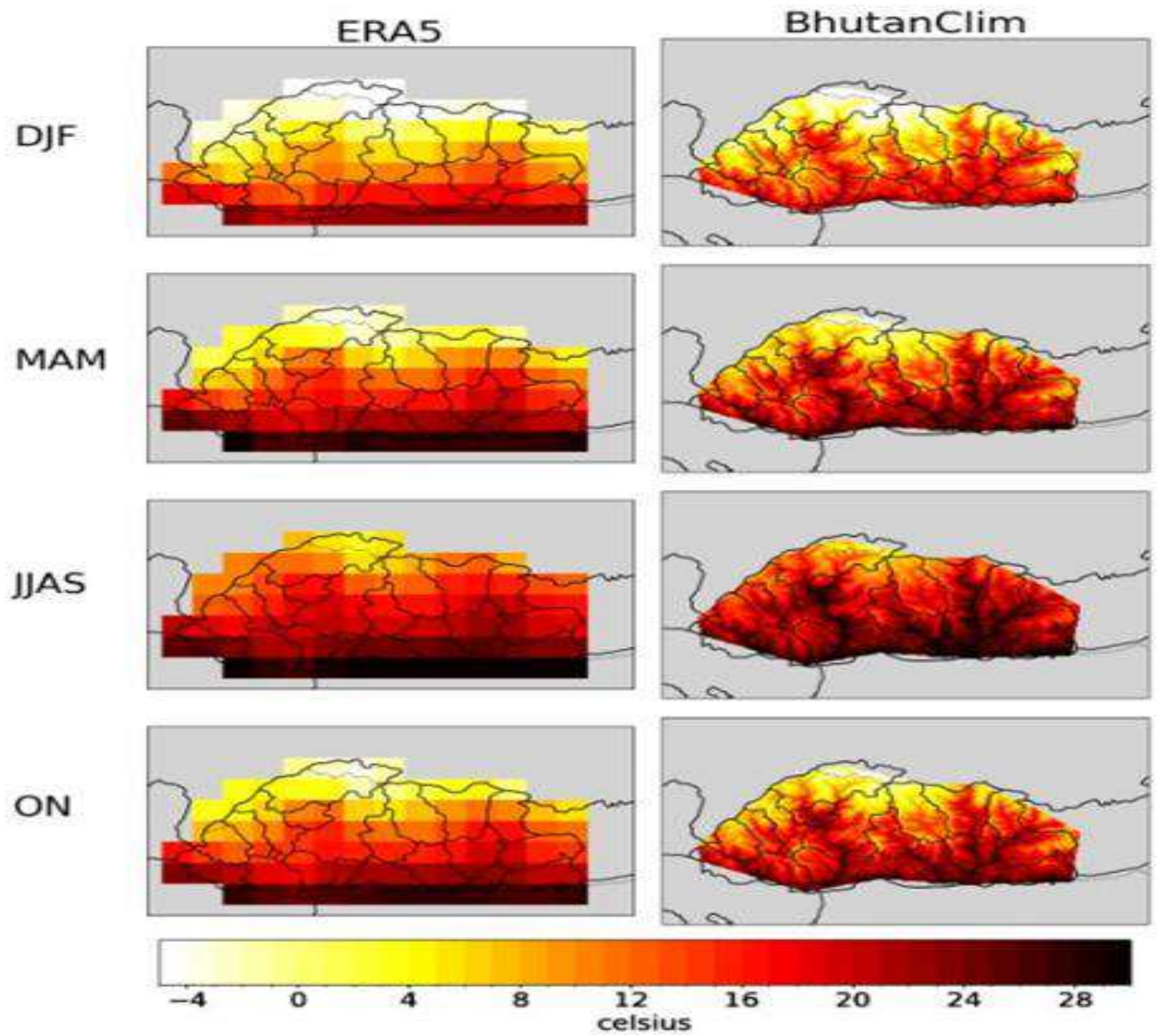


Figure 22: Seasonally averaged maximum temperature (°C) for Bhutan over the baseline period (1996-2019) from ERA5 (left) and BhutanClim (right).

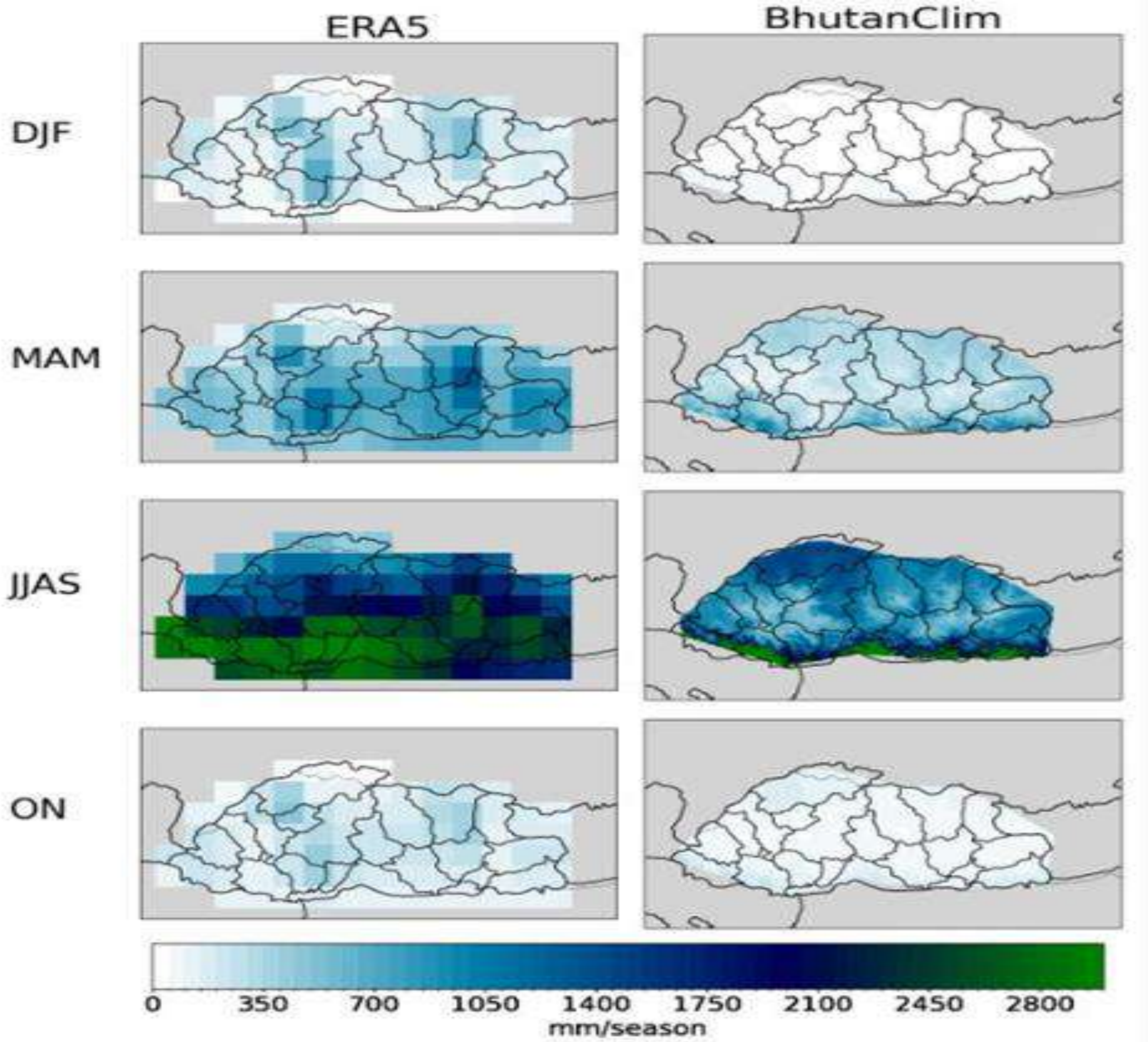


Figure 23: Seasonally averaged total precipitation (mm per season) for Bhutan over the baseline period (1996-2019) from ERA5 (left) and BhutanClim (right).

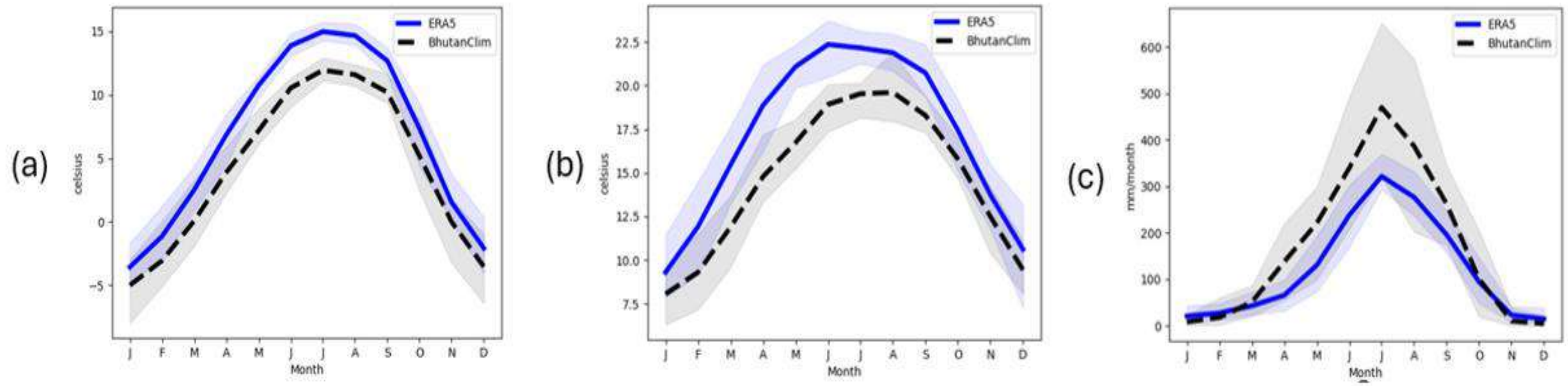


Figure 24: Averaged annual cycle of (a) minimum temperatures, (b) maximum temperatures, and (c) total monthly precipitation for Bhutan over the baseline period (1996-2019) from the BhutanClim dataset (black dashed line) and ERA5 reanalysis (blue line). The shading shows the maximum and minimum values over the baseline period.

Figures 21 and 22 show how seasonally averaged minimum and average maximum temperatures vary with latitude over the country, across all seasons, with the south being the warmest and the north the coldest. The summer months from June to September show the highest temperatures whilst the winter months from December to February show the lowest. The far northern mountainous regions remain below freezing for most of the year. The warmest time of year is pre-monsoon, with the highest mean temperatures of 24 °C occurring in June, July, and August. Averaged annual cycles of minimum and maximum temperatures, and of total precipitation, are shown in Figure 24. ERA5 and BhutanClim both generally follow the same patterns through the year, with the highest temperatures and precipitation occurring in summer and the lowest in winter. However, ERA5 is consistently warmer and drier than BhutanClim in Figure 24.

Seasonally averaged minimum temperatures, as shown in Figure 21, remain high in the south across all seasons, with temperatures reaching above 20 °C during summer and only dropping to 5-10 °C during winter. The averaged annual cycle of minimum temperatures for Bhutan, as shown in Figure 24a, shows how minimum temperatures peak in the pre-monsoon month of July at approximately 15°C for ERA5 and 12 °C for BhutanClim, and drop to their lowest in January at approximately -4 °C for ERA5 and -5 °C for BhutanClim. Figure 21 shows how the far north remains below 0 °C for most of the year, dipping to -20 °C during winter, -15 to -5 °C in spring and autumn, and only reaching -5 to 5 °C in summer.

The spatial variability of seasonally averaged maximum temperatures, as shown in Figure 22, are broadly consistent with the that of average minimum temperatures in Figure 21. The far south reaches 28 °C during summer, with spring and autumn also reaching 24-28 °C. Winter is cooler but the warmest regions still remain 16-20 °C. The averaged annual cycle of maximum temperatures for Bhutan, as shown in Figure 24b, shows how maximum temperatures peak at slightly different times for ERA5 and BhutanClim, but both still pre-monsoon, at approximately 22 °C in June for ERA5 and 19 °C in August for BhutanClim, dropping to their lowest in January for both at approxiamtely 9 °C for ERA5 and 8 °C for BhutanClim. Figure 22 shows how the coolest regions are to the far north, with temperatures reaching -4 °C during winter, -4 to 0 °C in spring and autumn, and 0-8 °C during summer.

Seasonally averaged total precipitation for Bhutan, as shown in Figure 23, shows how, overall, ERA5 is wetter across all seasons, whilst BhutanClim is drier. The high elevation mountain region to the far north of the country receives the lowest precipitation totals annually. Although BhutanClim is higher resolution, it shows less spatial variability in precipitation across most of the year when compared to ERA5. Annual total precipitation for Bhutan, as shown in Figure 24c, shows a clear peak in precipitation in July, consistent with the timing of the Southwest Monsoon, at about 480 mm/month for BhutanClim and about 320 mm/month for ERA5, after which precipitation gradually declines until it reaches near zero in November until February after which it gradually increases again.

Figure 23 shows how, during the winter months from December to February, precipitation is very low over the whole country. ERA5 shows precipitation dropping to below 350 mm/season in many regions across the country, and near or down to zero in areas across the country, but most prominently in the far northern extents. BhutanClim, however, shows minimal spatial variability in winter with the whole country receiving near zero across the whole season. ERA5, though lower in resolution, does provide the spatial variability across the country for winter precipitation, with higher precipitation between 350-700 mm/season broadly following the most prominent valleys.

The spring months from March to May and autumn months of October and November contribute about 22% to the total annual rainfall (NHCM, 2019). In Figure 23, ERA5 is overall wetter than BhutanClim in spring, with higher precipitation values of between 350-1050 mm/season occurring across most of the country. BhutanClim identifies the highest precipitation occurring to the far south along the country border at 1050-1200 mm/season. BhutanClim also shows precipitation falling to the far north of the country, at about 350-700 mm/season, whereas ERA5 shows the far north as receiving the least precipitation for spring (near or at zero). Autumn months show broadly the same patterns as spring across ERA5 and BhutanClim, but with lower overall precipitation.

The Southwest Monsoon from June to September contributes about 72% to the total annual rainfall of Bhutan with the highest amount received in the month of July, followed by August. In Figure 23, summer months from June to September show some different results across ERA5 and BhutanClim. Overall, ERA5 is much wetter than BhutanClim and has a clear north-south spatial pattern with the highest precipitation reaching above 2800 mm/season in the south and the lowest precipitation at around 350-750 mm/season in the north. ERA5 shows central Bhutan as receiving 1400-2800 mm/season. There are some consistencies across ERA5 and BhutanClim, such as the far south receiving the most precipitation in the country, with BhutanClim also showing values of around 2800 mm/season in this area. However, ERA5 shows this very high precipitation extending much farther northward into central Bhutan than BhutanClim, which limits these values to the far southern extents along the country border. ERA5 also shows the far northern extents as the least wet areas during summer, whereas BhutanClim shows the far north as having some of the highest precipitation, second only to the far south. BhutanClim also identifies the valleys in central Bhutan as the driest areas in the country, whilst ERA5 doesn’t show such a distinction due to the lower resolution and instead precipitation follows the general north-south spatial distribution.

Climate extremes

Climate hazards

Bhutan's mountainous landscape makes it particularly susceptible to climate hazards, with flooding and landslides causing the largest socio-economic damage (WB and ADB, 2021). Multi-hazard zoning shows that 70% of the 20 districts are vulnerable to moderate to severe multi-hazard risk (Tempa and Yuden, 2023). Extreme climate events can cause particularly major disruptions in agriculture and hydropower generation, the two most important economic sectors in Bhutan. Detrimental effects of extreme climate events in Bhutan (such as floods, flash floods, GLOFs, landslides, heavy rains, windstorms, hailstorms, droughts, heatwaves, heavy snowfall and forest fires) affect rural livelihoods in numerous ways, for example through destruction of crop yields, damage to livelihood assets (farming tools, irrigation systems), destruction of agricultural land which may take several months or years to recover, destruction of market access and increases in incidence of livestock diseases.

Climate hazards in Bhutan have distinct geographical and temporal patterns of exposure. The majority of the agricultural land and infrastructure is located along drainage basins that are highly exposed to flooding caused by heavy monsoon rains. For instance, the devastating 2016 floods in southern Bhutan, triggered by intense monsoon downpours, displaced over 100 families, and the 2009 Cyclone Aila brought unprecedented rain and flooding to 17 districts killing 15 people and causing Nu. 718 million losses (Tempa and

Yuden, 2023). Flood risk is concentrated in the central, northeastern and northwestern regions of the country as well as the Samtse province. Extreme climate events linked to heavy precipitation (such as riverine floods, flash floods, heavy rains and landslides) typically occur during the monsoon season, from June to September. During the same period, heavy and sustained rains also trigger landslides that can cause immense damage to agricultural land and infrastructure and isolate communities. For example, in 2021 alone, over 150 landslide events were registered in Bhutan (ibid.). In addition, glacial melt due to increasing temperatures is increasing the risk of GLOFs in northern Bhutan. The country possesses 677 glaciers that feed into 2,674 glacial lakes, of which 25 pose a dangerous risk of bursting (WB and ADB, 2021). The most recent GLOF occurred in 2015 in Gasa, washing away four bridges, livestock and one acre of agricultural land, and triggering numerous landslides 30 km downstream from the source (DesInventar, 2024). Major impacts on agriculture are also caused by windstorm and hail events in Bhutan. Particularly affected are the southern districts and some parts of central Bhutan. These hazards are catastrophic for crop in spring (March to May) and fall (September to November), often accompanied by torrential rain. For example, the March 2018 windstorm affected large areas of maize and areca nut of more than 240 households.

In considering Bhutan's climate hazards, it is important to recognize the limited availability of records of disasters in Bhutan. The Department of Disaster Management (DDM) is currently developing a Disaster Data Management Information System (DMIS) to address this gap (WB and ADB, 2021).

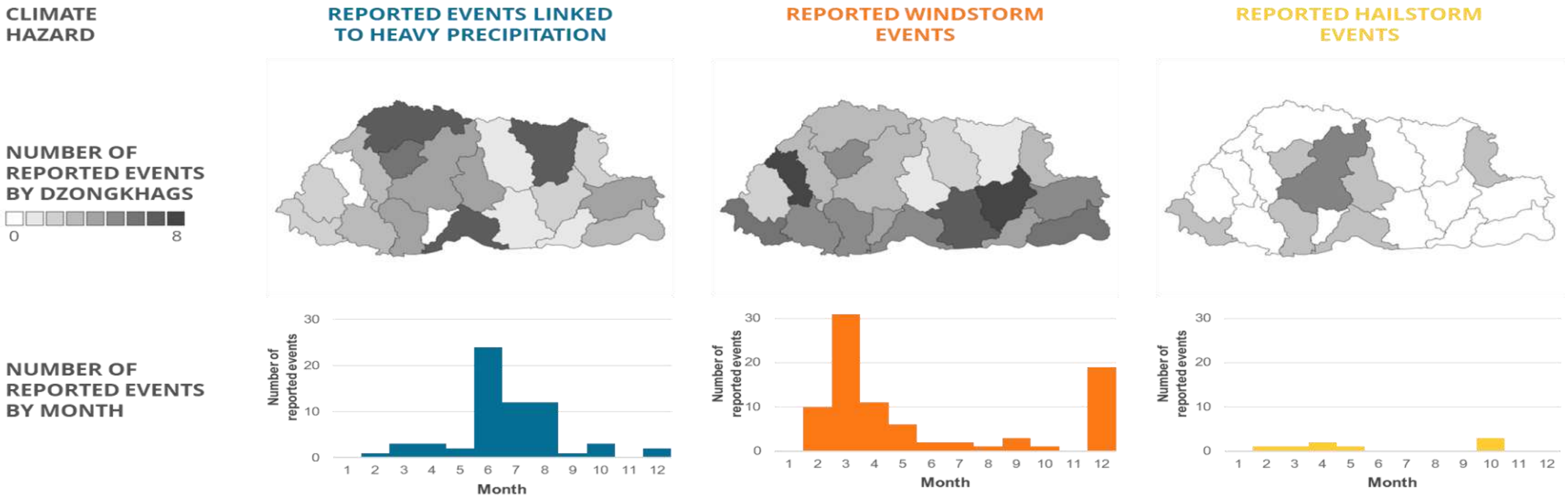


FIGURE 20. A GRAPHIC SHOWING THREE MAPS WITH A SPATIAL FREQUENCY OF EVENTS LINKED TO HEAVY PRECIPITATION (FLASH FLOODS, FLOODS, LANDSLIDES, AND HEAVY RAINS), WINDSTORM EVENTS AND HAILSTORM EVENTS ACROSS DZONGKHAGS IN BHUTAN, AND THREE GRAPHS WITH A TEMPORAL (SEASONAL) FREQUENCY OF THE SAME EVENTS ACROSS MONTHS. DATA RECORDS SPAN FROM 2009 TO 2015 (SOURCE: DESINVENTAR, 2024) AND FROM 2017 TO 2022 (SOURCE: NCHM, N.D., 2022).

FUTURE CLIMATE

Scenarios of future climate change for 2050

Bhutan has already experienced warming during the winter months (December to February) and pre-monsoon seasons (March to May). Based on climate model projections for 2050 for Bhutan, there is high confidence that temperatures will continue increasing over the twenty-first century, in all seasons. In conjunction with this, heat extremes (such as heat waves) will also continue to increase in both intensity and frequency. There is less confidence in the direction and magnitude of projected changes in precipitation, with some model simulations projecting an increase in annual average precipitation but some projecting a decrease; amounts range from around −10 percent to 20 percent compared to the recent past (1981–2010). In the high mountain areas, increasing temperatures mean that rainfall will replace snowfall, causing a decrease in snowpack levels, and an earlier spring melt of snow and ice, leading to an increased downstream river flow.

For the purpose of this study, two plausible scenarios of projected climate change for Bhutan in 2050 have been considered. Scenarios are not predictions but are a sample of what is plausible across the range of modeled changes. They provide a useful basis for exploring what different levels of climate change might mean for future food security in Bhutan. The scenarios were chosen to represent two different possible futures that sample the range of projected outcomes.

Assessment of climate change scenarios and outcomes for livelihoods

The projected climate change in Bhutan for each of the scenarios considered is summarised below. **Along with the projected trends in each scenario, year-to-year variability will continue to bring hotter, cooler, wetter and drier years as a result of natural variability in the climate system.**

Scenario 1

Most climate models project a warmer and wetter climate for Bhutan in 2050 and Scenario 1 represents these projected changes. In Scenario 1, annual mean temperatures are projected to be 2.5 °C higher on average and the annual average precipitation is projected to be 12.5 percent higher compared to the baseline values, when averaged across the whole of Bhutan. Maps of the projected changes from a climate model simulation representing this scenario are shown in Figure 26 and projected changes on seasonal timescales are shown in Figure 27; note the scales are the same for subsequent figures to allow comparisons. These figures show there is a large variation latitudinally in the projected changes in precipitation, with a large increase in the far south of the country, and a smaller decrease projected in the far north. This variation, along with the suggestion that the main increases occur during the monsoon season Jun-Sep, imply that the monsoon will become stronger in the future. Increases are also projected to occur in the pre-monsoon season Mar-May, suggesting a potential earlier start and lengthening of the monsoon season. There is little future change projected for precipitation in the autumn (Oct-Nov) and winter (Dec-Feb) seasons. Projected changes in temperature vary latitudinally across the country with the largest changes in the north (up to 4 °C) and smaller changes in the south (2.5 °C). There is warming in all seasons, with largest changes occurring in the autumn months Oct-Nov.

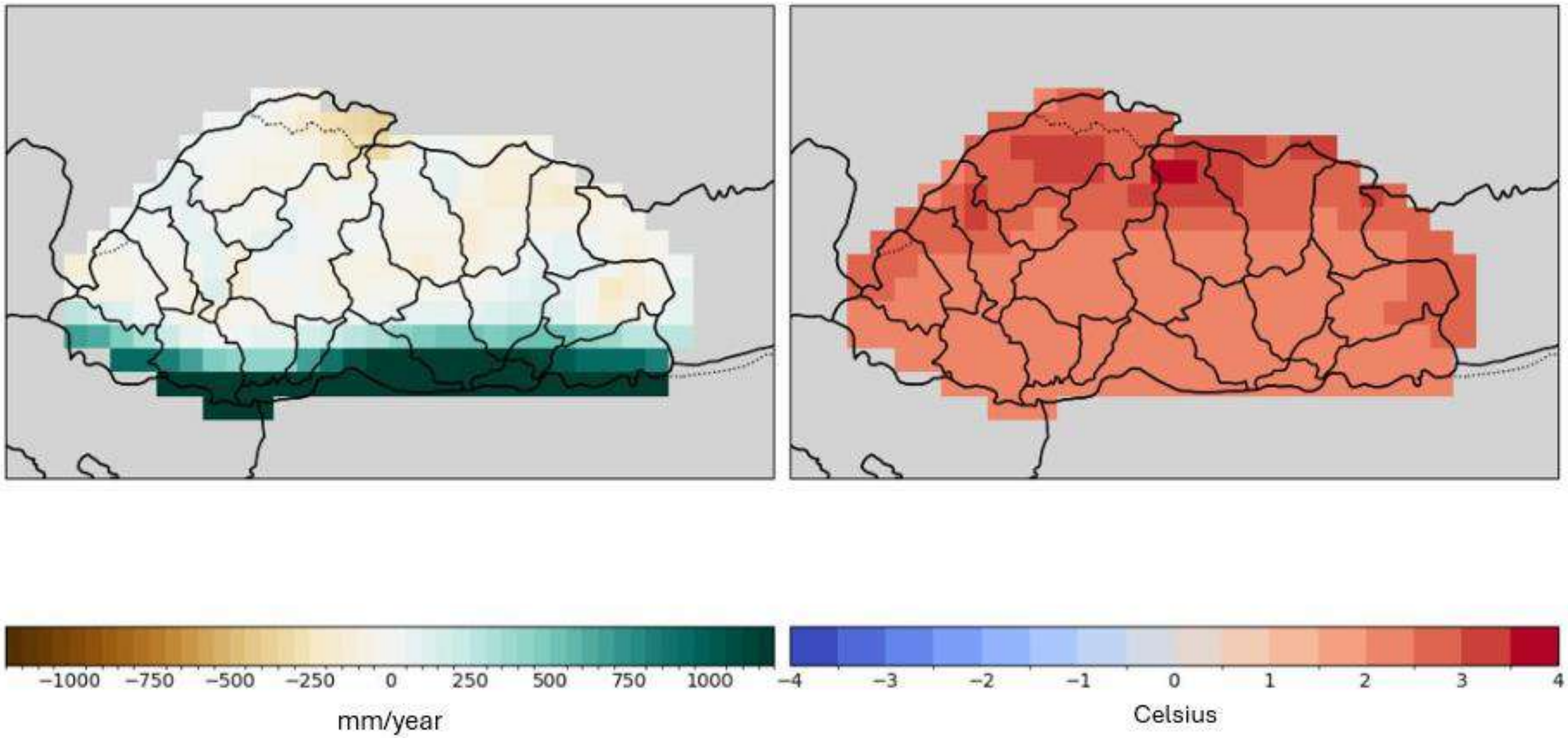


Figure 26: Projected changes in annual average precipitation (left) and daily mean temperature (right) in Scenario 1 for 2050 (2036 - 2065) relative to the baseline (1981–2010).

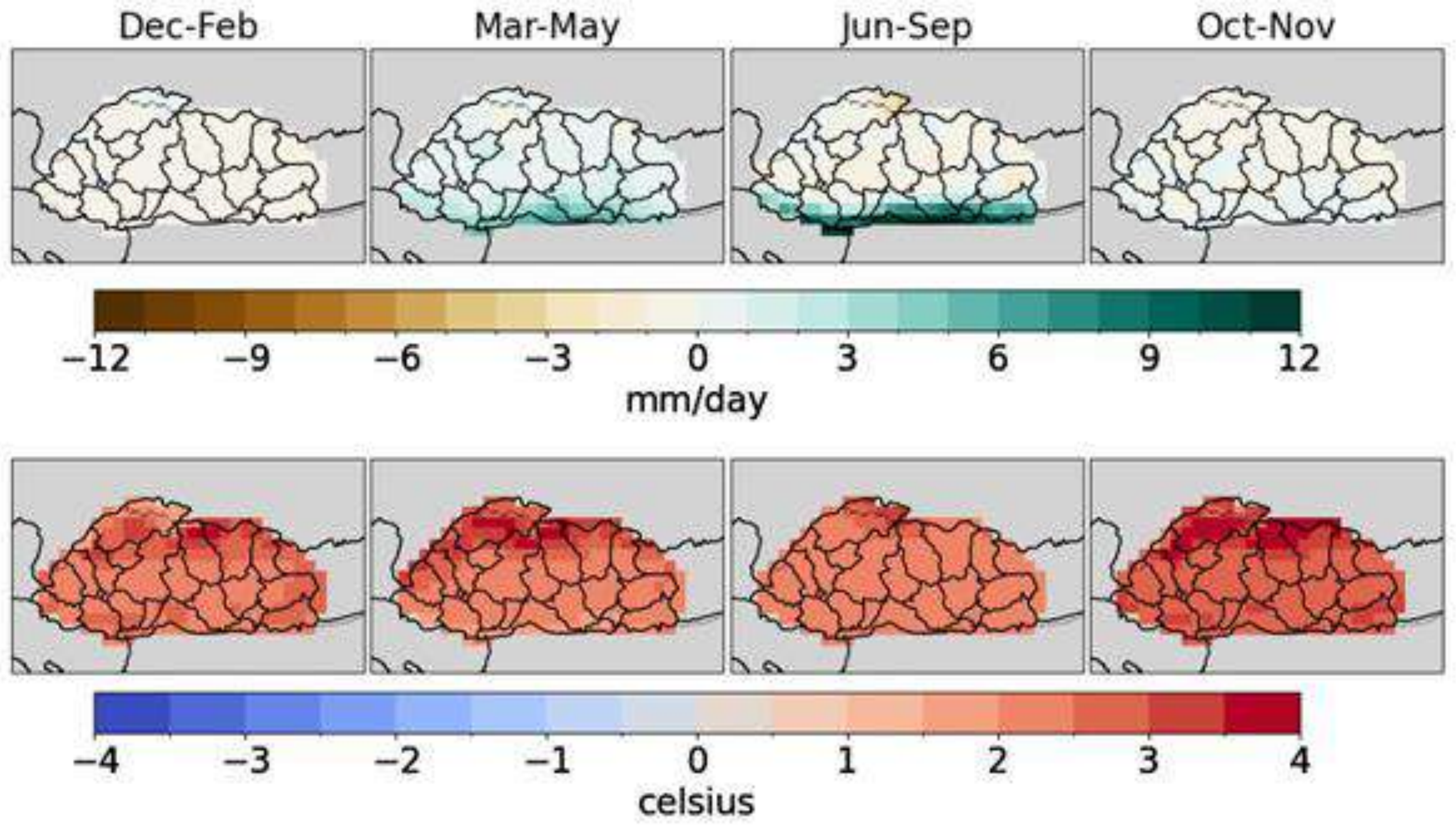


Figure 27: Projected changes in seasonal total precipitation (top panels) and seasonal average daily mean temperature (bottom panels) in Scenario 1 for 2050 (2036–2065) relative to the baseline (1981–2010).

The projected increase in temperature in Scenario 1 will result in much higher temperatures on average across the country, and larger increases at higher altitudes. This will mean that current peak temperatures will be exceeded earlier in the year and for longer through the year. As such, heatwave conditions will increase in frequency and intensity compared with the baseline climate. This will increase heat stress impacts on crop production where optimum temperatures may be exceeded (e.g., for paddy rice) and health impacts on livestock, particularly in the hottest regions. However, warmer temperatures will also reduce the impacts of frost damage on certain crops, such as vegetables and mandarin oranges, and may also increase the areas in which these can grow.

Evaporation rates will increase with rising temperatures, and with larger increases in temperature the evaporation rates will also be larger. In Scenario 1, the projected increase in precipitation during the pre-monsoon and monsoon seasons will result in overall increases in water availability during these seasons, but only for those regions in the south of the country affected by the monsoon circulation. For the northern regions, the increase in evaporation will result in a decrease in water availability due to the higher temperatures, exacerbating water stress impacts on crops and pasture availability for livestock.

Projected higher temperatures in the northern mountainous regions will result in more precipitation falling as rain at higher altitudes, and a higher rate of snow and glacial melt, which will affect the seasonality of river flows and water availability downstream. An additional impact of the higher temperatures is that the snowmelt will likely begin earlier in the year, and this combined with the increases in pre-monsoon and monsoon precipitation could result in very full rivers and increase the risk of riverine flooding.

As well as the projected increase in mean precipitation, the intensity of heavy precipitation events is also projected to increase due to the changing nature of precipitation in a warmer climate (Zhang et al., 2018; Supari et al., 2020), further exacerbating the risk of flash flooding, landslides and Glacial Lake Outburst Flood (GLOF) events in this scenario and the associated damage to crops, infrastructure and access to markets and supply chains.

Other impacts on crops and livestock in Scenario 1 are shifts in cropping seasons linked with precipitation variability, increases in heat stress in years when the monsoon rains are delayed, and the incidence and habitable areas of pests and diseases.

Scenario 2

Although most climate models project a wetter climate on average for Bhutan in 2050, there are some plausible climate model simulations that project a drier climate on average. Scenario 2 represents this warmer and drier future climate and is an example of a high impact, low likelihood future for Bhutan.

In Scenario 2, annual mean temperatures are projected to be 2.1°C higher on average and the annual average precipitation is projected to be 4.5 percent lower compared to the baseline values, when averaged across the whole of Bhutan. Maps of the projected changes from a climate model simulation representing this scenario are shown in Figure 28 and projected changes on seasonal timescales are shown in Figure 29. These figures show little variation across the country in the projected changes in precipitation. The largest drying occurs in the winter (Dec-Feb) and monsoon (Jun-Sep) seasons, while changes are mixed in spring (Mar-May) and autumn (Oct-Nov), where some areas show a slight increase in precipitation. However, projected changes are small. Projected changes in temperature vary latitudinally across the country with the largest changes in the north (up to 3.5 °C) and smaller changes in the south (1.5 °C). There is warming in all seasons, with largest changes occurring in the winter months December – February. Temperature increases in this scenario are not as large as those projected in Scenario 1.

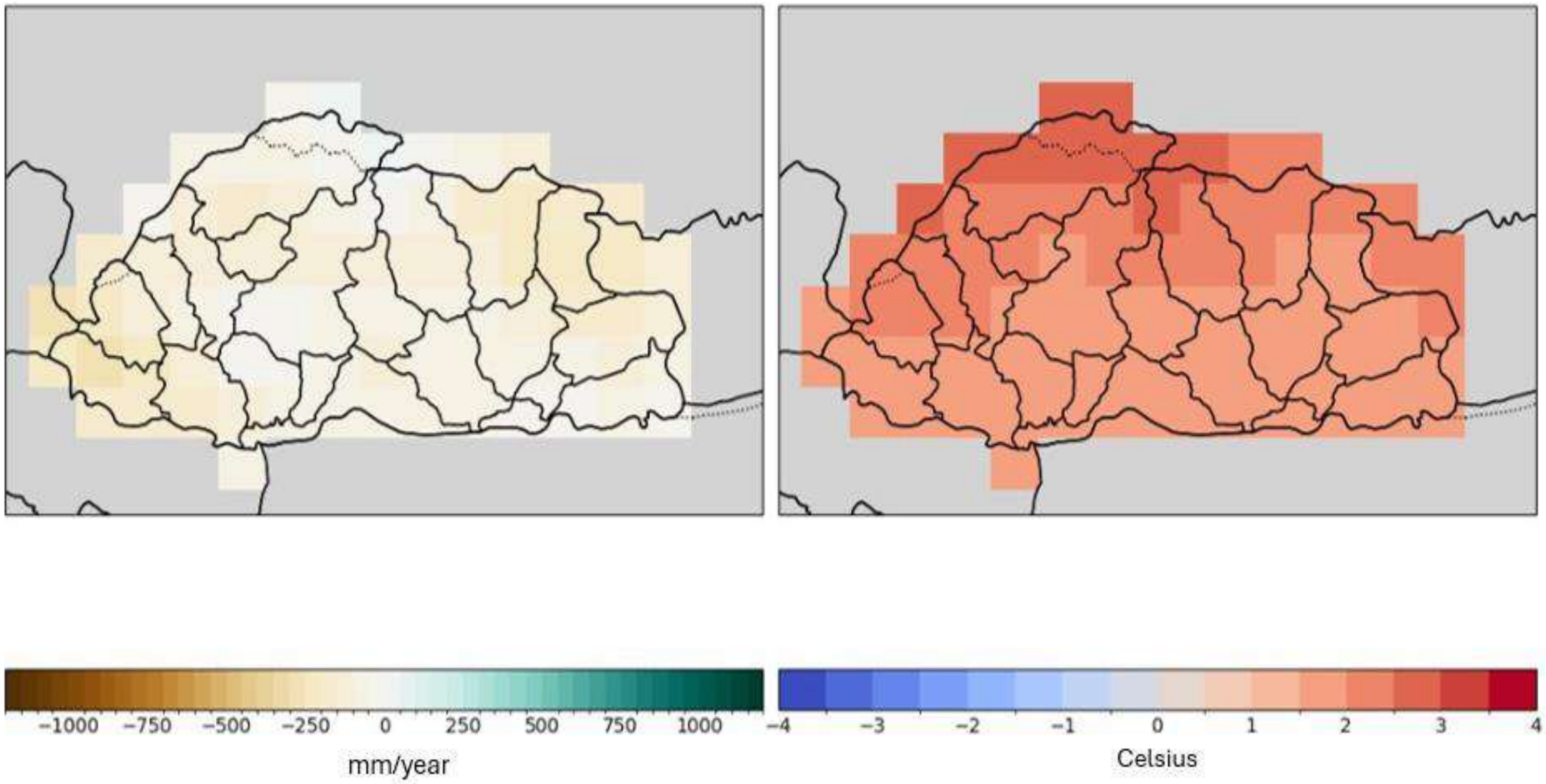


Figure 28: Projected changes in annual average precipitation (left) and daily mean temperature (right) in Scenario 2 for 2050 (2036 - 2065) relative to the baseline (1981–2010).

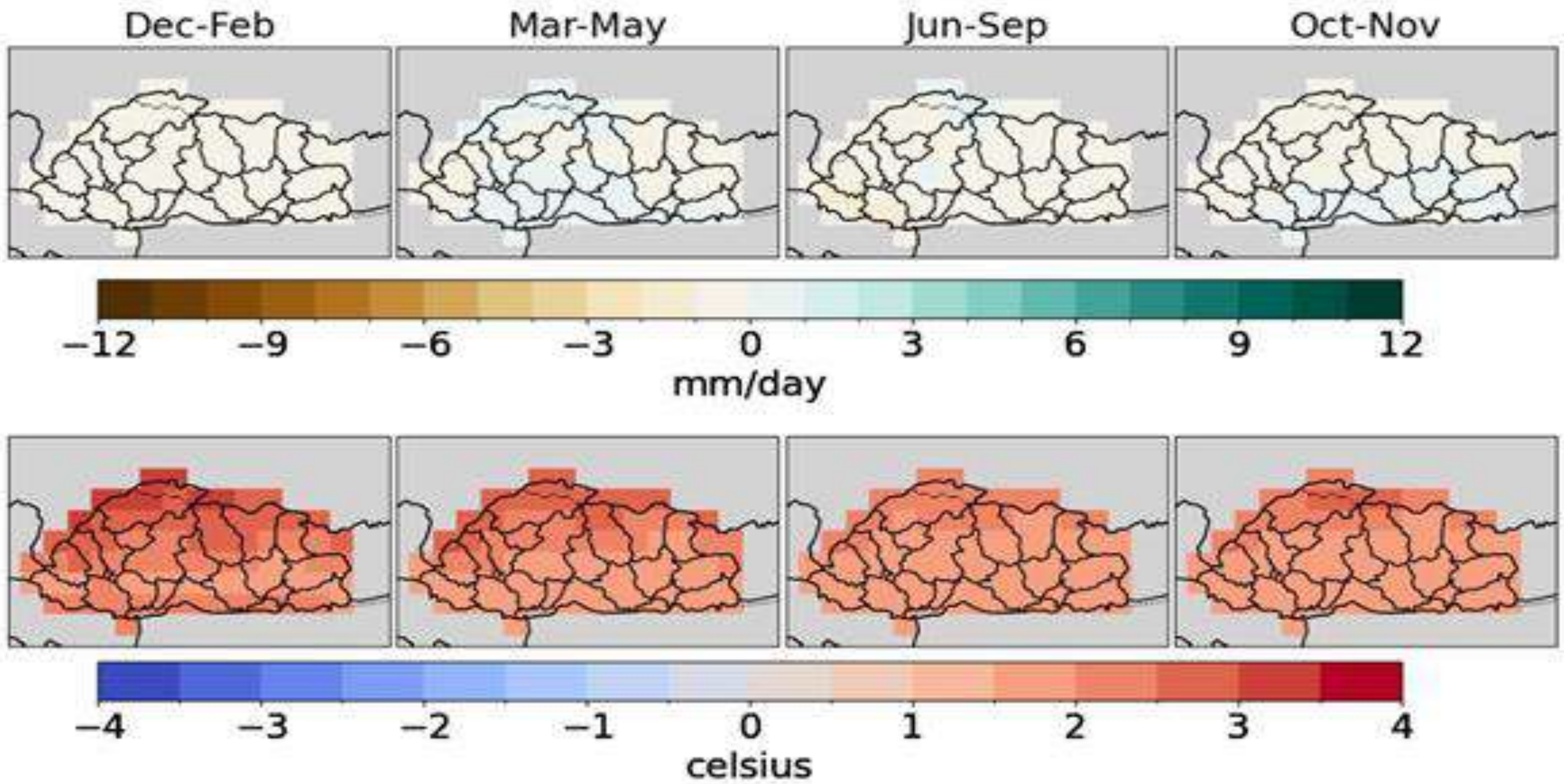


Figure 29: Projected changes in seasonal total precipitation (top panels) and seasonal average daily mean temperature (bottom panels) in Scenario 2 for 2050 (2036–2065) relative to the baseline (1981–2010).

The projected increase in temperature in Scenario 2 will result in higher temperatures on average across the country, and larger increases at higher altitudes, although these increases are lower than those in Scenario 1. This will mean that current peak temperatures will be exceeded earlier in the year and for longer through the year. Heatwave conditions will therefore increase in frequency and intensity. This will increase heat stress impacts on crop production where optimum temperatures may be exceeded (e.g., for paddy rice) and health impacts on livestock, particularly in the hottest regions. However, warmer temperatures will also reduce the impacts of frost damage on certain crops, such as vegetables and mandarin oranges, and may also increase the areas in which these can grow.

Due to the projected drier climate in Scenario 2 and the increase in evaporation associated with higher temperatures, increases in heat stress will be higher in this scenario. Water scarcity will increase across the country in all seasons. Reduced precipitation combined with higher temperatures will further exacerbate the impacts of accelerated melting of snowpack, with long-term implications for water availability and seasonality of river flows. In addition, a hotter and drier climate on average will mean that groundwater sources will not be recharged as in the other scenarios, causing long-term depletion and reduction in water availability. This will particularly impact water availability during the drier seasons, and with continued year-to-year variability in precipitation amounts and timings, dry years will be drier in this future scenario, resulting in an increase in drought conditions. This scenario presents a higher risk of water stress impacts on crops and livestock across the country and throughout the year. These conditions are also more conducive to forest fires, and the risk of these and subsequent impacts on crop production and pollution levels will also increase.

Despite the projected drier climate on average, the intensity of heavy precipitation events is still projected to increase due to the changing nature of precipitation in a warmer climate (Zhang et al., 2018; Supari et al., 2020). These increases are most likely to occur during the monsoon season, further exacerbating the risk of flash flooding, landslides and GLOF events and resulting in damage to crops, infrastructure and access to markets.

Future extremes

Extreme precipitation events and related flooding already occur frequently in monsoon Asia (i.e., Southeast, South and East Asia) (Mori et al., 2021) and an increase in heavy precipitation occurred recently in South Asia (Seneviratne et al., 2021). Future warming of 1.5°C to 2°C will increase extreme precipitation events across all of Asia but especially East and South Asia (Zhang et al., 2018; Supari et al., 2020). Heatwaves and humid heat stress will also be more intense and frequent as temperatures increase during the 21st century.

These changes are likely to increase regional risks to Bhutan. For example, increasing temperatures will increase the occurrence of high overnight minimum temperatures during summer, which will have impacts on human health, such as heatstroke and lack of sleep. Furthermore, increasing cumulative exposure to heatwave events is expected, leading to increased potential for heat-related mortality when summer temperatures will regularly exceed 40°C.

Extreme weather events, such as flooding caused by heavy rainfall, can cause damage and disruption to many livelihoods in Bhutan, affecting infrastructure, transport, and access to remote parts of the country. This is expected to increase substantially as hazards intensify with more frequent and intense extreme weather events. Changes to seasonal precipitation, such as greater rainfall variability and more frequent and prolonged droughts, will also impact livelihoods such as agriculture and the rearing of livestock, as well as run-of-river hydropower generation which have limited storage capacity.

Climate change indicators

In order to manage the risks associated with extreme events, it is useful to have a measure of the future trends in extreme values i.e. the high or low values of meteorological variables. To gain a uniform perspective on changes in extremes, the joint CCl/WCRP-Clivar/JCOMM Expert Team on Climate Change Detection and Indices (ETCCDI) has defined a core set of 27 descriptive indices of extremes for temperature and precipitation (Klein Tank et al., 2009).

Not all indices in the set will be useful to analyse for this study. A review of Bhutan's existing and future climate (UNDP, 2022) identified several threats to the agriculture sector including increased air temperatures, an increase in average annual rainfall, and the intensity of extreme rainfall events. Thus, indices reflecting these hazards have been calculated for the two future climate change scenarios presented earlier in this section and are summarised here in Table 3.

Table 3: Climate change indices that are included in this study to identify future hazards related to agriculture.

S. No.	Index code	Index name	Description

1	TXx	Maximum value of daily maximum temperature	The maximum value of maximum daily temperature recorded over one year i.e. the highest temperature of the year
2	TNn	Minimum value of daily minimum temperature	The minimum value of minimum daily temperature recorded over one year i.e. the lowest temperature of the year
3	CHD	Count of Hot Days	Count of the number of days in which the maximum daily temperature exceeds 30 °C over one year
4	FD	Frost Days	Count of the number of days in which the minimum daily temperature is below 0 °C over one year
5	NWD	Number of Wet Days	Count of the number of days in which the precipitation is greater than 1 mm/day over one year
6	RX1Day	Maximum one-day precipitation	The maximum value of daily precipitation recorded over one year i.e. the precipitation total on the wettest day of the year
8	CDD	Consecutive Dry Days	Maximum length of dry spell i.e. longest number of consecutive days where precipitation is less than 1 mm/day CDD is calculated seasonally.

The results for the calculated indices are presented below as maps of Bhutan, showing the value of each index in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between the baseline and 2050 periods. Results are shown for the two future climate change scenarios presented in the earlier future climate section, with the upper panels corresponding to Scenario 1 and the lower panels corresponding to Scenario 2.

Temperature extremes

The first set of indices corresponds to future changes in extremes of temperature: TXx, TNn, CHD, and FD.

Figure 30 shows the baseline, future, and change, in the maximum value of daily maximum temperature (TXx), for Scenario 1 (upper panels) and Scenario 2 (lower panels). In common with the baseline temperature profiles, the southern parts of the country experience the maximum temperatures, especially along the southern edge. The change in TXx shows that in 2050, maximum temperatures will increase throughout the whole country by at least 1 °C in both scenarios but particularly in the northern regions, where they will increase by 3 °C in Scenario 1 and 2.5 °C in Scenario 2. These increases will affect yields of many crops which are sensitive to high temperatures, for example maize, which suffers yield reduction if temperatures are above 25 °C for a prolonged period (5 days), and tomatoes, which can drop flowers if several days of daytime temperatures above 29°C and nighttime temperatures above 21°C are experienced (NCHM and DoA, 2022).

Figure 31 shows the baseline, future, and change, in the minimum value of daily minimum temperature (TNn), for Scenario 1 (upper panels) and Scenario 2 (lower panels). The northern mountainous regions experience the lowest temperatures in the baseline, down to -35 °C in Scenario 1 and -25 °C in Scenario 2. The change in TNn shows that in 2050, maximum temperatures will increase throughout the whole country, by up to 4 °C in both scenarios. The maximum change occurs in the northern and central regions. These increases in minimum temperatures may expand the regions in Bhutan that are suitable for growing various crops, as they often require a minimum temperature for germination. For example, both paddy and maize require a minimum temperature of 10 °C for emergence and nursery stages, tomatoes require a minimum temperature of 10 °C during flowering stage, and potato favours temperatures above 18 °C for the sprout development stage (NCHM and DoA, 2022).

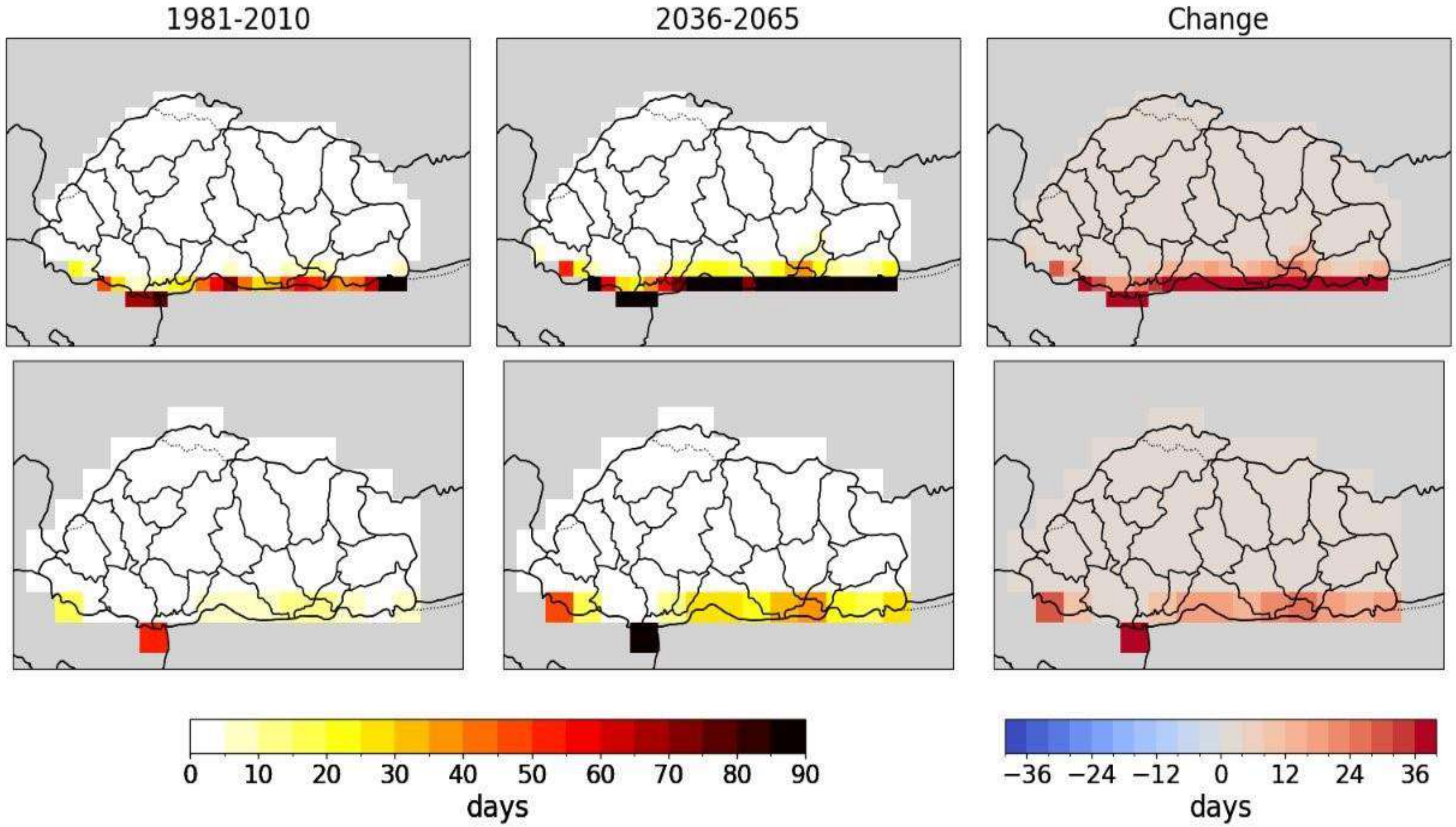


Figure 30: The maximum value of daily maximum temperature (TXx) in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

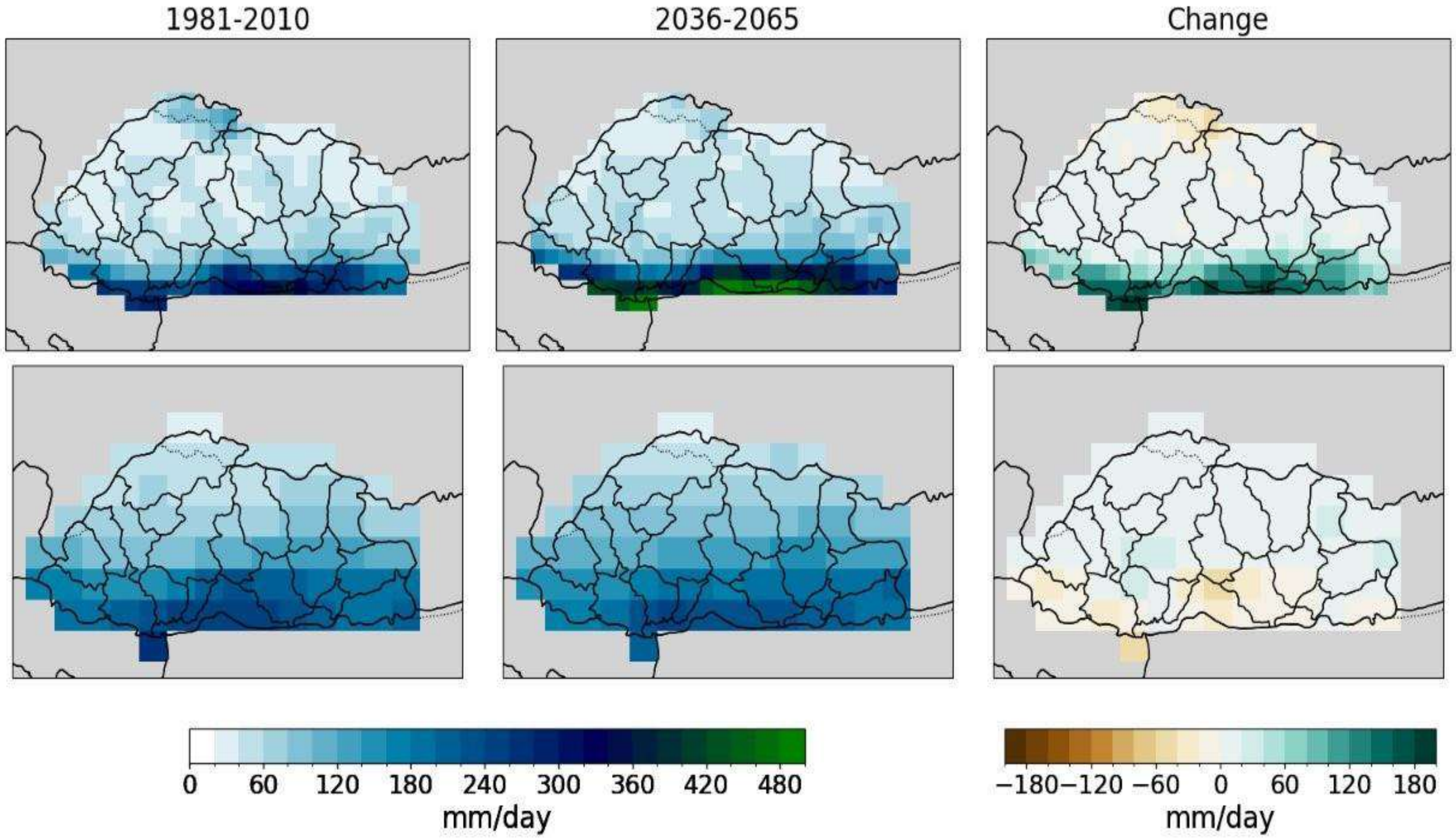


Figure 31: The minimum value of daily minimum temperature (TNn) in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

Figure 32 shows the baseline, future, and change, in the Count of Hot Days (CHD), which here is defined as the number of days in which the maximum daily temperature exceeds 30 °C over one year. Figure 32 shows that these temperatures occur only along the southern edge of the country in both the baseline and future climate. In Scenario 1, the number of hot days is projected to increase by up to 36 days in one year for the most southern parts. In Scenario 2, the increase is projected to be lower, approximately 10-20 days. These increases will affect crops grown in these areas. The threshold of 30 °C was chosen as a range of crops (including potato and tomato) suffer yield reduction at temperatures above this. Many crop pests and diseases favour these warmer temperatures, including Chili Pod Borer and Cut Worm (chilli), Grey Leaf Spot and Armyworm (maize), and Brown Plant Hopper (paddy) (NCHM and DoA, 2022).

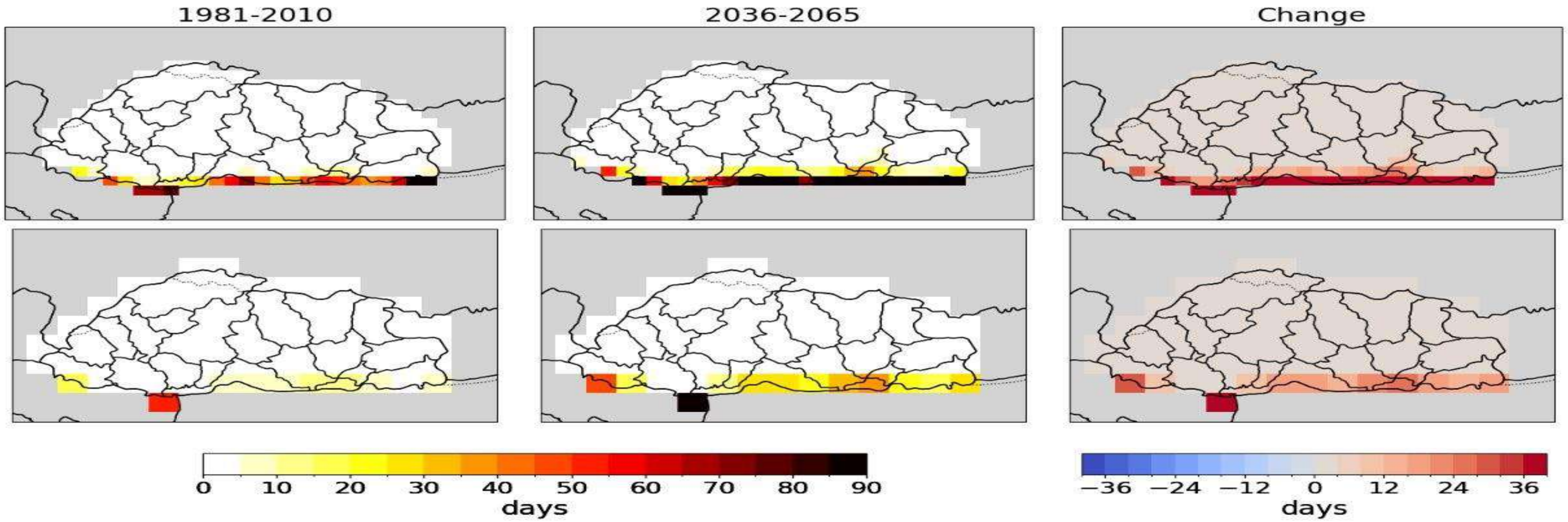


Figure 32: The Count of Hot Days (CHD) where maximum daily temperature is above 30 °C in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

Figure 33 shows the baseline, future, and change, in the count of Frost Days (FD), which is defined as the number of days in which the minimum daily temperature is below 0 °C over one year. Figure 33 shows that Frost Days are widely experienced in the northern half of Bhutan in the baseline period, with the most northern mountainous regions having temperatures below 0 °C nearly every day of the year. However, in the 2050 future period, the number of days per year is reduced in both future scenarios: Scenario 1 shows a reduction of up to 45 days in FD in the far northern region and other mountainous regions. Scenario 2 also shows a reduction in FD, with again up to 45 fewer days in the far northern region and approximate 30-35 days in lower altitude mountainous regions. These reductions will result in more precipitation falling as rain rather than snow at higher altitudes, and a higher rate of snow and glacial melt, which will affect the seasonality of river flows and water availability downstream.

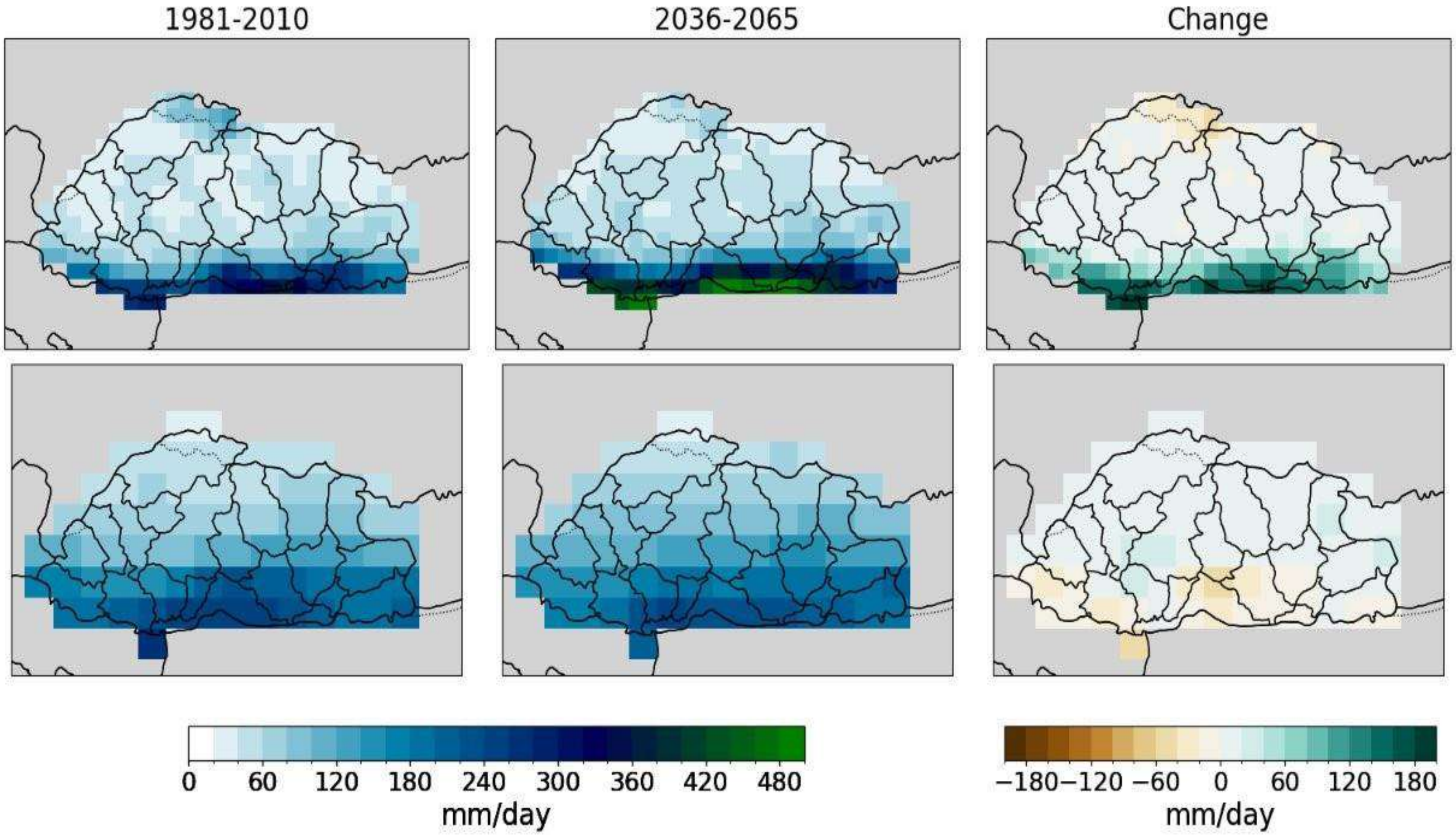


Figure 33: The Count of Frost Days (FD) where minimum daily temperature is below 0 °C in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

Precipitation extremes

The second set of indices corresponds to future changes in extremes of temperature: NWD, RX1Day, and CDD.

Figure 34 shows the baseline, future, and change, in the Number of Wet Days (NWD), which here is defined as the number of days in which the daily total precipitation exceeds 1 mm over one year. Figure 34 shows that the regions in Bhutan with the highest number of wet days are the valleys in the northern and western parts of the country. In the 2050 period, the NWD is reduced in both the future scenarios: by an average of approximately 10 days in Scenario 1 and 20 days in Scenario 2. This result is in contrast to the overall precipitation total projected in Scenario 1 in the future, as Scenario 1 is projected to be 12.5% wetter overall in the future period. The result here suggests this increase in precipitation totals will be over a reduced number of days per year, i.e., the days when it does rain in the future, the rain will be heavier than at present.

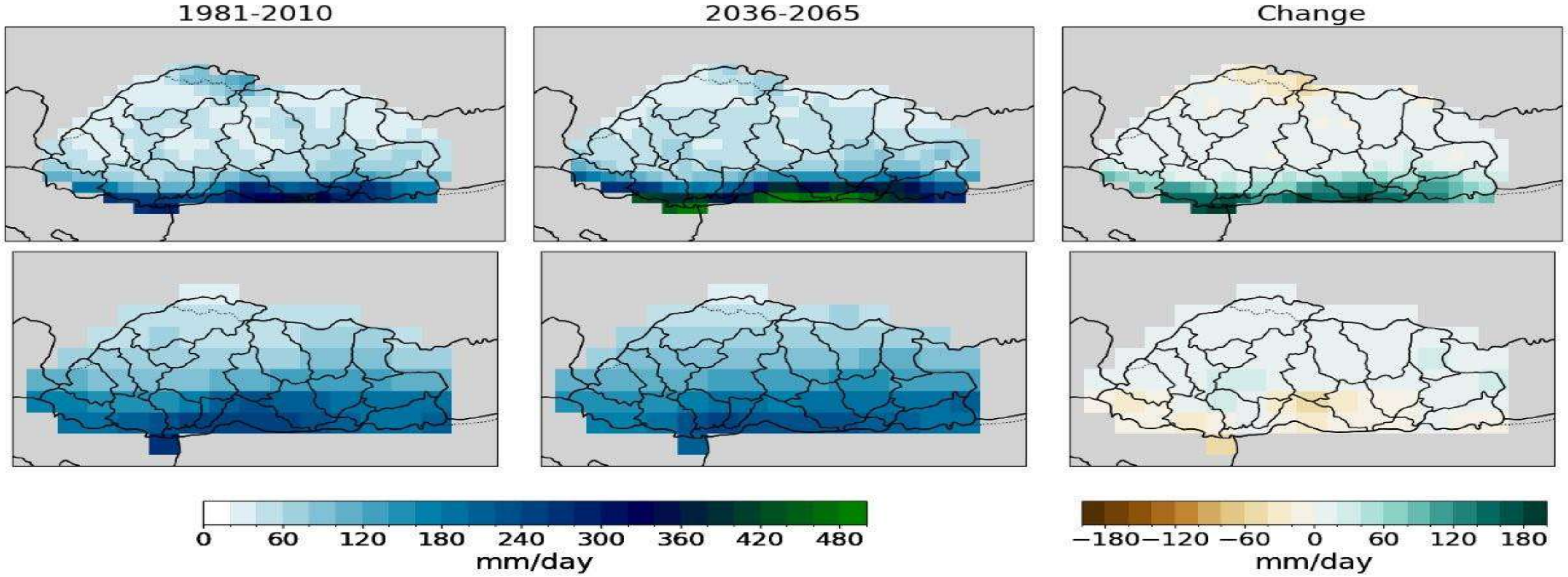


Figure 34: The Number of Wet Days (NWD) where daily total precipitation exceeds 1 mm over one year where in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

Figure 35 shows a precipitation indicator: RX1Day. This is a measure of the maximum total daily rainfall over one day (i.e. the total rainfall on the wettest day of the year). This is a useful metric for measuring how the intensity of rainfall changes between the baseline and the future. Figure 35 shows the most intense rainfall occurring along the southern edge of the country. In Scenario 1, the wettest values of RX1Day are approximately 350 mm/day, which is projected to increase to up to 480 mm/day by 2050 – an increase of 37 %. This implies that rainfall events will become more intense in the future, with up to a third larger total amounts falling on the wettest days. This will cause impacts such as flooding, and crop damage from heavy rain. In Scenario 2, which is a scenario with a drier future on average, RX1Day shows some projected decreases (of approximately 50 mm/day) in southern regions but small projected increases (of 10-50 mm/day) in northern regions. This implies that even in a future scenario with lower rainfall annually, there will be some days which are wetter than in the baseline period.

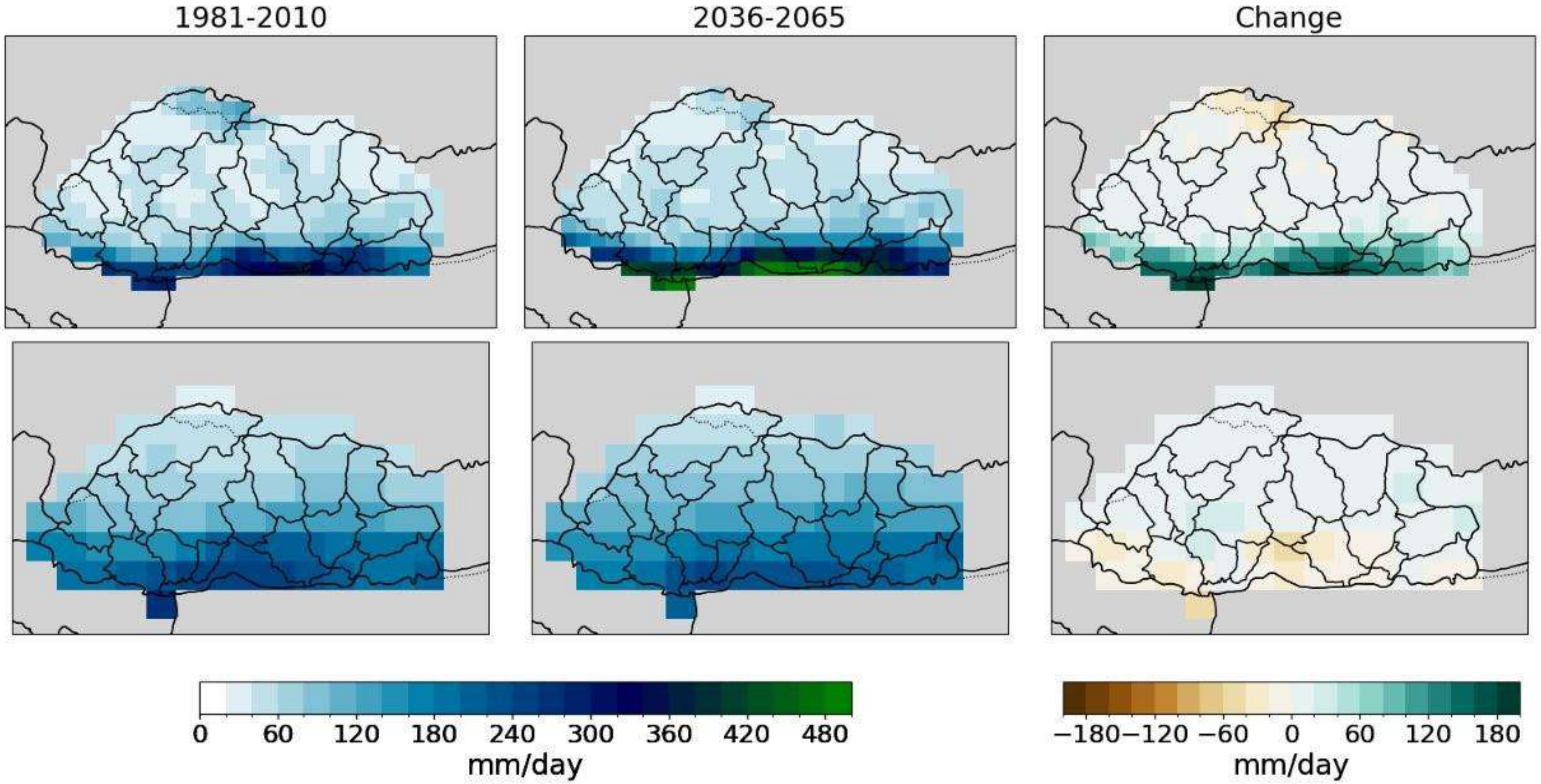


Figure 35: The maximum precipitation in one day annually (RX1Day) in the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

Figure 36 shows the seasonally averaged future changes in Consecutive Dry Days (CDD), which is a count of the longest number of days without any precipitation per season. This index has been calculated seasonally to allow analysis of changes in monsoon rainfall as well as other seasonal patterns. Figure 36 shows that the season with the longest number of CDD is the winter DJF, where in the baseline period CDD is up to 80 days in the mountainous north (scenario 1), and 20-50 days elsewhere in the country (both scenarios). In the future period the two scenarios show differing projections: Scenario 1 shows a decrease in the far north of -12 days, meaning that precipitation is expected to occur more often in the future in this area. Both scenarios show an increase in CDD for the rest of the country of around 8-12 days, corresponding to a decrease in winter precipitation days. The two seasons of pre-monsoon (MAM) and monsoon (JJAS) both have low values for CDD in the baseline period as might be expected, as this includes the main rainy season. They also show little change in the future period, which implies that no major changes to the monsoon length or regularity is projected for 2050. The autumn season ON has the second longest

CDD values (after DJF) in the baseline period, with an average of around 25 days across the country, and up to 50 days in the far northern areas in Scenario 1. In the future period, this is projected to increase by approximately 5 days in Scenario 2 and 10 days in Scenario 1.

On average over the course of a year, the number of CDD is projected to increase in the future, in both scenarios. This result is in contrast to the generally wetter future expected in Scenario 1 and implies that the increase in rainfall is as a result of more extreme rainfall (as shown by the previous indicator RX1Day), rather than an increase in wet days (which in general are projected to decrease). These higher occurrences of extreme rainfall events will cause impacts such as flooding, and crop damage from heavy rain.

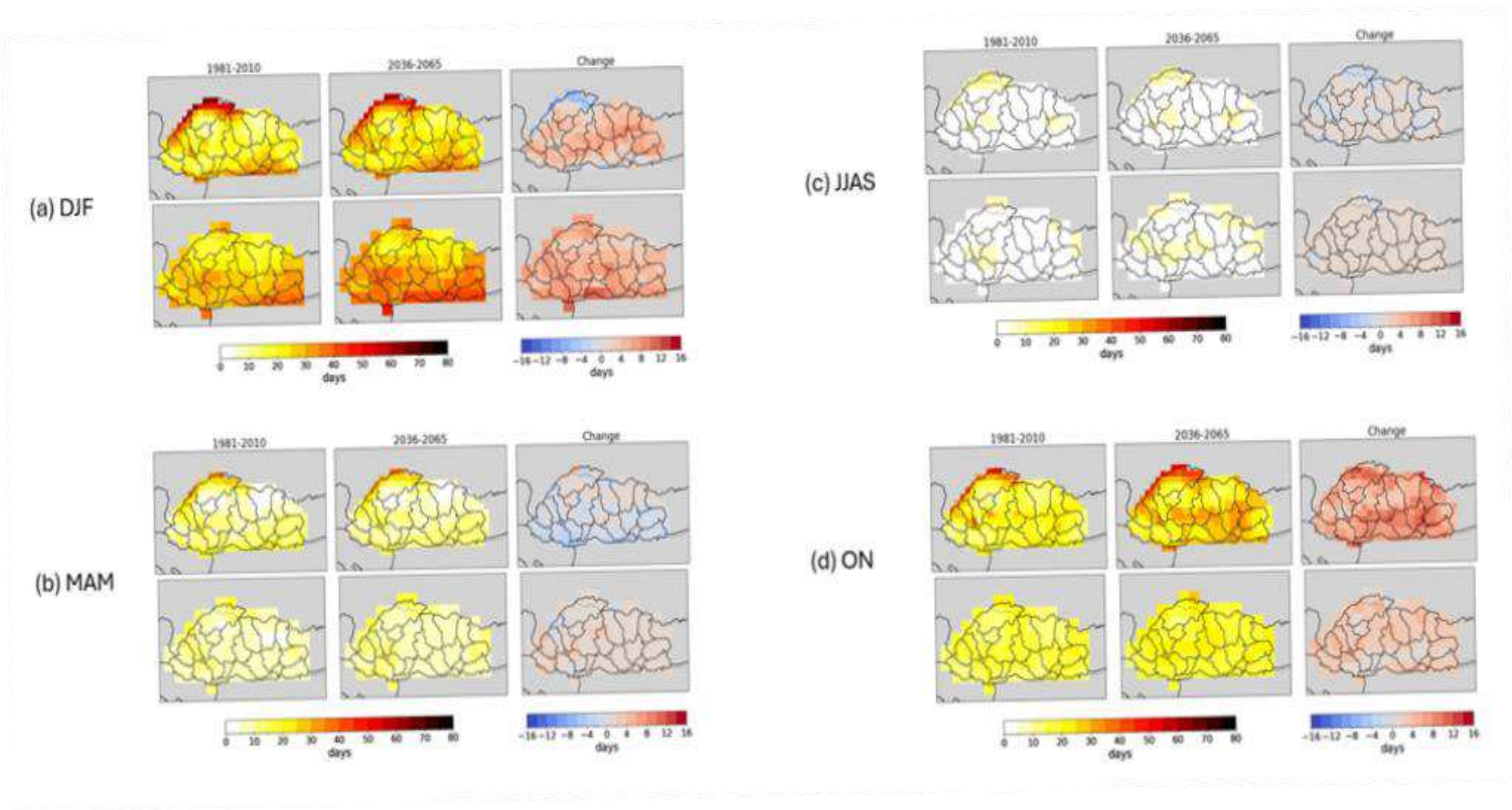


Figure 36: The number of Continuous Dry Days (CDD) where daily total precipitation is less than 1 mm, per season (a) December-January-February DJF; (b) March-April-May MAM; (c) June-July-August-September JJAS; and (d) October-November ON. For each season averages are shown for the baseline period (1981-2010), the 2050 period (2036-2065), and the change between these two periods, for Scenario 1 (upper panels) and Scenario 2 (lower panels)

FUTURE CROP SUITABILITY

Changes in temperature and rainfall will also affect the climate suitability of key crops—particularly rice, maize, potato, cardamom, chili and mandarin orange. While the climatic suitability maps provide insights about potential growing areas and areas gaining and losing in suitability, they do not provide seasonal advice, nor do they take into account topography or other biophysical factors.

Paddy cultivation practices are highly diverse; it is therefore difficult to assess with certainty the potential impacts of climate change on rice production. However, model evaluations suggest that while Bhutan might gain additional rice areas since cultivation would move to higher temperate areas, it would also experience loss in area mostly in southern lowlands and eastern lower altitude valleys (Parker et al., 2018). Additional areas might be lost also due to changes in the onset of the rainy season, more frequent and intense droughts and increased frequency of extreme weather events.

Areas suitable for maize will likely expand; particularly, where maize already contributes significantly to livelihoods in eastern and southern districts of Bhutan (ibid.). However, in the absence of adaptation measures, maize yield could be affected by extremely dry conditions, more frequent windstorms, and delays in the onset of rains. The model results for potatoes reveal a gradient, where lower altitude areas in the south (<1,000 m) become unsuitable, driven by increasing temperatures, whilst the mid-altitude areas (1,000–3,000 m) experience expansion in areas that are suitable (ibid.). Similarly, most of the lower altitude valleys will also become less suitable for one of Bhutan’s staple vegetables, chili (ibid.).

Increases in both temperature and rainfall suggest a reduced climate suitability for one of the main cash crops in Bhutan – lower altitudes in southern districts will become less suitable for cardamom production with some gains in their mid-altitude areas (ibid.). Another important cash crop in Bhutan, mandarin orange, is projected to see expansion in suitability due to increasing temperatures, particularly in Samtse, Punakha and eastern districts, while at the same time some losses in the warm low-altitude valleys in the south (Phuntsho and Dorji, 2018). However, this does not consider the likely increase in pests and disease pressure under increased temperature which could offset the gain made in terms of areas.

Future crop suitability for Bhutan

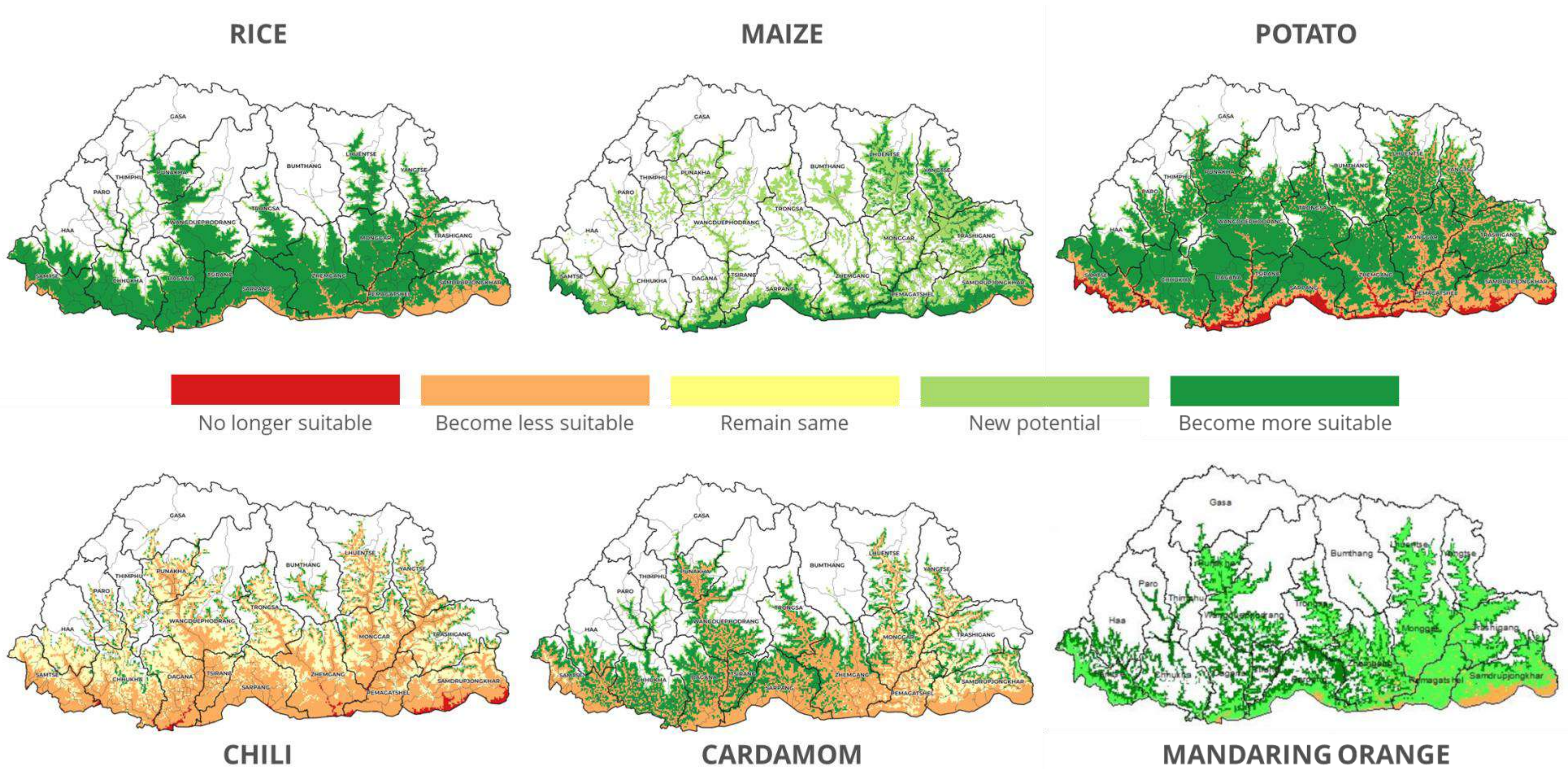


FIGURE 21. MAPS SHOWING THE FUTURE CLIMATE SUITABILITY FOR RICE, MAIZE, POTATO, CHILI, CARDAMOM, AND MANDARIN ORANGE BY 2050 UNDER RCP8.5 SCENARIO. FOR THE MANDARIN ORANGE MAP, COLOURS ARE SWITCHED WITH LIGHT GREEN SHOWING MORE SUITABLE AREAS AND DARK GREEN SHOWING NEW POTENTIAL. SOURCE: BASED ON PARKER ET AL., 2018; PHUNTSHO AND DORJI, 2018.

Future value chains

- A description of future value chain risks, opportunities and interventions (incl. case studies for four Dzongkhags) (Information from value chain analysis and stakeholder/community consultations)
- Can utilize the proposed template below for each identified/target value chain:

Value chain actor	Future risks	Future opportunities	Potential intervention (recommendations)	Target beneficiary	Potential partnerships for implementation
Input Suppliers					
Producers (Farmers)					
Processors					
Traders					
Distributors					
Consumers					

Dzongkhag	Source	Risks	Opportunities
Sarpang	Value chain analysis	Continued human-wildlife conflict, climate change effects (unpredictable monsoon), water scarcity.	Expansion of winter vegetable production, development of water management infrastructure, leveraging bulk market access within Dzongkhag.
	Community consultations	Increased temperature and erratic rainfall impacting water-intensive crops like paddy.	Investment in irrigation infrastructure, introduction of drought-resistant crop varieties, and development of local markets.
Tsirang	Value chain analysis	Vulnerability to climate change (hailstorms), biosecurity threats from disease outbreaks, market saturation for new crops like avocado.	Strengthening controlled environment vegetable production, establishing sugarcane processing facilities, promoting dairy product value addition and branding.
	Community consultations	Labor shortages and climate variability affecting crop and livestock productivity Pests and diseases in poultry and increased heat stress.	Promoting labor-saving technologies, improving market access, expanding greenhouse farming and promoting/diversifying climate-resilient vegetable varieties.
Trongsa	Value chain analysis	Human-wildlife conflict, market volatility for cash crops like potatoes, climate unpredictability.	Enhancing dairy product branding for premium markets, improving market linkages for vegetable and potato producers, promoting eco-tourism to support agricultural livelihoods.
	Community consultations	Human-wildlife conflict and climate change affecting traditional crops like cardamom.	Developing community-based wildlife management programs, promoting high-value crops, and enhancing agricultural extension services.

			Diversifying into less water-dependent crops and enhancing irrigation infrastructure.
Zhemgang	Value chain analysis	Isolation and market access issues, high predation rates on livestock, crop damage from wildlife.	Developing eco-tourism as a supplementary income source, centralized milk processing to create an assured market, expanding ginger and turmeric cultivation for export markets.
	Community consultations	Pest and disease outbreaks, infrastructural deficiencies climate variability (hot and dry conditions leading to decline in orange production)	Strengthening pest management programs, investing in infrastructure, and promoting value-added products. Promoting bamboo and cane crafts as alternative livelihoods and adopting greenhouse farming techniques.

Recommendations:

1. **Climate-Resilient Crop Introduction**: To bolster agricultural resilience in the face of climate change, introduce and promote climate-resilient crops in Gewogs most affected by erratic rainfall and rising temperatures. Prioritize regions where traditional, water-intensive crops like paddy are struggling to thrive. Shifting cultivation towards less water-dependent alternatives such as pulses, vegetables, or cardamom can significantly reduce vulnerability to unpredictable weather patterns.

2. **Water Management and Irrigation Infrastructure**: Enhance water security and prioritize the development of water management systems, including catchment protection, construction of both source and on-farm water storage infrastructures, rainwater harvesting initiatives, and widespread adoption of efficient irrigation systems to mitigate water scarcity challenges in agriculture.

3. **Enhancement of Agricultural Value Chains**: Strengthen value chains for both crops and livestock by focusing on post-harvest processing, storage, and market access. Prioritize investments in post-harvest handling, processing, capacity development of farmers, and market access for crops like oranges, ginger, vegetables and cardamom, as well as livestock products including dairy, eggs, and meat. Establishing local processing units and improving cold storage facilities can reduce post-harvest losses and increase the marketability of these products.

4. **Human-Wildlife Conflict Mitigation**: Prioritize interventions to mitigate human-wildlife conflicts, which are a significant threat to agricultural productivity. This could include the installation of more effective barriers such as chain-link fencing and develop alternative livelihoods that are less prone to wildlife damage.

5. **Training in Climate-Resilient Agricultural Practices:** Develop and implement capacity-building programs focused on climate-resilient agricultural practices. This includes training farmers in techniques such as crop diversification, use of poly-houses, water-efficient irrigation methods, and organic farming. These programs should be tailored to the specific needs of different Dzongkhags based on their unique climatic challenges and livelihood activities.

6. **Gender-Inclusive Capacity Building**: Ensure that capacity-building programs are inclusive of women, who are a large part of the agricultural workforce but often lack access to training and resources. Special attention should be given to empowering women in decision-making roles and equipping them with the skills needed to engage in higher-value agricultural activities.

7. **Policy Development for Sustainable Land Use**: Advocate for policies that support sustainable land use, while addressing issues like land fragmentation, wildlife threats, and climate challenges. This includes facilitating easier access to state land for commercial agriculture, and providing incentives for the adoption of climate-smart agricultural practices.

8. **Strengthening Institutional Support and Market Linkages**: Develop policies that provide more institutional support to small farmers, including better access to credit, insurance, and extension services. Improve market linkages by building better road infrastructure, establishing more efficient supply chains, and creating opportunities for direct farmer-to-market sales.

9. **Climate-integrated agricultural- planning**: Promote the integration of climate data and forecasting into agricultural planning and decision-making processes. This will enable farmers to better anticipate and adapt to shifting climatic conditions, reducing the likelihood of crop failures and financial losses. This approach is crucial in Bhutan, where farming is highly dependent on climatic conditions, and where climate change is already altering traditional weather patterns.

Next steps for CLEAR+ in Bhutan

- Conduct community consultations and field validation of livelihood zones and activities in Dzongkhags other than Trongsa, Tsirang, Sarpang and Zhemgang; following the same methodology as it was developed for the four selected Dzongkhags. This would provide an in-depth information on local climate and non-climate challenges and livelihood activities of rural farming communities that could be then used together with the climate information provided in the present study to develop specific adaptation options to enhance food security and income generation.
- Carry out a livelihood-level nutritional study in Bhutan to provide critical data to inform and optimize agricultural practices, ensuring that crop choices and farming methods support better nutrition outcomes for the population. Additionally, this analysis could guide the development of targeted livelihood programs that address specific nutritional deficiencies, thereby enhancing overall community food security, health and productivity.
- Carry out a livelihood-level social safety nets analysis in Bhutan to provide critical insights into how existing support mechanisms are meeting the needs of vulnerable rural populations, thereby allowing for targeted adjustments to livelihood activities to enhance resilience and food security. Additionally, this analysis could help identify gaps and opportunities for integrating traditional practices with modern safety nets, fostering sustainable development and improved well-being across communities.

REFERENCES

AAA and CGIAR, 2024. *Feeling the heat – the effects of higher temperatures on people, crops and livestock*. Available online: https://adaptationatlas.cgiar.org/data-insights/feeling-the-heat

Asian Development bank (2013). Bhutan Critical Development Constraints. Available online: https://www.adb.org/sites/default/files/publication/30350/bhutan-critical-development-constraints.pdf

Chhogyel, N. and Kumar, L., 2018. Climate change and potential impacts on agriculture in Bhutan: a discussion of pertinent issues. *Agriculture & food security*, 7(1), pp.1-13. Available online: https://link.springer.com/article/10.1186/s40066-018-0229-6

DesInventar, 2024. *DesInventar: Bhutan*. Available from: https://www.desinventar.net/DesInventar/results.jsp

FAO, 2023. *National gender profile of agriculture and rural livelihoods – Bhutan*. Country gender assessment series. Thimphu: FAO. Available online: https://www.fao.org/3/cc5273en/cc5273en.pdf

Google Imagery and TerraMetrics, 2024. *Satellite imagery of Bhutan*. Available online: https://maps.app.goo.gl/mi53b6n8eA71sTtX9

Gross National Happiness Commission (GNHC), 2019. *12th Five Year Plan Document*. Thimphu: GNHC, Royal Government of Bhutan. Available online: https://lpr.adb.org/resource/twelfth-five-year-plan-2018-2023-volume-i-ii-bhutan

Katwal, T.B., Dorji, S., Dorji, R., Tshering, L., Ghimiray, M., Chhetri, G.B., Dorji, T.Y. and Tamang, A.M., 2015. Community perspectives on the on-farm diversity of six major cereals and climate change in Bhutan. *Agriculture*, 5(1), pp.2-16. Available online: https://www.mdpi.com/2077-0472/5/1/2

Ministry of Education (MoE), 2011. *National Youth Policy*. Available online: http://www.education.gov.bt/wp-content/uploads/2021/09/youth-policy-1.pdf

MoAL and BES, 2023. *Developing Bhutan Agro-Ecological Zones (BAEZ): Bhutan PyAEZ Version 1.0*. Report and data.

NCHM, 2019. *Analysis of Historical Climate and Climate Projection for Bhutan*. Report. Available online: https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/Analysis%20of%20Historical%20Climate%20and%20Climate%20Change%20Projection.pdf

NCHM, n.d. *Compendium of Climate and Hydrological Extremes in Bhutan (2017-2021)*. Available from: https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/Compendium%20of%20extreme%20events%20vol2.pdf

NCHM, 2022. *Records of Extreme Weather Events in Bhutan 2022*. Available from: https://www.nchm.gov.bt/attachment/ckfinder/userfiles/files/Extreme%20Weather%20Events%20Records%202022_docx-compressed.pdf

NCWC, 2020. *National Gender Equity Policy*. Available online: https://www.ncwc.gov.bt/publications/National_gender_equality_policy1583629305.pdf

NCWC, the World Bank and AusAID, 2013. Bhutan Gender Policy Note. Available online: https://www.ncwc.gov.bt/publications/Bhutan%20Gender%20Policy%20Note.pdf

NEC, 2023. *National Adaptation Plan (NAP) of the Kingdom of Bhutan*. Available from: http://www.nec.gov.bt/publications/climate-change

NEC and UNDP, 2023. *Climate Change Vulnerability Analyses and Mapping for National Adaptation Plan (NAP) Formulation Process in Bhutan*. Report and data. Report available from: http://www.nec.gov.bt/publications/climate-change

NLCS DoR, 2016. *Road network of Bhutan*.

NLCS, n.d. *Water drainage network of Bhutan*.

NLCS DoSAM, 2023. *Land Use Land Cover of Bhutan 2020: Maps and Statistics*.

NPPC, 2024. *Vertebrate pests (Wildlife)*. Available online: https://pestsofbhutan.nppc.gov.bt/crop-and-pest-identification/wildlife-vertebrate-pests/

NSB, 2018. 2017 *Population and Housing Census of Bhutan (PHCB)*. Report and data. Report available online: https://www.nsb.gov.bt/publications/census-report/

NSB and MoAF, 2019. *RNR Census of Bhutan 2019*. Report and data. Report and some data available online: https://www.nsb.gov.bt/rnr-census-reports/

NSB, 2022a. *Integrated Agriculture and Livestock Census of Bhutan*. Report. Available online: https://www.nsb.gov.bt/integrated-agriculture-and-livestock-census-of-bhutan-2022/

NSB, 2022b. *Agriculture Spatial Information for Paddy Cultivation (2022 ASI4PC)*. Report. Available online: https://www.nsb.gov.bt/agriculture-spatial-information-for-paddy-cultivation-2022-asi4pc/

NSB, 2022c. *Poverty Analysis Report: Bhutan 2022*. Report. Available online: https://www.nsb.gov.bt/publications/poverty-analysis-report/

NSB, 2022d. *2022 Bhutan Living Standards Survey Report*. Report. Available online: https://www.nsb.gov.bt/publications/bhutan-living-standard-survey-report/

NSB, 2023. *Statistical Yearbook 2023*. Report. Available online: https://www.nsb.gov.bt/publications/statistical-yearbook/

NSB and the World Bank, 2023. *Poverty Mapping in Bhutan. Small Area Estimation: Gewog and Town Level Results*. Report. Available online: https://www.nsb.gov.bt/wp-content/uploads/dlm_uploads/2023/12/BSAER.pdf

Parker, L., Guerten, N., Nguyen, T.T., Rinzin, C., Tashi, D., Wangchuk, D., Bajgai, Y., Subedi, K., Phuntsho, L., Thinley, N. and Chhogyel, N., 2017. *Climate change impacts in Bhutan: challenges and opportunities for the agricultural sector*. CCAFS Working Paper. Report and data. Report available online: https://cgspace.cgiar.org/items/74d5253f-e7e4-4212-906f-776889cf372c

Phuntsho, L. and Dorji, L., 2018. Potential Impact of Climate Change on the Scope of Important Fruit Crops. *Bhutanese Journal of Agriculture*, 1(1), pp. 35-42. Available online: https://www.bja.gov.bt/wp-content/uploads/2019/06/4.pdf

Tempa, K. and Yuden, K., 2023. Multi-hazard zoning for national scale population risk mapping: a pilot study in Bhutan Himalaya. *Geoenvironmental Disasters*, 10(1), p.7. Available from: https://link.springer.com/article/10.1186/s40677-023-00239-4

Tenzin, J., Phuntsho, L. and Lakey, L., 2019. Climate Smart Agriculture: Adaptation and Mitigation Strategies to Climate Change in Bhutan. In: *Climate Smart Agriculture: Strategies to Respond to Climate Change in South Asia*. SAARC Agriculture Centre (SAC): Dhaka, Bangladesh. Pp.37-61. Available online: https://www.researchgate.net/publication/335137542_Chapter_3_Climate_Smart_Agriculture_Adaptation_and_Mitigation_Strategies_to_Climate_Change_in_Bhutan

UNEP-WCMC and IUCN, 2024. *Protected Planet: The World Database on Protected Areas (WDPA)*. Cambridge, UK: UNEP-WCMC and IUCN. Available online: www.protectedplanet.net

Verma, R., and Ura, K., 2021. Gender differences in gross national happiness: Analysis of the first ever nationwide survey in Bhutan. *World Development*, 150, p.105714. Available online: https://www.sciencedirect.com/science/article/abs/pii/S0305750X21003296

WFP, 2015. *Policy on Building Resilience for Food Security and Nutrition*. Available online: https://www.wfp.org/publications/policy-building-resilience-food-security-and-nutrition

WFP, 2016. *The CLEAR approach: The Consolidated Livelihoods Exercise for Analyzing Resilience*. Available online: https://weadapt.org/knowledge-base/vulnerability/the-clear-approach/

WFP, 2021. *Six ways Bhutan is building better food systems – from farm to table*. Available online: https://www.wfp.org/stories/6-ways-bhutan-building-better-food-systems-farm-table

WFP, in preparation. *CLEAR+ Guideline: Consolidated Livelihood Exercise for Analyzing Resilience*.

World Bank and Asian Development Bank (ADB), 2021. *Climate Risk Country Profile: Bhutan (2021)*. Available from: https://www.adb.org/publications/climate-risk-country-profile-bhutan

WorldPop and CIESIN, 2020. *Global High Resolution Population Denominators Project: Population density in2020, Bhutan*. Estimated population density per grid-cell (People/Km^2) at a resolution of 30 arc (approximately 1km at the equator). Available online: https://hub.worldpop.org/geodata/summary?id=40255

GLOSSARY

ASI4PC	Agriculture Spatial Information for Paddy Cultivation
ARP	Agriculture Resilience Plan
BAEZ	Bhutan Agro-ecological Zones
BES	Bhutan Ecological Society
BRECSA	Building Resilience Enhancing Sustainable Commercial Agriculture
CLEAR	Consolidated Livelihood Exercise for Analyzing Resilience
CO	Country Office
DoSAM	Bhutan Department of Surveying and Mapping under NLCS
DoR	Bhutan Department of Roads under NLCS
FAO	Food and Agriculture Organization of the United Nations
GLOF	Glacial lake outburst flood
IALC	Integrated Agriculture and Livestock Census of Bhutan
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
LULC	Land Use Land Cover
MoAF	Bhutan Ministry of Agriculture and Forestry

MoAL	Bhutan Ministry of Agriculture and Livestock
NAP	National Adaptation Plan
NCHM	Bhutan National Center for Hydrology and Meteorology
NCWC	Bhutan National Commission for Women and Children
NEC	Bhutan National Environment Commission
NLCS	Bhutan National Land Commission
NPPC	Bhutan National Plant Protection Centre
NSB	Bhutan National Statistics Bureau
NWFP	Non-wood forest product
PHCB	Population and Housing and Census
PWD	Persons with disabilities
RBB	WFP Regional Bureau for Asia and the Pacific
RNR	Renewable Natural Resources
WFP	World Food Programme

ANNEXES

Annex I: Methodology

Overview

The present study uses WFP's Consolidated Livelihood Exercise for Analyzing Resilience (CLEAR+) framework to assess the climate resilience of smallholder farmers and rural communities in Bhutan (WFP, 2016; WFP, in preparation). The methodology explores the relationship between climate change and food security by putting communities and their livelihoods at the center of the analysis. This information can be used to design and implement interventions within the Building Resilience Enhancing Sustainable Commercial Agriculture (BRECSA) project that enhance food security and promote sustainable agricultural practices in a changing climate.

The CLEAR+ framework is a participatory process that involves four general steps: scoping, livelihood zoning, resilience analysis, and analysis of climate change impacts. While the steps build on each other, the results of each step can also be used independently. In each of these steps, data is collected through a combination of secondary sources, and stakeholder and community consultations at the field level. The CLEAR+ methodology is designed to be flexible and adaptable to local needs and contexts. During the scoping step in Bhutan, the following CLEAR+ methodology was developed in order to inform the development of Gewog- and Dzongkhag-level Agriculture Resilience Plans in the four pre-selected Dzongkhags (Sarpang, Trongsa, Tsirang, and Zhemgang):

SCOPING	• Adaptation of CLEAR+ methodology to address Bhutan and BRECSA's thematic priorities (i.e., focus on smallholder farmers, food security and value chains) in close collaboration with relevant stakeholders and national authorities. • Formulation of core CLEAR+ technical working group, supported by WFP Bhutan CO and RBB experts. • Identification and collection of relevant secondary data and information.
LIVELIHOOD ZONING	• Preliminary livelihood zone mapping for the whole Bhutan using secondary data sources and expert knowledge. • Government and community consultations in the four selected Dzongkhags for additional livelihood information, field validation, and participatory identification of current and anticipated climate change impacts on local livelihoods. • Revision of livelihood zones in the four selected Dzongkhags based on the field, stakeholder and community validation.
CLIMATE RESILIENCE ANALYSIS	• Communities identified factors that help households bounce back after climate-related shocks. The most common responses were: Access to wealth, food and land; Livelihood diversity; Access to irrigation and non-climate sensitive livelihood options. • Relevant socioeconomic indicators were identified from the population census (2017), agricultural census (2019) and the small area estimations of poverty (2023). • Combined resilience score was calculated using the identified data for the whole Bhutan.
VALUE CHAIN MAPPING	• Consultations and mapping of value chain functions for additional information on overall agricultural system and livelihoods in the four selected Dzongkhags. • Participatory identification of current and anticipated climate change impacts on current and potential future value chains.
ANALYSIS OF CLIMATE CHANGE IMPACTS	• Analysis of past climate trends using historical data (i.e., indicators on historical climate variability and seasonality and record of climate disasters). • Analysis of future climate trends using model-based projections of future climate conditions. • Translating the climate analysis findings into food security and livelihood impacts, based on expert knowledge and interpretation of climate science.
AGRICULTURE RESILIENCE PLANS	• Participatory identification of agroecological approaches and technologies to reduce food and nutritional insecurity and increase resilience of rural communities to current and anticipated impacts of climate change. • Tailored climate adaptation options and solutions that respond to community level needs and market access related blockages.

Methodology:

The purpose of the CLEAR+ exercise was to conduct face to face interaction and consultation with communities to understand and assess their livelihood ststus and to study the impacts of the climate change on their livelihood activities. 37 gewogs in Sarpang, Zhemgang, Trongsa and Tsirang were covered under this project and the CLEAR consultants met local leaders, men and women, youth and people with disabilities. The CLEAR consultation include the following approaches:

Objective

1. To identify the following key components of the community livelihood
    - Main livelihood activities
    - Risks, gaps, and opportunities
    - Availability of assets
    - Vulnerability to climate-related hazards and its coping strategies
    - Role of gender
2. To identify the key challenges and opportunities

Participant identification

A total of 619 individuals (464 male and 155 female) participated in the consultation meetings across 37 gewogs. The participants were highly engaged and openly shared their views without concerns. They also used the meetings as an opportunity to express their concerns and discuss the challenges they face in improving their livelihoods.

The following participants are expected to attend the consultation:

1. Local leaders
2. Community members
    - Village elders
    - Women
    - Youth
    - People with disability
3. Agriculture Extension Officer
4. Livestock Extension Officer
5. Forestry Extension Officer

Number of participants (see number of participants in Table 3)

- 20 to 30 participants

Development of Questionnaire (see the questionnaire in Table 2)

With support from the CLEAR+ team:

1. Design a comprehensive consultation questionnaire that includes components on
    - Priority livelihood activities
    - Seasonal calendar
    - Asset availability
    - Labor market dynamics
    - Climate hazards and coping mechanism
    - Human wildlife conflict
    - Value chain activities
    - Market
    - Gender roles
    - Food security

Besides, livelihood maps for all the 37 gewogs were printed and used extensively during the consultation meetings.

2. Livelihood mapping

Timing

Community consultations were carried out between 11th March to 7th April 2024. The BRESCA office in Gelephu communicated and made schedule arrangements with the gewogs.

Community consultation

The CLEAR community consultations were conducted by two consultants, beginning in Sarpang Dzongkhag and then moving on to Trongsa, Zhemgang, and finally Tsirang. In Zhemgang and Tsirang Dzongkhags, the consultants paid courtesy visits to the Dasho Dzongdhas and Dzongrabs, respectively. However, in Sarpang and Trongsa, such visits were not made due to the local government leaders being fully occupied.

The CLEAR community consultations were successfully conducted, yielding a wealth of information and data that were instrumental in developing the Agriculture Resilience Plan (ARP). The meetings were highly interactive and inclusive, ensuring that all participants had the opportunity to express their views, share their concerns, and communicate their expectations. Given that agriculture is the primary livelihood activity, the communities were deeply engaged and actively participated in all sessions. The information and data collected included the following:

- Livelihood and economic activities
- Asset availability and economic welfare
- Labour market dynamics
- Climate hazards and coping mechanisms
- Human-wildlife conflicts
- Value chain activities
- Market
- Gender roles and
- Food security

As evidence, with prior consent, video recordings on some of the sessions were done and a lot of pictures were collected.

Data compilation

- The information and data collected were reviewed, analyzed and refined using both qualitative and quantitative approaches. A CLEAR community consultation report was produced.
- During the data review and analysis processes, to validate, telephone calls were made to local leaders, villagers and extension workers to confirm the data and information.

Submission of Community Consultation Report

1. Submission of daily summary report of the consultation meeting

2. Final report submission to WFP office

TABLE 2. QUESTIONNAIRE USED DURING THE COMMUNITY CONSULTATIONS IN SARPANG, TRONGSA, TSIRANG AND ZHEMGANG.

COMMUNITY CONSULTATIONS: LIVELIHOODS AND CLIMATE RESILIENCE

1. General Information

Date	
Gewog	

Dzongkhag	
Coordinates	

2. Respondents' details

Number of Participants by Gender	Male:		Female:	
Number of Participants by Age Group	Below 18:	19 – 30:	31 – 50:	50 and above:
Number of Participants by Ability	Abled:		Persons with Disabilities:	

FOCUS GROUP DISCUSSION CONTENTS

Section 1: Livelihoods and Economic Activities

Question	Reflection	Summary
What are the four main livelihood activities in your community?		
Seasonal calendar: Legends: Seeding/nursery: S, Transplanting: T, Basin preparation: B, Weeding: W, Harvesting: H, Off-farm work: O, Season (S=Summer, W=Winter)		

Activity/Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Question	Reflection	Summary
In the Gewog what percent of the people would carry out **activity 1?**		
What portion of food/income does it represent?		
In the gewog what percent of people would carry out **activity 2?**		
What portion of food/income does it represent?		
In the gewog what percent of people would carry out **activity 3?**		
What portion of food/income does it represent?		
In the gewog what percent of people would carry out **activity 4**?		

What portion of food/income does it represent?		
In the gewog what percent of people would carry out **activity 5**?		
What portion of food/income does it represent?		
In the gewog what percent of people would carry out **activity 6**?		
What portion of food/income does it represent?		
What are the key challenges related to each of the livelihood activities?		

Section 2: Asset availability and economic welfare

Question	**Reflection**	**Summary**
Please provide information on the current availability of assets crucial for community welfare and economic activities		
Assets holding - Land - Livestock - Machineries - Education		
What are the main differences between the rich and a poor?		

Section 3: Labor market Dynamics

Question	**Reflection**	**Summary**
How would you describe the current dynamics of the local labour market?		
Are there any trends or changes in the labour market that you have observed recently?		
Has any member of your household engaged in wage labour or employment outside your primary livelihood activities? (yes or no)		
What % of the people in the Gewog would perform off-farm works?		
What is the approximate household income contributed by off-farm work?		
What are the characteristics of households that engage in off-farm works?		

Section 4: Climate Hazards and Coping Mechanisms

Question	**Reflection**	**Summary**
How has the climate in your community changed over the past decade?		

What specific climate-related hazards do you consider most threatening to your community?		
When does it occur		
How is the community currently coping with climate-related changes and hazards?		
Who are the most impacted/vulnerable community/why they are vulnerable		
What are climate induced risks the community faces? Risk per crop		

Section 5: Human-Wildlife Conflict (HWC)

Question	**Reflection**	**Summary**
Key species of HWC:		
Impact and extent of crop damage		
How is the community currently coping with wild animals?		
What support is needed		

Section 6: Value Chain Activities

Question	**Reflection**	**Summary**
Describe the value chain processes involved in your main livelihood activities.		
What are the main risks and gaps, in the current value chain processes?		
Are there any opportunities in the current **activity 1 value chain**		
Is **activity 1** cultivated for sale or own consumption		
If sale how much % is sold		
What are the main climate risks in **activity 1**?		
Are there any opportunities in the current **activity 2 value chain**		
Is **activity 2** cultivated for sale or own consumption		
If sale how much % is sold		
What impacts does climate change cause to **activity 2**		
Are there any opportunities in the current **activity 3 value chain**		
Is **activity 3** cultivated for sale or own consumption		

If sale how much % is sold		
What impacts does climate change cause to **activity 3**		
Are there any opportunities in the current **activity 4 value chain**?		
Is **activity 4** done for sale or own consumption		
If sale how much % is sold		
What impacts does climate change cause to **activity 4**		
Are there any opportunities in the current **activity 5 value chain**?		
Is **activity 5** done for sale or own consumption		
If sale how much % is sold		
What impacts does climate change cause to **activity 5**		

Section 7: Market

Question	**Reflection**	**Summary**
Where is/are the market(s)		
How far is the market from your GC?		
How is the road connectivity		
Market		
Value addition		
Can you sell all your products		

Section 8: Gender roles

Question	**Reflection**	**Summary**
What are the main activities taken up by women in farming?		
What are the main activities taken up by men in farming?		
Who brings the main income to the household?		
Who makes the decision about farming?		

Section 9: Food security

Question	Reflection	Summary
What are the main sources of food		
Does it come from own production, or they buy them?		
What would be the % of food bought?		
Are there any food insecurity problems in the Gewog		
When does food insecurity occur?		
Which chiwogs and communities experience them?		
Why are these places food insecure?		
What is the Gewog doing to resolve it?		

Section 10:

Additional comments or aspirations of the participants:

TABLE 3. NUMBER OF MALE AND FEMALE PARTICIPANTS IN THE COMMUNITY CONSULTATIONS BY GEWOG.

GEWOG	MALE	FEMALE	TOTAL
1. Zhemgang Dzongkhag			
Trong	13	3	16
Ngangla	15	5	20
Bjoka	14	1	15
Goshing	12	0	12
Bardo	7	5	12
Nangkhor	13	0	13
Shingkhar	13	1	14
Pangkhar	14	0	14
	101	**15**	**116**
2. Trongsa Dzongkhag			
Tangsibji	5	4	9
Korphu	7	3	10
Nubi	8	3	11
Langthel	7	6	13
Dragten	7	9	16

	34	**25**	**59**
3. Sarpang Dzongkhag			
Chudzom	13	1	14
Samtenling	1	9	10
Jigmechholing	9	1	10
Serzhong	4	7	11
Gadkiling	6	4	10
Umling	8	6	14
Chuzaygang	6	7	13
Tareythang	4	2	6
Gelephu	11	3	14
Dekiling	13	2	15
Shompangkha	4	5	9
Senggel	9	4	13
	88	**51**	**139**
4. Tsirang Dzongkhag			
Barshong	22	0	22
Mendrelgang	15	10	35
Patshaling	31	4	35
Selrithang	19	8	27
Phuentenchu	23	0	23
Tsirangtoe	20	3	23
Shemjong	17	6	23
Dunglagang	23	1	24
Gosarling	20	3	23
Tsholingkhar	13	14	27
Kilkhorthang	17	12	29
Rangthaling	21	3	24
	241	**64**	**305**
Total	**464**	**155**	**619**

LIVELIHOOD MAPPING

Livelihood zones are broad geographic areas where communities engage in relatively similar food production and cash income-earning activities, and have comparable access to markets (or other discerning characteristics). By focusing on livelihoods (rather than administrative units), the spatial analysis allows for targeted interventions that address the specific needs and capabilities of smallholder farmers within each zone. This ensures that interventions are more effective and have a greater impact on improving food security and building climate resilience.

Livelihood zone mapping for Bhutan was carried out through the three main activities:

1. Draft livelihood zone map and characterisation for Bhutan

The first activity in livelihood zoning in Bhutan was to create a rough livelihood map by overlaying the following secondary data sources: population density (WorldPop, 2020), road density (DoR, 2016), water bodies (NLCS), elevation and slope (AsterDEM from Parker et al., 2017), agro-ecological zones (MoAL and BES, 2023), land use and land cover (NLCS DoSAM, 2023; NSB, 2022b; Chhogyel and Kumar, 2018), population census (NSB, 2017), agriculture censuses (NSB, 2019; NSB, 2022a), protected areas (UNEP-WCMC and IUCN, 2024), and annual rainfall and temperature (NCHM, 2019). This map served as a starting point and was corrected and refined through multiple meetings and reviews with food security and country experts and validated through Google satellite imagery (Google Imagery and TerraMetrics, 2024) in order to produce a draft livelihood zone map and descriptions for the whole country of Bhutan.

ELEVATION AND SLOPE
(AsterDEM from Parker et al., 2017)

ROADS AND RIVERS
(NLCS; DoR, 2016)

LAND USE
(NLCS DoSAM, 2023)

AGRO-ECOLOGICAL ZONES
(MoAL and BES, 2023)

PROTECTED AREAS
(UNEP-WCMC and IUCN, 2024)

SATELLITE IMAGERY
(Google Imagery and TerraMetrics, 2024)

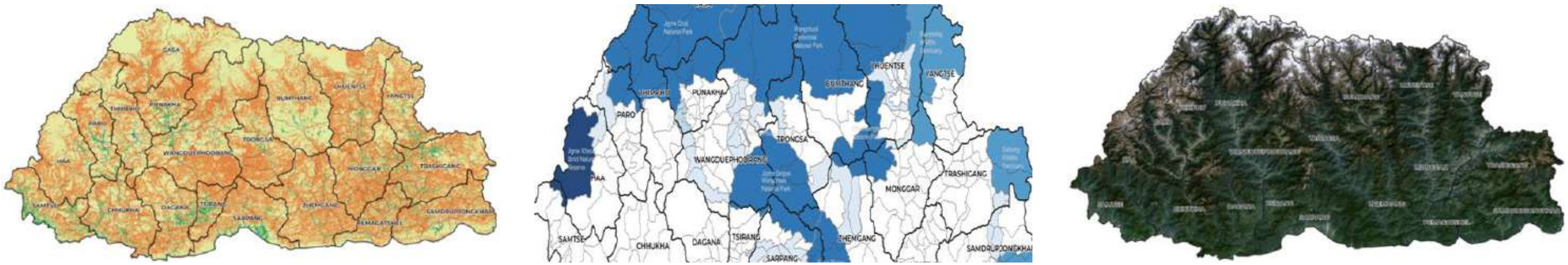


FIGURE 22. SOME OF THE DATA THAT WAS USED FOR THE PRELIMINARY LIVELIHOOD ZONING.

2. Validation of draft livelihood zones through field visits in four selected Dzongkhags

The second activity was to develop three maps (a draft livelihood map; a map of agro-ecological zones based on elevation; an empty map for participatory mapping of livelihood zones) that were used for livelihood zone validation in consultations with Dzongkhag and Gewog authorities and local communities in the four selected Dzongkhags during field visits. These consultations not only validated livelihood zones, but also provided additional information on livelihood dynamics (for more information, see detailed consultations methodology).

EMPTY MAP LIVELIHOOD MAP ELEVATION MAP

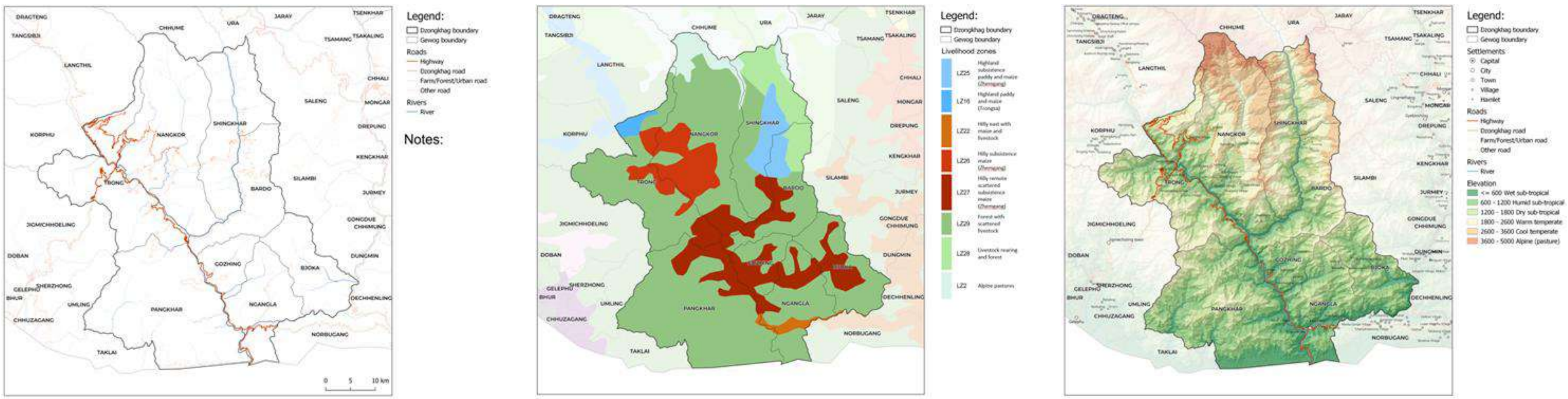


FIGURE 23. AN EXAMPLE OF MAPS PRODUCED FOR PARTICIPATORY MAPPING DURING THE COMMUNITY CONSULTATIONS IN BHUTAN.

3. Final livelihood zone map and characterisation for Bhutan

Based on the observations and consultations during field visits, livelihood zones were revised for the four selected Dzongkhags, and a final livelihood map and livelihood profiles were developed for Bhutan (see Annex II for livelihood profiles). In the future, it is recommended to also carry out field visits to Dzongkhags not covered in the present exercise in order to validate livelihood information in those areas.

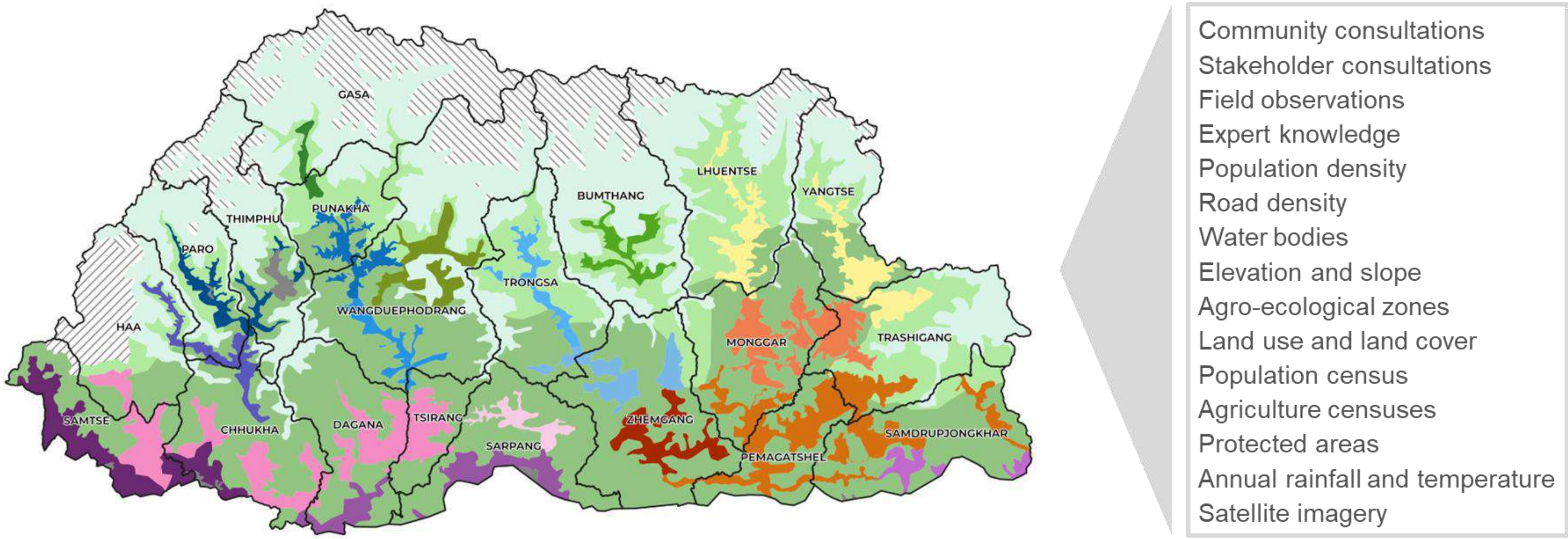


Figure 24. Data used for the final livelihood zone map for Bhutan.

Climate resilience analysis

WFP, along with FAO and IFAD, defines resilience as “the capacity to ensure stressors and shocks do not have long-lasting adverse developmental consequences” (WFP, 2015). The CLEAR approach focuses specifically on climate resilience – in other words people’s ability to recover after climate-related stressors and shocks (such as changes in rainfall patterns, climate disasters or glacial melt). The present analysis ranks the level of climate resilience of rural livelihoods in Bhutan - i.e., the factors that enable rural communities to bounce back faster and build back better after a climate shock - and identifies areas for additional investment to enhance climate resilience.

Climate resilience analysis for Bhutan was carried out through the two main activities:

1. Identification of climate resilience factors

The selection of the climate resilient factors was based on the needs of BRECSA project and on the stakeholder and community consultations. The communities themselves identified factors that make smallholder farmers more resilient to climate shocks - the most common responses were classified into four categories: access to wealth, food, land and markets; livelihood diversity; and, access to irrigation and non-climate sensitive livelihood options.

2. Calculation of climate resilience indicators

Each of the identified factors was then matched with the available national secondary data sources. The indicators were calculated for each rural Gewog, normalized and divided into four parts (quartiles), each with an equal number of observations, ranking from 1 (most resilient) to 4 (least resilient). Autocorrelation and variance tests were applied to potential indicators in each category to avoid double-counting and select the datasets that enhance robustness of results. For the four selected Dzongkhags, the information was further complemented with primary data collected through consultations.

The climate resilience indicators and their data sources are described below:

• Access to wealth: Poverty is widely used for determining resilience. The indicator used was small area estimations of poverty using poverty incidence - also called the poverty rate or poverty headcount ratio, defined as the proportion of the population living in households whose per capita expenditure is below the poverty line (NSB and the World Bank, 2023). Ranking from 1 (lowest poverty rate) to 4 (highest poverty rate) was allocated based on quartiles.

• Remoteness: The consultations showed that road connectivity and distance to services greatly influences households' livelihood options and income in Bhutan. The indicator used was the proportion of households that are located more than 30 minutes away from the nearest motorable road head (NSB, 2017). Ranking from 1 (least remote) to 4 (most remote) was allocated based on quartiles.

• Access to food: Food insufficiency is an important factor of climate resilience. The indicator used was the proportion of households that faced a situation in the previous 12 months when there was not enough food to feed all members of the household (NSB, 2017). Ranking from 1 (least food insufficient) to 4 (most food insufficient) was allocated based on quartiles.

• Access to land: The consultations showed that land size and its usability are an important factor influencing households' livelihood options and income in Bhutan. The indicator used was an average value of the following two indicators: the average land size owned by farming households (ranking from 1 for largest to 4 for smallest land size), and the average proportion of the land owned by farming households that is left fallow (ranking from 1 for lowest to 4 for highest proportion of fallow land; NSB and MoAF, 2019).

• Livelihood diversity: A measure of the availability of alternative activities which households can rely on when their main source of food or income is diminished or destroyed by a shock. Livelihood diversity was quantified for each farming household by summing up the individual activities based on RNR statistics using the formula below (NSB and MoAF, 2019). Ranking from 1 (most diverse) to 4 (least diverse) was allocated based on the quartiles of the average number of activities households engage in for each rural Gewog.

Livelihood diversity = paddy (irrigated or upland) + maize + wheat + barley + millet + buckwheat (sweet or bitter) + amaranth or quinoa + legumes + vegetables + tubers + cardamom + areca nut + mandarin + other permanent crops + cattle + other livestock + fishery + forestry (wood or NWFP) + non-farming activities (agro-processing + handicrafts + trade + hotel/restaurant + agrotourism + other)

• Climate sensitivity of income: Households deriving the majority of their income from activities heavily dependent on climatic factors, such as agriculture and livestock, are estimated to be more climate sensitive than those that derive most or all their income from less or not climate-sensitive activities. Within agriculture, the degree of climate sensitivity also varies between different types of farming techniques and crops. In Bhutan, irrigated agriculture and crops protected by plastic cover tend to be less climate-sensitive than rain-fed agriculture or crops without protective cover. The indicator used was an average value of the following four indicators: the proportion of individuals over 14 years old whose main activity is RNR (ranking from 1 for lowest to 4 for highest engagement in RNR; NSB, 2017), the proportion of farming households that derive the majority of their income (>51%) from RNR activities (ranking from 1 for lowest to 4 for highest proportion of households deriving majority of their income from RNR activities), the proportion of farming households without any irrigation (ranking from 1 for lowest to 4 for highest proportion of households without any irrigation), and the proportion of farming households that do not use any protective cover for their crops/land (ranking from 1 for lowest to 4 for highest proportion of households without protective cover; NSB and MoAF, 2019).

Finally, once each of the categories was measured, we aggregated them into an index to obtain an overall measure of climate resilience for each rural Gewog. This index was created by adding up the rankings for each of the individual indicators, to come up with an overall resilience score. This final score presents a picture of Bhutan's overall climate resilience at the Gewog level, which allows for the development of targeted interventions that strengthen smallholder farmers' ability to withstand and recover faster after climate shocks thus ensure long-term food security.

TABLE 4. LIST OF INDICATORS USED IN THE PRESENT RESILIENCE ANALYSIS FOR BHUTAN.

Major components	Sub-components (Indicators)	Unit	Scale available	Year available	Data source
Access to wealth	Poverty rate, defined as the proportion of the population living in households whose per capita expenditure is below the poverty line	%	Gewog	2023	NSB and the World Bank (Small area estimates of poverty)
Remoteness	The proportion of households that are located more than 30 minutes away from the nearest motorable road head	%	Gewog	2017	NSB (PHCB)
Access to food	The proportion of households that faced a situation in the previous 12 months when there was not enough food to feed all members of the household	%	Gewog	2017	NSB (PHCB)
Access to land	The average land size owned by farming households	Acres	Gewog	2019	NSB and MoAF (RNR)
	The average proportion of the land owned by farming households that is left fallow	%	Gewog	2019	NSB and MoAF (RNR)
Livelihood diversity	The average number of livelihood activities carried out by farming households	Number	Gewog	2019	NSB and MoAF (RNR)

Climate sensitivity of income	The proportion of individuals over 14 years old whose main activity is RNR	%	Gewog	2017	NSB (PHCB)
	The proportion of farming households that derive the majority of their income (>51%) from RNR activities	%	Gewog	2019	NSB and MoAF (RNR)
	The proportion of farming households without any irrigation	%	Gewog	2019	NSB and MoAF (RNR)
	The proportion of farming households that do not use any protective cover for their crops/land	%	Gewog	2019	NSB and MoAF (RNR)

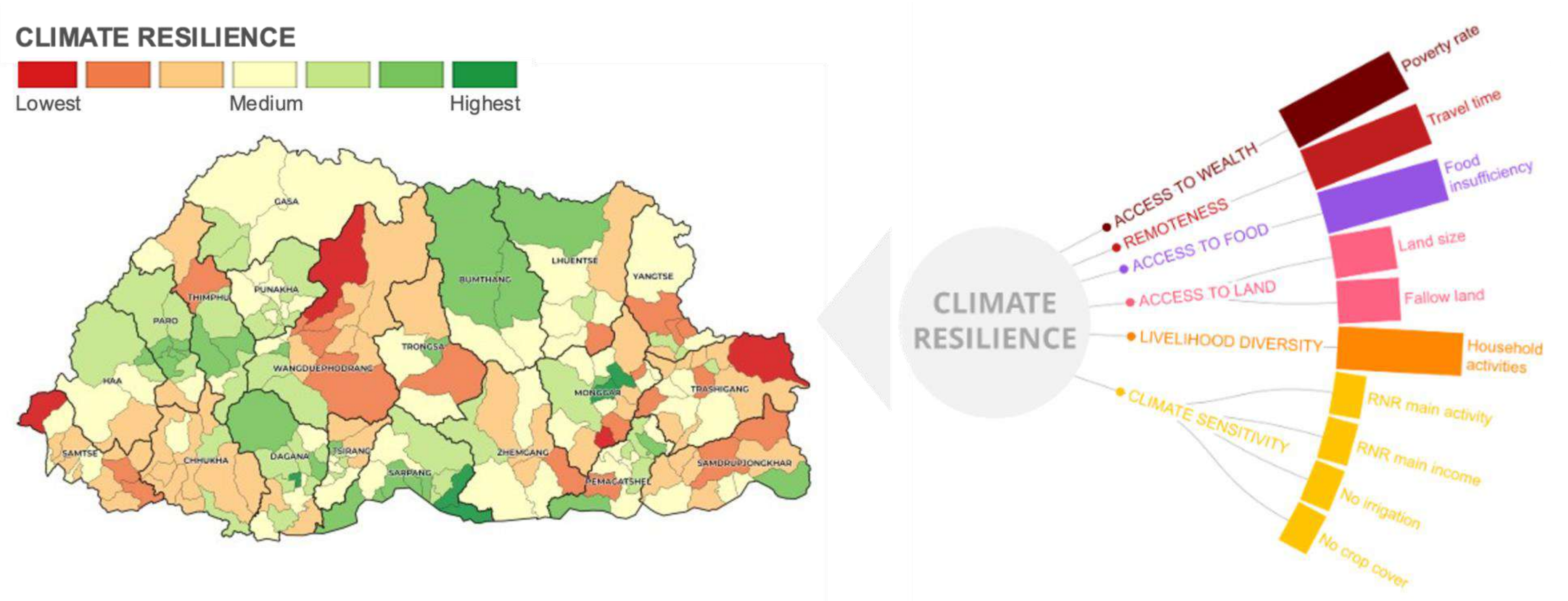


FIGURE 25. INDICATORS FOR CALCULATING THE OVERALL CLIMATE RESILIENCE FOR BHUTAN.

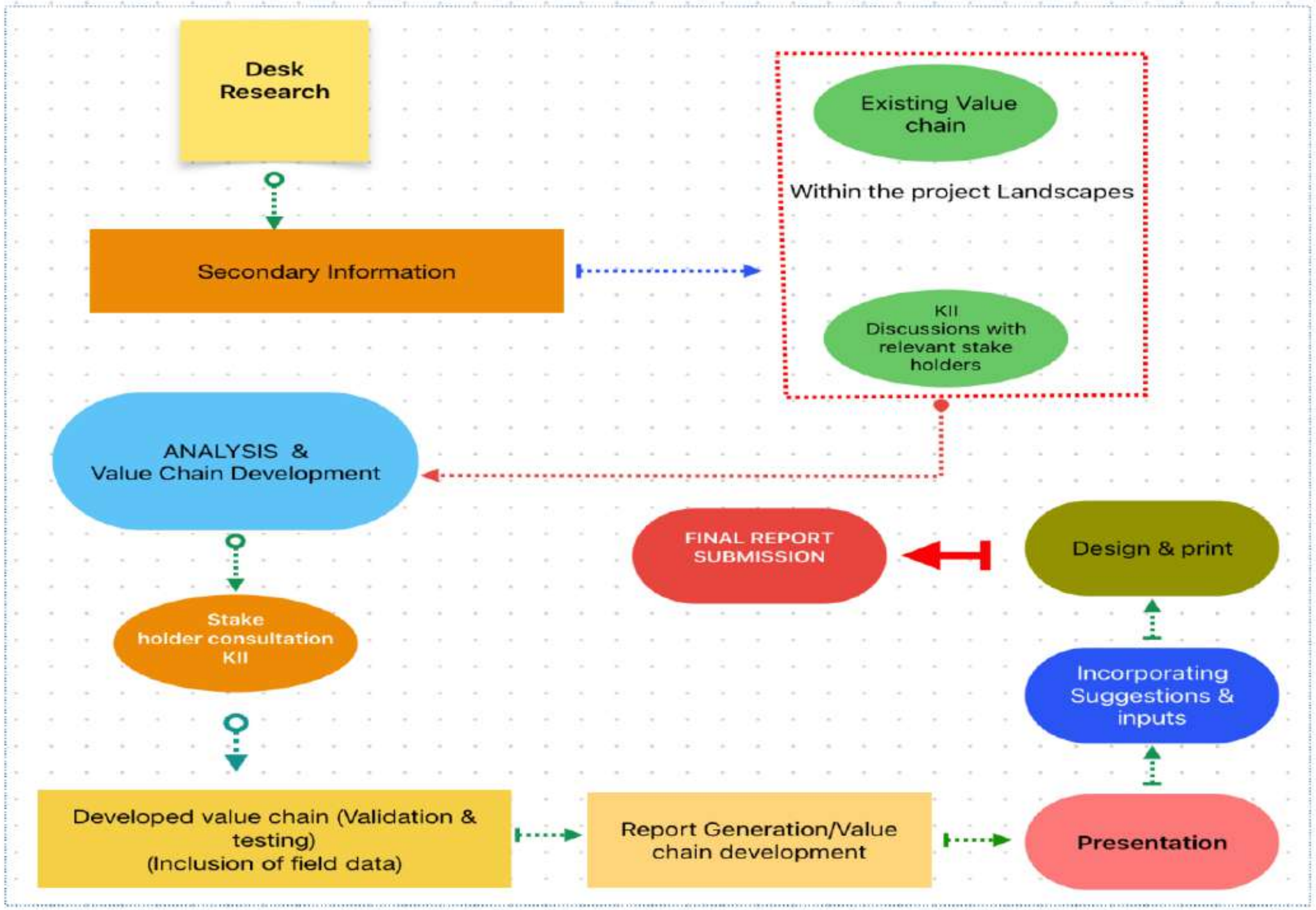
VALUE CHAIN ANALYSIS

APPROACH AND METHODOLOGY

For the assignment the following approaches were adopted in achieving the expected outputs as specified in the TOR.

Desk Research

An inventory of value chain documents developed by various agencies under various programs , projects and purposes was taken. Based on the inventory list of the documents, selected value chain literatures and documents were critically reviewed for the purpose to identify the gaps that impede it from efficient functioning. While carrying out the analysis, online consultations and webinars were also carried out with key focal persons from various agencies in the project landscape such as "research centers, Dzongkhag agriculture and livestock office, market infrastructure management teams, farmer groups and cooperatives, Department of Agriculture & Marketing Cooperatives etc.



-

ii. Online survey of Extension agents

An online questionnaire was designed and administered to the extension agents to study and understand their socio economic profile, engagement in agriculture and livestock activities, pattern of farming, population dynamics, livelihood activities and the shift in the farming systems at the communities. The survey also gathered data on the crop importance ranking for their livelihood and the market infrastructure and systems prevailing in the communities as a means to earn their livelihood.

iii. Stake holder Consultation

For the stake holder consultations in the Dzongkhags falling in the project landscape, the stakeholder were identified and consulted in all the project landscape Dzongkhags. Through the consultation, various primary data were gather specifically qualitative data such as planning visions and outcomes of the 13^{th} five year plan of the Dzongkhags in the context of agriculture and livestock sector. The stake holder consultations provided various insights in the context of food security and access in the communities and the potentials of enhancing their livelihood through sale of any marketable surpluses produced within the communities through a perpetual market system operation.

iv. Internal Consultation with WFP

Several workshops were attended organized by WFP in the context of commodity selection and prioritization. The workshops directed on the utility of the value chain report that could be incorporated into the agriculture resilience plans of all the 37 Gewogs. Further the workshops and the meetings also guided the assignment in reviewing it and providing relevant feedback and inputs to enrich the relevance of the report in the context of creating user friendly contents usable pragmatically at the field implementation level.

v. Presentation & Consultation with Project Management Unit

For the purpose of gathering the expectations of the PMU from the technical assistance of the assignment, preliminary findings presentations were made and their expectations were discussed and gathered in the report. One of the key outcomes of the presentation of the preliminary findings were the need of the framework in implementation of the recommendations of the study to ease out their planning approach which implementing activities at the community report.

Vi. Value chain analysis & Development report

Based on the desk research, primary data collection, online survey, community consultations, PMU consultations, Internal workshops and through the stakeholders consultation, the value chain analysis and development report has been developed for each Dzongkhag.

Climate analysis

Climate models are a mathematical representation of the physical processes that govern the Earth's climate and are used to provide projections of climate change under different pathways of future greenhouse gas concentrations, known as representative concentration pathways (RCPs; van Vuuren et al., 2011). However, there is no unique way of representing the key processes or solving the mathematical equations, meaning that there is inevitably some uncertainty in climate projections. It is, therefore, extremely important to quantify that uncertainty in order to provide context for climate projections. Indeed, many climate modelling groups around the world have developed their own climate models. Each model has strengths and weaknesses with some performing better than others in certain geographical regions (McSweeney et al., 2015).

To be able to robustly compare outputs from different models, the models are run with the same experimental set up. This is achieved through the Coupled Model Intercomparison Project (CMIP), which promotes a standard set of model simulations so that models can be compared and evaluated. Climate projections from multiple models from the CMIP5 (Taylor et al., 2012) and CMIP6 (Eyring et al., 2016) sets of climate projections are used to inform the Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, AR5 (IPCC, 2013) and AR6 (IPCC, 2021b), where the mean of the multi-model ensemble and spread across the models is used to communicate the projected change. One benefit of using many different models is that the spread of projections obtained provides a range of uncertainty for each variable of interest. For some variables, such as surface temperature, the projections from different models indicate a similar direction and magnitude of change. However, some other variables, such as rainfall for example, are more complex to model and the magnitude and direction of projected change may differ among different climate models.

For the South Asia region, including Bhutan, there is high confidence that temperatures will increase as all models in the CMIP6 and CMIP5 ensembles show a projected increase in temperature, but there is uncertainty across the models as to the exact value of the increase. For example, by the 2050s (2041–2060), the median temperature increase across the ensemble is 1.9°C for CMIP6 and 2.0°C for CMIP5, with a 5%-95% range of 1.1°C to 2.7°C for CMIP6 and 1.5°C to 2.5°C for CMIP5. In contrast, the projected changes in rainfall across the models show uncertainties in both the direction and magnitude of the projected changes. In this case, focusing only on the multi-model ensemble mean does not reflect the full range of uncertainty.

In addition to the multi-model mean not representing the full range of uncertainty, the multi-model mean also gives equal weight to all models, even those that are known to perform less well for certain geographic regions, such as Africa (McSweeney et al., 2015). A different way of presenting model projections is to take a scenario-based approach, where the outputs of individual models (selected based on criteria relevant to the task in hand) are considered as plausible scenarios of future change.

For the analysis in this study, the following climate projections were analysed for suitability to be used as scenarios of future change:

- 19 CMIP6 global model simulations
- 30 CMIP5 global model simulations
- 20 dynamically downscaled projections from the Coordinated Regional Climate Modelling Downscaling Experiment (CORDEX; Giorgi & Gutowski, 2015) for the South Asia domain, and
- one dynamically downscaled projection of the CMIP5 GCM HadGEM2-ES. The regional model used for this downscaling is the HadREM3-GA7.05 RCM (Tucker et al. 2021) which has a resolution of 0.11 degrees (~12km).

The range of projections in daily mean temperature and annual precipitation amounts for the CMIP6, CMIP5, CORDEX, and HadREM3-GA7.05 model simulations for 2050 (2036-2065) under the RCP8.5 greenhouse gas concentration pathway are shown in Figure 27.

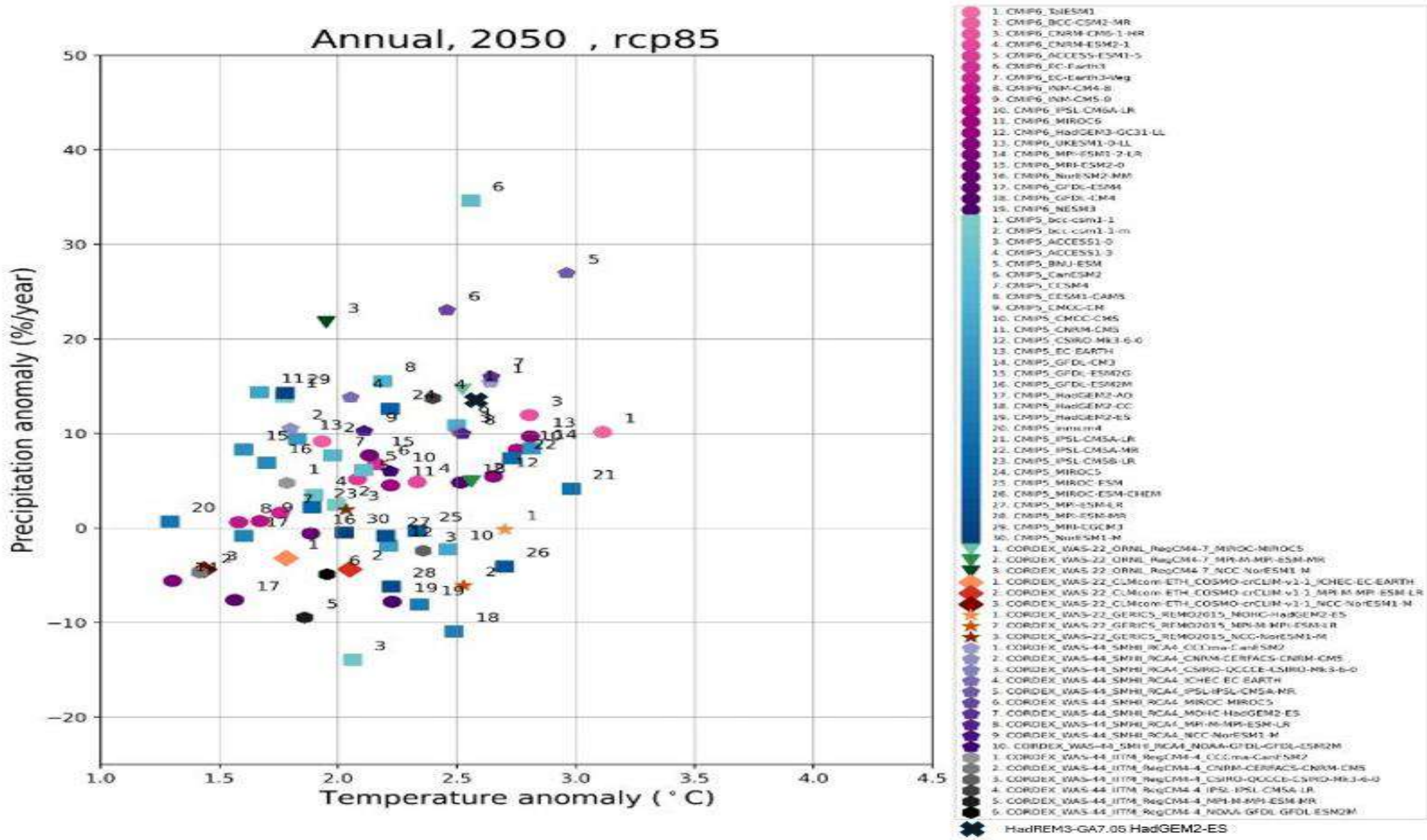


Figure 27: Scatter plot of projected changes in annual average temperature and annual total precipitation from 19 CMIP6 global climate model simulations (pink circles), 30 CMIP5 global climate model simulations (blue squares, 20 downscaled projections from CORDEX (other icons), and one HADREM3-GA7.05 (black cross) under a very high greenhouse gas emissions pathway (RCP8.5) for 2050 (2036–2065) relative to the baseline (1981–2010).

Two model simulations were selected to represent the range of plausible scenarios of future climate for Bhutan in 2050 based on that shown in Figure 27. These were selected based on the following criteria:

• Resolution of the model simulations – the global models from CMIP6 and CMIP5 have a resolution of the order ~100s of kms. Given that Bhutan is a small country with varied topography, this resolution would not give any useful information, as there would only be 2-4 grid boxes covering the entire country. This means that, for example, temperatures at the top of the high mountains and those in valleys would be averaged out, giving a result that would be valid for neither. Additionally, depending on the placement of grid boxes, some important global circulation patterns may be missed in some CMIP6 or CMIP5 models. Bhutan is affected by the edge of the SW Monsoon. If a CMIP6 or CMIP5 model places the Monsoon system slightly to the south, by even one grid box, this could mean that in that model the Monsoon does not reach Bhutan at all. This would not give useful results for future climate. As this study focuses on agriculture, a higher resolution is required, such as that provided by CORDEX, which is an experiment where several of the global CMIP5 models have been dynamically downscaled using regional climate models at several different modelling centres. These models have a resolution of 25km, which equates to around 70 grid boxes covering the country of Bhutan. The equivalent CORDEX downscaling of CMIP6 models is an ongoing project and these are not yet available to be used for this study. The HadREM3-GA7.05 model is available at 12 km, an even higher resolution than the CORDEX models.

• Model performance should capture the large-scale regional climate drivers - simulating the regional climate of South Asia is challenging due to the complex topography and monsoon system. It is known that climate models have difficultly simulating the regional distribution and variability of monsoon rainfall (Singh et al., 2017; Sperber et al., 2013; Turner & Annamalai, 2012). Therefore, the ability of climate models to capture the large-scale dynamics and driving processes of the regional climate should be evaluated – i.e., a 'process-based' evaluation – as these processes are often better represented compared to the direct precipitation outputs. If the large-scale processes are well captured, then there is greater confidence in model outputs over the region. However, if these processes are not well simulated then projected changes are unlikely to provide a plausible representation of the future climate, and these model simulations should be excluded from the ensemble of projections used to construct a set of plausible future climate conditions (UK Met Office 2021, McSweeney et al., 2012; McSweeney et al., 2015).

• Models should reflect the scale and direction of trend across the majority of model projections (i.e., most models project a hotter and wetter future to varying degrees of magnitude).

• Low likelihood scenarios (i.e. model simulations with different direction of future trends to the model consensus) should be considered if deemed plausible and relevant to food security and livelihoods (i.e. some plausible model simulations project a hotter and drier future).
Based on these criteria, the following model simulations were selected:
• Scenario 1: the HadREM3-GA7.05 downscaling of MOHC-HadGEM2-ES under the RCP8.5 greenhouse gas concentration pathway was selected to represent the high climate sensitivity scenario: the higher end of projected increases in annual average temperature and annual total precipitation.

• Scenario 2: the COSMO downscaling of MPI-ESM-LR under the RCP8.5 greenhouse gas concentration pathway was selected to represent a lower likelihood scenario: a medium level of projected increases in annual average temperature and a small decrease in annual total precipitation.

CLIMATE HAZARD ANALYSIS

Data on climate hazards is sparse in Bhutan; however, an analysis is warranted to assess potential areas at risk. This helps to understand the types of shocks that vulnerable livelihoods are currently facing, and how this might change in the future. Bhutan does not yet record consistent and comprehensive information on climate hazard events, so the information on historical climate events had to be compiled using the DesInventar dataset with records of events from 2009-2015 (DesInventar, 2024) and the NCHM's report with records of events from 2017-2022 (compiled using the news articles; NCHM, n.d., 2022). Due to the limitation of these two datasets, we could only carry out the statistical frequency and seasonality analysis at Dzongkhag level and a descriptive analysis of the impacts (intensity) of these climate hazards. The data was reported for the following climate hazards: windstorm, flash flood, flood, GLOF, heavy rain, heavy rain-induced landslide, hailstorm, heavy snowfall, and forest fire.

- Describe methodology for the future climate analysis

LOCATION	CODE AND NAME (most important activities)		DESCRIPTION
	LZ2	Alpine livestock rearing and NWFPs	Areas with elevation between 3500 and 5000m elevation. Very sparse small settlements that predominantly engage in high-altitude nomadic and semi-nomadic pastoralism (including yak herding) and seasonal gathering of NWFPs (such as cordyceps). Crops cannot be grown in this area, so income is primarily derived from selling of NWFP and some from livestock products like meat, dairy, and wool. Access to markets and other services is very restricted due to limited road connectivity and rugged terrain.
	LZ3	Livestock rearing and NWFPs	Areas with elevation between 1800 and 3600m. Small disbursed settlements or single houses that depend on cattle rearing (sedentary and semi-nomadic) and NWFS (including cordyceps) for food and income. In addition, communities in these areas often also rely on small potato, cereal (maize and buckwheat) and/or vegetable gardens for own consumption. In general, market access is very limited due to forested and mountainous terrain. However, communities in Trongsa and Bumthang have access to good market for dairy products.
	LZ4	Forest with some livestock rearing and NWFPs	Areas largely covered by thick forest. Rare settlements here engage in small-scale semi-nomadic or nomadic cattle rearing and subsistence NWFS gathering (such as wild yams). Small kitchen gardens with a few vegetables or small maize fields are also common. Productivity is low due to steep terrain and wildlife damage. The market access is very limited due to heavily forested and steep terrain.

LZ5 Livestock rearing and NWFPs with small-scale agriculture (Jigme Dorji National Park)

Steep valleys provide only limited areas for crop growing during a short summer season. Due to this, communities mostly engage in cattle and horse rearing with seasonal migratory grazing and NWFPs (including cordyceps) gathering. In addition, they practice small-scale subsistence agriculture (a mix of paddy with potato, barley and buckwheat), and receive a small income from high-altitude tourism in the national park. Due to remoteness and challenging terrain, market access is limited.

LZ6 Highland subsistence cattle rearing and potato

Communities engage in cattle and some goat rearing, practicing both sedentary grazing and seasonal migrations. This is supplemented by subsistence growing of potato with some barley, buckwheat and vegetables such as turnip and radish in the short summer season. The activities are carried out mostly for own consumption, with the exception of Phobjika valley where potato is grown primarily as cash crop for sale. Communities in Phobjika valley also receive a small amount of income from tourism due to black-necked cranes migration.

LZ7 Highland commercial cattle rearing with potato and buckwheat

Flatter terrain in central Bumthang enables communities to grow a wide range of crops in a single (summer) season, largely for sale with some own consumption. Potato growing has been traditionally the main livelihood activity in this area, supplemented by buckwheat, barley and wheat production. However, over the last few years there has been a shift from potato to cattle rearing, with commercial dairy farming supported by good processing facilities and market access becoming the main livelihood activity. In addition, communities also derive some income from a wide range of other activities, including vegetable growing (such as turnip and radish), chili production (increasing), beekeeping, NWFPs and tourism.

LZ8 Highland high productive paddy and mixed farming system (Paro and Thimphu)

Areas at an altitude between 1800 and 2600m, covering Paro and Thimphu valleys, with accessible markets, nearby urban centers, and well-developed irrigation network. Paddy production here is combined with a small-scale production of wheat, potato, vegetables (such as cabbage, beans and carrot), chili and apple, and with sedentary cattle rearing for dairy products. Wheat and some of the vegetables can be grown also during the winter season. Agricultural produce is consumed within the households but also sold to urban markets (as cash crops). Agricultural activities are supplemented by income from tourism and trade.

LZ9 Highland high productive paddy and mixed farming system (Punakha and Wangdue Phodrang)

Areas at an altitude between 1200 and 1800, covering the southern valleys of Punakha and southeastern ones of Wangdue Phodrang. Accessible markets enable communities to sell their agricultural produce as cash crops. Paddy growing is combined with the famous chili production; but also includes small-scale sedentary cattle rearing (mostly for dairy) and production of wheat, potato and vegetables (such as cabbage and radish).

LZ10 Highland paddy and cattle (Wangdue Phodrang)

Southern valleys of Wangdue Phodrang are located further from markets and feature steeper terrain. Because of this, livelihood activities here are focused more on own consumption with only little sales. Main activity is paddy production that is complemented with small-scale vegetable growing and cattle rearing.

LZ11 Highland paddy, maize and cattle (Trongsa)

In most of the Trongsa valleys, the main livelihood activities are paddy and maize cultivation with dairy production. While paddy and maize are grown mostly for own consumption, the income is made primarily from dairy and limited small-scale cash crops such as potato, chilli, some cardamom and Sichuan pepper (particularly in Nubi). Some areas cultivate also wheat and buckwheat but for own consumption only. Steep terrain limits market access to already distant markets and increases product costs due to higher transportation expenses. The only exception is the dairy market which is well developed. Access is further affected during the summer, when heavy rainfall and landslides cause frequent roadblocks. A notable issue in this area is the scarcity of irrigation water during paddy cultivation, significantly impacting agricultural productivity. This is also causing shortages of drinking water. Agricultural production is further affected by windstorms, hail, wildlife, erratic rainfall, and pests and disease.

LZ12 Hilly paddy, maize, cattle and cash crops

In the most southern valleys of Trongsa and northern valleys of Zhemgang, livelihood activities are focused on a combination of subsistence paddy and maize with small-scale cattle rearing (for dairy) and vegetable gardens. To supplement minor income from sale of dairy, communities here also engage in cash crops, particularly cardamom and mandarin orange, and off-farm work during the winter months (around a third of households). Distant markets for cash crops (such as Gelephu) increase transportation costs and are too far to market perishable produce such as vegetables. In addition, heavy rain and landslides cause road connectivity problems during summer. In addition, communities are experiencing also other challenges that are reducing productivity, including water shortages for paddy cultivation, erratic rainfall, windstorms, snowstorms affecting cardamom plants, rising temperatures reducing orange productivity, wildlife damage, and pest and disease.

LZ13 Highland maize and paddy

Communities in northeastern valleys engage in subsistence maize and paddy cultivations that is supplemented by potato and chilli production and small-scale cattle rearing (for dairy). Most is grown for own consumption with very little sale. However, a famous maize variety comes from Yangtse. Communities living here are isolated and located far from markets with heavy rainfall further impacting their accessibility in summer. A handful of communities derive additional income from handicrafts (particularly weaving such as in Khoma village in Lhuntse).

LZ14 Hilly maize, potato and livestock

Reduced precipitation (compared to the western parts of Bhutan) limits the crops that can be cultivated here. In addition, rugged terrain confines the cultivation to the valley slopes. Main activities are maize and potato cultivation with some chilli and vegetable growing. Crops are mostly grown for own consumption; however, potato and chilli are also sold on a smaller scale. This income is supplemented by rearing cattle, particularly for dairy production, and limited production of mandarin orange. The communities have relatively good market access.

LZ15 Hilly maize, cattle and cash crops

Reduced precipitation (compared to the western parts of Bhutan) limits the crops that can be cultivated here. In addition, rugged terrain confines the cultivation to the valley slopes. Main activity is maize cultivation supplemented by cattle rearing for dairy production. Additionally, communities also grow vegetables and potato on a smaller scale, mostly for own consumption with little sale. An important source of income are cash crops such as mandarin orange and, particularly in the southern part of the zone, areca nut and cardamom. Communities are located relatively far from markets, within a challenging steep terrain, and especially during the summer, road connectivity can be an issue due to heavy rain and landslides. Additionally, communities struggle with erratic rainfall patterns, wildlife damage and pests and disease. Off-farm work is an important additional income source during the winter months.

LZ16 Remote hilly maize and cash crops (Zhemgang)

Steep hilly terrain and reduced precipitation (compared to the western parts of Bhutan) limit the crops that can be cultivated here and confine agriculture to very small cultivable areas on the valley slopes. Due to this, communities living here are small and scattered. Main cereal grown is maize which can be grown twice in a year and is used as food, animal feed and alcohol production. Maize agriculture is complemented also with small-scale vegetable growing for own consumption and cattle rearing for dairy production, also mostly for own consumption with little sale. A main source of income are cash crops (such as mandarin orange, cardamom, ginger and some areca nut in the southern lower-elevation areas) and off-farm work during the winter months (around a third of all households here engage in this). For some communities, particularly in Bjoka, handicrafts such as cane and bamboo crafts are also an important livelihood activity. When maize food stocks are low (particularly in June and July before the harvest), communities also collect NWFPs such as wild yams to aid their food consumption. Market access is very limited due to the difficult terrain and poor road connectivity – distant markets for cash crops (Gelephu) result in high transportation costs and make it difficult to market perishable products such as vegetables. Additionally, heavy rains and landslides in summer further affect road connectivity. Farmers also struggle with erratic rainfall, windstorms, rising temperatures (particularly affecting mandarin oranges), wildlife damage and pests and disease.

LZ17 Highland mixed crop system (Haa, Paro, Chhukha)

Due to higher elevation, communities here rely on growing different cereals (such as paddy, maize and other) and potato for their own consumption. Income is mostly derived from the cultivation of vegetables such as carrot, turnip and cabbage and their sale in the relatively accessible markets in Paro and Thimphu. Communities also rear a bit of cattle for dairy production, primarily for own consumption.

LZ18 Hilly high productive vegetables and livestock

Main source of income is from vegetables cultivation (as cash crops; particularly beans and chilli) and livestock rearing (mainly cattle and some goats for dairy, pigs for meat, and chickens for meat and eggs). Main harvest of vegetables is in winter months, but some areas have also a smaller harvest in summer. Rearing of livestock for meat is primarily carried out by Nepali ethnic groups due to the stigma attached to the slaughter of animals in Buddhist communities. Some income is also derived from cash crops such as cardamom, mandarin orange, ginger and fruits such as banana, mango, and avocado. Main cereals, paddy and maize, are grown for own consumption and animal feed. However, due to shortages of water in some areas, paddy is being replaced by mung bean (green gram) which is less water intensive and mostly grown as cash crop. Some households derive a bit of income also from beekeeping and seasonal off-farm work (particularly communities near Damphu). This zone has a well-developed market for vegetables, cash crops and dairy; however, main markets are located far (Thimphu and Gelephu) which increases costs and can be challenging during summer when roads get blocked due to heavy rainfall and landslides. Farmers also highlighted challenges with water and irrigation shortages, erratic rainfall, wildlife damage, pests and disease, windstorms and hail (particularly problematic for maize) and increasing temperatures (affecting mandarin orange cultivation and causing heat stress to livestock).

LZ19 Hilly cash crops and livestock (Sarpang)

Main source of income are cash crops, particularly cardamom and some mandarin orange. Additional income is also derived from cattle rearing (for dairy), poultry (for egg production), and some piggery, goats and beekeeping. Main cereal grown for own consumption is paddy; however, in areas without sufficient irrigation, farmers also grow some maize. Vegetables are grown in both summer and winter, but only for own consumption with little sale. Communities have to travel further to markets which results in high transportation costs, which is additionally challenging in summer due to heavy rains causing roadblocks. Farmers here face issued related to erratic rainfall, rise in temperatures, wildlife damage, and pest and disease (particularly problematic for Chhudzom as vegetables are grown organically there).

LZ20 Western lowland high productive mixed farming system

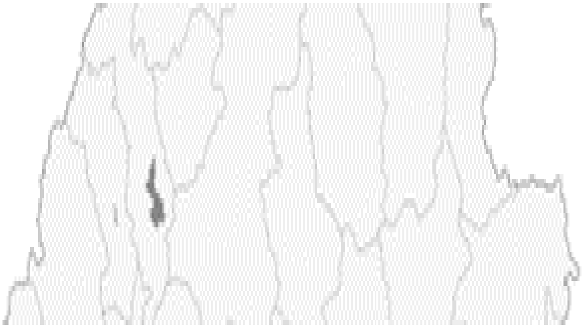
Accessible markets, low elevation and extensive rainfall enable a wide range of livelihood activities here. Main income for communities living here comes from areca nut cultivation, cardamom, ginger and mandarin orange. Additional income is derived from livestock rearing - particularly cattle for dairy, but also poultry, piggery, beekeeping, and small-scale fishery. Rearing of livestock for meat is primarily carried out by Nepali ethnic groups due to the stigma attached to the slaughter of animals in Buddhist communities. Cereals, paddy and maize, are grown for own consumption. Communities have good access to both local and international markets for a range of products.

LZ21 Central lowland high productive mixed farming system

Accessible markets, low elevation and extensive rainfall enable a wide range of livelihood activities here. Main income for communities living here comes from areca nut cultivation, but also from other cash crops such as ginger and some turmeric and mandarin orange. Additional income is derived from livestock rearing - particularly cattle for dairy, but also poultry, piggery, beekeeping and small-scale fishery. Rearing of livestock for meat is primarily carried out by Nepali ethnic groups due to the stigma attached to the slaughter of animals in Buddhist communities. A bit smaller proportion of income is also derived from vegetable cultivation in both winter and summer and from selling of fruits (such as mango, litchi, banana, avocado and pineapple). Cereals are grown for own consumption and paddy cultivation is preferred. However, in areas without sufficient irrigation, farmers also grow maize, millet or mung bean (green gram). Farmers near Gelephu city also rely on off-farm income during the winter. Communities have good access to both local and international markets (Gelephu) for a range of products; however, high competition with cheaper Indian products affects the sale of vegetables and Indian import restrictions on areca nut have important implications for farmers in this zone. Heavy rains during the monsoon season can cause substantial flooding here, while farmers also struggle with wildlife damage (particularly from elephants), irrigation issues, erratic rainfall, windstorms and rise in temperatures.

LZ22 Eastern lowland mixed farming system

Accessible markets and low elevation enable a wide range of livelihood activities here; however, milder monsoon rains and drier winter months limit the cultivation of winter crops compared to the Central and Eastern lowland zones. Main income comes from cash crops (areca nut, ginger and some mandarin orange) and rearing of chickens and pigs (for meat - carried out by Nepali ethnic groups). Main cereal grown here is paddy, but only for own consumption. Communities have good access to markets, facilitated by proximity to international borders.



LZ1 Urban areas

Thimphu and other urban areas (Paro, border towns such as Gelepgu, Phuentsholing, and Samdrup Jongkhar). These are centers of trade and commerce with accessible local and international markets. Most of the households here engage in non-agricultural activities that are generally not highly sensitive to climate-related shocks and stressors.

0 Protected area

Jigme Khesar Strict Nature Reserve in the western Bhutan is the only protected area in Bhutan without any human settlements.

00 High mountains

Mountains with over 5000m elevation. There are no settlements and almost no livelihood activities due to steep terrain and elevation.

FIGURE 26. LIVELIHOOD ZONES AND CHARACTERISATION FOR BHUTAN.

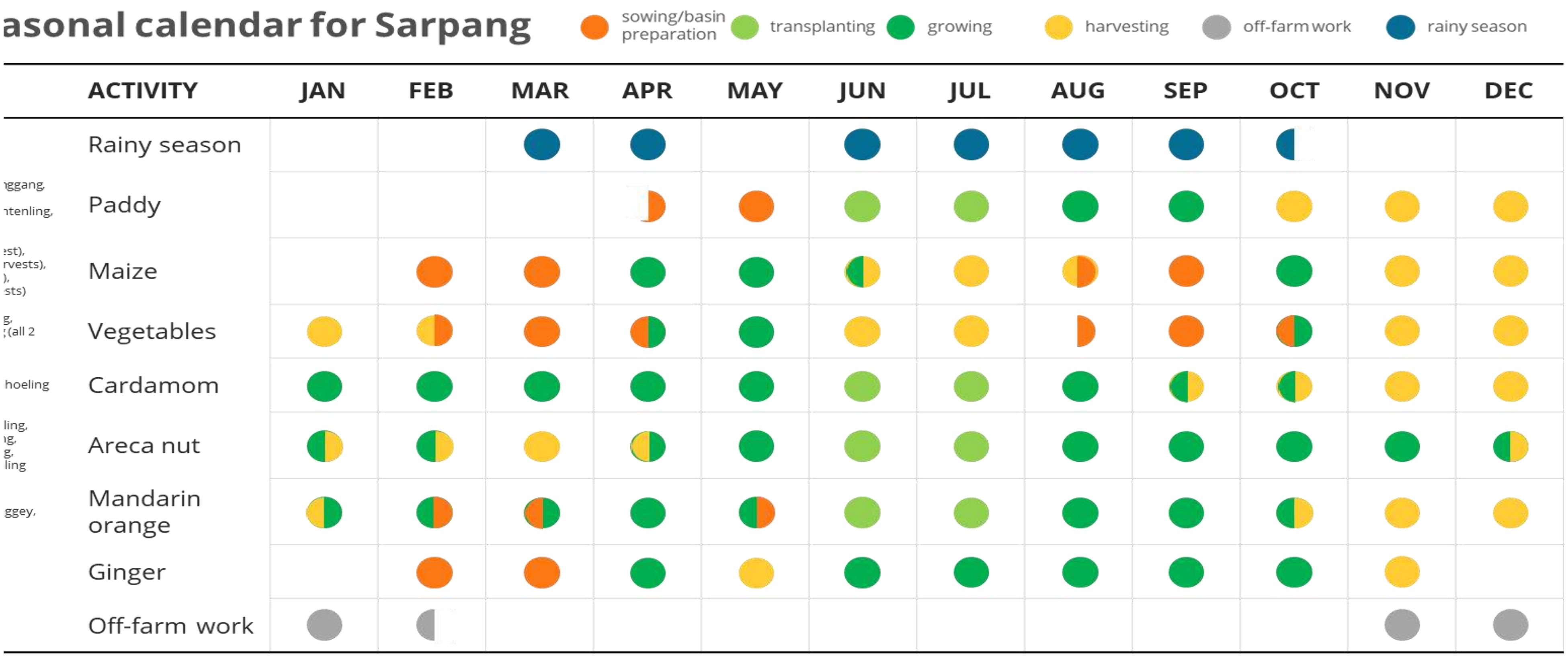


FIGURE 27. SEASONAL CALENDAR FOR THE MAIN LIVELIHOOD ACTIVITIES IN SARPANG.

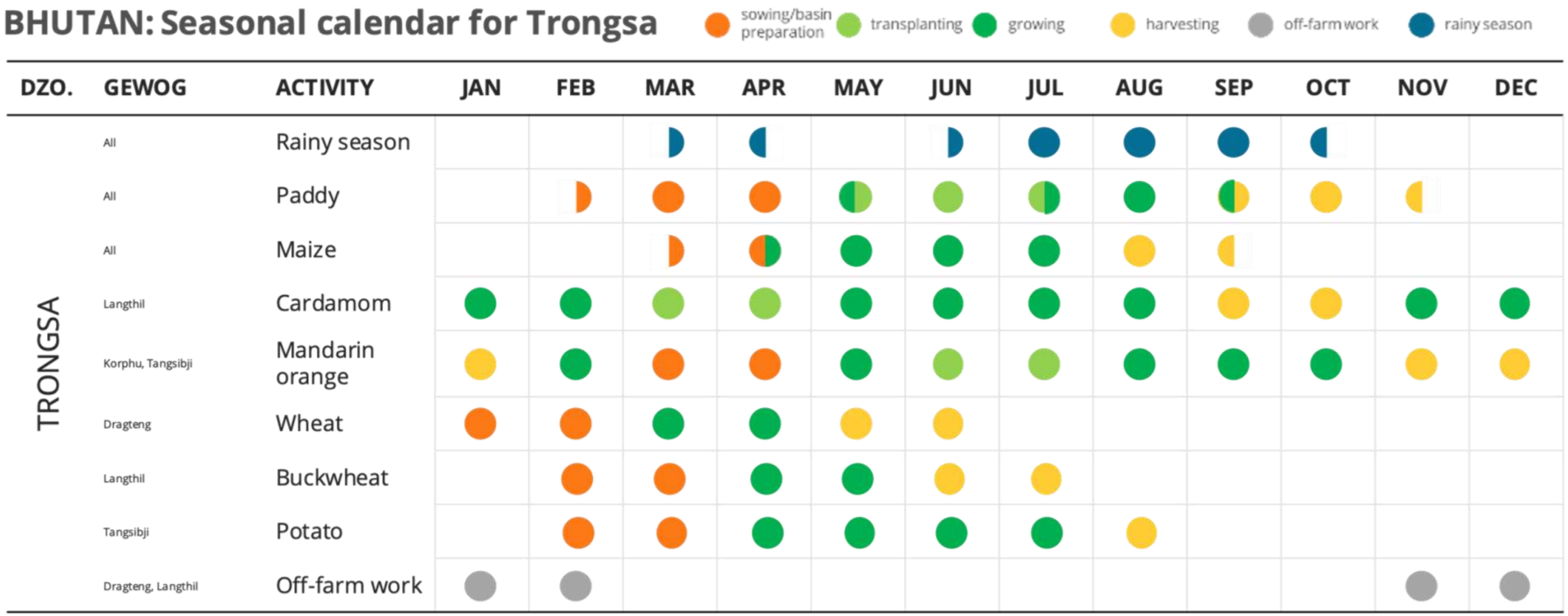


FIGURE 28. SEASONAL CALENDAR FOR THE MAIN LIVELIHOOD ACTIVITIES IN TRONGSA.

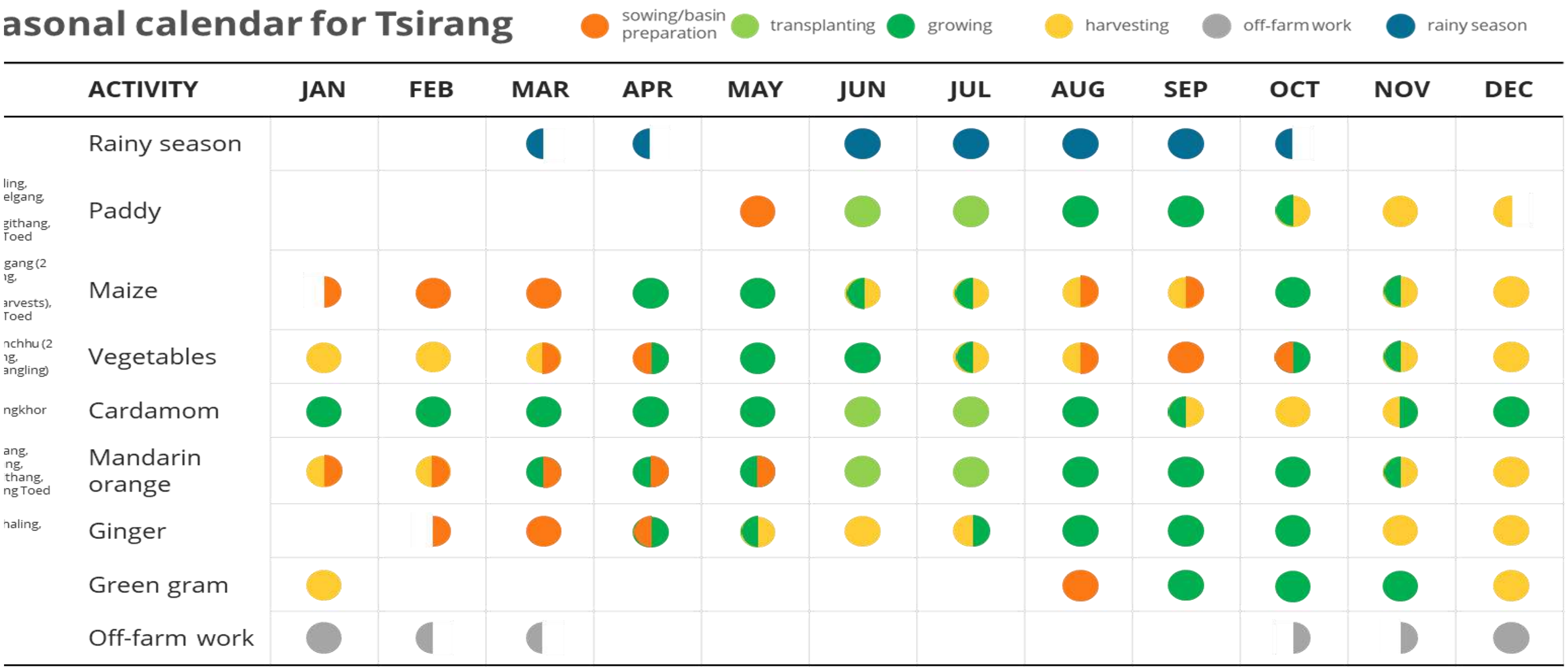


FIGURE 29. SEASONAL CALENDAR FOR THE MAIN LIVELIHOOD ACTIVITIES IN TSIRANG.

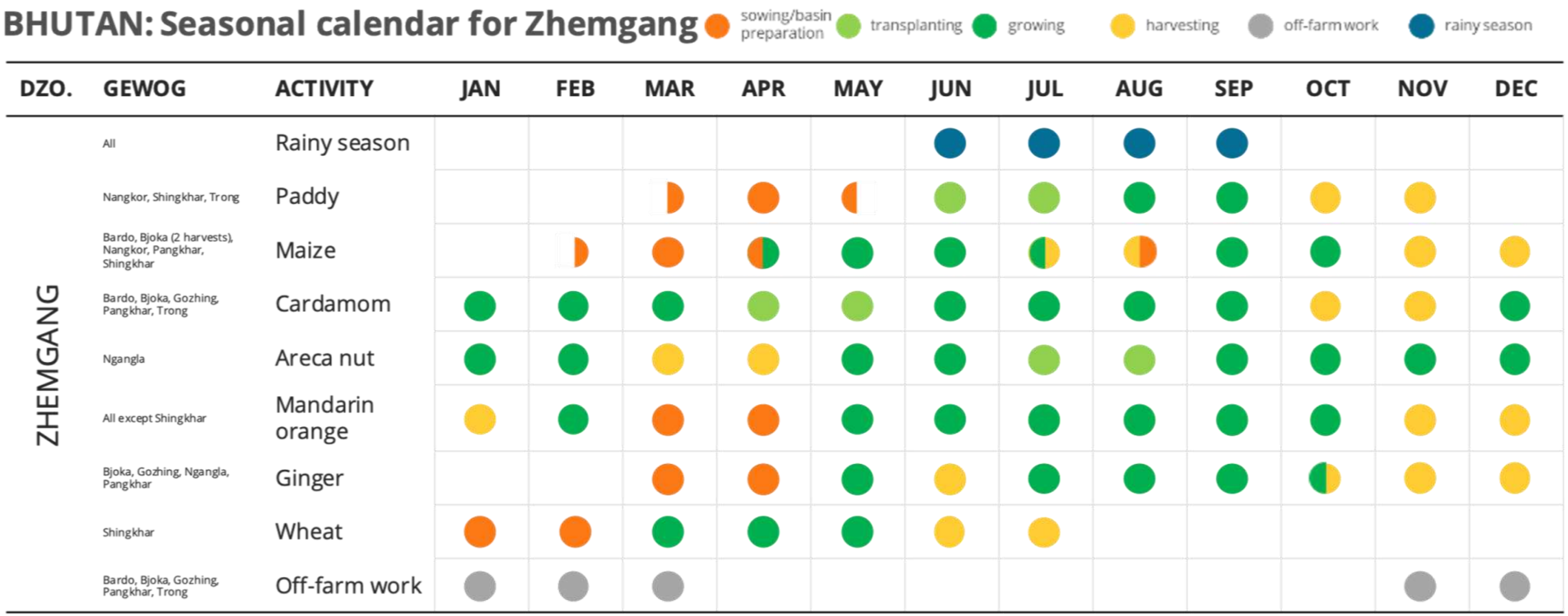
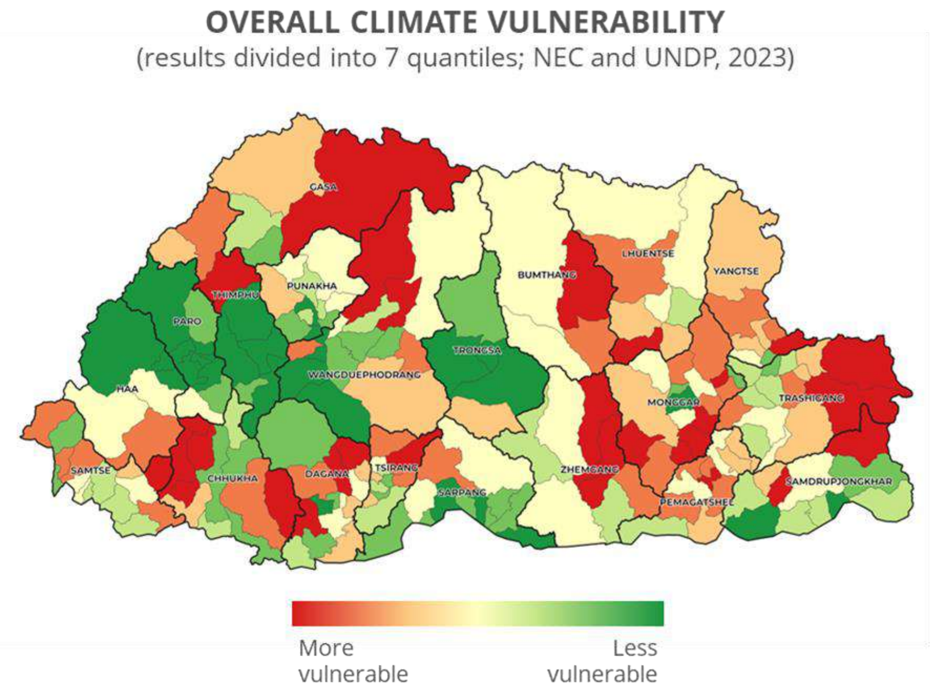


FIGURE 30. SEASONAL CALENDAR FOR THE MAIN LIVELIHOOD ACTIVITIES IN ZHEMGANG.

Annex IV: Vulnerability analysis

The vulnerability analysis, carried out by NEC and UNDP in 2023, identified vulnerable regions and communities in Bhutan. The analysis focused on socio-economic factors that contribute to vulnerability – i.e. the predisposition of communities to be adversely affected by climate change, including climate variability and extremes. It aggregated two concepts following the IPCC framework: sensitivity (the intrinsic predisposition of communities to suffer harm) and adaptive capacity (the ability of communities to adjust to impact). To determine the degree of vulnerability, the study looked at indicators from the following components: demographic, social, economic, food and water, and infrastructural components (see Table 5). The findings highlighted that strong dependence on agriculture, comparatively low economic growth, illiteracy, lack of access to safe drinking water, sanitation and other services make several regions of the country vulnerable to climate induced hazards. In addition, the eastern part of Bhutan appeared socio-economically more vulnerable than the western and central parts.

Both vulnerability and resilience analyses are important, each providing different but complimentary outcomes. Climate vulnerability analysis highlights areas and communities most susceptible to climate impacts, while climate resilience analysis looks at the communities' ability to bounce back (build back better) after a climate shock (and avoid/minimize future shocks). The climate vulnerability analysis for Bhutan was carried out just in 2023 and did not need an update yet. In addition, the focus of CLEAR under BRECSA was to provide a baseline for developing targeted interventions to improve rural communities and farmers' ability to bounce back after a shock (ARPs). Resilience analysis is better suited to recommend interventions for bouncing back after a climate change shock. At the same time, the resilience analysis was adjusted to focus primarily on rural communities and farming households (and their commodity value chains); compared to the vulnerability analysis from the NAP that focused on all populations in Bhutan. This aligned better with thematic focus of BRECSA on developing strategies to enhance resilience of smallholder farmers in Bhutan. Finally, the purpose of the resilience analysis conducted for the CLEAR exercise in Bhutan is to inform the ARPs – which are done at the Gewog level; hence, the data that feed into the resilience analysis is processed at the Gewog level. In contrast the vulnerability analysis derived from the NAP combined data at Gewog- and Dzongkhag-level scales; therefore, there is a risk that the vulnerability analysis masks some of the diversities at Gewog level.



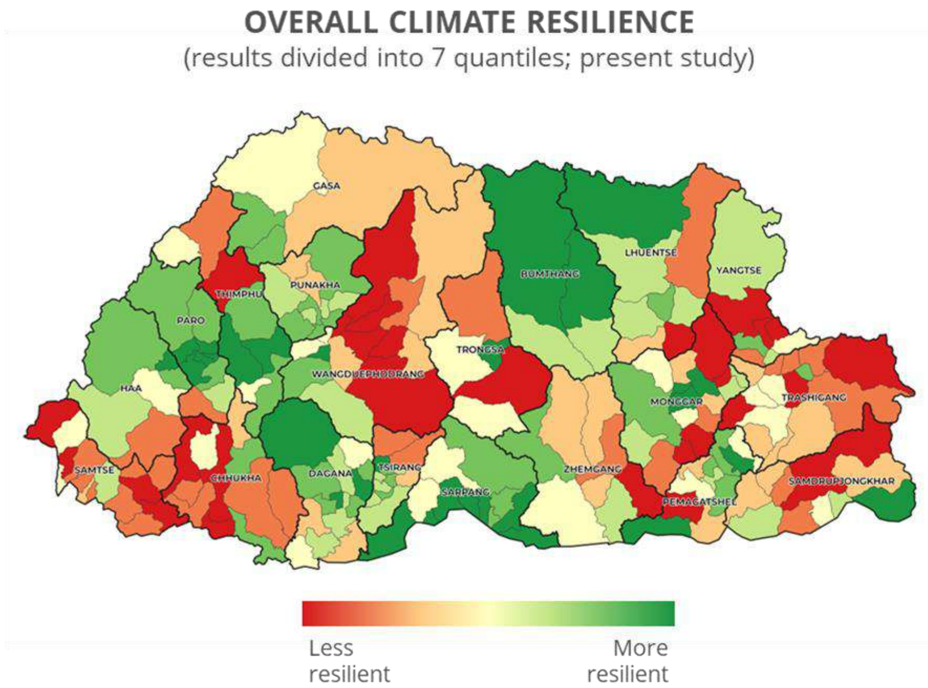


FIGURE 31. A MAP OF THE OVERALL CLIMATE VULNERABILITY FOR BHUTAN (LEFT; NEC AND UNDP, 2023), AND A MAP OF THE OVERALL CLIMATE RESILIENCE FOR BHUTAN (RIGHT; PRESENT STUDY).

TABLE 5. LIST OF INDICATORS USED IN THE VULNERABILITY ANALYSIS FROM THE NAP FOR BHUTAN (NEC AND UNDP, 2023).

IPCC Risk Framework (2014)	Major components	Sub-components (Indicators)	Unit	Scale available	Year(s) available	Data source
Sensitivity	Socio-demographic profile	Female headed households	%	Dzongkhag	2017	PHCB
		Average household size	Number	Gewog	2017	PHCB
		Children	%	Gewog	2017	PHCB
		Elderly people	%	Gewog	2017	PHCB
	Economic status	Population involved in agriculture	%	Dzongkhag	2017	PHCB
		Outmigration rate	%	Dzongkhag	2017	PHCB
		Consumption poverty rate	%	Dzongkhag	2017	PHCB

	Health issues	Infant mortality rate	Number	Dzongkhag	2017	PHCB
		Food insufficiency (not enough food to feed all household members)	%	Gewog	2017	PHCB
		Disability prevalence rate	%	Gewog	2017	PHCB
	Environmental degradation	Urbanisation (urban population growth rate)	%	Gewog	2005, 2017	PHCB
		Change in agricultural land	%	Dzongkhag	2010-2018	DoA
		Change in forest area	%	Dzongkhag	2010-2018	DoFPS
Adaptive capacity	Knowledge	Literacy rate	%	Gewog	2017	PHCB
	Infrastructure	Permanent housing (wall, floor, roof cement/concrete)	%	Gewog	2017	PHCB
		Road density	Number	Dzongkhag	2017	PHCB
		Health facilities per 1000 pop	Number	Dzongkhag	2017	PHCB
	Economy	Tourist arrivals	%	Dzongkhag	2017	PHCB
		Establishments covered by Dzongkhag and area	%	Dzongkhag	2017	PHCB
		Labour force participation rate	%	Gewog	2017	PHCB
	Access to basic facilities	Drainage facilities	%	Dzongkhag	2017	PHCB
		Reliable water supply/HH with functional piped water supply	%	Dzongkhag	2017	PHCB
		Improved sanitation facilities	%	Gewog	2017	PHCB
		Electricity coverage	%	Gewog	2017	PHCB
		Cooking fuel - LPG	%	Gewog	2017	PHCB
	Adaptation strategies	Percentage of irrigated area	Km	Dzongkhag	2017	PHCB
		Agricultural assets		Dzongkhag	2017	PHCB
		Community Forest Groups per Dzongkhag/ Plantations by GBCL	Number	Dzongkhag	2017	PHCB
		Identified/ planned early warning systems (EWS)	Number	Dzongkhag	2017	PHCB

BHUTAN: Reference map (Dzongkhags)

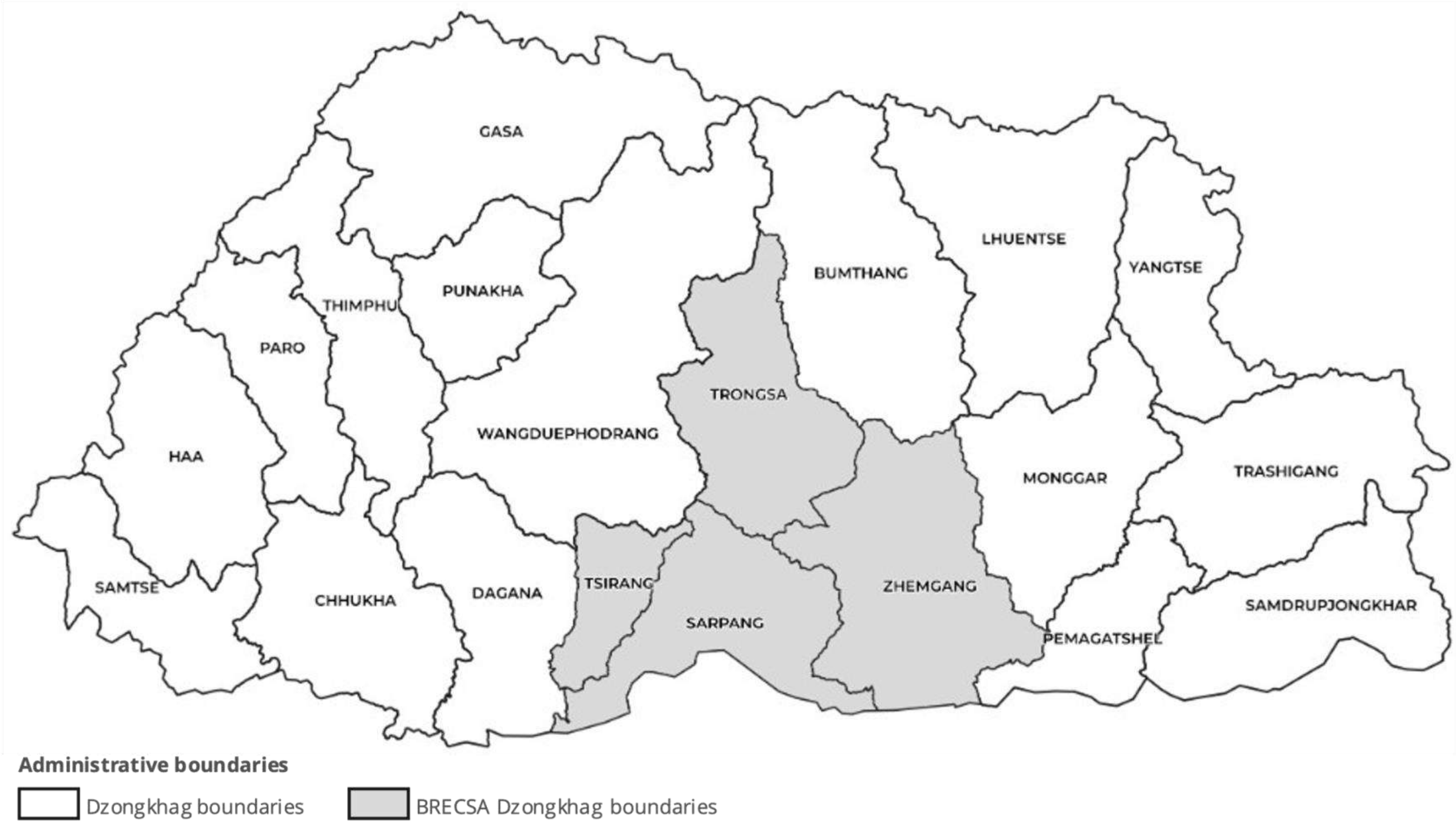


FIGURE 32. REFERENCE MAP OF BHUTAN: DZONGKHAGS ADMINISTRATIVE BOUNDARIES.

SARPANG: Reference map (Gewogs)

Administrative boundaries

Dzongkhag boundaries — Sarpang: Gewog boundaries

TSIRANG: Reference map (Gewogs)

Administrative boundaries

Dzongkhag boundaries — Tsirang: Gewog boundaries

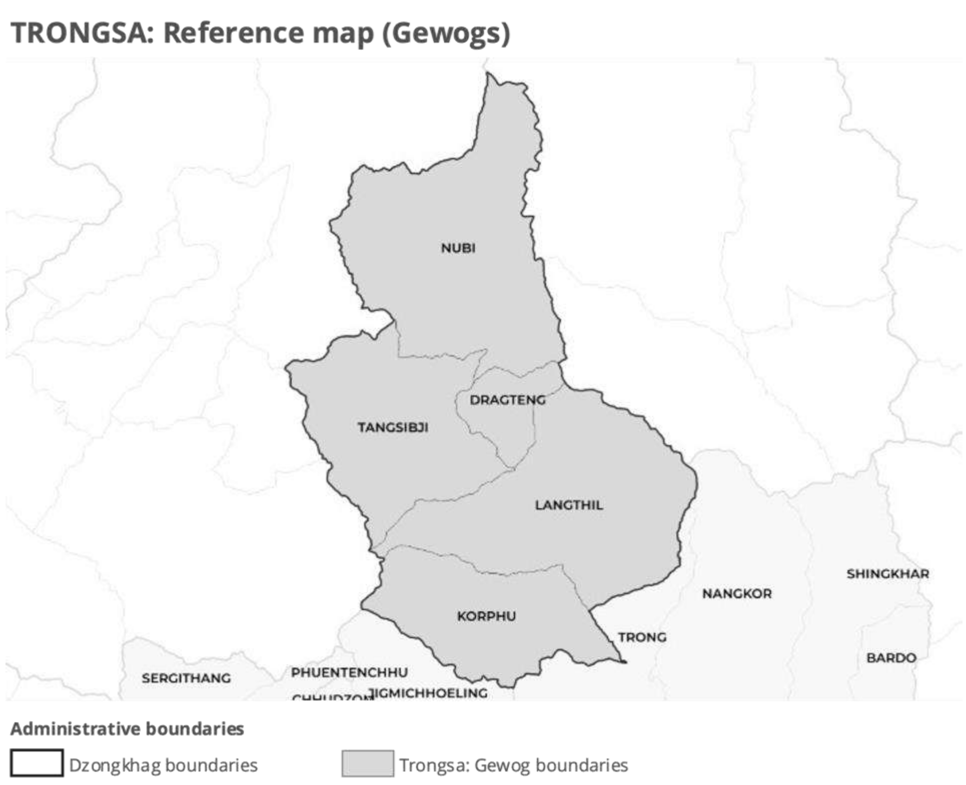


FIGURE 33. REFERENCE MAP OF SARPANG, TSIRANG, TRONGSA AND ZHEMGANG DZONGKHAGS: GEWOG ADMINISTRATIVE BOUNDARIES.