Climate change impacts in Bhutan: challenges and opportunities for the agricultural sector

Working Paper No. 191

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CGIAR

RESEARCH PROGRAM ON
Climate Change, Agriculture and Food Security

CCAFS

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Abstract

The Kingdom of Bhutan is nestled in the Himalayas, sharing borders with India to the south and China to the north. The country is a net carbon sink and has committed to ensuring that 60% of its total land area will remain as forest. Despite efforts to encourage sustainable economic growth at the national level, the impacts of climate change, driven partly by the global greenhouse gas emissions, will continue to affect Bhutan. The agricultural sector, which employs about 69% of the total population, is the most vulnerable to the changing climate.

There is need to identify which crops may become unsuitable under climate projections and, equally, which crops may offer new opportunities to rural communities. A joint study by the International Center for Tropical Agriculture (CIAT) and the Ministry of Agriculture and Forestry (MoAF), funded by the United Nations Environment Programme (UNEP), was undertaken to assess the impacts of climate change on five key crops (i.e. rice, maize, potato, chili and tomato) and three diversification crops (i.e. quinoa, kiwi and cardamom).

The results of the study will help decision makers identify which areas may require interventions due to the imminent loss of climate suitability for the crops. Equally, the results can be used to provide input on suitable locations to test the diversification crops and potential areas for expansion of the key crops. The analysis was undertaken using the most up-to-date climate models and an ecological niche model and was analyzed in ArcGIS. It was a collaborative study, which included a 2-week capacity building workshop between CIAT and MoAF and an additional case study to integrate knowledge on gender and climate change.

Keywords

Climate change, agriculture, crop modelling, capacity building, gender, Bhutan.

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Acronyms

AP-CTNFC	**Asia-Pacific Climate Technology Network and Finance Center**
CIAT	**International Center for Tropical Agriculture**
CSA	**climate-smart agriculture**
FAO	**Food and Agriculture Organization of the United Nations**
GCM	**Global Circulation Model**
IPCC	**Intergovernmental Panel on Climate Change**
m.a.s.l.	**meters above sea level**
MoAF	**Ministry of Agriculture and Forests**
RCP	**representative concentration pathways**
SNV	***Stichting Nederlandse Vrijwilligers***
UNDP	**United Nations Development Programme**
UNEP	**United Nations Environment Programme**

1. Introduction and rationale

Bhutan is, and will be, strongly affected by climate change, which is projected to increase temperatures and alter precipitation patterns. Changes in weather and climate are already having an impact on regional ecosystems, which is evident by significant losses in the size and distribution of Himalayan glaciers, as well as decreased water availability for irrigation, agriculture, hydropower and household uses (Shrestha et al., 2012). Furthermore, Bhutan is at risk of glacier lake outburst floods (UNDP, 2012). These trends and risks, which will be exacerbated in the coming decades, demonstrate a clear need for strategic planning and regionally appropriate adaptation practices for the agricultural sector. The majority of agricultural production in Bhutan is smallholder subsistence farming (MoAF, 2016) and about 69% of the Bhutanese population is employed in the agricultural sector (FAO, 2015). However, given the mountainous and extreme biophysical conditions, less than 3% of the country is used for agriculture (Meenawat and Sovacool, 2011), highlighting the need for efficient and sustainable agricultural management. Many adaptation strategies for the agricultural sector are constrained by a lack of information on regionally specific climate change impacts on key crops. Previous analyses of climate change impact have been generic and the wider South Asian region has been taken as a reference for Bhutan.

This project was established to examine the suitability of various crops in Bhutan under different climate scenarios up to 2050. This was a collaborative initiative between MoAF, CIAT and UNEP, funded through the Asia-Pacific Climate Technology Network and Finance Center (AP-CTNFC). The project had two principal objectives:

> Objective 1: Build capacities of key technical staff to produce suitability maps for a wider range of crops under different emission scenarios. Furthermore enhance the understanding and interpretation of uncertainties of the projections and introduce climate-resilient crop management practices in Bhutan.
>
> Objective 2: Assess the impacts of climate change on the climatic suitability of maize, rice, potato, chili and tomato growing areas in Bhutan. Share and discuss the results and implications of crop suitability studies with key stakeholders from Bhutan and relevant international agencies such as UNEP and FAO.

In addition, in consultation with UNEP, a gender component was integrated into the project. This consisted of: gaining an understanding of gender roles in agricultural decision-making; ensuring gender-inclusiveness in agricultural research projects; and creating a short video providing insights on gender roles and climate change impacts in agriculture from both farmers' and decision-makers' perspectives (see Chapter 4).

2. Project structure

The project started with an intensive 2-week training workshop to build the capacities of 15 participants from MoAF in independently conducting crop suitability modeling through training in ArcGIS, R and EcoCrop. A step-by-step approach for crop suitability analysis was conducted, including the refinement of crop parameters, creating layers of elevation and sunlight exposure and assessing current and future suitability under different climate change scenarios. Participants received training in: climate change science, the potential use of projections and crop modeling, with a focus on resulting uncertainties and correct interpretation. The training was adapted to the participants' needs, for example participants requested and were given an introduction to the IPCC and how it operates, and the concept of climate-smart agriculture (CSA) was introduced and discussed in relation to Bhutan. The inclusion of gender components in MoAF's work was discussed and a methodology to prioritize CSA practices with a gender-inclusive approach (CSA rapid appraisal, see Mwongera et al., 2014) was introduced. Selected elements of this were applied during the farmer workshop, which was led by crop modeling workshop participants. Finally, as a result of the 2-week workshop, maps for the current suitability of key crops were developed, as well as projections for 2050 under different emission scenarios (RCP 8.5 and RCP 4.5) with a number (31) of global circulation models (GCMs).

During the workshop, a work plan was established; MoAF teams were responsible for using the new skills and producing draft climatic suitability maps for CIAT staff members, who then provided them with support and recommendations. To refresh the methods and skills learned, MoAF independently organized a second 2-day workshop in Thimphu in July 2016. Preliminary results were then reviewed and adjusted by CIAT staff members and further biophysical suitability maps were generated, in consultation with the respective crop experts at MoAF.

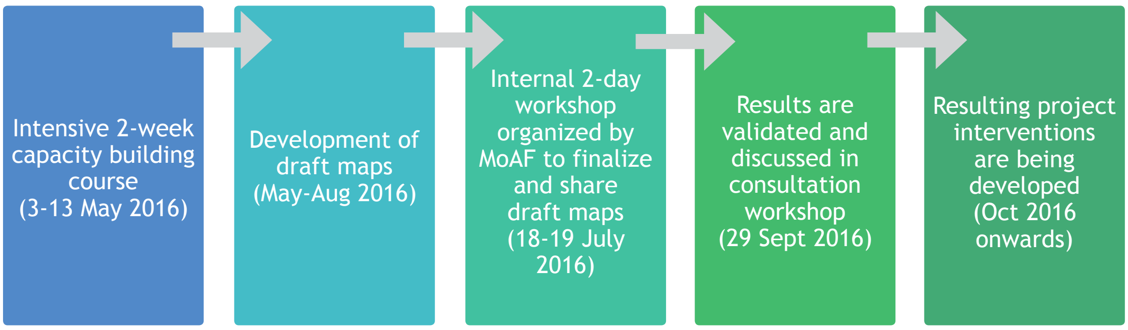


Figure 1: Project process

3. Methodology and results for potato

Crop suitability modeling

Crop suitability modeling is a process that requires integration and analysis of multiple layers of biophysical and socioeconomic information. Crop suitability is a measure of how well a crop can be grown in a given locality. It is complex and heterogeneous, and many variables influence where a particular crop is grown, and what crops are grown. Farmers must weigh up many variables in order to decide what crop is most suitable to grow in a particular location. Usually farmers make decisions based on a combination of biophysical and socioeconomic factors. Understanding such information requires expert knowledge on local conditions. With this in mind, the MoAF expert participants included a range of disciplines ranging from soil scientists, plant pathologists and agronomists, to social scientists, and they held fruitful and engaging discussions. During the capacity building workshop, a group discussion was undertaken to identify which variables were considered to be most important in Bhutan in determining what crops farmers should grow and where. Both biophysical (e.g. soil quality, slope, solar radiation, pest and disease presence, flood occurrence) and socioeconomic (e.g. irrigation, distance from roads and towns, population density, labor availability, and poverty) variables were identified by the participants, and the required data, availability and resolutions were documented (Annex 2). While most of the biophysical variables were mapped for this project, a full vulnerability assessment, including a thorough exposure and adaptive capacity component is recommended as a logical follow-up intervention to this project.

Crops of interest

The project identified five key crops that were analyzed in detail to develop accurate crop suitability maps. The crops of interest, which were chosen by MoAF were: maize, rice, potato, chili and tomato. Three additional crops, quinoa, kiwi and cardamom, were also selected based on a number of favorable socioeconomic, institutional and biophysical factors, as potential diversification crops that were analyzed in detail. Quinoa has recently been introduced into various areas and trials are currently underway. Kiwi is a potential cash crop that could offer farmers new economic opportunities, and cardamom is an important cash crop for Bhutan. In summary, the project identified the crop suitability for current and future conditions, for rice, maize, potato, chili, tomato, and the three additional diversification crops (i.e. quinoa, kiwi, cardamom).

Climate data – Visualization and analysis

Participants used R and ArcGIS to analyze the monthly temperature and precipitation data for Bhutan. They used geospatial techniques to calculate the mean annual precipitation and the mean annual temperature (Figure 2a). Validating the reliability of the climate data was highlighted as being important, as the data was used as input into the climate suitability model. The participants discussed the climate data validity for Bhutan. It was deemed satisfactory (Figure 2a), with an agreed plan to further improve climate data by adding national weather station information into the WorldClim database (Hijmans et al., 2004).

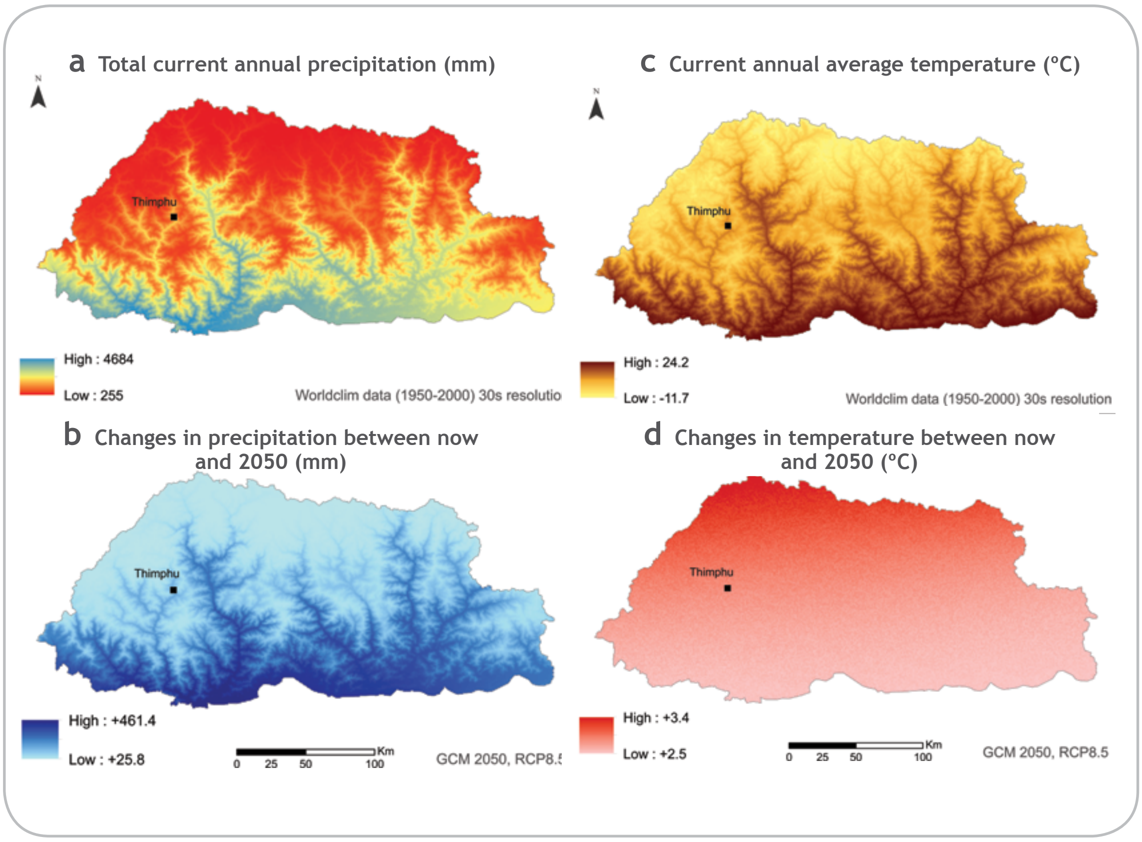


Figure 2: Climate in Bhutan

a) Total precipitation (mm) for current conditions b) Total precipitation (mm) for future conditions (2050) under RCP 8.5, using the mean ensemble of the GCMs. c) Mean annual temperature (°C) for current conditions. Temperature is represented at *1 decimal place. d) Mean annual temperature (°C) for future conditions (2050) under RCP 8.5, using the mean ensemble of the GCMs.
Source: Hijmans et al. (2004).

The participants then analyzed the future projected data using both representative concentration pathway RCP 8.5 and RCP 4.5. Information on these different emission pathways was provided and their applicability to Bhutan was discussed. Figure 3 reveals the differences between the different RCPs.

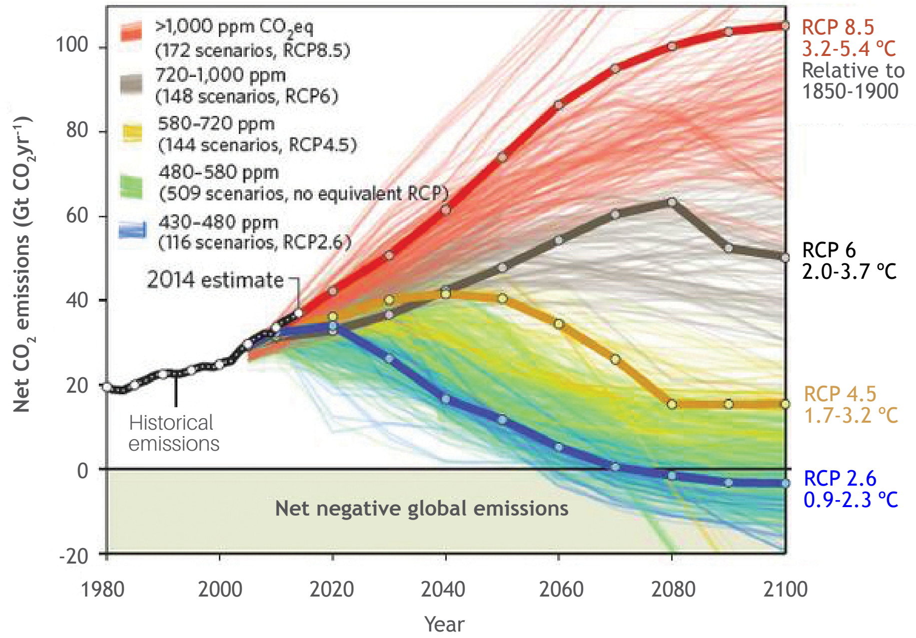


Figure 3: Representative concentration pathways (RCPs).

Source: Global Carbon Project (2016)

With an understanding of climate projections and scenarios, participants carried out future climate modeling. Figure 2b reveals the projected changes in the temperature and precipitation for the year 2050 under RCP 8.5. It is the mean ensemble of the general circulation models (GCMs). Participants analyzed the different GCMs and discussed the difficulties in identifying the future climate. A minimum increase in temperature of 2.5°C was projected for Bhutan, with some high-altitude areas experiencing an increase of up to 3.4°C by 2050. The total annual rainfall is expected to increase, with some areas expecting +461 mm of rainfall per annum by 2050 (Figure 2b).

EcoCrop

The EcoCrop model is an ecological niche model that can assess the climatic suitability of a crop (Figure 4). It runs on monthly climate data (i.e. precipitation and temperature) and both current and future climatic suitability of the crop can be modeled. Climatic suitability is an important layer in the overall suitability of a crop. In order to identify the climate suitability of a crop, the climatic niche of the respective crop must be developed. The EcoCrop model was used in combination with an ensemble of 31 GCMs, under one relatively low-emission scenario (RCP 4.5) and a high-emission scenario (RCP 8.5), as visualized in the representative concentration pathways in Figure 3. Potato was selected as the first crop to be modeled and will be used as an example for this report, while results for all other crops can be found in Annex 4.

The participants collectively discussed the climate requirements needed for each crop during its growing period. Table 1 displays the final parameters used to drive the EcoCrop model for potato.

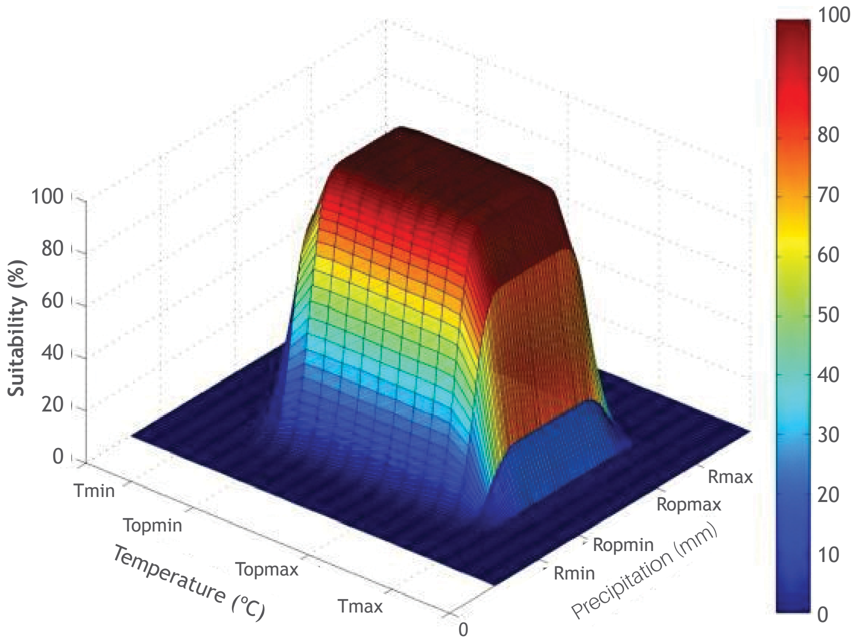


Figure 4: EcoCrop niche model

Table 1. Preliminary parameters developed for potato during the practical session

	Growing season minimum	Growing season maximum	Temp killing	Temp minimum	Temp minimum optimum	Temp maximum optimum	Temp maximum	Rainfall minimum	Rainfall minimum optimum	Rainfall maximum optimum	Rainfall maximum
potato	90	160	-1	7	15	25	30	400	600	900	2000

*Values for temperature (°C) refer to the average temperature for the length of growing season
*Values for precipitation (mm) refer to the total precipitation for the length of the growing season

The EcoCrop model was first run for current conditions (Figure 5a). The current climatic suitability of potato (Figure 5a) was in accordance with the expert participants' knowledge of the crop. EcoCrop was then run for future climate conditions (2050), and the mean of the GCMs was calculated for RCP 8.5 (Figure 5b) and RCP 4.5 (Annex 4). The change (RCP 8.5 and RCP 4.5) was then calculated (Figure 5c and Annex 4).

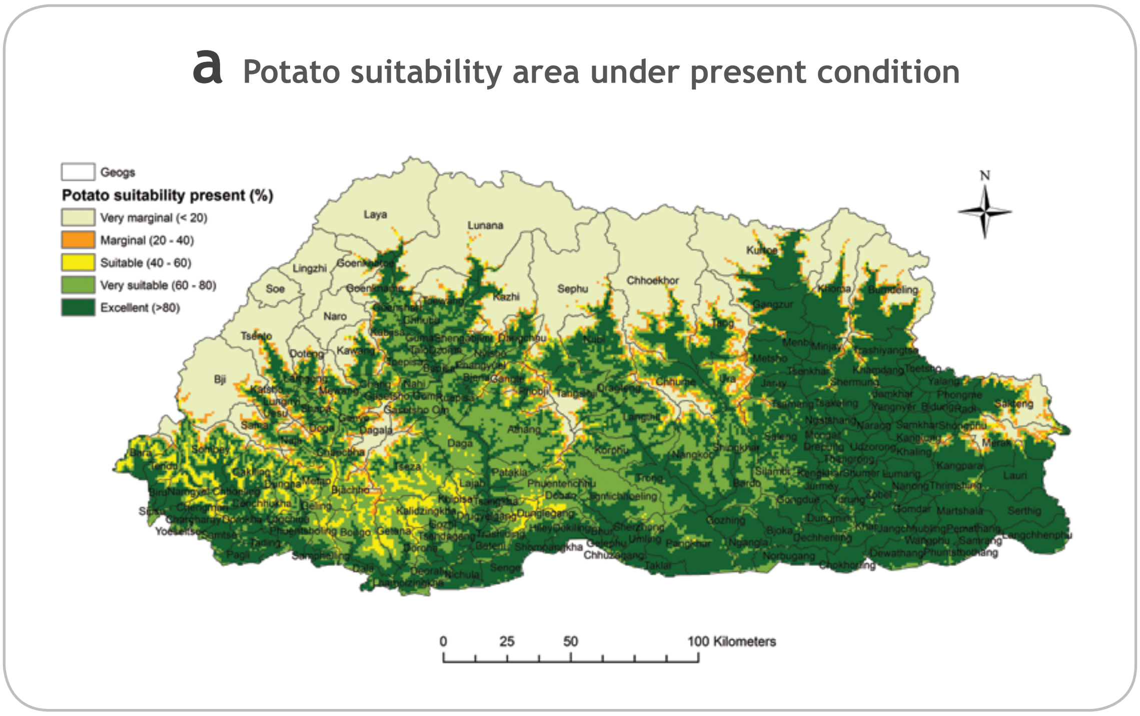


Figure 5: Current climate suitability of potato

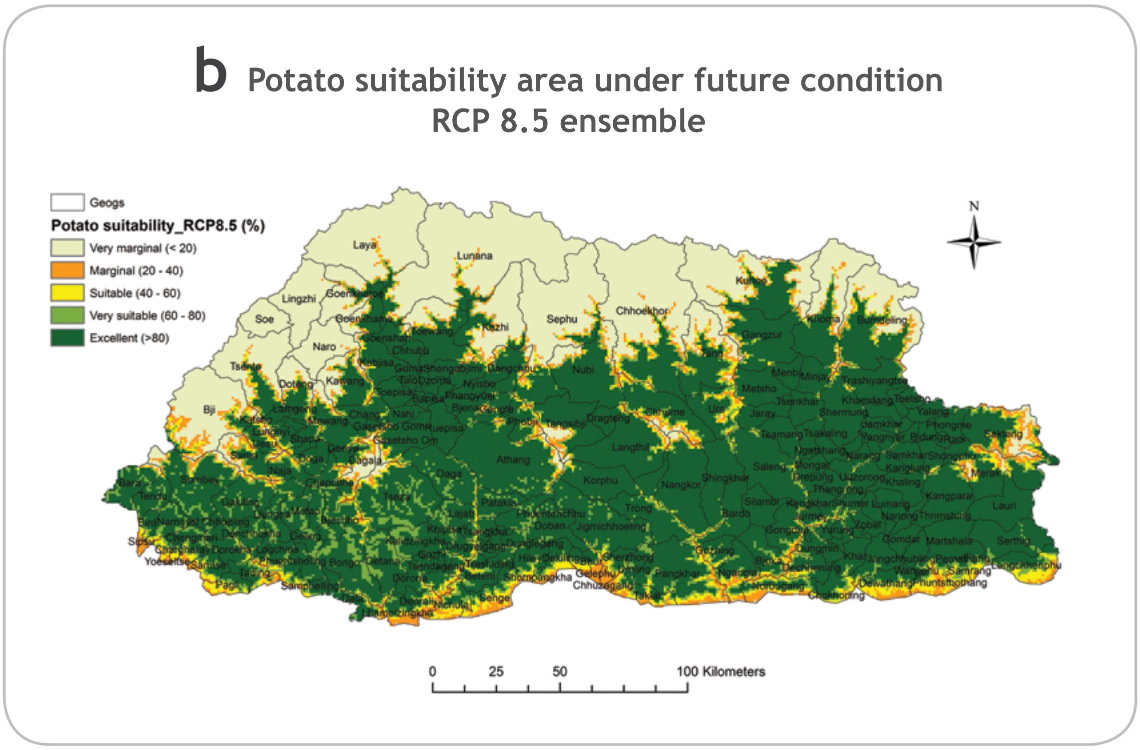


Figure 6: Projected change in potato climate suitability up to the year 2050, under RCP 8.5

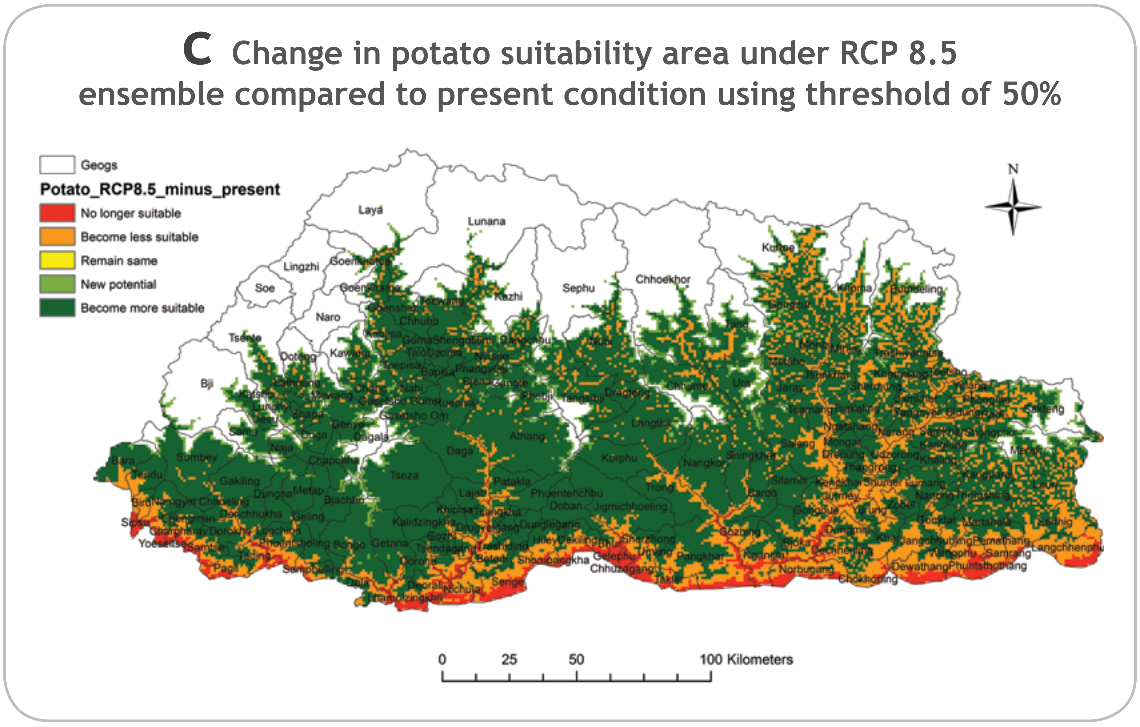


Figure 7: Change (%) in suitable areas of potato based on the allocated suitability threshold (%)

In order to identify which areas gain and loose in terms of suitability, a percentage threshold was developed, above which it was deemed that the crop would grow effectively. This was undertaken through participatory dialogue with the experts on the respective crops. The input of Dr Yadunath Bajgai, National Potato Coordinator for MoAF, helped to identify a suitability threshold of above 50% as sufficient conditions for potato to grow. Figure 5c reveals the areas which under RCP 8.5, for the year 2050, are "no longer suitable", as indicated by those areas that were suitable under current conditions (≥ threshold) and not suitable under future (< threshold), "become less suitable", this indicates those areas that are suitable in current conditions and are suitable but less so in the future. "Remain same", indicate areas that remain suitable in the future, "new potential" are areas were not suitable in current conditions and are now suitable under future conditions, and "become more suitable" are those areas that are suitable under current conditions and become more suitable under future conditions.

The results for potato reveal a gradient, where lower altitude areas in the south (<1,000 m) become unsuitable, driven by increasing temperatures, whilst the mid-latitude areas (1,000–3,000 m) experience expansion in areas that are suitable. This is notable in both RCP 8.5 and to a lesser extent in RCP 4.5. The high-elevation areas (>3,000 m) remain largely climatically unsuitable for potato. The parameters and EcoCrop model was rerun after expert input from the participants. The results presented are the efforts of multiple attempts, which combined expert knowledge and the academic literature, to ensure a more representative picture of current and future climate suitability for potato in Bhutan. The EcoCrop model was used to project the future climate suitability using multiple GCMs, under a relatively low-emission scenario (RCP 4.5) and a high emission scenario (RCP 8.5), as visualized in the representative concentration pathways in Figure 3.

While new areas will become available for potato growers in the future, climate adaptation strategies need to be developed for potato farmers in lower altitudes that may lose suitability or even become unsuitable. According to Yadunath Bajgai, farmers in southern Bhutan may in response grow off-season potato, i.e. planting in October/November and harvesting in March/April. Furthermore, farmers may have to grow heat-and-moisture tolerant varieties of potato, which may not yield as well as the varieties that are grown currently. Dr Yadunath also explained that these heat-and-moisture tolerant varieties would need to be introduced by the Department of Agriculture as farmers do not have the capacity to test and introduce new varieties, or existing regulations do not actively facilitate such actions. Overall improved water management will be needed and potentially new intercropping models could be trialed – currently potatoes are mostly intercropped with maize.

Eventually potato farmers in future low-suitability areas might decide to diversify to new and more suitable crops or even transform their livelihood strategy and moving towards off-farm employment.

Biophysical context

The suitability of a crop is not solely defined by the climate. Additional biophysical criteria exist. Several biophysical suitability layers were selected by the participants: elevation, slope, soil and solar radiation. These variables were deemed to influence the spatial distribution and suitability of cropping areas. The following section presents the biophysical data and layers that were used.

Slope

Slope is a huge constraint to agriculture in Bhutan. It was identified as one of the key biophysical constraints that influences crop suitability. Based on the FAO classification of slope, much of Bhutan possess slope beyond 30 degrees and is only suitable for forestry systems (FAO, 2005). However, also workshop participants noted that some farmers might still find techniques to grow crops in areas that were beyond the FAO classification limits for agriculture.

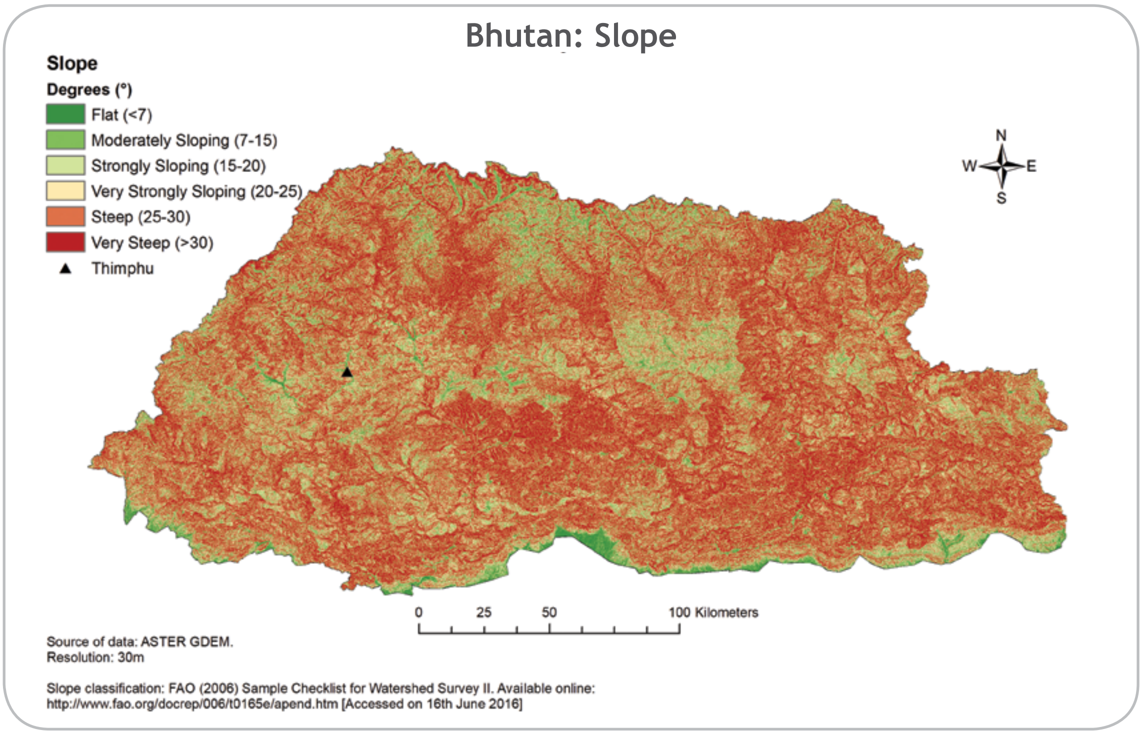


Figure 8: Slope map

Elevation

Elevation is a key factor for the climatic suitability of crops in a mountainous country such as Bhutan, which ranges from 97 m.a.s.l. in the southern lowlands to 7,570 m.a.s.l. at its highest peak. The elevation was mapped with a 30 m resolution ASTER GDEM.

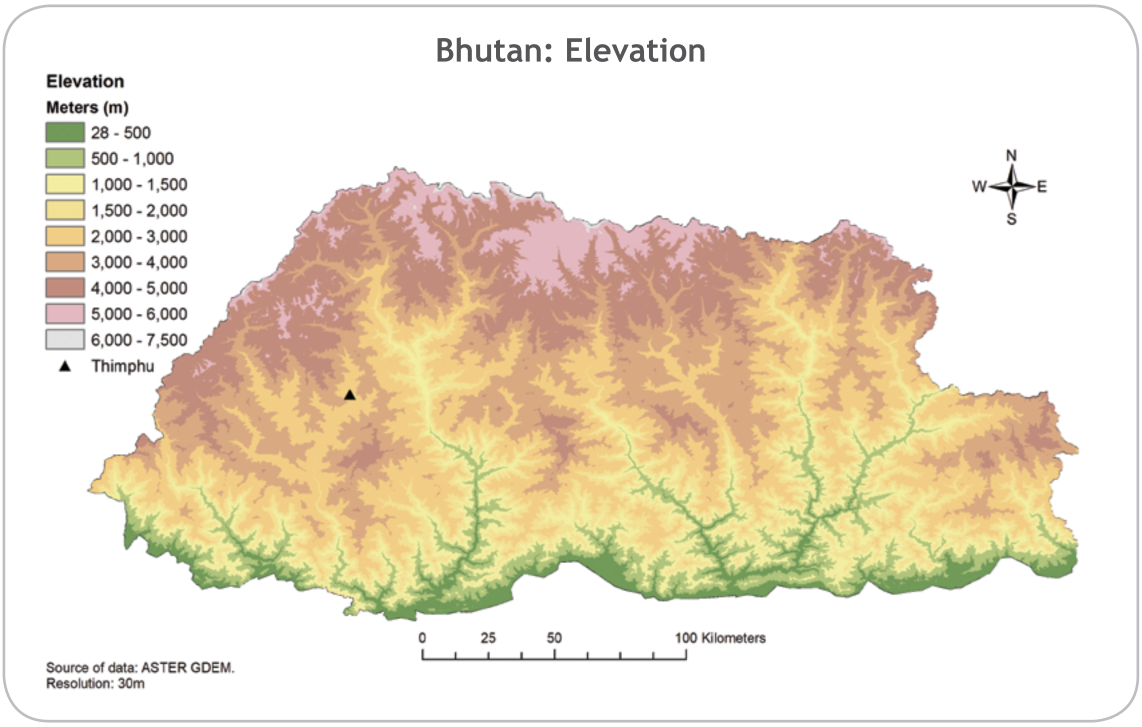


Figure 9: Elevation map

Soil

The soil map was taken from the ISRIC World Soil Information (2014). This is currently the best available soil map for Bhutan, but provides an unreliable picture as it has an estimated accuracy level of 23–51%. National efforts to develop a more reliable soil map are underway but are not expected before 2020.

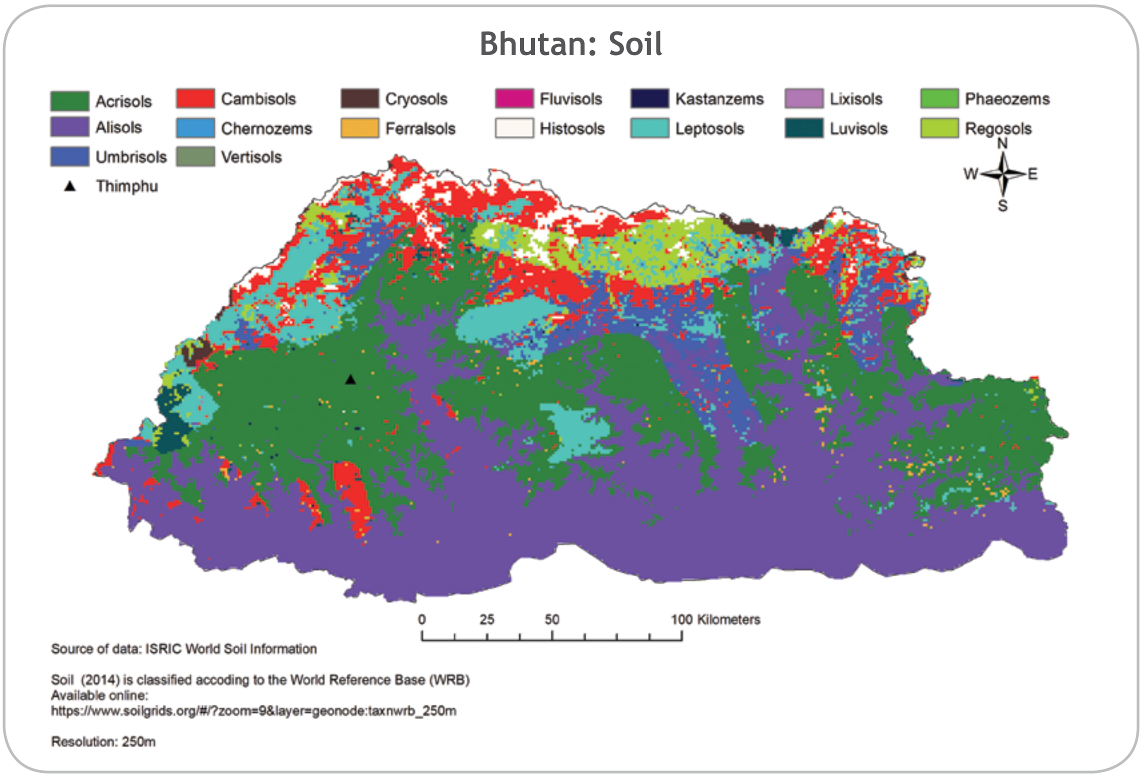


Figure 10: Soil map

Source: ISRIC, 2014

Solar radiation

The participants identified solar radiation as a key variable influencing crop suitability. There are various methodologies that can be used to create solar radiation, with both ArcGIS and QGIS providing different tools to assess solar radiation. Therefore it is necessary to produce and analyze the solar radiation map using both software and various approaches. A 90-meter resolution digital elevation model is available for Bhutan and was used to develop the solar radiation map.

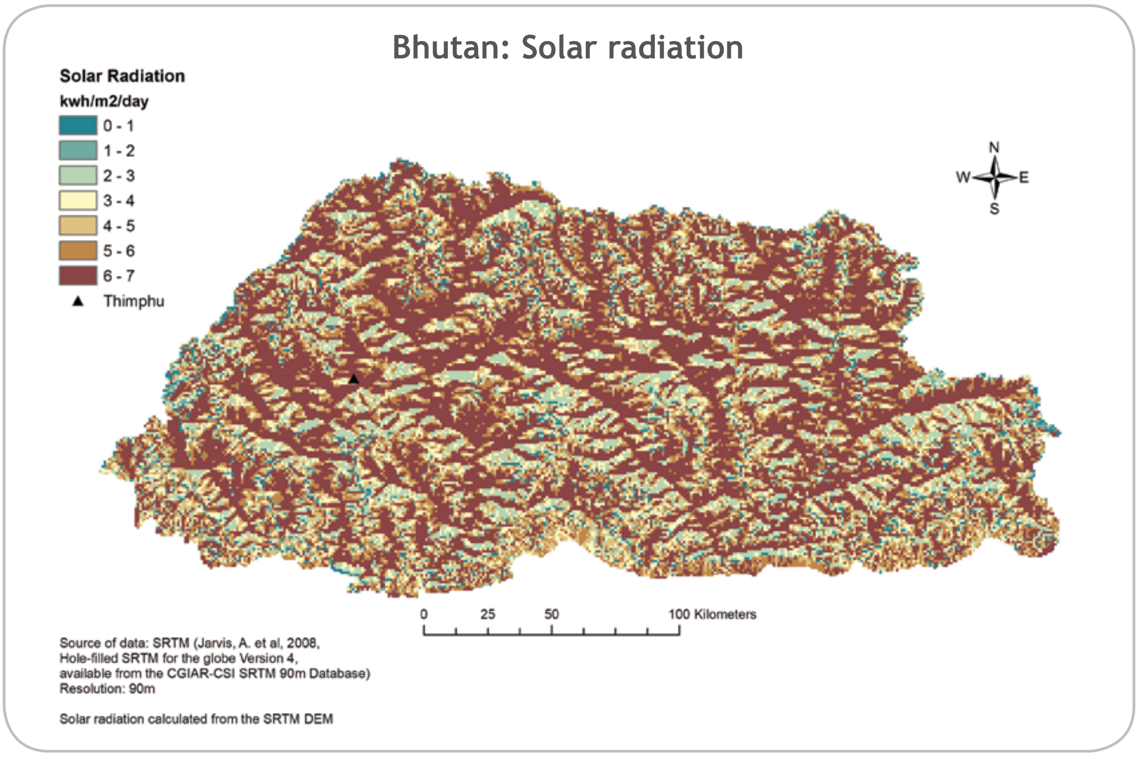


Figure 11: Solar radiation map in kwh/m²/day

Overall crop suitability

Combining climate suitability with biophysical suitability data can provide a more integrative picture of overall crop suitability. Dr Yadunath Bajgai defined the biophysical requirements for potato (Table 2), as well as the climate suitability parameters.

Slope for potato is similar to that of maize, as maize–potato intercropping is common in Bhutan.

Solar radiation: Generally, solar radiation of at least 5 kwh/m²/day is good for potato productivity. However, exact requirements for potato in Bhutan need to be clarified further as they are based on current potato growing area conditions.

Soil: The current existing soil maps for Bhutan are not very accurate and do not provide us with enough confidence to properly assess crop suitability. Generally, potato prefers sandy to silty loams textures of soils for ease of tuberization. Hence, soils are also identified by correlating the potato growing areas with the presence of the appropriate soil type, as suggested.

Elevation: About 70% of potato in Bhutan is grown at 2,000–3,500 m.a.s.l. (Roder et al., 2008) and others are spread over other elevation ranges as shown in the table below. This is for the main season potato and not for the off-season (spring potato).

Table 2: Biophysical suitability variables for potato

	Slope (° degrees)	Solar radiation	Soil	Elevation (m)
Not suitable	>35	<4	NA	>3500m, <800
Marginally suitable	25-35	4-5	NA	800-1200
Suitable	15-25	5-6	NA	1200-2000
Highly suitable	0-15	>6	NA	2000-3500

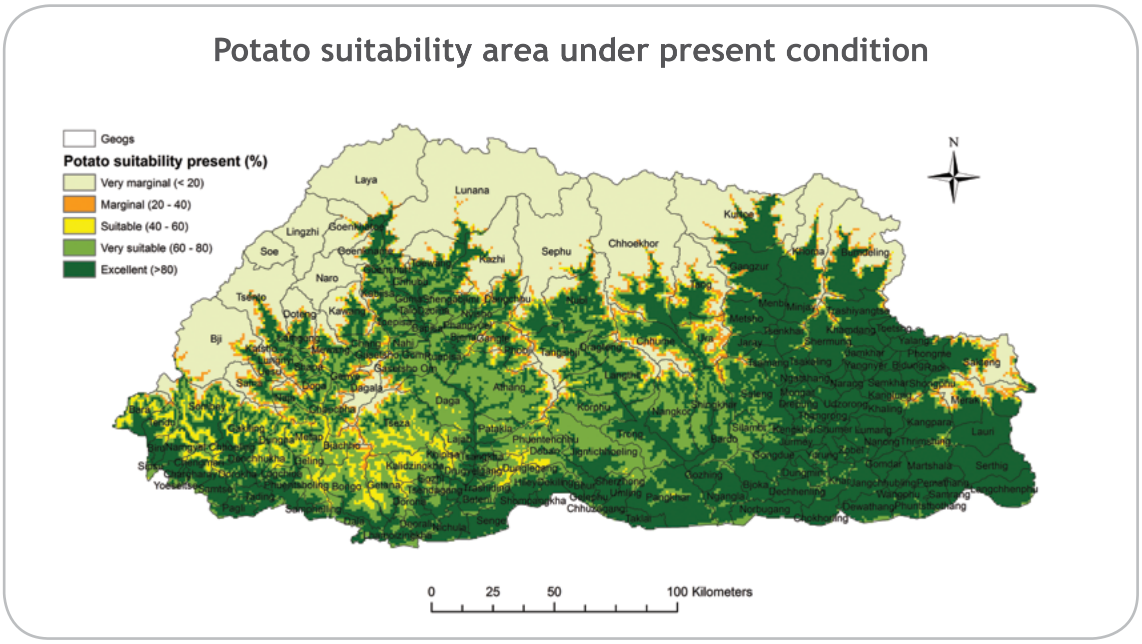


Figure 12: Potato suitability area under present condition

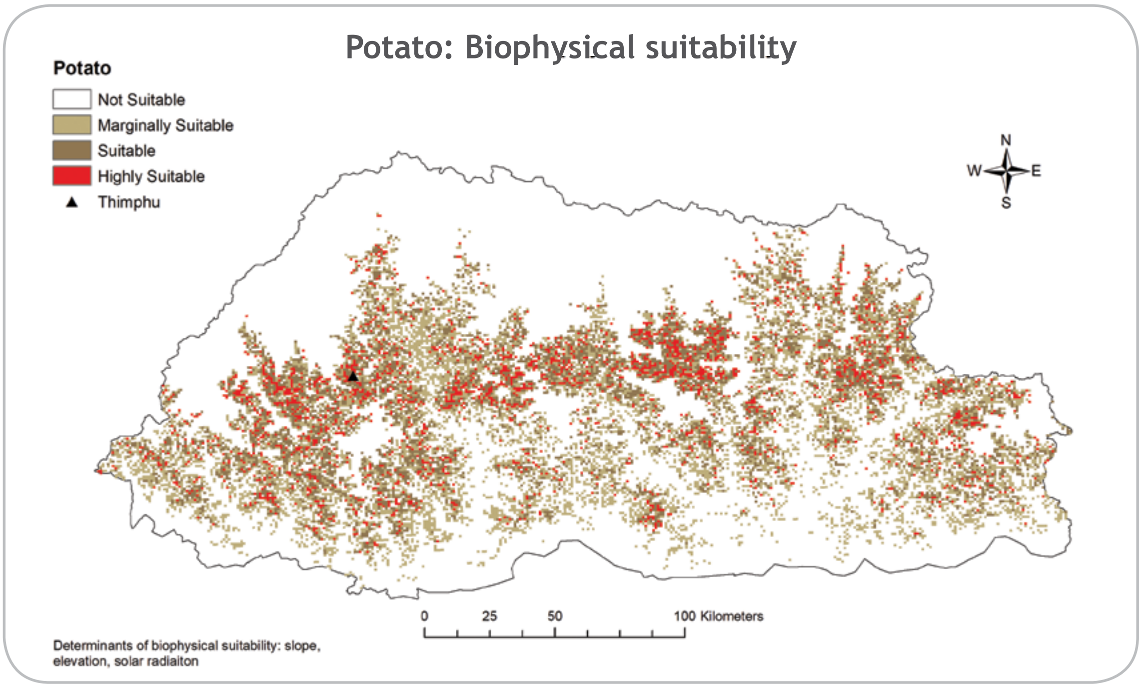


Figure 13: Compiled biophysical potato suitability (excluding soil due to low accuracy)

Soil erosion risk

The following section presents a soil erosion risk map, which is based on biophysical data. It can be used to identify which areas may require conservation agricultural management practices. The topography of Bhutan with steep slopes and valleys means that soil erosion is commonplace. In order to identify the areas with highest soil erosion risk, the Universal Soil Loss Equation (USLE), a well-established methodology was adopted (Stone and Hilborn, 2000).

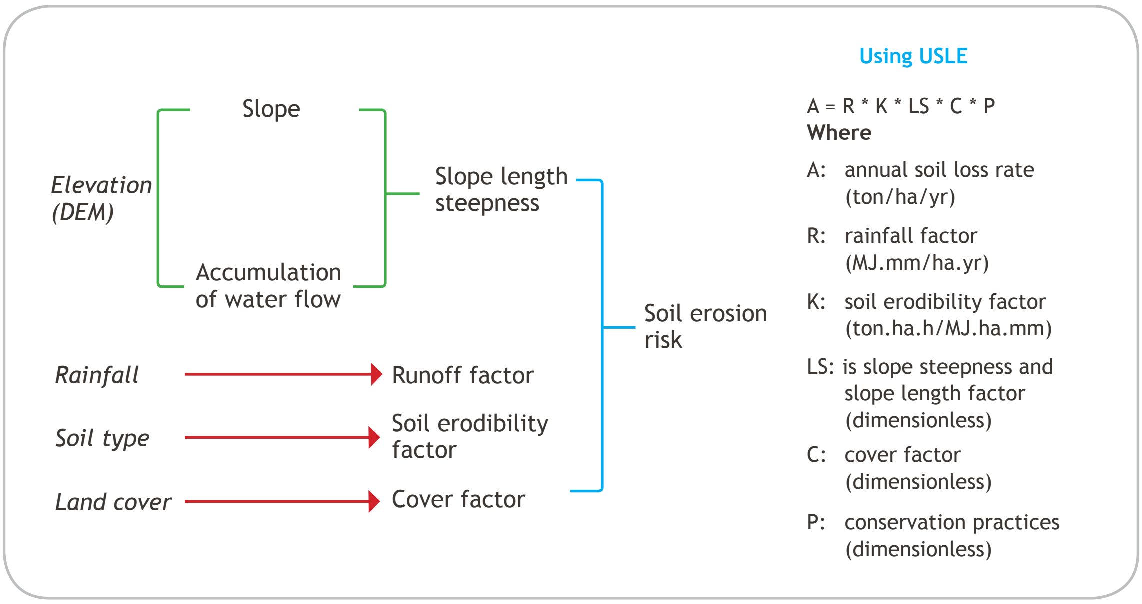


Figure 14: USLE equation

Source: Stone and Hillborn (2000)

The data sets were collected from a number of sources (see below) and data processing and analysis was undertaken in ArcGIS.

The **slope length** was calculated using a digital elevation model (ASTER GDEM V2, 2011). First the slope was calculated in ArcGIS, and then an equation was used to calculate slope length (Bien Le Van, 2014). **Run-off factor** (Bien Le Van, 2014) was calculated from the WorldClim data (Hijmans et al., 2004) for total precipitation for current conditions. **Soil erodibility** was calculated based on the ISRIC Word soil database (Hengl et al., In press). The erodibility of the soil was based on the available literature.

Table 3: Soil erodibility factor

Soil	K	Source
Acrisols	0.28	Nguyen (2009)
Alisols	0.25	Gelagay and Minale (2016)
Cambisols	0.05	Ranzi et al (2012)
Chernozems	0.45	Podhrázská J, Dufková J (2005) cited in Hrabovski (2013)
Cryosols	0.0197	Same as Histosols as according to FAO have similar conditions
Ferralsos	0.2	Nguyen (2009)
Fluvisols	0.23	Nguyen (2009)
Histosols	0.0197	da Silva et al (2011)
Kastanozems	0.45	Same as Chernozems according to FAO
Leptosols	0.028	Ranzi et al (2012)
Lixisols	0.25	Gelagay and Minale (2016)
Luvisols	0.12	Nguyen (2009)
Phaeozems	0.2	Gelagay and Minale (2016)
Regosols	0.2	Gelagay and Minale (2016)
Umbrisols	0.24	Comolli R (2005)
Vertisols	0.15	Gelagay and Minale (2016)

Source: Adapted from Rodriguez et al. (2006).

The **cover factor** was based on the land-cover map (ICIMOD, 2010), and the land-cover types were classified according to Morgan (2005). Combining all the variables enabled us to produce a soil erosion risk map.

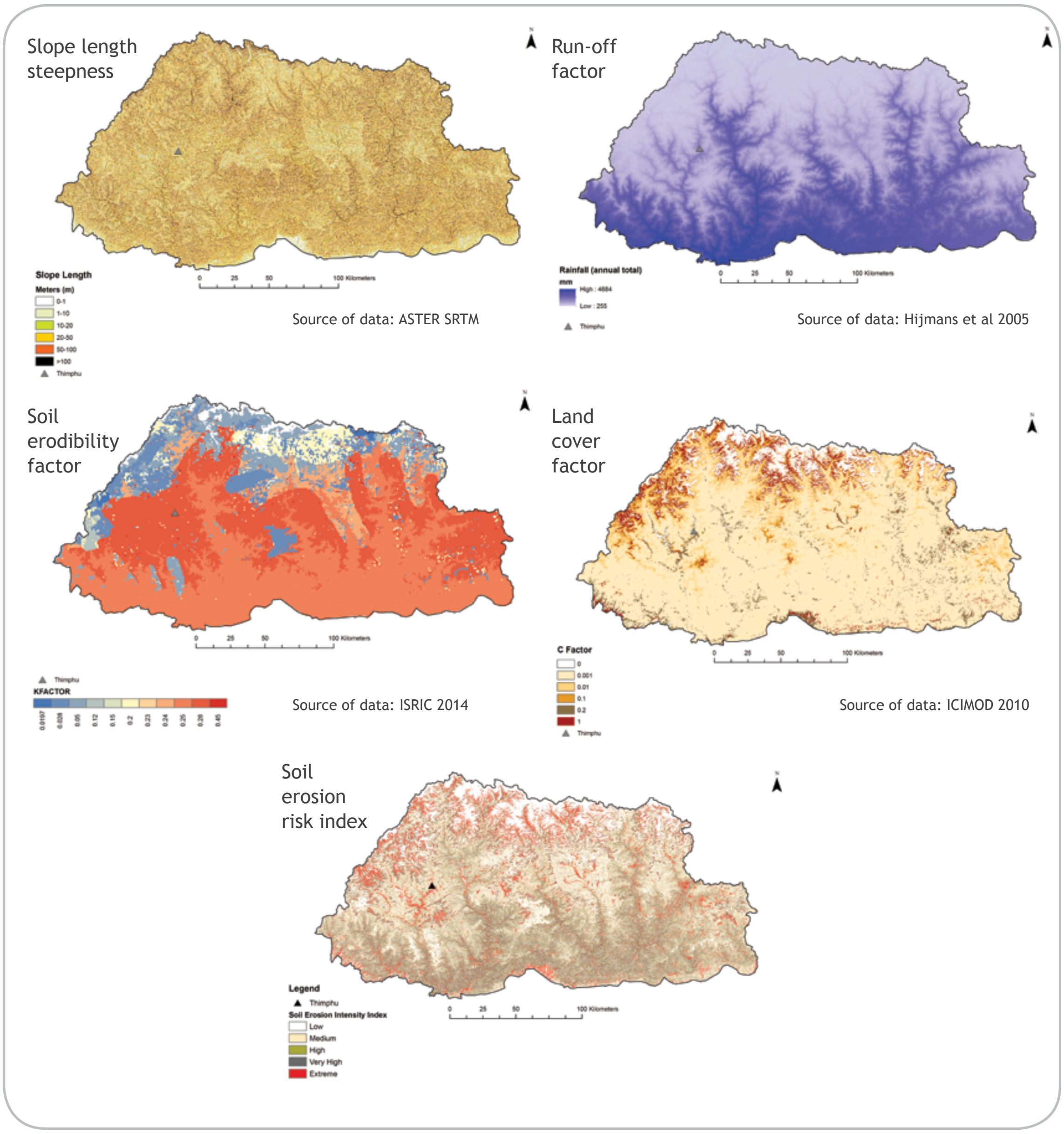


Figure 15: Soil erosion risk index

The soil erosion risk index is derived from four components: slope length steepness; run-off factor; soil-erodibility factor; and land-cover factor. The soil erosion risk map revealed that that the southern area was at risk of soil erosion. This area is one of the key agricultural regions of Bhutan. The bare slopes in the mountainous areas of the northwest and northeast of the country were also identified as being high-risk erosion areas. MoAF participants at the final workshop stated that this soil erosion risk map would be critical for planning and targeting future interventions.

4. Farmer workshop and gender component

A farmer workshop was held in order to integrate a gender component into the project and to give us an overview on decision-making roles in agricultural production a short video was also developed. However, as this was just one case study example, no scientific analysis or recommendations could be conducted from the sample workshop. We would need to run a larger number of workshops using relevant selection criteria to provide a representative case for either a certain region or for the whole country. This workshop was designed to provide us with a snapshot and to compare and validate some of the opportunities and challenges highlighted during the mapping exercise with farmers. In addition, the capacity-building workshop provided participants with information about potential methods to conduct gender-sensitive workshops.

The farmer workshop was held in Hongtsho, Thimphu on 10 May 2016. In order to better understand the contextual challenges related to climate change and agricultural production, as well as gender roles, some activities of the more comprehensive CSA rapid appraisal (Mwongera et al., 2014) were chosen, which have been implemented in Nicaragua, Tanzania, Uganda, and Vietnam to date.

Picture 1: Farmers discussing climate challenges in agriculture

After joint identification of key regional crops, farmers were assembled into smaller groups, divided by gender for discussions on: the cropping calendar, activities by crop during production cycle, labor division between men and women, vulnerability during the cropping cycle in a “normal year” and under conditions characterized by climate variability. Seasons with the likelihood of extreme events and their impact were also recorded. This exercise generated contextual information for the study area, agricultural production customs and habits, climate concerns and period of vulnerability. A guided discussion deliberated on main practices and key challenges related to: (1) climate variability, (2) market access, (3) input availability, (4) access to credit, (5) land access, (6) pests and disease, and (7) seed supply. From these challenges, farmers were asked for their coping strategies and CSA practices responding to the identified challenges.

Cropping calendar

The following four major crops were assessed/selected as the most important sources of livelihood of the farmers of Hongtsho, Thimphu: potato, radish, cole crops and apple.

Picture 2: A female farmer who participated in the workshop

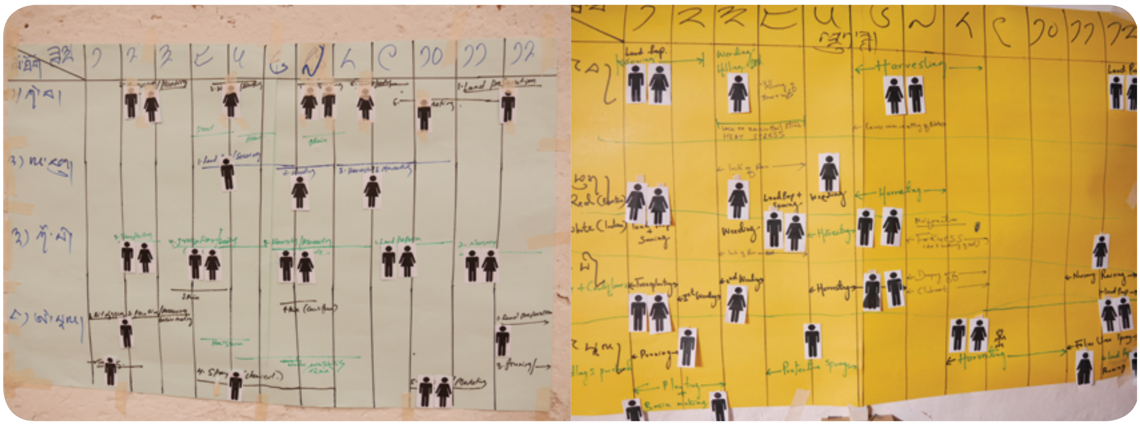
The chart shows the cropping calendar for the four selected major crops cultivated by the farmers of Hongtsho. Activities are highlighted for each crop, and for the key actor undertaking most of the work, female, male or jointly. When reporting the results of each group back to all participants it became obvious that there were some differentiating conceptions, e.g. harvesting seasons were reported slightly different. Furthermore, men claimed that they did more of the agricultural activity and the women argued the opposite. Many repetitive activities, such as land preparation, were highlighted as male-only activities by the male group whereas the women's group reported land preparation as an activity that was jointly conducted by men and women.

Table 4: Cropping calendar (male group)

Crop	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
	Farming activities during different months/crop stages and gender role (male group)											
Potato											Land preparation	
		Sowing/furrowing/manuring/ fertilizer application		Weeding/earthing up			Harvesting					
								Sorting		Marketing		
Radish (red type)				Land preparation and sowing								
					Weeding			Harvesting and marketing				
Cauliflower/ cabbages									Land preparation		Nursery	
		Transplanting		Intercultural practices			Harvesting and marketing					
Apple												Land preparation
	Land preparation	Pit digging and planting										
		Weeding, basin making, Irrigation and manuring		Insecticide and fungicide application						Harvesting/Marketing		
	Training and pruning											

Table 5: Cropping calendar (female group)

Crop	Farming activities during different months/crop stages and gender role (Male Group)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Potato											Land preparation	
	Sowing/furrowing/manuring/ fertilizer application		Weeding/earthing up			Harvesting						
Radish (red type)				Land preparation	Weeding							
					Harvesting							
Cauliflower/ cabbages											Nursery	
	Transplanting	Weeding			Harvesting							Land preparation
Apple	Land preparation	Planting		Insecticide and fungicide application			Harvesting					Pruning Foliar application of urea



Picture 3: Cropping calendar for male group (white) and female group (yellow) according to the Bhutanese calendar

Farmers reported the main reasons for crop choice as: income and access to inputs (e.g. seeds, technical skills/human capital). Climate risks for the four selected crops were highlighted as follows:

1. Potato

- Frost in the period February–March
- Hailstones in March and April
- A dry spell in May and June without rain
- Untimely rain in the period July–August during the harvest and tuber rotting problems

2. Radish

- Poor quality seed (bolting, radish prematurely produces flowering stems)

3. Cauliflower and cabbage

- Drought during growing season (March–June)
- Heavy rain during harvesting (June–August)

4. Apple

- Hailstones during flowering in April–May
- Drought during fruit set and development from April/May–June

Table 6: Summary of the reported challenges

Theme	Female group	Male group
Reported climate change impacts on crops	· Untimely rain during sowing and main crop development stages affecting yield · Cold followed by dry spells (winter-spring) · Warmer temperatures with more weather extremes and less snowfall over the last few years compared to a decade ago	· Lack of rainfall (moisture stress) · Change in potato storage practice where seed potatoes have to be covered with jute rugs, blankets · Cereals such as barley, mustard, and millet are now being replaced by more lucrative crops such as vegetables · Cabbage is now being cultivated; this is due to climate change · Need to irrigate potato due to climate change/lack of rainfall · Increased incidence of mosquitoes
Reported key challenges in agricultural production	· No competitive advantage over cheaper Indian products · Delay in production due to shift in rain pattern · Lack of market information and uncertainties in market dynamics, price fluctuations, etc. · Many farmers are sharecroppers or many do not own land · Smaller landholding · No irrigation facilities · Clubroot disease in cruciferous vegetables · Grubs in potatoes · Poor seed quality (bolting) of cole crops · Access to credit is limited · No financial institutions available to lend money to marginal farmers	· Low-quality seeds especially with the seeds supplied from Bhutan Alpine where radishes bolted (premature flowering without tuber formation) · Low quality of potato seeds · Incidence of cabbage white butterfly, aphids, clubroot · Wildlife predation on agricultural crops (wild boar, bear, monkeys) · Cattle from the city allowed to roam freely in the village · Damage by stray dogs on agricultural crops · Lack of irrigation water, lack of irrigation channels & water harvesting techniques despite the existence of a local good water source which remains untapped · Diversion of drinking water for irrigation
Reported CSA practices and technologies	· Protected cultivation (poly-tunnels for nurseries) · Mulching practices with plastics and blankets during harsh winters to save crops · Farmers are aware of efficient irrigation methods/systems such as drip and sprinkler irrigation but their use is limited to a few farmers	· Cultivation of crops under protected cultivation · Requests for technical assistance in CSA practices and technologies, e.g. drip irrigation

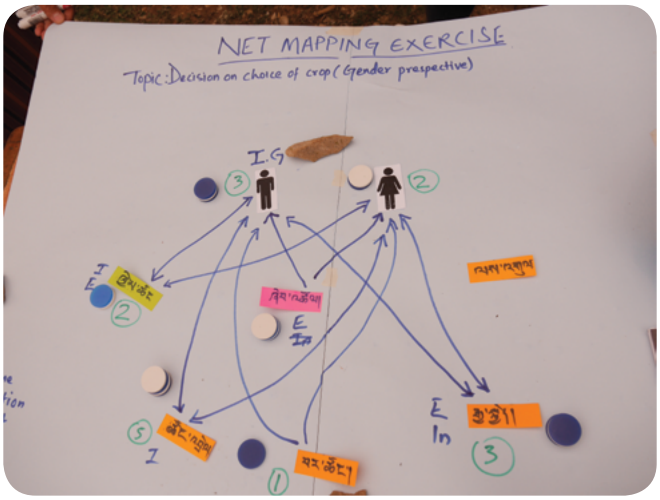
Note: The table includes the economic, biophysical and climatic challenges that affect agriculture with additional information on the reported CSA practices used by the farmers.

Net-Map on decision-making influence for the choice of crops

Net-Map, developed by Schiffer and Hauck (2010), a tool for social network analysis, was modified to be used in a simple format (Table 7) for the farmer workshop's household gender insights. The influence of different actors was scored from 1 (lowest influence) to 5 (highest influence).

Table 7: Influence of the different stakeholders and factors on the crop choice for female and male groups (1=lowest; 5=highest).

Influence	Female group	Male group
Gender	5 (women) 4 (men)	3 (male) 2 (female)
Market	5	5
Research/technical skill	3	4
Extension officer	5	3
Retailer/middlemen	1	1
Neighbor	Not named	2



Picture 4: Net-Map exercise (male group)

Video

In addition to the farmer workshop, some short video sequences were recorded to explain and visualize different viewpoints in the form of statement snapshots. The videos were recorded during and after the farmer workshop with two groups: farmers who participated in the one-day workshop and members of MoAF who participated in the 2-week crop suitability workshop. The questions asked were slightly different; farmers were asked a combination of two or three of the following questions:

- Do you feel men and women have equal decision-making power at home? Can you share with us examples of how men and women share decision making at home?
- Is there a difference between men and women with regard to: (i) handling of assets (e.g. monetary and nonmonetary)? (ii) agricultural production (e.g. who owns livestock, ox-cart, axe, hoe, wheelbarrow, car and sprayer) and (iii) ownership of land?

- Would you like to change the roles of men and women in agricultural production? If so, what in particular? From the current roles that men and women play in agricultural production, what could be improved if the roles changed? And why?
- How has climate change affected your production of crops? If so, what has changed and has it been good or bad? Because of change in production of crops, have the way men and women live and work changed? If so, in what way?
- Have you learned something new during today's workshop or do you have a key message to share?

Participants of MoAF were asked the following set of questions:

- How do you think climate change will affect the role of men/women in crop production in Bhutan? And how will these changes have an impact in the longer term?
- During this workshop, what surprised you about gender, agriculture and climate change and what have you learned? Will something change in the way you carry out your work?
- What are some ideas for integrating a stronger gender component into your work? How might you implement it?

Two short videos were developed from the material recorded, one that mainly focused on gender roles and a second one that highlighted some of the key climate challenges, such as water access issues, and opportunities, such as the introduction of new cash crops.

The videos can accessed through the following temporary links:

Gender, climate change and agriculture insights:
http://bit.ly/2lrAlA8

Climate change and agriculture insights:
http://bit.ly/2kstIPR

5. Discussion

Soil maps

To date, there is no comprehensive soil map in Bhutan. There are current efforts by the National Soils Services Centre (NSSC) to map the country in detail, but progress is slow and soil samples are still being analyzed in laboratories. A complete soil map of the country is not expected before 2020–2025. Therefore this analysis has to rely on previous efforts; the only ones available are a low-resolution soil map from FAO from 1995 and ISRIC (2014). ISRIC used a satellite technique to spatially map soil types. However, accuracy levels are very low, at between 23 and 52%, which results in high uncertainties using the existing soil layer. Once a sample of the new national soils map is available, it would be interesting to compare two case studies of crop suitability with the new mapping efforts (NSSC) and existing soil maps (FAO and ISRIC). During the workshops, the key role soil layers play in assessing crop suitability was thoroughly discussed.

Parameters are country specific

The generic crop parameters for Ecocrop from FAO for assessing the climatic suitability of a crop were adjusted for Bhutan. Before adjusting, the generic parameters did not reflect optimal growing conditions or showed no suitability for a currently widely grown crop. National experts identified the climatic and biophysical parameters (such as optimum slope and sunlight exposure) for each of the assessed eight crops. However, during the final consultation workshop, it was also reported that some parameters might need to be adjusted, depending on the crop variety.

Sowing date

While the climatic suitability maps provided insights about potential growing areas and areas gaining and losing in suitability, they did not provide seasonal advice. New crops still require thorough testing; the most suitable sowing date for quinoa in Bhutan is currently still being explored through field trials.

Stakeholder diversification

All training participants were members of MoAF. A broader engagement, for example with the National Environment Commission (NEC) and other end users, such as civil society groups is envisioned for the final results sharing workshop and further training.

The participants rated the workshop as being very helpful for their work (Figure 14), based on the feedback survey shared with participants (SurveyMonkey). The mapping and modeling exercise was adopted by some of the participants; for example, one participant presented some of the resulting maps to demonstrate the potential climatic suitability of quinoa in Bhutan to the quinoa awareness-raising forum that was held in June 2016.

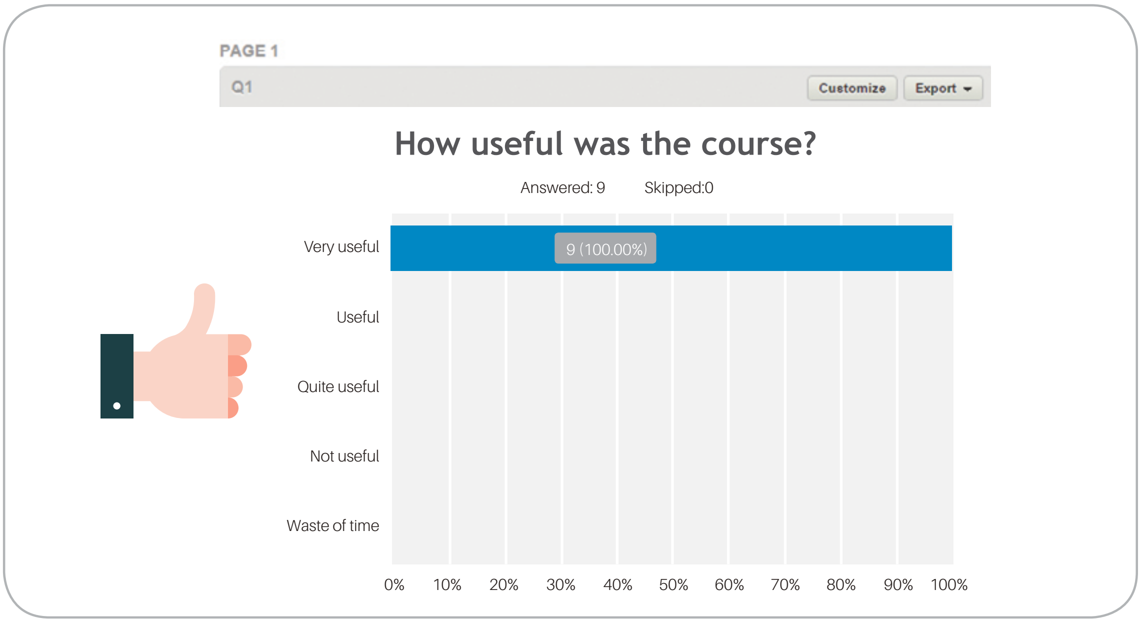


Figure 16: Results for question 1 of the feedback survey (shared via SurveyMonkey)

Picture 5: Participants discussing during capacity building workshop.

6. Outlook

Climate-smart agriculture

Climatic crop suitability modeling enables end users to identify risks and opportunities for crops under progressing climate change. While some crops will benefit from higher temperatures and altering precipitation patterns, other crops will have a reduced climatic suitability in the future. Therefore site-specific adaptation options need to be identified. Crop suitability maps are a first step in allowing for evidence-based spatial planning and highlighting adaptation needs and opportunities. In order to build on the results presented here, consecutive projects on the theme of climate-smart agriculture are currently being discussed which will consider the key needs as identified by MoAF. All crops show reduced suitability to various extents in some current growing areas, especially in the lower altitudes in the south. Therefore these areas require more intensive adaptation efforts or need a diversification of crops, with selected crops becoming more suitable in new altitudes.

Bhutan's potential for benefiting from climate-smart agricultural initiatives remains so far largely untapped, with a SNV project from five years ago the most acknowledged initiative. A current UNDP project is installing more than 90 state-of-the-art automatic weather stations (AWS) that will prove to be useful for improved analysis, seasonal forecasting and site-specific decision-making in agriculture and other sectors.

Ecosystem services on a landscape scale

During the farmer workshop, many participants reported a shortage of or difficulty in accessing water as one of the key agricultural challenges for their community. Decision makers would benefit from: a landscape analysis of watersheds; the downstream effects on water supply and climate change impacts on Bhutan's main water storage (glaciers); and the impact of numerous hydropower dams in the country. Furthermore, erosion remains one of the highest risk factors in Bhutan and fertile topsoil layers are frequently washed away. Eco-efficient soil management is necessary to sustain the little land area that is suitable for agriculture.

During the consultation- and results-sharing workshop in September 2016, participants were divided into three groups, outlining research needs and recommendations:

Include further national climate data and land-cover map

Climate data was derived from the WorldClim database as outlined in the methodology for the presented crop suitability assessment. However, uploading national climate data of Bhutan, even if the number of stations is limited, would improve the accuracy of the results. Newly installed automatic weather stations under a UNDP-funded project should also be considered for the future. Furthermore, there is a more detailed land-cover map provided by the Bhutanese government that will increase the accuracy of the overall suitability as an additional layer to the climatic suitability assessment. This layer could also improve the accuracy of the soil erosion risk map as it has more land-cover classes.

Develop a full vulnerability assessment

As a follow-up activity, the results of crop modeling can be used to develop a full agriculture vulnerability assessment, including an exposure, sensitivity and adaptive capacity component. Parts of the exposure components have already been covered (e.g. soil erosion map, changes in temperature and precipitation), but a more thorough assessment of flood and drought risk areas under progressive climate change would prove useful. The sensitivity component has been covered by the crop modeling exercise. Regarding adaptive capacity, a lot of socioeconomic data is available on a high resolution and is partly sex-disaggregated for recent years in Bhutan; in addition new, comprehensive census data will be available in early 2017. Together these three components would provide a more holistic assessment for the agricultural sector. It would enable a greater understanding of the areas of the country that are most vulnerable to climate change and the farming systems that are under threat. This information can help policy makers and nongovernmental organizations to make strategic and effective interventions.

Validation and ground truthing of results

Validating the modeling results and understanding if the challenges are coherent or different to the projections is key to developing effective interventions for climate change adaptation. During the workshop it was suggested that areas that are projected to become unsuitable in the future should be visited and site-specific coping strategies such as adaptation, to potential transformation and/or off-farm employment should be developed.

Economic modeling and qualitative socioeconomic research

Further research on the criteria for adoption of crops in Bhutan is needed, e.g. many new crops such as quinoa could be suitable under current climatic and biophysical conditions, but farmers do not grow them. This might be due to cultural preferences in diets, lack of awareness, lack of technical skills and knowledge on cultivation, access to markets or seed challenges.

Site-specific agriculture advice

In addition to more regional specific weather and seasonal forecast, site-specific agricultural advice was raised as a key issue that would improve the resilience of farmers in Bhutan. Big data approaches using crop, soil and climate data taking seasonal forecast into account could increase productivity and advise on ideal planting dates.

Farmer schools and workshop to improve post-production management practices

Participants expressed a need to improve post-harvest storage and preparation. This could be undertaken through farmer schools, where particular farmers with a good understanding of post-harvest technology and techniques could share their experiences. The introduction of new crops such as quinoa will need to be introduced strategically as it is a crop that farmers have not grown before, and both pre- and post-harvest techniques will be relatively new. Exchanges of information with experts from quinoa producing countries is necessary to ensure that quinoa yields are high and that post-harvest losses are minimized.

Breeding

Apart from better access to a higher number of crop varieties, participants want increased breeding efforts to develop varieties that are more resilient to climate change impacts as well as to pests and diseases.

Community of practice and further capacity building

Participants highlighted a need for continuous capacity building measures to develop further crop modeling skills for all commodity coordinators and researchers. They also agreed to provide trainers-to-trainee guidance, teaching other members of their respective teams the skills they acquired during the project. The modeling workshop participants agreed on the need to regularly practice and apply the new tools and methods to maintain their new knowledge. Various modes of doing so were discussed from joint meetings every Friday afternoon to regular internal workshops. The workshop participants expressed interest in continuously using the new tools and methods they had learned. A community of practice was established and in July 2016, MoAF participants organized an additional workshop independently to develop draft suitability maps and additional layers such as soils, elevation, sunlight exposure and socioeconomic information, with remote technical support provided by CIAT staff. Learning efforts should be examined, for example climate change science should be incorporated into the curriculum of agricultural science students.

Dissemination of results

Relevant results will be published in a policy brief. The results could also lead to a peer-reviewed scientific publication. Commodity coordinators in Bhutan will share the findings through their professional networks. MoAF participants mentioned the use of relevant project outputs for the upcoming 12th 5-year plan for Bhutan.

Annex 1: All crop modeling results

Compiled maps for cardamom,chili, kiwi, maize, potato, quinoa, rice, and tomato, for current suitability, future suitability under RCP 4.5 and 8.5, projected change in suitability and biophysical suitability.

CONTENTS

Climate data

1.1. Maps of total current and change annual precipitation

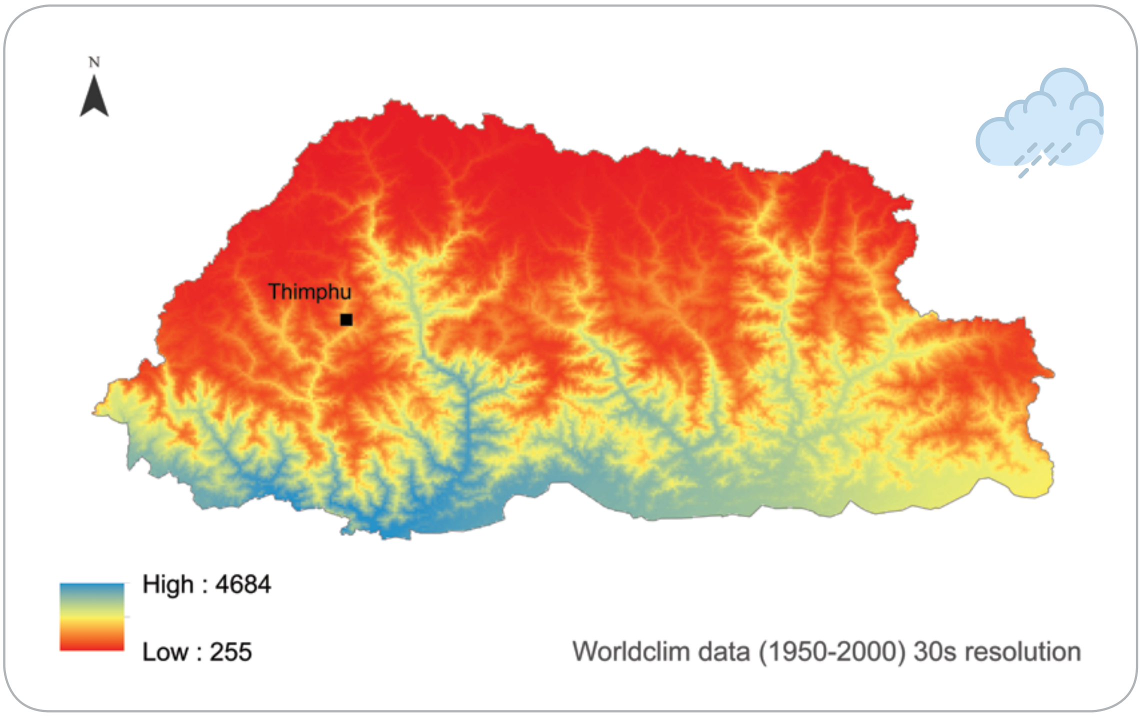


Figure 17: Total current annual precipitation (mm)

1.2. Changes in precipitation between now and 2050 (mm)

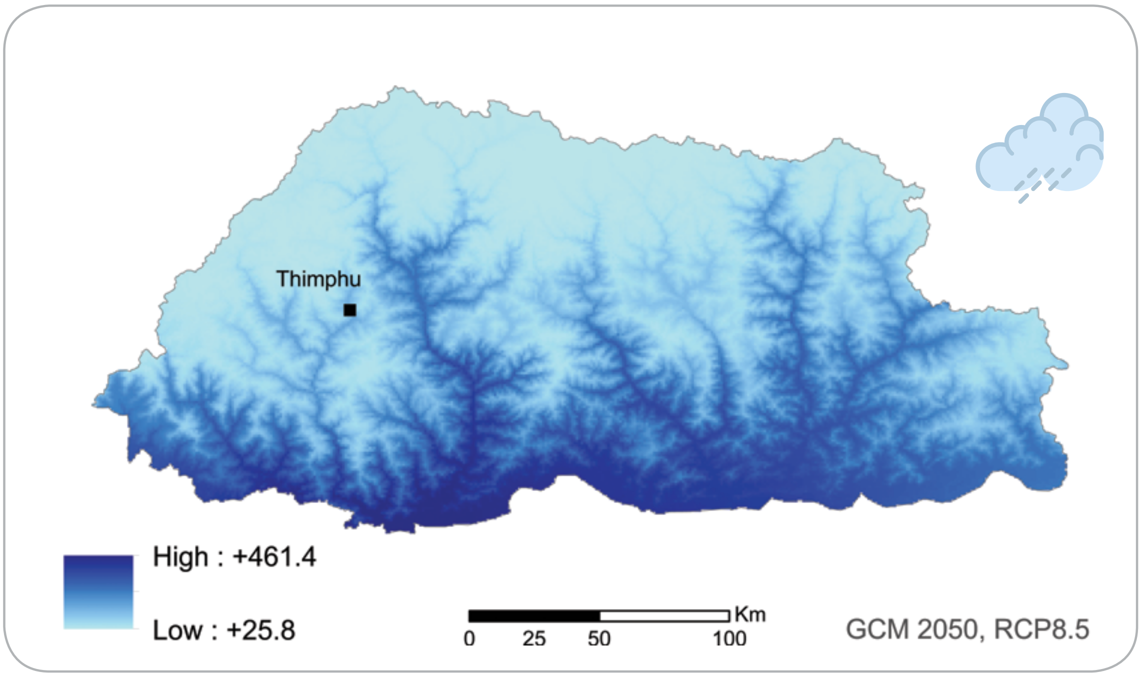


Figure 18: Changes in precipitation between now and 2050 (mm)

1.3. Current annual average temperature (°C)

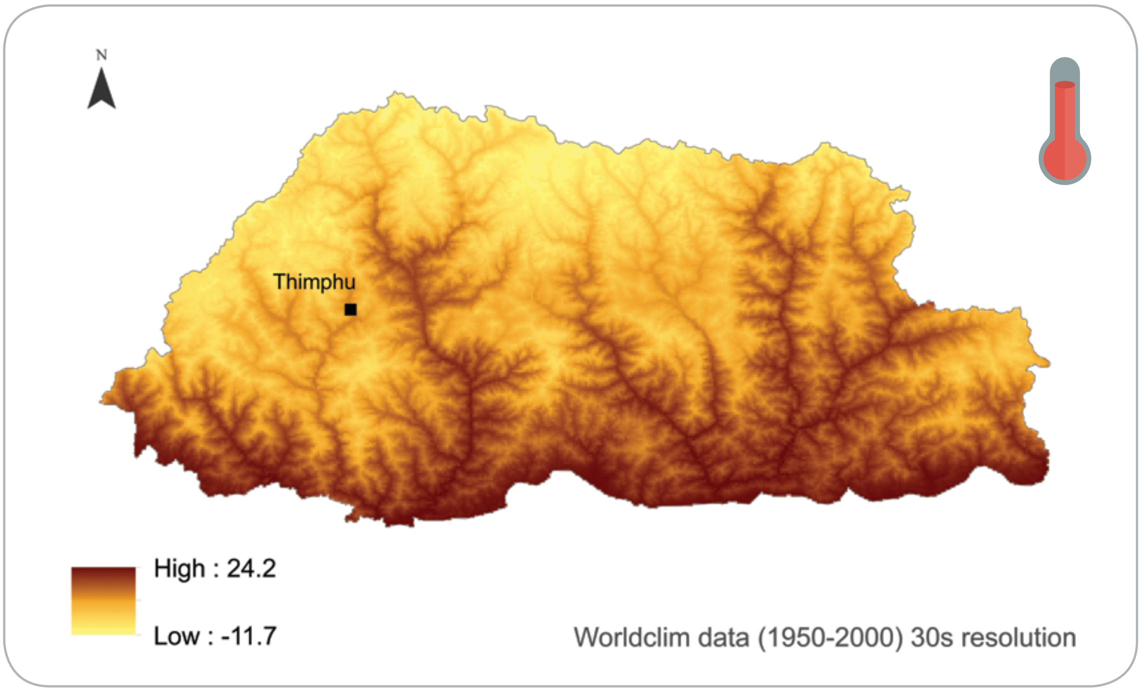


Figure 19: Current annual average temperature (°C)

1.4. Changes in temperature between now and 2050 (°C)

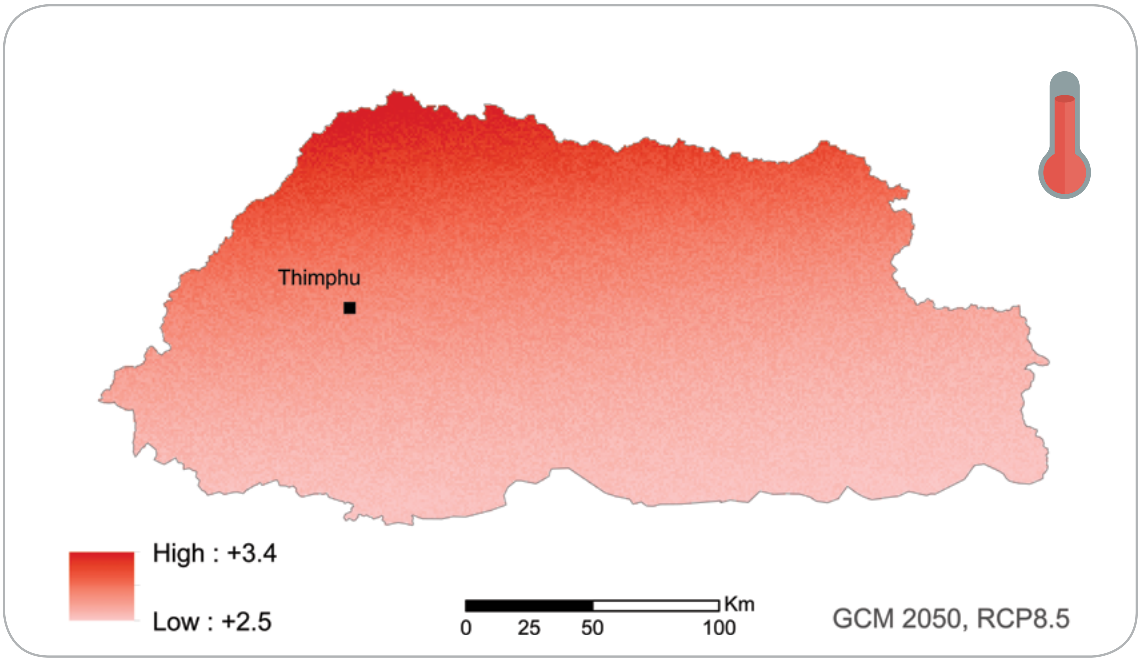


Figure 20: Changes in temperature between now and 2050 (°C)

1.5. Total current seasonal precipitation (mm)

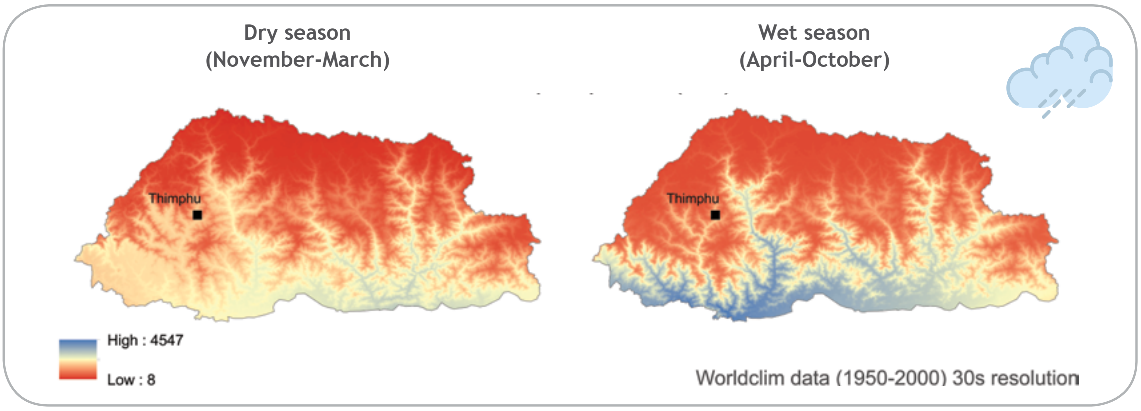


Figure 21: Total current seasonal precipitation (mm)

1.6. Changes in seasonal precipitation between now and 2050 (mm)

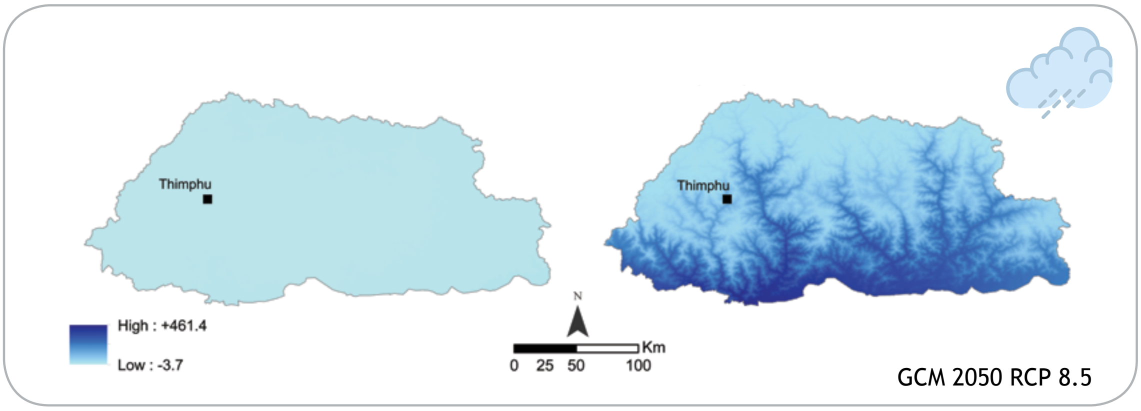


Figure 22: Changes in seasonal precipitation between now and 2050 (mm)

1.7. Current seasonal average temperature (°C)

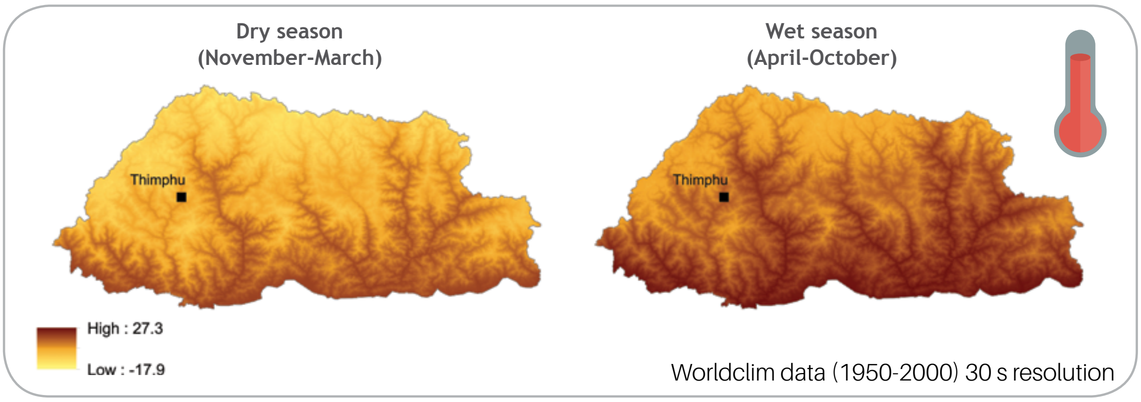


Figure 23: Current seasonal average temperature (°C)

1.8. Changes in seasonal temperature between now and 2050 (°C)

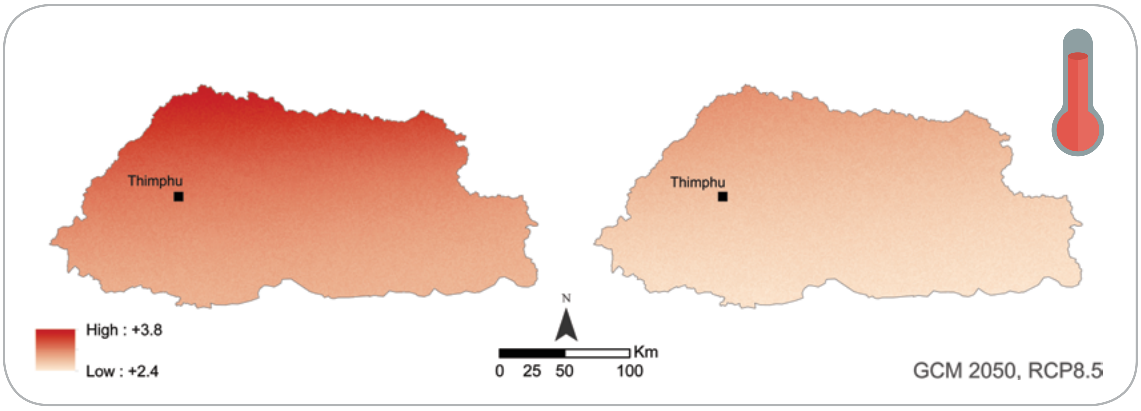


Figure 24: Changes in seasonal temperature between now and 2050 (°C)

1.9. Land cover

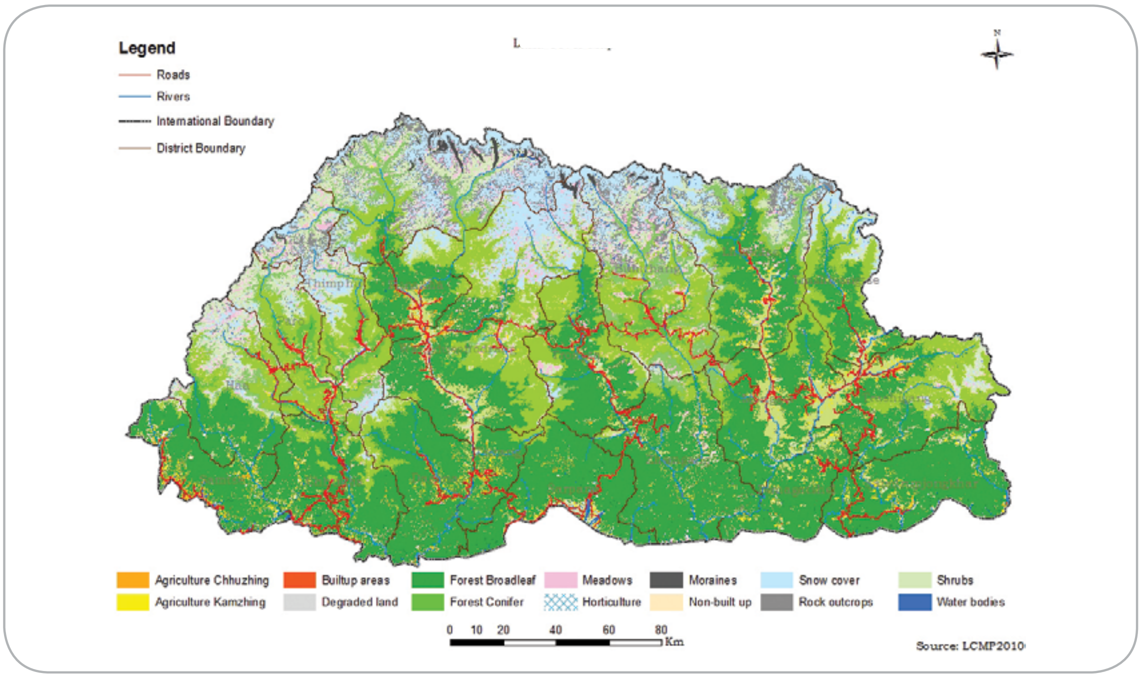
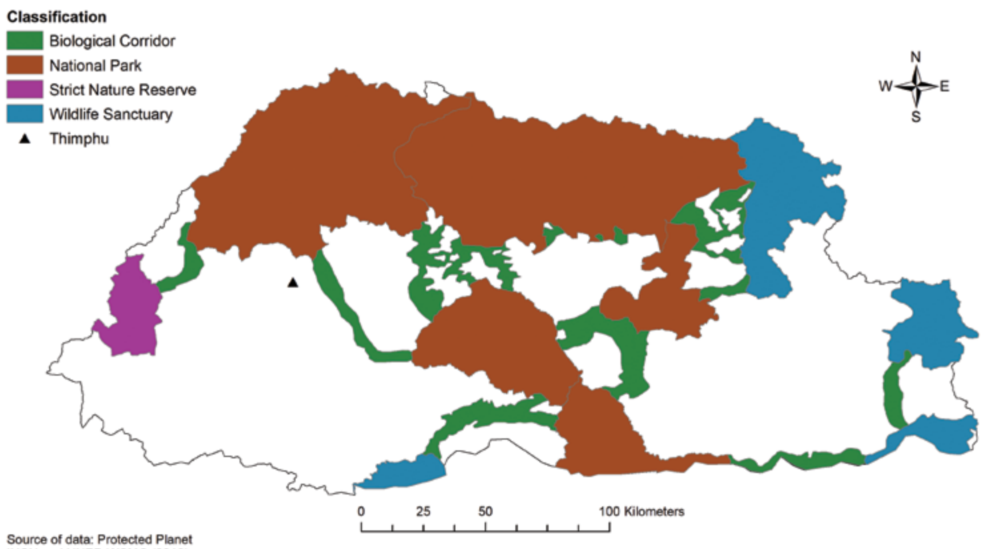


Figure 25: Land cover map 2010 in Bhutan

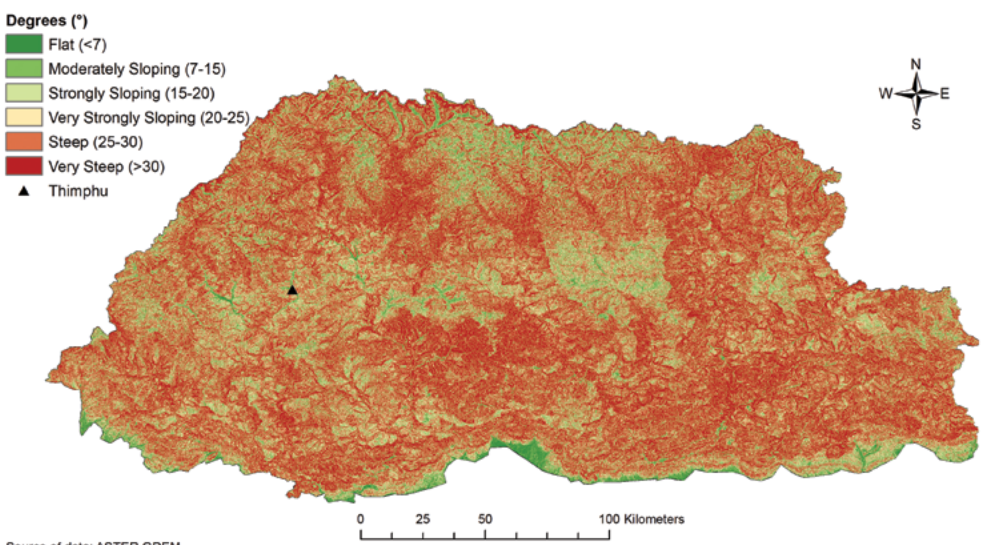
1.10. Protected area



Source of data: Protected Planet
IUCN and UNEP-WCMC (2016),
The World Database on Protected Areas (WDPA) [On-line], [August/2016 of the version downloaded], Cambridge, UK: UNEP-WCMC.
Available at: www.protectedplanet.net.

Figure 26: Protected area in Bhutan

1.11. Slope



Source of data: ASTER GDEM.
Resolution: 30m

Slope classification: FAO (2006) Sample Checklist for Watershed Survey II. Available online:
http://www.fao.org/docrep/006/t0165e/apend.htm [Accessed on 16th June 2016]

Figure 27: Slope in Bhutan

1.12. Elevation

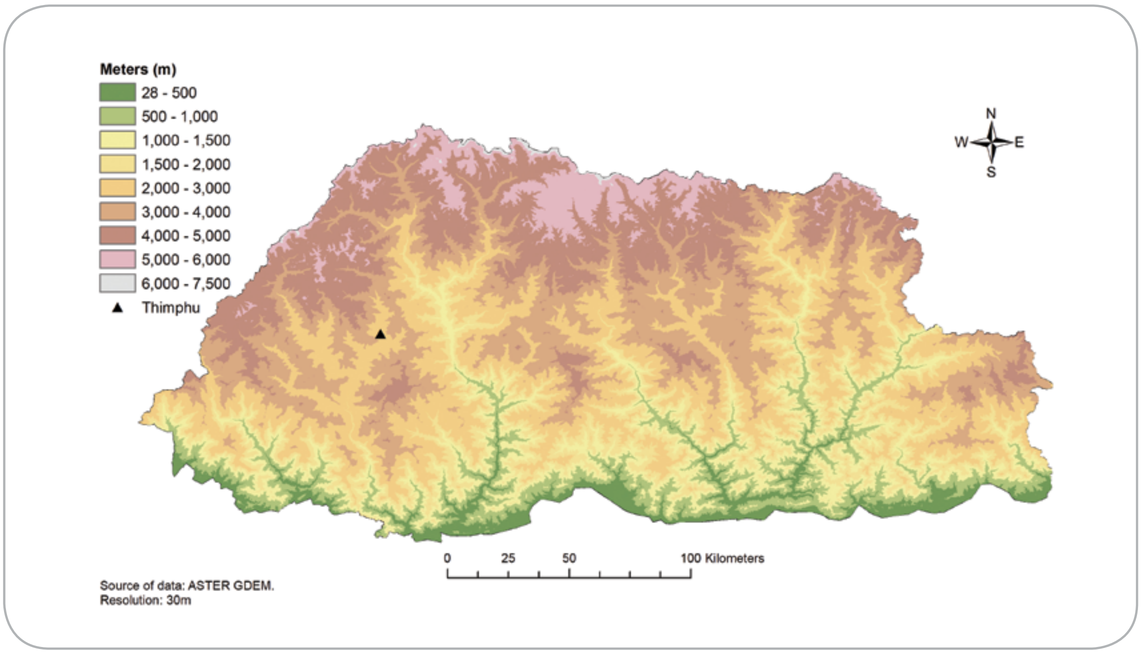


Figure 28: Elevation in Bhutan

1.13. Soil

1.13.1. Soil in Bhutan

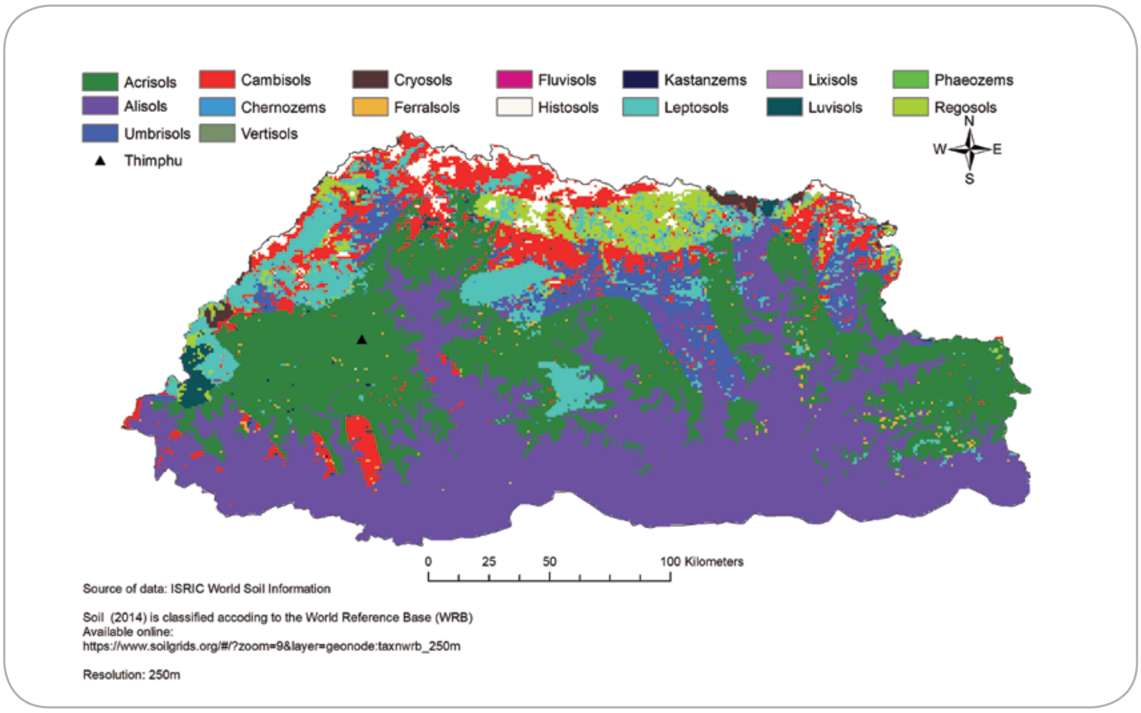


Figure 29: Soil in Bhutan

1.13.2. Soil erosion intensity

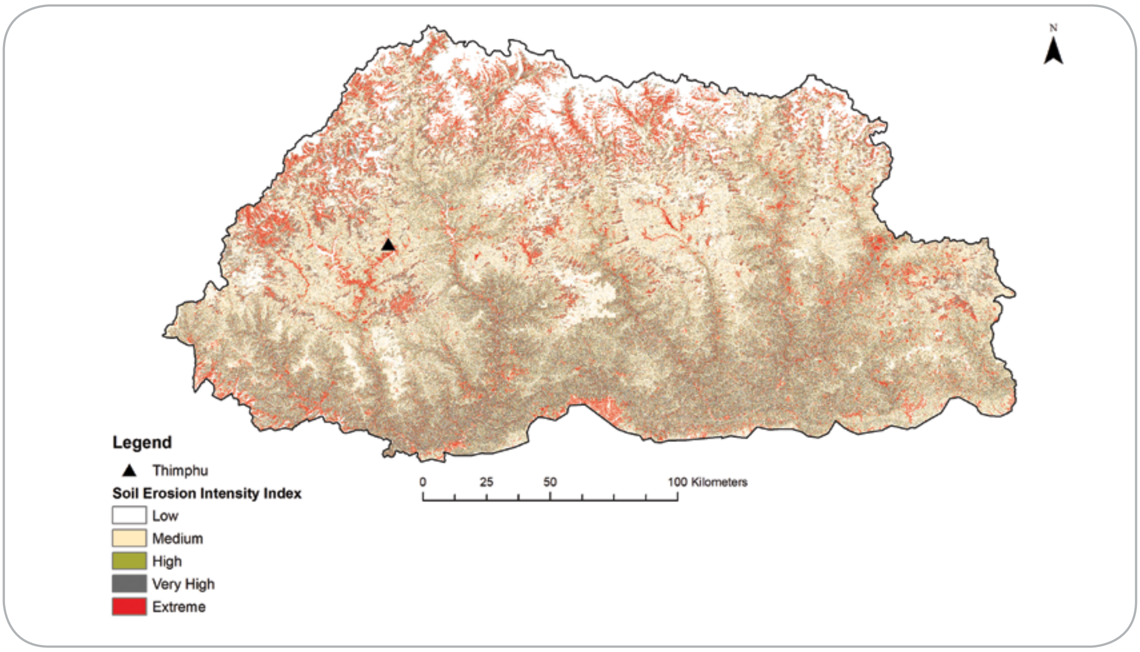


Figure 30: Soil erosion intensity index

1.14. Solar radiation

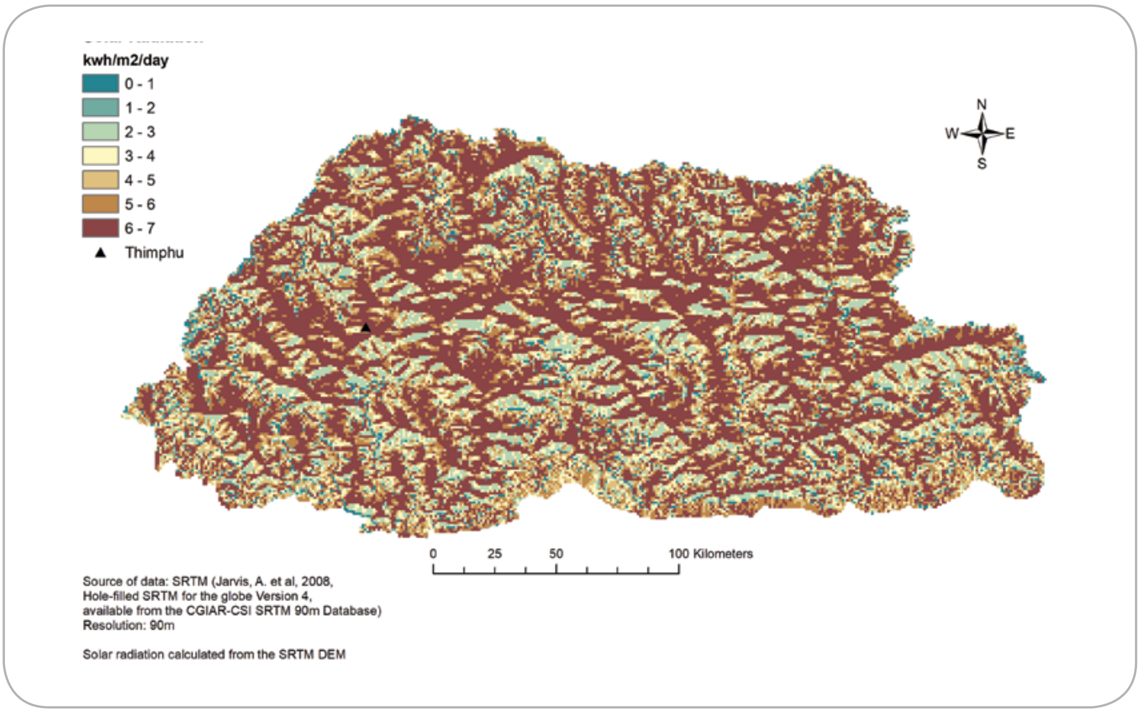


Figure 31: Solar radiation in Bhutan

2. Climate suitability

2.1. Cardamom

2.1.1. Present and future cardamom suitability area, RCPs, year 2050

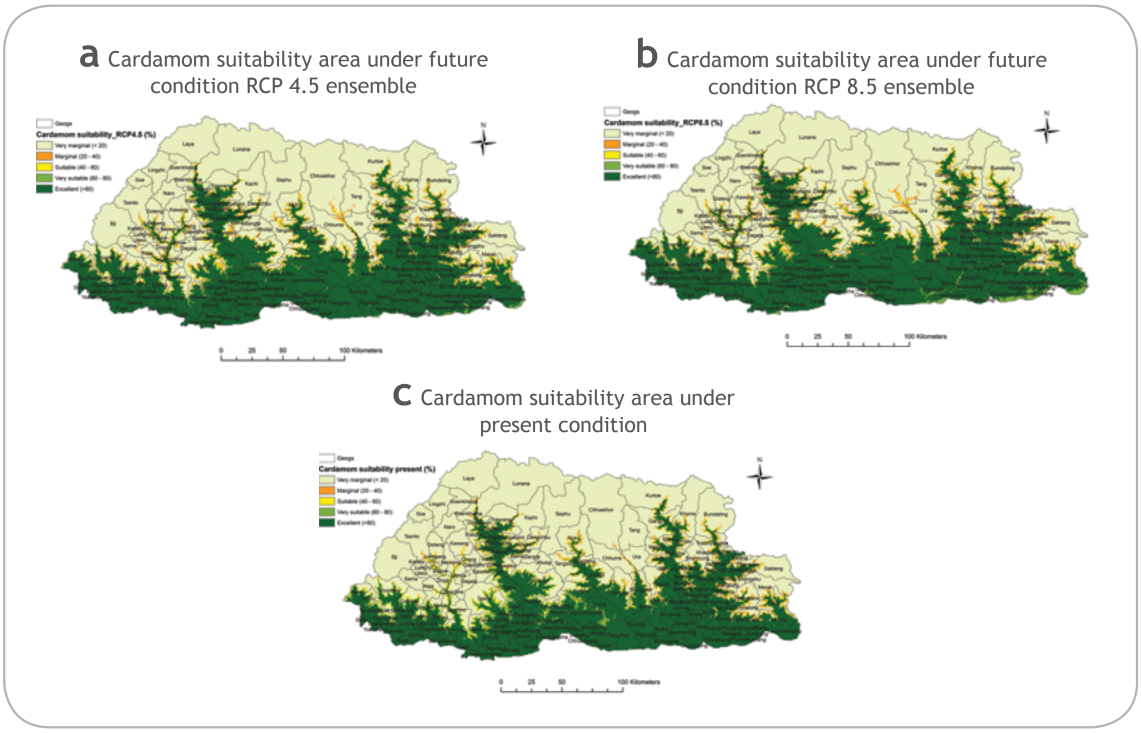


Figure 32: Cardamom suitability area under future condition RCP 4.5 (a) and RCP 8.5 ensemble (b) and cardamom suitability area under present condition (c)

2.1.2. Change in cardamom suitability area, RCPs, year 2050

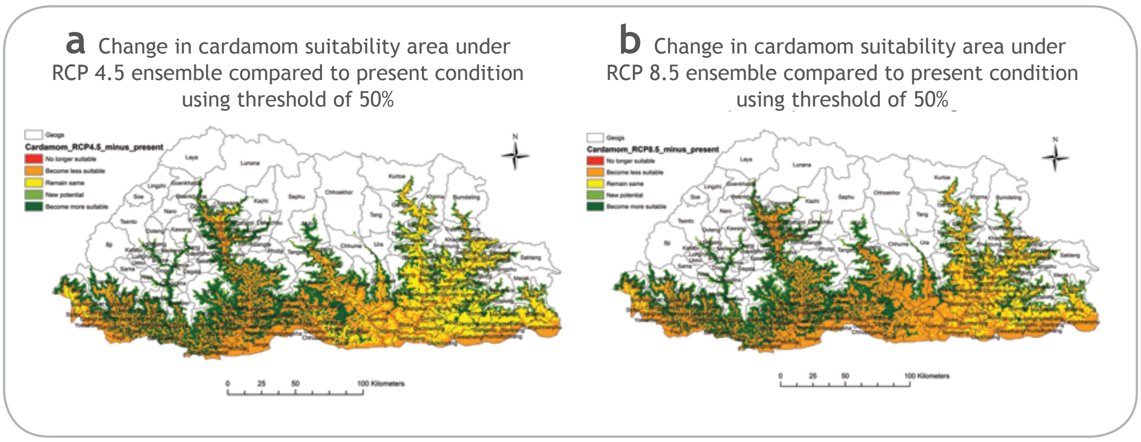


Figure 33: Changes in cardamom suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.2. Chili

2.2.1. Present and future chili suitability area, RCPs, year 2050

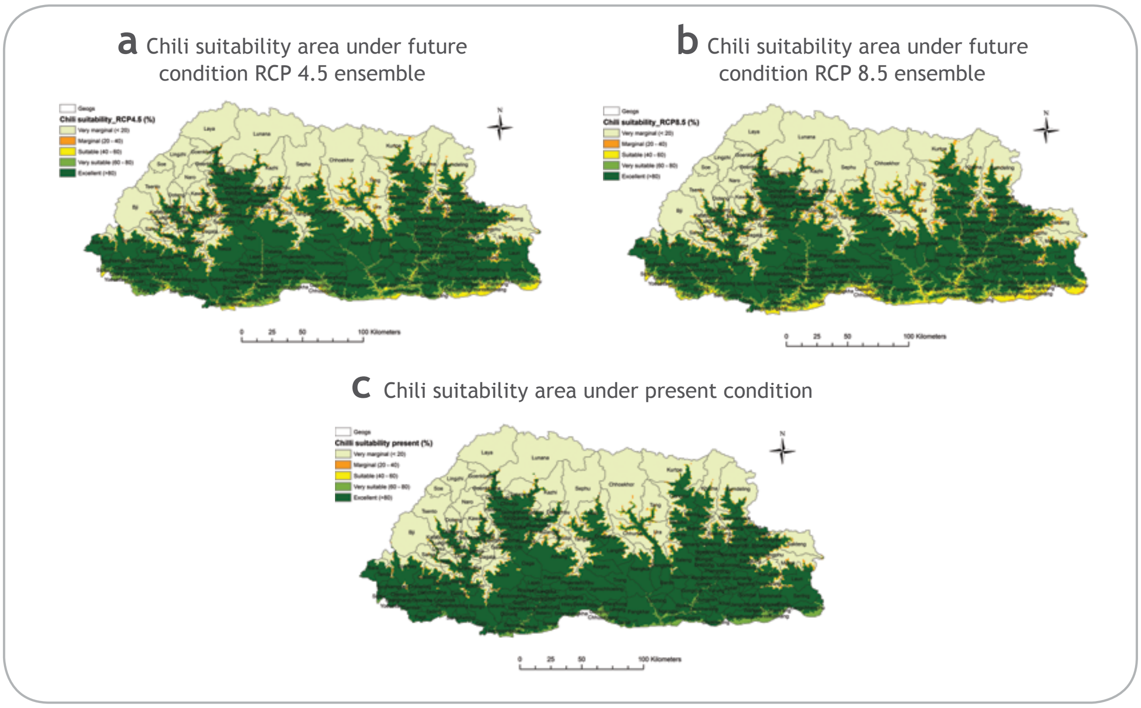


Figure 34: Chili suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and chili suitability area under present condition (c)

2.2.2. Change in chili suitability area under RCPs, year 2050

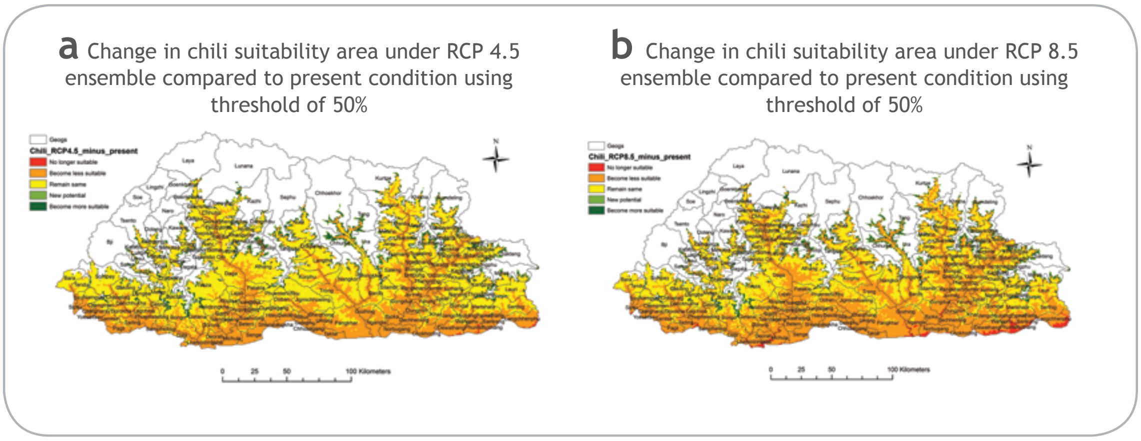


Figure 35: Changes in chili suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.3. Kiwi

2.3.1. Present and future kiwi suitability area, RCPs, year 2050

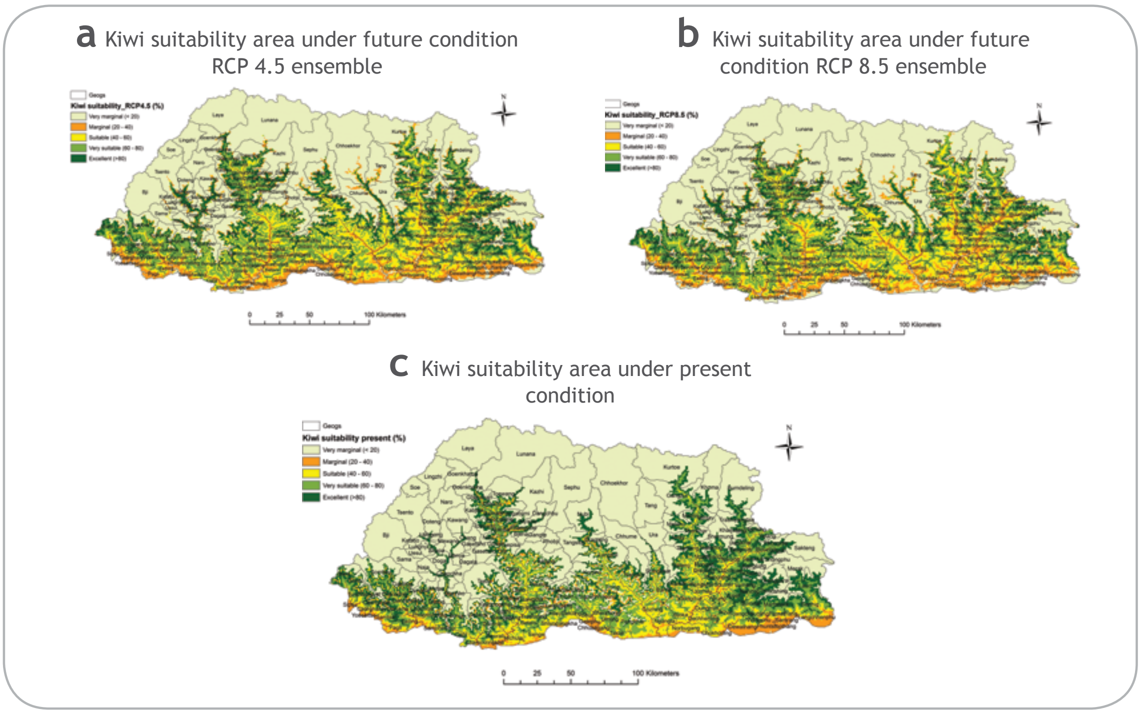


Figure 36: Kiwi suitability area under future condition RCP 4.5 (a) and RCP 8.5 ensemble (b) and kiwi suitability area under present condition (c)

2.3.2. Change in kiwi suitability area under RCPs, year 2050

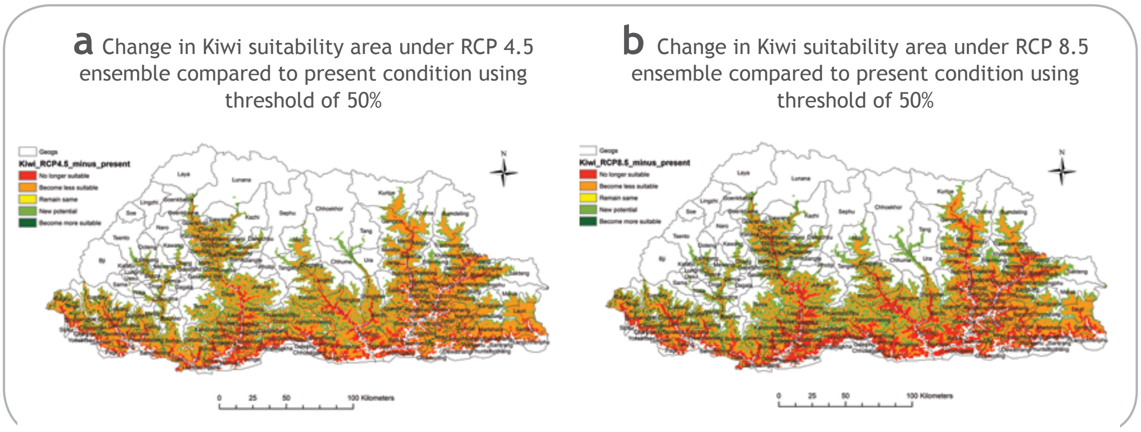


Figure 37: Changes in kiwi suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.4. Maize

2.4.1. Present and future maize suitability area, RCPs, year 2050

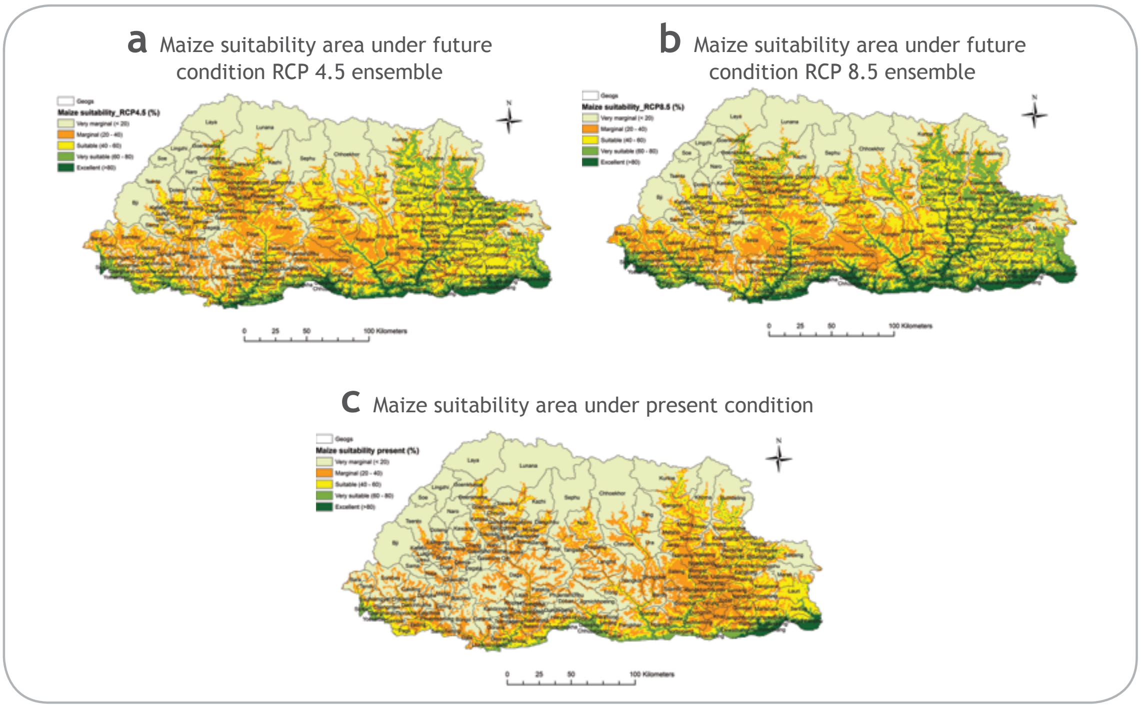


Figure 38: Maize suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and maize suitability area under present condition (c)

2.4.2. Change in maize suitability area under RCPs, year 2050

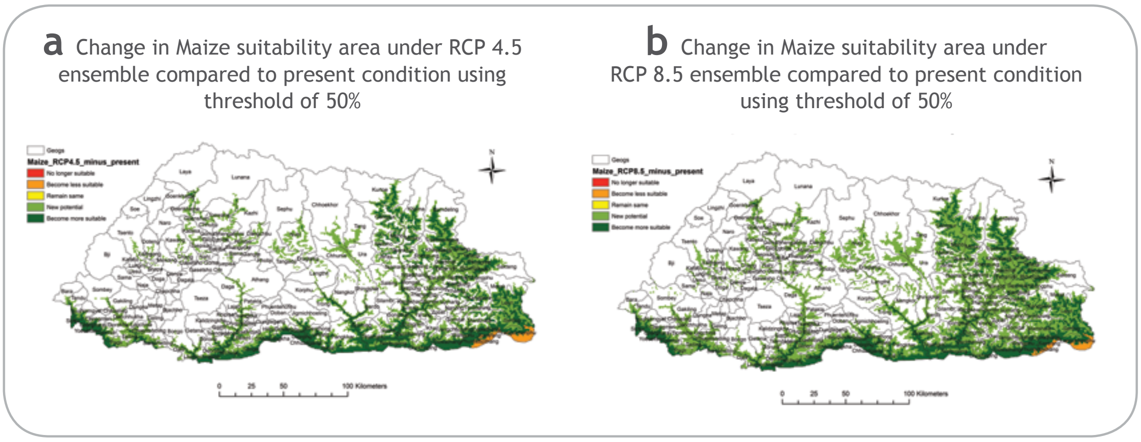


Figure 39: Changes in maize suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.5. Potato

2.5.1. Present and future potato suitability area, RCPs, year 2050

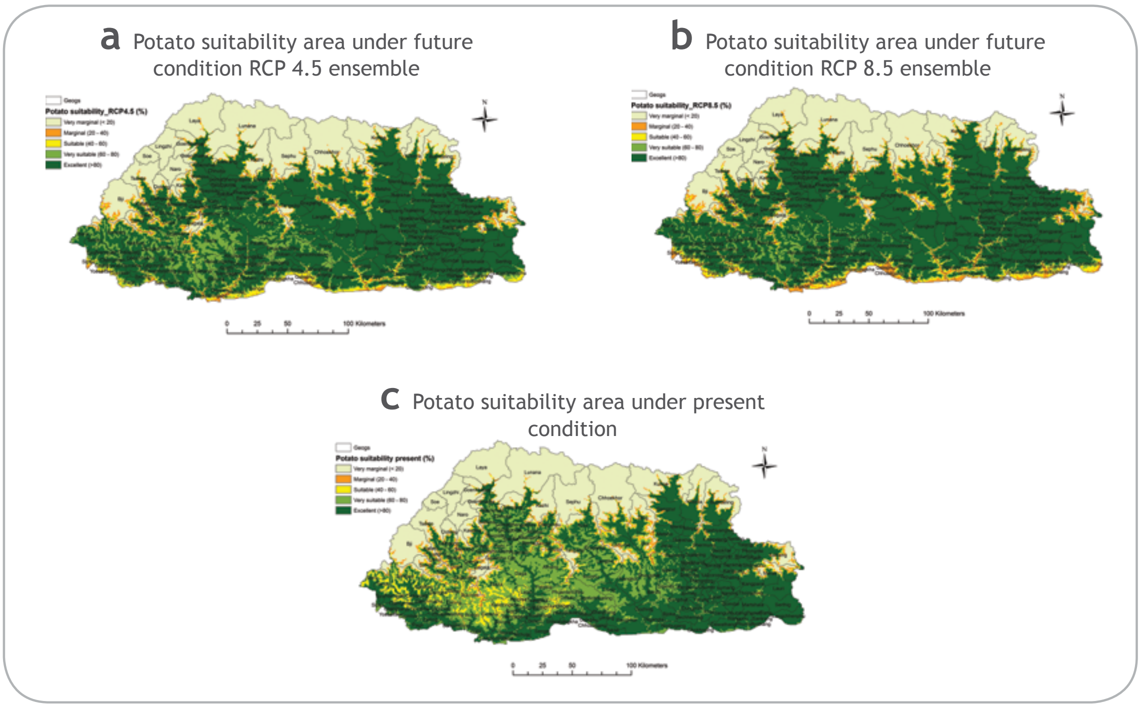


Figure 40: Potato suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and potato suitability area under present condition (c)

2.5.2. Change in potato suitability area under RCPs, year 2050

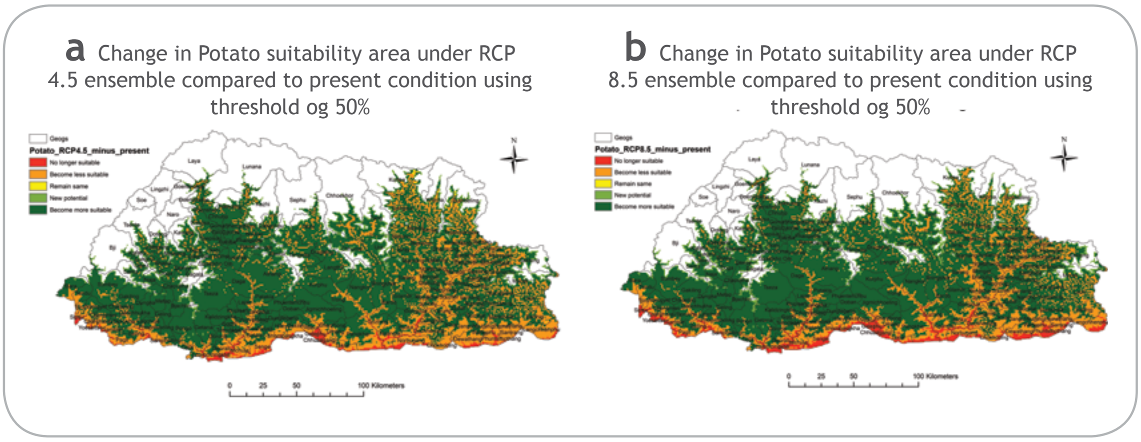


Figure 41: Changes in potato suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.6. Quinoa

2.6.1. Present and future in quinoa suitability area, RCPs, year 2050

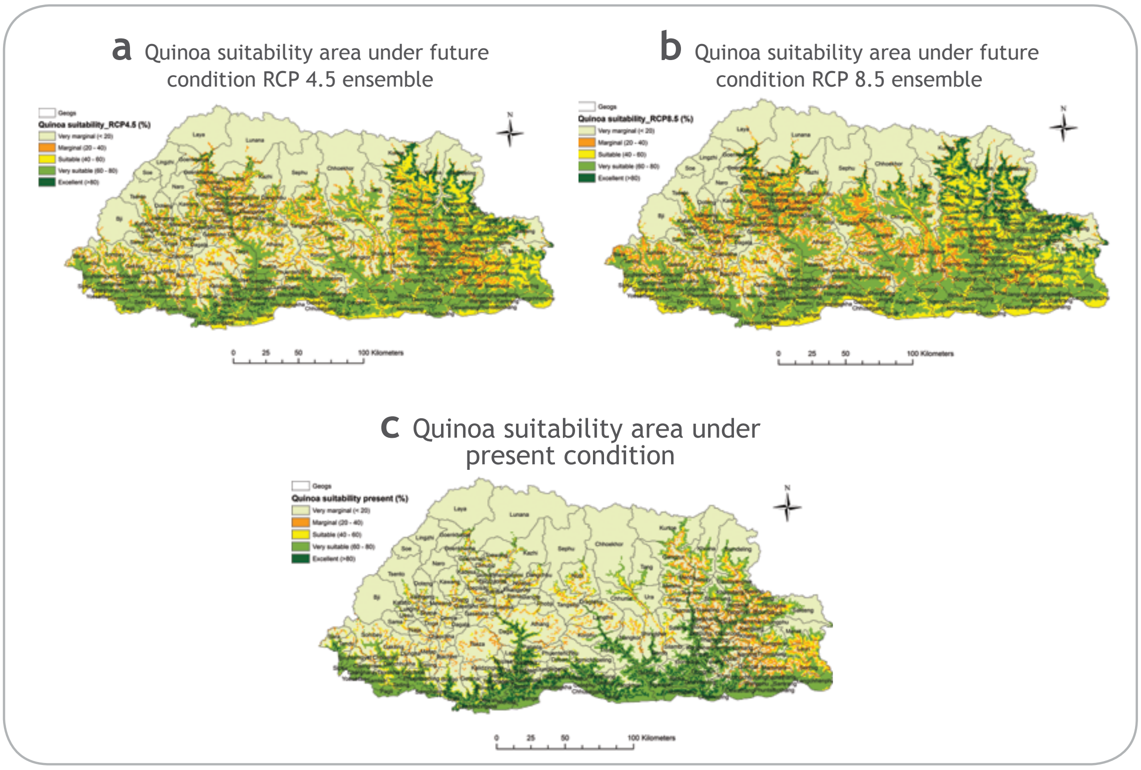


Figure 42: Quinoa suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and quinoa suitability area under present condition (c)

2.6.2. Change in quinoa suitability area under RCPs, year 2050

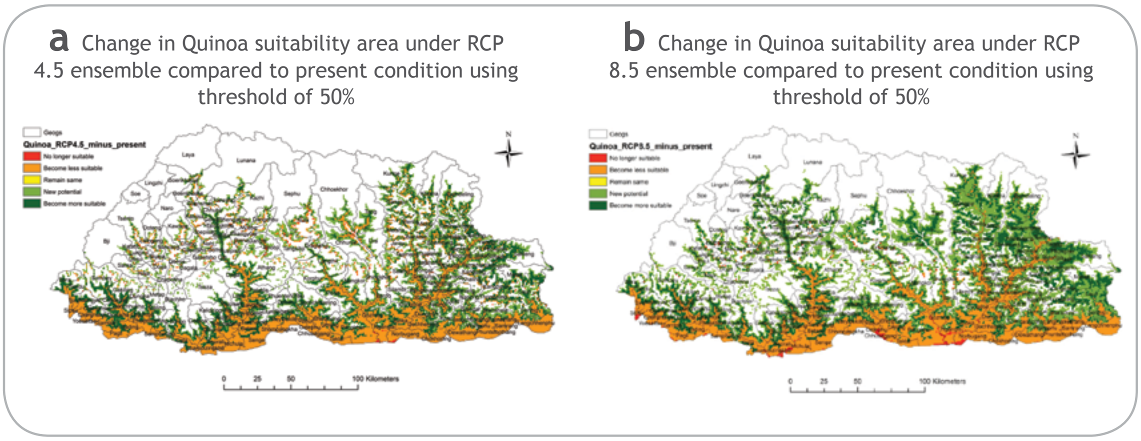


Figure 43: Changes in quinoa suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.7. Rice

2.7.1. Present and future in rice suitability area, RCPs, year 2050

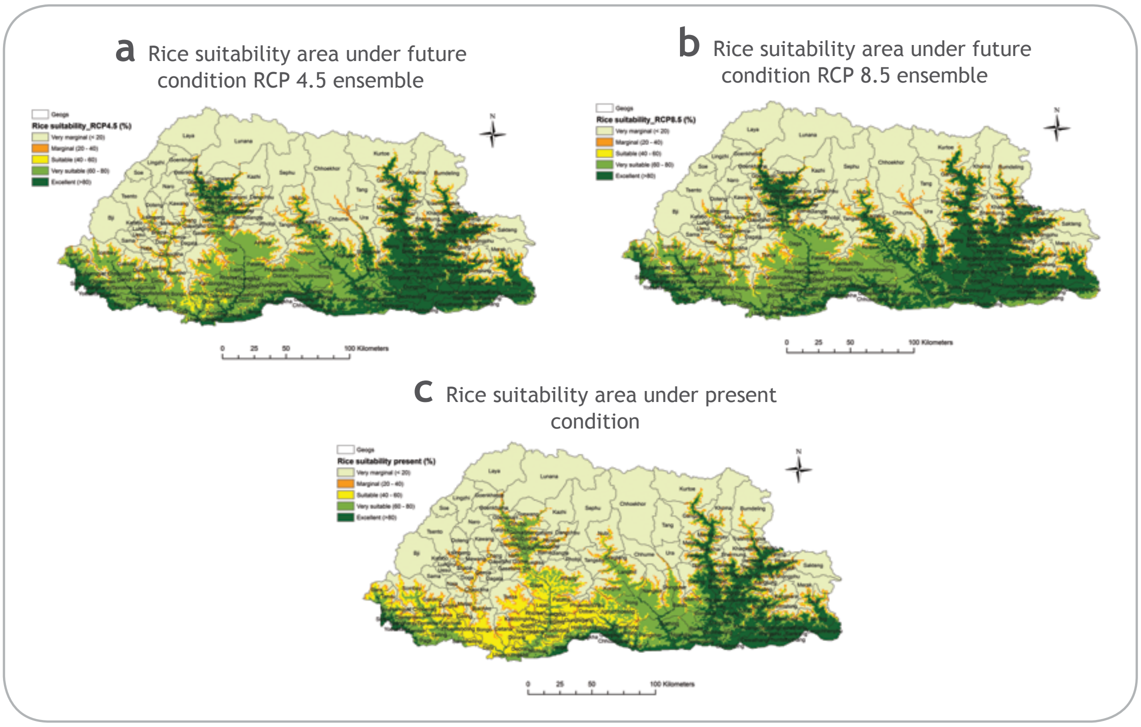


Figure 44: Rice suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and rice suitability area under present condition (c)

2.7.2. Change in rice suitability area under RCPs, year 2050

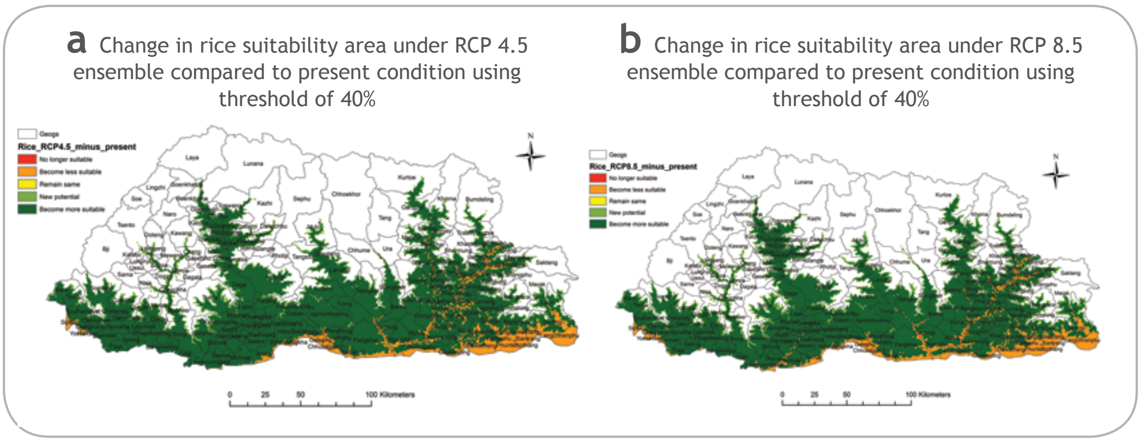


Figure 45: Changes in rice suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 40%

2.8. Tomato

2.8.1. Present and future in tomato suitability area, RCPs, year 2050

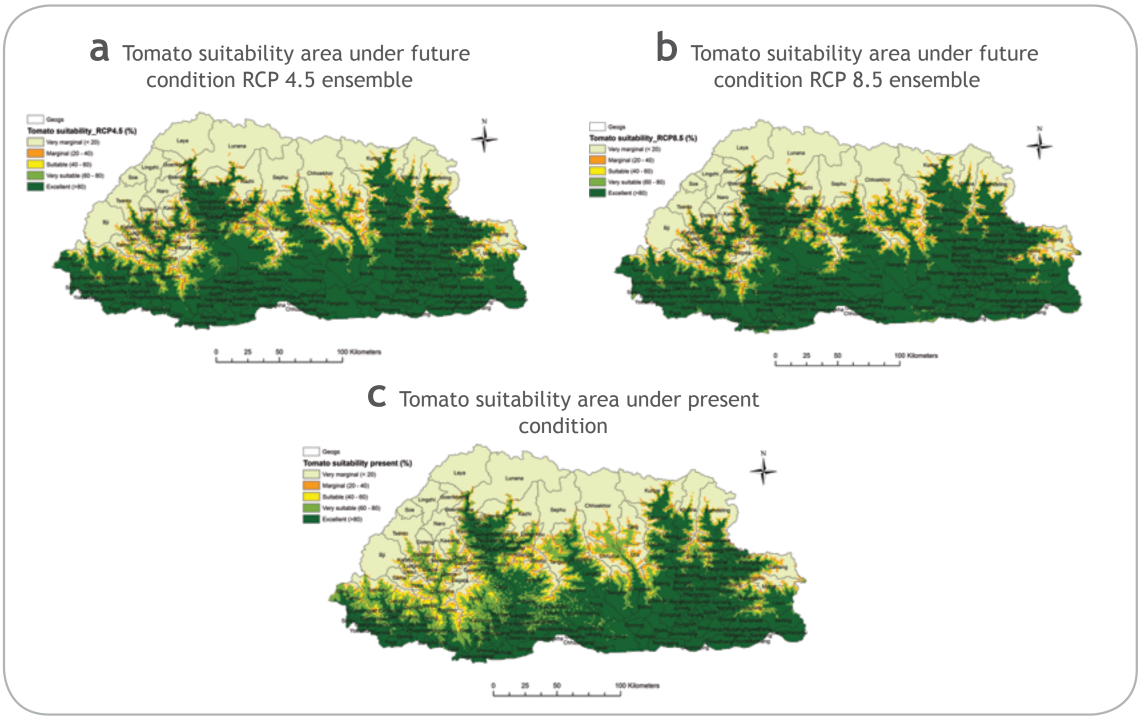


Figure 46: Tomato suitability area under future condition RCP 4.5 (a) and RCP 8.5 (b) ensemble and tomato suitability area under present condition (c)

2.8.2. Change in tomato suitability area under RCPs, year 2050

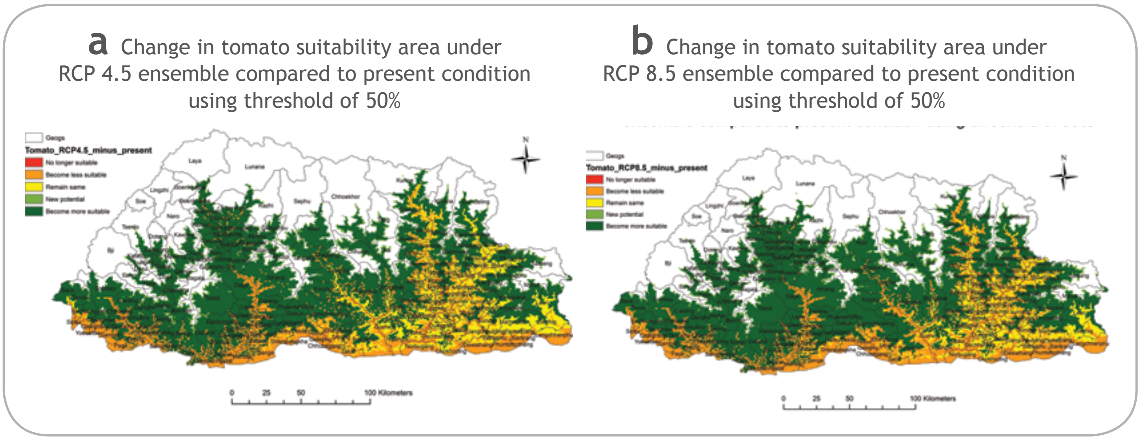


Figure 47: Changes in tomato suitability area under RCP 4.5 (a) and RCP 8.5 (b) ensemble compared to present condition using threshold of 50%

2.9. Change in climate suitability for all crops

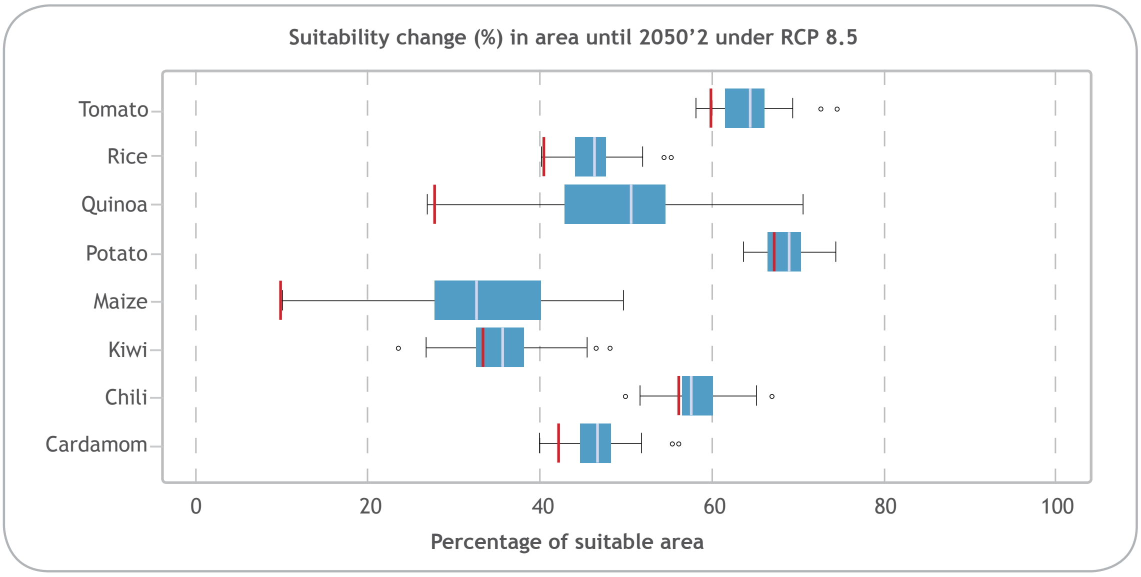


Figure 48: Box plots showing the percentage of change until 2050s under RCP 8.5.

Figure 48: The red line reflects the total current area of suitability for the respective crop above the allocated suitability threshold. The box plots reveal the area of projected future climate suitability for the respective crops based on the allocated suitability threshold as a function of the 31 GCMs, under RCP 8.5, for the period 2050. The box plots indicate the median of the GCMs, the upper quartile (25%) and lower quartile (25%) and the spread of the GCMs (whiskers extend to 5% and 95% of the distribution in the area that is climatically suitable for the respective crop). The outliers are shown as dots away from the main box plots.

Annex 2: Data availability and sources

Data	Progress	Extent	Resolution	Accessibilty	Year	Format	Reliability	Source	Origin	Georeference
Elevation	Ready	Bhutan	30 m	Yes	2013 (aprox)	Raster (image)	High	ASTER-DEM	Global	Yes
Slope	Ready	Bhutan	30 m	Yes	2013 (aprox)	Raster (image)	High	ASTER-DEM	Global	Yes
Soil	Ready	Bhutan	Coarse	Yes	1995 (aprox)		Low	FAO	Global	Yes
Soil	Ongoing	Bhutan	High	Yes	2020 (aprox)	shp	#Too early to tell	NSSC/MOAF	National	Yes
Land cover	Ready	Bhutan	10 m	Yes	1994/2010	shp	Ok	MOAF	National	Yes
Solar radiation	Required	Bhutan	Depends	Yes	1986-2016	_xcl	Ok	Department Hydromet services (OHMS)	National	Yes
Solar radiation	Ready	Bhutan	30 m	Yes	2013 (aprox)	Raster (image)	Requires expert validation	ASTER-DEM (ArcGIS/QGIS)	Global	Yes
P&D (inc weeds)	Ongoing	Local		Yes	1960 - present	_xcl	Ok	NPPC	National	No
Climate suitability (temperature/precipitation)	Ready	Bhutan	1 km	Yes	Current (1970-1990)	Raster (image)	#Too early to tell	MOAF-CIAT	National	Yes
Wind storm/Frost/hail stone/Heat stress/drought	Ongoing	Bhutan	Depends	Yes	1986-2016	_xcl	Ok	Department Hydromet services (DHMS)	National	Yes
Flood	Ready	Regional		Yes			Ok	Department of Disaster Management & Department of Geology and Mines	National	Yes

(continues)

(continued)

Data	Progress	Extent	Resolution	Accessibilty	Year	Format	Rellability	Source	Origin	Georeference
Socio economic										
Irrigation sources	Ready	Bhutan		Yes	2012	shp	High	DOA	National	Yes
Distance farm roads	Ready	Bhutan		Yes	2012	shp	High	DOA	National	Yes
Distance towns	Ongoing	Bhutan		Yes	2016	shp	High		National	Yes
Population density	Ready	Bhutan		Yes	2005 (updated 2016)	shp	High	NSB	National	Yes
Labour availability (rural)	Ready	Bhutan		Yes	2005 (updated soon)	shp	High	NSB	National	Yes
Poverty	Ready	Bhutan	Subdistrict	Yes	2010 & 2012	shp	High	NSB	National	Yes

Annex 3: Agenda capacity building workshop - May 2016

Building capacity in assessing the impacts of climate change on the climatic suitability of maize-, rice-, potato-, chili- and tomato-growing areas in Bhutan

3-7 May 2016
Week 1

Tuesday
3
May 2016

Time	Content	Presenter	Venue
9:00 - 9:20	Welcome & introduction of participants	Nora Guerten	
9:20 - 10:00	Objectives of workshop and expectations on deliverables	Nora Guerten	
10:00 - 12:00	Exploring participants existing skills and setting up teamwork	Louis Parker	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 17:00	Introduction on climate change and variability in Bhutan (understanding latest climate science, ENSO, GLOFs, impacts on agriculture, cross-border issues)	Nora Guerten	

Wednesday
4
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Introduction of EcoCrop, crop modeling, and available GIS data	Louis Parker	
12:00 - 13:30	Lunch		Ro-Chog Pel Hotel, Thimphu
13:30 - 17:00	Preparation of necessary GIS data	Louis Parker	

Thursday
5
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Analysis of necessary GIS data	Louis Parker	
12:00 - 13:30	Lunch		
13:30 - 14:30	Introduction to IPCC	Nora Guerten	Ro-Chog Pel Hotel, Thimphu
14:30 - 17:00	Introduction to R	Louis Parker	

Friday
6
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Introduction from participants e.g. National Soil Services Center, exploring previous work and uncertainties, data availability	TBD	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 17:00	Introduction to climate data	Louis Parker	

Saturday
7
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Climate data analysis	Louis Parker	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 17:00	Future climate data	Louis Parker	

9-13 May 2016
Week 2

Monday
9
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Crop modeling with EcoCrop	Louis Parker	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 17:00	Introduction to climate-smart agriculture and preparation for farmers workshop	Nora Guerten	

Tuesday
10
May 2016

Field trip: Farmer focus group discussion

Time	Content	Presenter	Venue
9:00 - 9:20	Welcome and introduction of workshop objectives and participants	Nora Guerten	
9:20 - 9:40	Discussion and inventory of main crops and their purposes	Nora Guerten	All
9:40 - 10:40	Discussion on cropping calendar, activities taking place during production period and decision-making process in households, abnormal weather events and their impacts on agricultural production	Louis Parker & Nora Guerten	Division of 2 groups (women and men) for discussion
10:40 - 11:00	Tea break	Louis Parker	Ro-Chog Pel Hotel, Thimphu
11:00 - 12:00	Discussion on (i) main issues related to climate change, market, land use, diseases, varieties, credit and (ii) current challenges in the agricultural production	Louis Parker & Nora Guerten	Division of 2 groups (women and men) for discussion
12:00 - 13:00	Lunch		
13:00 - 14:00	CSA practices in response to challenges in agricultural production Feasible CSA practices in future (appropriate and high income creation)	Louis Parker & Nora Guerten	Division of 2 groups (women and men) for discussion
14:00 - 15:00	Documenting lessons learned: Short video or voice recording	Louis Parker & Nora Guerten	Volunteers

Wednesday
11
May 2016

<table>
<tr><th>Time</th><th>Content</th><th>Presenter</th><th>Venue</th></tr>
<tr><td>9:00 - 12:00</td><td>Crop modeling with EcoCrop - under climate change</td><td>Louis Parker</td><td rowspan="3">Ro-Chog Pel Hotel, Thimphu</td></tr>
<tr><td>12:00 - 13:30</td><td>Lunch</td><td></td></tr>
<tr><td>13:30 - 17:00</td><td>Crop modeling with EcoCrop - under climate change</td><td>Louis Parker</td></tr>
</table>

Thursday
12
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Crop modeling - analyzing results	Louis Parker	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 17:00	Crop modeling - analyzing results	Louis Parker	

Friday
13
May 2016

Time	Content	Presenter	Venue
9:00 - 12:00	Wrapping up & identifying next steps and responsibilities	Nora Guerten	Ro-Chog Pel Hotel, Thimphu
12:00 - 13:30	Lunch		
13:30 - 15:00	Q&A	Louis Parker & Nora Guerten	
15:00 - 16:00	Evaluation of training	All	

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