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The impact of climate change on mandarin production in Dumtoed Chewa Chiwog under Samtse Dzongkhag

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Abstract

Climate change which refers to a long-term shift in temperature, precipitation, wind patterns, and other elements of the Earth's climate system has a significant impact on agricultural practices across the world. Climate change has caused a notable impact on Bhutan, an agriculturally reliant nation, particularly affecting the production of mandarin, a crucial cash crop in the southern regions of the country. The study explored the impact of climate change on mandarin production in Dumtoed Chewa Chiwog under Samtse Dzongkhag. Employing the mixed methods research approach the study explored community perception of the impact of climate change on mandarin production, identified the impact of climate change on the production of mandarin, and explored the adaptations to reduce the impact of climate change on mandarin production in their locality. The study revealed that farmers are increasingly vulnerable to climate change. Erratic rainfall, rise in temperature, storms, drying soil moisture, and the emergence of new diseases and pests attributed to climate change have declined both the quality and quantity of their mandarin production, ultimately resulting in decreased income levels for farmers. While local indigenous practices have proven effective in safeguarding mandarin plants, there is a need to strengthen the resilience of mandarin cultivators against the influence of climate change. This can be achieved through policy support, raising awareness, and the provision of training.

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1. Introduction

Agriculture is one of the main sources of income in Bhutan, as approximately 57% of the Bhutanese population depends on agricultural resources for a living (Chhogyel & Kumar, 2018) ^[5]. Bhutan's diverse agro-climatic conditions are ideal for growing a wide variety of horticultural crops. Mandarin, along with a variety of other horticultural crops, is the most widely grown fruit plant in Bhutan. Mandarin is one of the most essential fresh fruits exported to India and Bangladesh. As a result, it contributes to the economy through export revenue (National Statistical Bureau [NSB], 2021). Furthermore, Tshering *et al.* (2020) ^[20] reported that in 2017, mandarin accounted for 38.28% of the income earned from the sale of fruits.

However, Bhutan has witnessed a rapid decline in mandarin production in recent years, which the government ascribes to infestations of citrus greening, phytophthora rot, citrus fruit fly, and powdery mildew. Piao *et al.* (2010) ^[15], claimed that climate change is widely regarded as the greatest threat to the world of the twenty-first century. Moreover, Salinger (2005) ^[17] states that

agriculture is the most sensitive sector in terms of impact. Consequently, Bhutan being an agrarian country is completely reliant on biophysical factors and is extremely vulnerable to the effects of climate change. The literature demonstrates that climate change is occurring, and the decline in mandarin productivity is cause for concern. Moreover, there is limited literature on the impact of climate change on mandarin production in Bhutan. This necessitates appropriate and timely intervention to mitigate the impact. Additionally, noted that the dramatic drop in the yield of mandarin due to climate change has affected almost all the mandarin orchards across the southern belt.

1.1. Farmers' perception of the impact of climate change

Several studies have now examined farmer perspectives on climate change and its risks, as well as the potential adoption of adaptation and mitigation. The impacts of climate change are already being felt, and the resulting damage will most likely be enormous. The impacts of climate change are one of the greatest challenges the country is facing today and will continue to be so in the near future. Farmers perceive that the impacts and changes are mainly driven by increased global emissions of greenhouse (Malhi *et al.*, 2021) ^[13]. These fluctuation affects soil moisture and hampers the growth of the fruits. Earlier, the rainfall was timely and people did not need to water mandarin plants. The survey conducted by reveals that for most of farmers, climate change meant unpredictable weather (79%), less or no rain (70%), and drying of irrigation sources (55%). Some farmers referred to climate change as the emergence of diseases and pests (45%), high-intensity rains (30%), less or no snow (24%), and shorter winters (11%). Chaudhary and Bawa (2011) ^[4] also shared a similar view that farmer feels that the weather is getting warmer, the water sources are drying up, the onset of summer and monsoon has advanced during the last 10 years and there is less snow on mountains than before.

1.2. Impact of Climate Change on Mandarin Production

The agricultural and environmental research communities are increasingly alarmed by the implications of climate change for mandarin production. Climate change, marked by stable alterations in temperature, precipitation, wind patterns, and various climatic factors, poses extensive impacts on mandarin production on a global scale. Abbass *et al.* (2022) ^[1] highlighted how climate change-induced alterations in plant biology led to defective growth and development. It was observed that climate change-induced alterations in plant biology have complex and interconnected effects that disrupt the health and development of the plant.

Mandarin growers in Bhutan are impacted by a decline in mandarin production attributable to the effects of climate change. The exports of mandarin brought to 19,259 MT in Bhutan in 2021 but unfortunately, this prosperity is now under threat revenue (National Statistical Bureau [NSB], 2021). Delma (2014) ^[8] reported that the suitable altitude for the growth of mandarin is actually 1,100 meters above sea level, but the growth pattern has shifted to 1,200 meters above the sea level in recent years, Similarly, Gyelmo (2016) ^[11] reported that in Bhutan the size and growth quantity of mandarin in lower elevation has reduced while the upper elevation areas have started bearing bigger oranges along with increased production. According to Zangpo (2016) ^[21] mandarin growing farmers suffered major losses because of erratic rainfall due to climate change, are also affecting the

flowering and fruition of orange groves. Abobatta (2019) ^[2] also reported that exceeding high temperatures in the winter season during flower bud initiation reduces the conversion rate to flowering buds and increases the vegetative bud ratio which reduces the final fruit yield. In recent years, Bhutan, like several other nations, has become afflicted by a disease known as 'citrus greening,' also referred to as Huanglongbing. This disease is transmitted by insects that feed on citrus plants, causing a blockage in the plant's nutrient system and resulting in the production of bitter, green fruit. ultimately, once the trees become infected, they cannot be salvaged and must be removed.

1.3. Adaptation to reduce the impact of climate change on mandarin production

Implementing sustainable agricultural methods, cultivating heat-resistant mandarin cultivars, enhancing irrigation methodologies, and employing pest control techniques are proven strategies for mitigating the influence of climate change on mandarin production. Smit and Skinner (2002) ^[18] claimed that adapting to climate change primarily involves the adjustment of agricultural practices, and they are significantly shaped by policy choices aligned with climate variations and extremes, as well as by social, political, and economic circumstances. Altieri and Nicholls (2017) ^[3] suggest that both traditional management systems and agroecological management systems, including practices like biodiversification, soil management, and water harvesting, can play a crucial role in enabling farmers to adopt climate-resilient technologies. Mulching underneath the trees is often used as a technique for water conservation. Mulches are used to maintain moisture levels high in the soil, control soil temperature, and evaporation thereby reducing the need for irrigation during growing seasons. Dorji *et al.* (2016) ^[9] stated that hands-on training on orchard management had a positive impact on the adoption of management practices, yield, and income. They also found out that one of the constraints in citrus orchard management was a lack of know-how among growers besides a shortage of farm-skilled labour. Lack of irrigation and erratic rainfall affect yield and production. Therefore, promoting resilient agricultural practices in the face of changing climate patterns and integrating climate change risks into water and land management practices are found to be important.

2. Research method

The study employed a mixed methods research approach as it offers a better way of addressing the research problem than qualitative and quantitative in isolation. In order to conduct this study a convergent mixed methods research design was an appropriate design that can help to guide this study. Therefore, both the data were collected simultaneously. The target population is the source of primary data to answer the research questions. In this study, the target population were the head of the household who had a mandarin plantation. The researchers chose 25 households out of 30 households from Dumtoed Chiwog under Dumtoed Gewog as our sample size. The 25 samples are those households whose livelihood depends on mandarin. Data collection tools such as a survey questionnaire comprising 19 items and 2 Focus Group Discussions were used. The first set of survey questionnaires employing 6 Likert Scale was used to collect the respondents' perceptions of the impact of climate change on mandarin production, and second to identify the impact of climate

change on the production of mandarin. FGDs comprising 5 members each were conducted to gather valuable insights and perspectives from a diverse group of farmers.

For the data analysis, the researchers checked for the completeness of the questionnaire before compiling and coding the data. The data collected using the quantitative method was summarized in the form of descriptive statistics using SPSS. Analysis of qualitative data basically involved coding and categorizing into themes from interview transcripts and reporting the details of patterns adapting Pimentel's (2019) [16] scale interpretation. Employing the thematic analysis of, raw data gathered from qualitative data were transcribed, coded, and categorized into various themes to interpret the qualitative data.

3. Result and Findings

The results are generated from the quantitative and qualitative data categorized into three themes. Farmers'

perception of the impact of climate change on mandarin production, the impact of climate change on the production of mandarin, and the interventions to reduce the impact of climate change on mandarin production in their locality.

3.1 Farmers' perception of the impact of climate change on mandarin production

In this study, climate change is defined as a long-term shift in temperature, precipitation, wind patterns, and other elements of the Earth's climate system that affect the production of mandarin. Hence, it was an overall perception of climate change from respondents, based on their experience in the last 5 years, not for a specific weather event in the last five years. A 6-point scale was used to measure farmers' perceptions of the impact of climate change, with 1 as a very strongly disagree and 6 as a strongly agree. Farmers' perception of climate change on the impact on mandarin production is shown in Table 1.

Table 1: Farmers' perception of climate change's impact on mandarin production

	Statements	N	Mean	SD	Level of opinion
1	An increase in summer temperature over the past few years has decreased the growth of mandarin.	25	5.76	.43	Highly Positive
2	I have noticed changes in temperature and weather patterns which impact mandarin production	25	5.64	.48	Highly Positive
3	I have observed more frequent or severe weather events (e.g., droughts, floods, storms) in your area in recent years that affect mandarin production.	25	5.72	.45	Highly Positive
4	The climate change makes mandarin trees more vulnerable to pests and diseases.	25	5.60	.50	Highly Positive
5	The low productivity of the mandarin over the past few years is mainly due to the rise in temperature.	25	5.84	.37	Highly Positive
6	I have experienced difficulties in managing water resources, such as irrigation, due to changing climate conditions.	25	5.68	.47	Highly Positive
7	Erratic rainfall due to climate change is also affecting the flowering and fruition of mandarin orchards.	25	5.84	.37	Highly Positive
8	I have experienced difficulties in managing water resources, such as irrigation, due to changing climate conditions.	25	5.64	.49	Highly Positive
9	I feel that climate change has the potential to have a long-term impact on mandarin production.	25	5.88	.33	Highly Positive
	Overall Mean		5.73	.43	Highly Positive

Note: 1-1.82=Highly Negative, 1.83-2.65=Negative, 2.66-3.48=Moderately Negative, 2.49-4.31=Moderately Positive, 4.32-5.14=Positive, 5.15-6.00=Highly Positive. Adapted from Pimentel (2019)

Table 3.1 presents the mean and standard deviation of farmers' perception of climate change on mandarin production. The overall average mean ($M = 5.73$, $SD = 0.43$) of 9 items under the theme of farmers' perception of climate change on mandarin production was rated at a highly positive level. This indicates that farmers have a positive or favourable perception of how climate change affects mandarin production. The farmers expressed strong agreement with statements describing the impacts of climate change on mandarin production. Among 9 items, item 9 "I feel that climate change has the potential to have a long-term impact on mandarin production." was rated the highest with the mean value ($M = 5.88$, $SD = 0.33$) at a highly positive level, while item 4 "The climate change makes mandarin trees more susceptible to pests and diseases." with a mean ($M = 5.60$, $SD = 0.50$) was rated lowest. However, both items are rated at a very good level, indicating that the respondents had a high level of agreement against all the items which describes the perception of climate change on mandarin production.

The qualitative findings from FDG also confirm that climate change has the potential to have a long-term impact on mandarin production. This means climate change is expected to affect mandarin production in future. For instance, FGD 1

said, "Climate change has the potential to significantly influence mandarin production in the long term. We've been witnessing shifts in weather patterns, increased instances of extreme weather events, and alterations in temperature and precipitation levels. All of these factors can directly impact the quality and quantity of mandarin fruit we produce." An increase in the frequency of rainfall and windstorms during the mandarin flowering season has had a negative impact on mandarin yield and unpredictable rainfall patterns, attributed to climate change, are influencing the flowering and fruit development in mandarin orchards. FGD 2 stated "The erratic rainfall, often attributed to climate change, has disrupted the normal flowering and fruition of our mandarin orchards. It's been a challenge to adapt to these changing conditions and ensure consistent yields."

3.2. The impacts of climate change on the production of mandarin

The study aimed to explore the effects of climate change on Mandarin production across three critical dimensions: quality, quantity, and income. It considered not only the physical attributes of the fruit (quality and quantity) but also the economic aspects (income) to better understand the challenges faced by mandarin growers in the context of a

changing climate. The impacts of climate change on mandarin production are shown in Table 2.

Table 2: The impacts of climate change on mandarin production

	Statements	N	Mean	SD	Level of opinion
1	Extreme weather events, such as heavy rainfall or drought, negatively impacted mandarin production (quantity)	25	5.52	.71	Highly Positive
2	High temperatures affect flower bud induction and fruit development.	25	5.84	.37	Highly Positive
3	Variations in temperature and precipitation levels have influenced the quality of mandarin fruit.	25	5.76	.43	Highly Positive
4	Climate change has influenced the size and uniformity of mandarins.	25	5.87	.20	Highly Positive
5	The decrease in mandarin production is due to citrus diseases or pests caused by climate change.	25	5.96	.20	Highly Positive
6	Changes in climate have led to shifts in the ripening patterns of mandarin fruit.	25	4.13	.94	Positive
7	The availability of water resources, including irrigation, has impacted mandarin quality in the face of climate change.	25	5.72	.45	Highly Positive
8	Extreme weather events, such as droughts and storms, have impacted the quality of mandarins.	25	5.88	.33	Highly Positive
9	The quality of mandarin has been impacted by climate change, leading to changes in market prices and income.	25	5.72	.45	Highly Positive
10	Climate change has led to an increase in production costs, affecting overall mandarin income	25	5.64	.48	Highly Positive
	Overall Mean		5.60	.45	Highly Positive

Note: 1-1.82=Highly Negative, 1.83-2.65=Negative, 2.66-3.48=Moderately Negative, 2.49-4.31=Moderately Positive, 4.32-5.14=Positive, 5.15-6.00=Highly Positive. Adapted from Pimentel (2019)

Table 3.2 presents the mean and standard deviation of the impact of climate change on mandarin production. With an average mean ($M = 5.60$, $SD = 0.45$) of 10 items under the theme were rated at a highly positive level indicating that climate change has affected the mandarin production in the village resulting in the deteriorating quality of mandarin, and a decrease in the quantity and the income of farmers.

“The decrease in mandarin production due to citrus diseases or pests caused by climate change.” was rated the highest with the mean value ($M = 5.96$, $SD = 0.20$) at a highly positive level. Therefore, the majority of farmers strongly agree or have a very positive outlook on the idea that climate change is causing a decrease in mandarin production due to citrus diseases or pests. While item 6 “Changes in climate have led to shifts in the ripening patterns of mandarin fruit.” with a mean ($M = 4.13$, $SD = 0.94$) was rated lowest. This means the farmers do not strongly agree with the idea that climate change has caused shifts in the ripening patterns of mandarin fruit.

The qualitative findings from FDGs also confirm that climate change which leads to the emergence of mandarin diseases citrus greening, citrus canker and Citrus Tristeza Virus has an adverse impact on mandarin production. For instance, FGD 1 said, “Due to change in the climate diseases like citrus greening affect the entire tree, leading to damage, bitter fruit and ultimately damaging the tree. Mandarin production is not like before now”. Similarly, FGD 2 also stated that climate change has now created favourable conditions for pests and diseases that they have never seen before.

3.3. Adaptation to reduce the impact of climate change on mandarin production

Farmers have attempted various strategies and techniques to eliminate or control diseases and infestations of pests in their mandarin orchards. The indigenous knowledge to protect the drying of mandarin plants is found to be effective at the local level. Farmers tried several methods to get rid of diseases and pest outbreaks in the orchards. The FDG 1 revealed:

To minimize the impact, we can apply lime on the tree bark so that harmful insect does not climb on the trees but it is risky as the bark of the orange tree is thin, it may affect the bark of the tree. Thus, it may do more harm than good. Moreover, many of our villages have not practised it.

As an intervention farmer also applied lime on the tree bark to keep away the insect pests on mandarin trees. However, they lacked the skills to apply since they were quite worried that unskilled may damage the thin bark of plants. This indicates that farmers required training in terms of applying lime on the tree bark to prevent further damage.

FDG 1 also revealed that they heard the practice of applying diesel engine oil on the bark of the trees from the Gewog Agriculture Extension Officer but they did not get proper training and sensitization from them.

Another solution we can practice is applying diesel engine oil to the bark of the tree. We heard from the Gewog agriculture extension officer but we have not tried it. Moreover, they did not sensitize it on how to use it. But some of the villagers practice wrapping around the orange tree with sacks around it. But there also involves risk as it may not be feasible during extreme heat continuous sunshine will make the tree bark brittle and susceptible to pests and diseases.

The farmers also express that as an indigenous knowledge, they wrap the sack around the tree to prevent pests and diseases but such practices are not feasible during extreme heat. Therefore, farmers required agriculture extension officers to validate these practices. Mulching is also seen as an effective strategy as helps to conserve soil moisture by reducing evaporation.

Farmers believed that local leaders and the government's active involvement in the impact of climate change on mandarin production would manage crises in the Chiwog. The FDG revealed the following support from the local leader and government:

So far local government could not extend any positive support to us to mitigate the climate change impact on oranges nor have we requested support from local leaders and relevant government agencies. However, we feel that the government need to do a proper study on the impact of climate change on mandarin production especially for farmers of southern Bhutan. If the government supply us with climate-resilient mandarin saplings after thorough research, and provides them to orange growers of southern Bhutan, it would be a great benefit to all of us.

FDG 1 also expect local leaders and the government to supply pesticides and fungicides on time to prevent the greater spread of pests and fungi in the community.

Another support that the government can provide to us is the timely supply of pesticides and fungicides through gewog administration. It would be of great help and relief to the farmers.

In addition, participants expect local leaders and the government to supply grafted saplings which can resist the effect of climate change compared to local species. FGD 1 claimed:

Moreover, if they supply us with a grafted sapling, it would be beneficial as it not only grows faster but is considered high-yielding. When it comes to local orange tree saplings, it takes time and is susceptible to pests and diseases. If these supports are provided, we will remain happy and grateful.

Providing training in terms of orchard management was found to be very important to overcome the challenges of climate change. In this regard participants also required local leaders and government to be proactive to solve the current problems of mandarin production in the Chiwog. FDG 1 added that another support the local government and dzongkhag can provide us is training for mandarin growers on pruning and grafting of the trees, the modern technique of making orchard and management, and canopy shedding training.

4. Discussion

This discussion segment explores deeper into the themes of farmers' perception of climate change on mandarin production, the impact of climate change on mandarin production, and the interventions to reduce the impact of climate change on mandarin production.

Farmers perceive that the impact of climate change on mandarin production is an ongoing process and will be continued in future. They believe that climate change has the potential to have a long-term impact on mandarin production. The study aligned with the conclusion made by the United Nations Organization (UNO, 2018). Which states that climate change is one of the greatest challenges the country is facing today and will continue to be so in the near future. Therefore, it is important to note farmers' perceptions that may motivate them to explore strategies to mitigate the impacts and ensure resilience in mandarin production. The study also reveals that farmers have observed changes in local weather patterns, including more frequent and intense weather events like droughts, floods, storms, and unseasonal temperatures. These changes have an impact on the mandarin production. The survey conducted also reveals that for most farmers, climate change meant unpredictable weather, less or no rain and drying of irrigation sources.

The findings from the study reveal that mandarin production have been affected due to diseases and pests that destroy plants. Climate change can create conditions that favour the reproduction and expansion of certain pest species leading to less production. The findings aligned with The Third Pole report (2016) which emphasises citrus greening which is known as Huanglongbing (HLB) or yellow dragon disease, with a devastating bacterial disease that affects citrus trees. The findings underscore the importance of addressing these issues through integrated pest management, research into disease-resistant citrus varieties, and other strategies to ensure the sustainability of mandarin production in the face of these challenges. The findings also reveal that more frequent and severe weather events, such as droughts, and storms damage mandarin trees, disrupt the growing cycle, and reduce fruit yield. Additionally, it also affects the

flowering and fruit-setting process leading to changes in fruit quality and quantity. The finding is similar to Zangpo (2016)^[21] who reported that mandarin growers suffered major losses because of erratic rainfall due to climate change, are also affected the flowering and fruition of mandarin groves. Therefore, climate change is significantly affecting mandarin production and addressing the impact is found to be important.

Farmers expressed that adaptation to reduce the impact of climate change on mandarin production is an important aspect of safeguarding their food security and generating income. Farmers have been practising various interventions such as applying lime solution, mulching and wrapping around the bark of the tree with sacks on the bark of the tree. The result aligns with Altieri and Nicholls (2017)^[3] who suggest that both traditional management systems and agroecological management systems, including practices like biodiversification, soil management, and water harvesting, play a crucial role in enabling farmers to adapt. Similarly, mulching underneath the trees is often used as a technique for water conservation were also in the view that mulching is used to maintain moisture levels high in the soil, control soil temperature, and evaporation thereby reducing the need for irrigation during growing seasons. The findings also suggest that farmers believe that stakeholders play a vital role in adapting to reduce the impact of climate change on mandarin production. Farmers expect their assistance in the field of supplying us with climate-resilient mandarin saplings, pesticides and fungicides and provide training in terms of orchard management. The finding aligns with Dorji *et al.* (2016)^[9] stated that hands-on training on orchard management had a positive impact on the adoption of management practices, yield, and income. Therefore, it is important to support farmers in obtaining climate-resilient mandarin saplings, pesticides, and fungicides, coupled with offering comprehensive orchard management training, representing a holistic strategy with positive outcomes for farmers, the environment, and society at large. It can tackle climate change-related challenges, boost food security, and foster sustainable and economically sound agricultural practices.

5. Conclusion

The findings reveal that farmers have been experiencing climate change and its impacts on mandarin production has now become a growing concern. Climate change has posed numerous challenges for mandarin production. It has changed the conditions that are less favourable, leading to reduced yields or lower quality. Changes in climate have also created more conducive environments for pests and diseases that affect mandarin trees. The frequency and severity of extreme weather events, such as storms, or heavy rainfall have damaged mandarin trees impacting fruit quantity and quality. They perceive that it is important to understand and address these challenges to ensure the resilience and sustainability of the agricultural sector. It is evident that mandarin production faces an uncertain future. Increased temperature variations, altered precipitation patterns, and the potential for extreme weather events disrupt mandarin production. To mitigate these effects, indigenous measures such as applying the lime solution, and covering of bark have been practiced but found to be ineffective. Effective measures such as the adoption of climate-resilient practices, the development of healthy risk management strategies, and the promotion of sustainable

agricultural techniques are demanded by farmers.

Therefore, the impact of climate change on mandarin production is found to be undeniable. It requires a constant effort from agricultural stakeholders and policymakers to adapt to these changing conditions. By acknowledging the challenges posed by climate change and implementing appropriate measures, the future of mandarin growers can be safeguarded.

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