Potential Impact of Climate Change on the Scope of Important Fruit Crops

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ABSTRACT

In Bhutan, Renewable Natural Resources Sector (Agriculture, Livestock and Forestry) provides livelihood for close to 57% of the total population and accounts for 16.8% of the total GDP, and Agriculture Sector alone contributes more than 10% to the total GDP. Hence, Agriculture in general and horticulture in particular has a critical role in the Nation's stride towards achieving self-reliance and sustainable development goals. Horticulture sector is recognized as one of the industries of the future given its potential for income generation and enhancing food and nutritional security. However, Agriculture sub-sector is buffeted by number of challenges and of particular interest is climate change since it is one of the sectors expected to bear the brunt of climate change. Climate in Bhutan is changing. Some studies show that over the last two and half a decade, temperature has risen by 0.3 to 0.5^{o}C and rainfall has become more erratic. Hence, the needs to study the potential impact of climate change on the scope of agricultural crops, particularly on economically important crops. In this study, impact of climate change on two most important fruit crops, apple and mandarin orange, was studied using FAO's EcoCrop Model in the year 2050 under two emission scenarios (RCP4.5 and RCP8.5). The result shows considerable change in the areas suitable for these two important horticultural fruit crops. Of the two, apple loses net suitability area under both the scenarios with maximum under RCP 8.5, whereas mandarin gains under both the scenarios with maximum under RCP 4.5. The study is expected to provide useful information regarding future adaption strategies.

Keywords: *Climate change; apple; mandarin orange; eco-crop model; suitability area*

1. Introduction

Renewable Natural Resources (RNR) Sector that comprises of Agriculture, Livestock and Forestry is the single largest sector that provides livelihood sources for close to 57% of population and contributes about 16.8% of the total GDP (MoLHR 2014). Agriculture sub-sector (field and horticultural crops) alone contributes more than 10% to the total GDP (NSB, 2016). Further, Horticulture is recognized as one of the important industries considering its potential for income generation and enhancing food and nutritional security (Planning Commission, 1999). In due course of time, the consumption of horticultural crops, especially fruits and vegetables, is expected to increase by about 47% as income doubles (Dukpa & Minten 2010). However, since agricultural activities are largely climate dependent, it is considered one of the most vulnerable sub-sectors to climate change (Solomon 2007). In Bhutan there are limited studies about climate change and its potential impact on agriculture. Few of the studies available have indicated that since 1985, temperature has risen by 0.3 to 0.5^{o}C and rainfall has become more erratic (Tse-ring 2010; Phuntsho & Dorji 2014), which suggest that there is a scope to study as to how such changes in climate parameters might

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affect crops, particularly economically important crops such as fruit crops.. Among others, one of the serious implications of climate change is the likely change or shift in agro-ecological zones for cultivation of any specific crop (Kurukulasuriya & Mendelsohn, 2008). This study thus assesses the potential impact of climate change on two most important fruit crops, Apple and Mandarin Orange, in terms of change or shift in areas suitable for cultivation, and corresponding economic implications. These crops arethe two most economically important fruit crops in Bhutan. In 2016, 6587 ton of apple and 42,700 ton of mandarin orange were produced earning Nu 215 million and Nu 432 million respectively (IMS 2016).

2. Materials and Method

Climate change studies require climate data for at least 30-year period (NOAA 2017). For the current study, data were extracted from WorldClim database. It provides average climate data from 1950 to 2000 (R. J. Hijman 2005). For future climate data, ensemble of three (BCC_CSM1.1, INM_CM$ and NIMR_hadgem2_ao) General Circulation Models' climate data for 2050 under two scenarios RCP4.5 (moderately low emission scenario) and RCP8.5 (high emission scenario) were used.

To model crop suitability, FAO's EcoCrop Model was used. EcoCrop is an ecological niche model that uses crop's biophysical requirement to predict its suitability. Biophysical parameters used in the model are: Gmin (Minimum length of growing season in days); Gmax (maximum length of growing season; Tkill (temperature at which the plant dies); Tmin (minimum temperature at which the plant grows; Topmin (minimum optimum temperature for plant growth); Topmax (maximum optimum temperature for plant growth); Tmax (maximum temperature at which the plant grows); Rmin (minimum amount of rain water in mm required to grow); Ropmin (minimum amount of optimum rain water required to grow); Ropmax (maximum amount of optimum rain water required to grow); Rmax (maximum amount of rain water required to grow). Biophysical requirement of Apple and Mandarin Orange were adapted to Bhutanese condition to model crop suitability (Table 1).

Table 1. Biophysical parameters used in the model

Parameter	Apple	Mandarin	Unit
Gmin	180	120	Days
Gmax	320	300	Days
Tkmp	-12	-3	^oC
Tmin	4	10	^oC
Topmin	8	19	^oC
Topmax	17	28	^oC
Tmax	19	32	^oC
Rmin	500	800	mm
Ropmin	700	1200	mm
Ropmax	2500	1800	mm
Rmax	3200	3500	mm

Impact of climate change on crop suitability was assessed by first modeling the crop suitability under present and future climate scenarios and then comparing the two as given in Table 2. EcoCrop suitability model was run in R version 3.4.3like in other studies (CIAT, 2017; J. Ramirez-Villegas; L. Parker 2017). Outputs from R were imported into ArcGIS 10.5, reclassified using threshold level of 50% and above, overlaid with 2010 agriculture land use data and area estimated.

Table 2. Classification of potential impact of climate change on crop suitability area

Type	Description
No longer suitable	Areas suitable under present condition but not suitable under future scenario
Become less suitable	Areas suitable under present condition but become less suitable under future scenario
Remain same	Areas suitable under present condition and remain suitable under future scenario as well
New potential	Areas not suitable under present condition but become suitable under future scenario
Become more suitable	Areas suitable under present condition but become more suitable under future scenario

3. Results and Discussion

In general, crop physiology is greatly influenced by climate, especially temperature. Rise in temperature is projected to have both positive and negative effect. Usually with rise in temperature, areas in the upper reaches are expected to become suitable for crop cultivation. However, in Bhutan, even if the upper reaches become suitable in terms of climate, steep topographic features present serious challenge for crop husbandry. Hence, in general, climate change could lead to change in cropping systems itself.

3.1. Impact of climate change on Apple

Apple is one of the most important cash crops that have an established market for export. Further, it is a crop that thrives well under cool biophysical environment. In order to ascertain impact of climate change on apple suitability area, it was studied under two scenarios: Representative Concentration Pathways (RCP) 4.5 (moderately low level of net CO_2 emission) and 8.5 (high level of net CO_2emission) were studied. As expected apple suitability area loses more under RCP8.5 than RCP4.5.

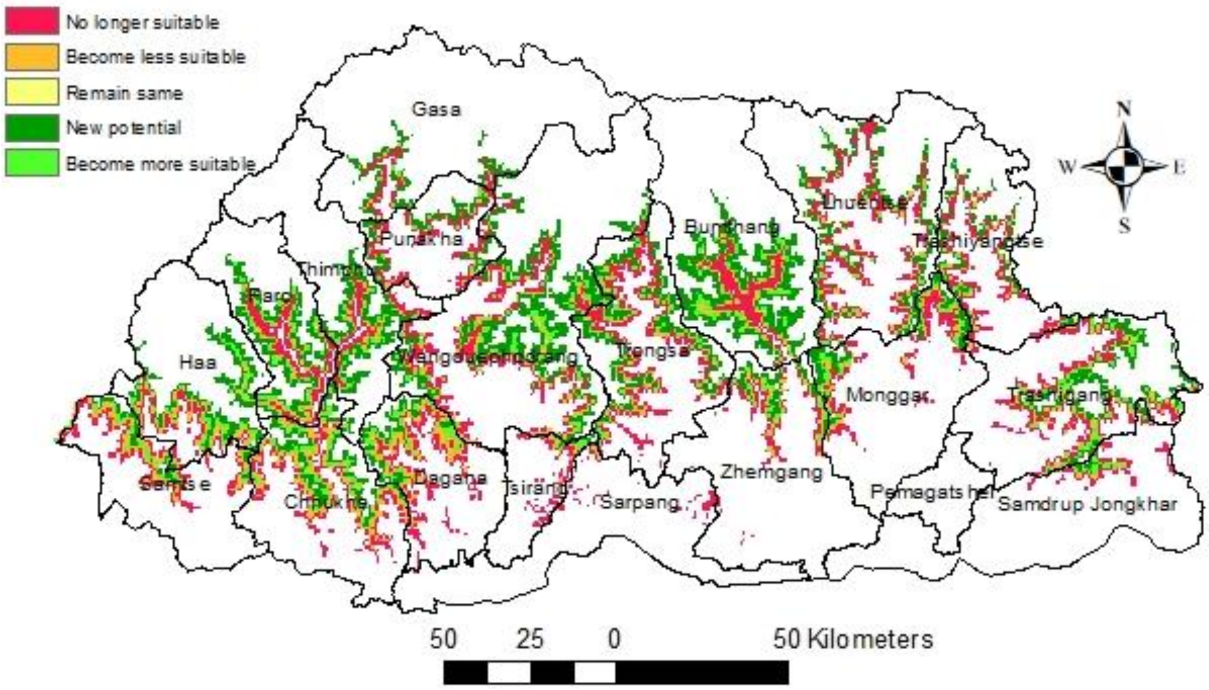

Figure 1. Impact of climate change on apple suitability under RCP4.5

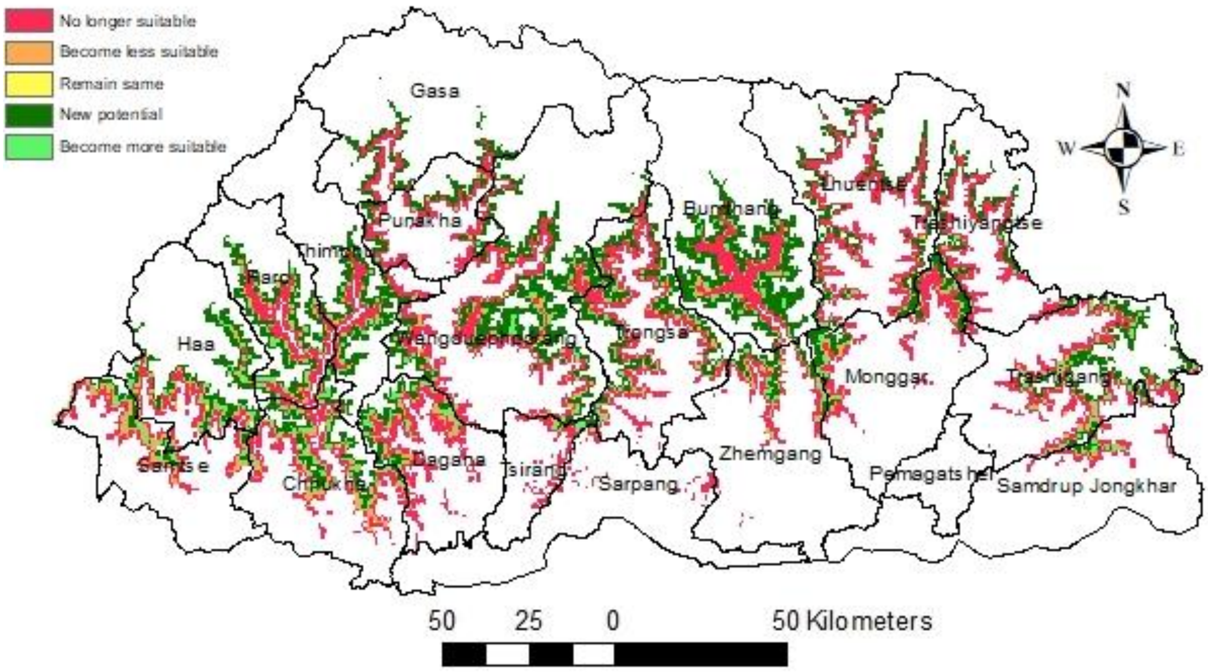

Figure 2. Impact of climate change on apple suitability under RCP8.5

3.2. Gainers and losers in Apple

On the whole, in 2050, Bhutan loses areas suitable for apple production under both the projected future climate scenario (Table 3). Under RCP4.5, Bhutan loses more than 15,000 acres of areas suitable for apple production and under RCP8.5, loses more than 16,000 acres. Under both the scenarios, all top apple producing Dzongkhags of Thimphu, Paro, Bumthang and Chukha loses considerable chunk of areas suitable for apple production in 2050. Among the top five apple producing Dzongkhags, only Haa gains under both the scenarios.

Table 3. Net result of climate change on apple suitability area (acres) under two scenarios

Scenario	No longer suitable	Become less suitable	Remain same	New potential	Become more suitable	Net result
RCP4.5	28230	19010	802	12245	19963	-15032
RCP8.5	30641	14748	0	12282	16678	-16429

3.3. Impact of climate change on Mandarin Orange

Among the fruit crops, Mandarin orange is the top cash earners in the country. In 2016, more than 42,000 ton of mandarin orange were produced. Unlike apple, prospect for mandarin orange is much brighter under both projected scenarios. However, this study does not consider the likely increase in pests and disease pressure under increased temperature which could offset the gain made in terms of areas. Among the two scenarios, RCP4.5 provides better scope for mandarin production than RCP8.5.

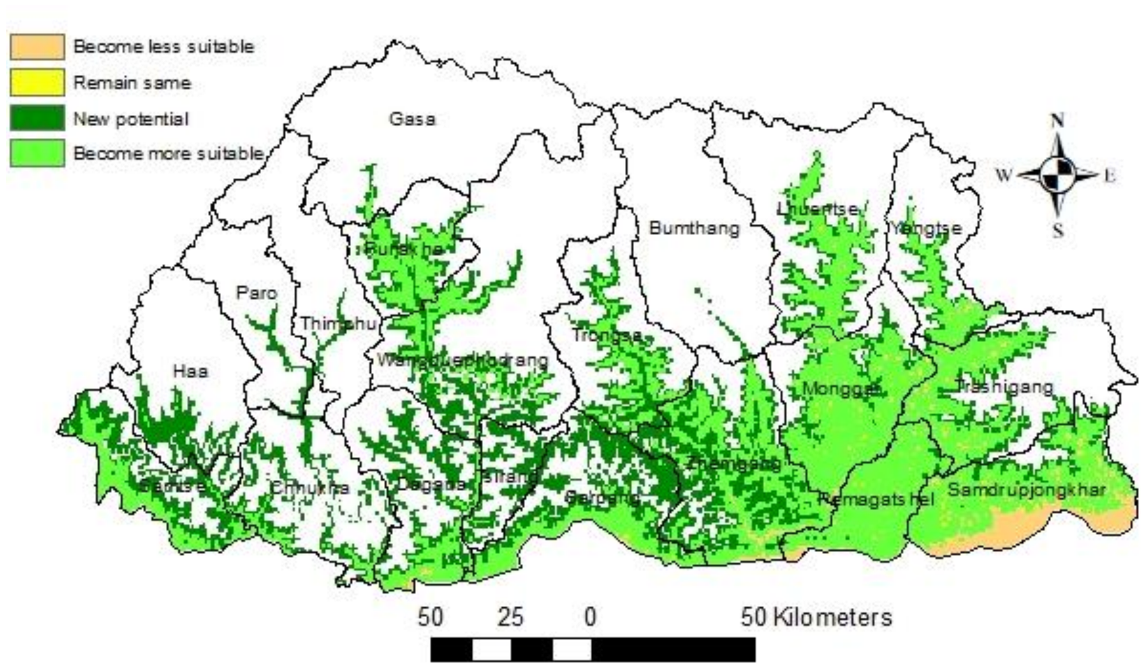

Figure 3. Impact of climate change on Mandarin orange suitability under RCP4.5

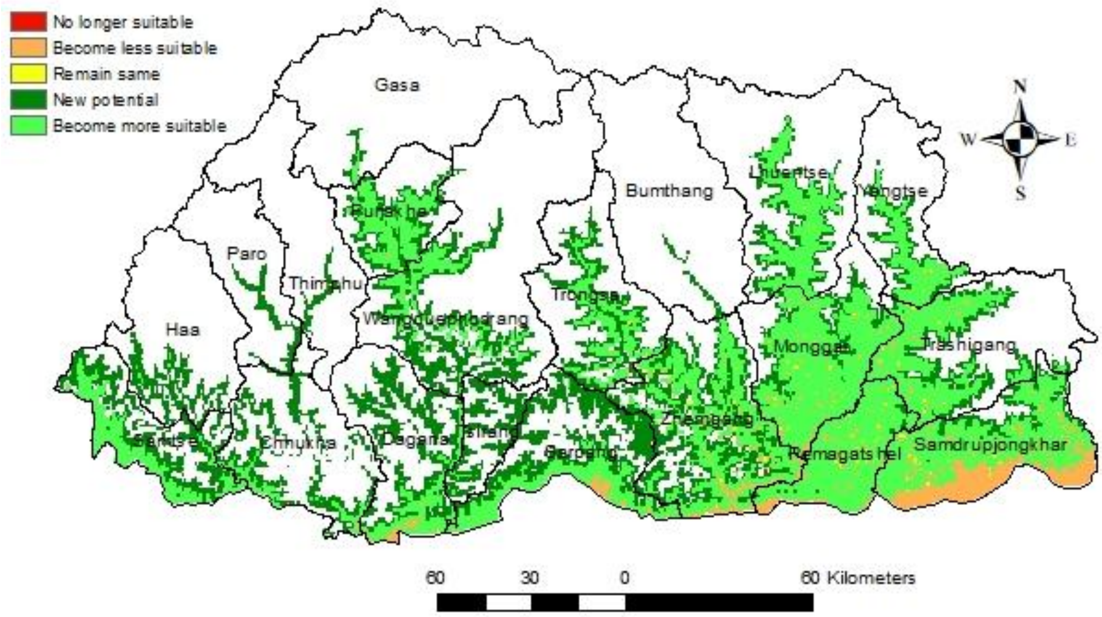

Figure 4. Impact of climate change on Mandarin orange suitability area under RCP8.5

3.4. Gainers under Mandarin orange

In general, notwithstanding other factors, climate change offers better prospect at least to the mandarin orange growers. In 2050, under the projected climate scenario RCP4.5, Bhutan gains more than 207,000 acres of land for mandarin orange production and more than 205,000 acres under RCP8.5. Under both the scenarios, Samtse, Punakha and Lhuentse Dzongkahgs are the biggest gainers.

Table 4. Net result of climate change on mandarin suitability area (acres) under two scenarios

Scenario	No longer suitable	Become less suitable	Remain same	New potential	Become more suitable	Net result
RCP4.5	0	23235	5004	76492	154125	207382
RCP8.5	6	25943	6687	79169	151951	205170

4. Conclusion

As for Apple, though some Dzongkhags gain and other lose, but on the whole, the model projects that Bhutan will lose quite a chunk of area for its cultivation both under the moderately low and high emission scenarios, especially for today's leading apple producing Dzongkhags. On the contrary, the model projects brighter prospects for mandarin orange growers under both the scenarios, provided rise in temperature does not exacerbate pests and disease incidences. Though any models should be read with caution, yet the analysis provides an interesting insight. It presents probable future scenarios – such as change in cropping systems andits impact on the income of the farming communities. It also tends to indicate that temperate crops are more likely to be impacted more than sub-tropical crops. Given these scenarios, diversification of crops, evaluation of biotic and abiotic stress tolerant crops, awareness on climate change and its impact could provide some wherewithal to deal with potential impact of climate change on Agriculture. Though agriculture is climate dependent, availability of reliable national data is one of the biggest challenges. Hence, there is a need to set up automatic weather stations in different agro-ecological zones since climate changes even within short span of distance due to complex topographic features.

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