

# Climate change effects of Nepalese fruit production

## Summary

The emission of greenhouse gases causes global warming which affect the fruit production. The main effect of climate change is shifting of climatic zone, drought, rise in temperature, disease and pest outbreak etc. Climate change has both negative and positive effect on fruits. Due to climatic zone shifting, tropical fruits can be grown in higher altitudes also. Climate change affects the fruits in its various growth stages. Delay maturity, delay ripening, poor quality fruit, poor color development, sun burn of fruit, poor panicle emergence, improper pollination etc. are some of the effect of climate change on fruits. Due to perennial nature of fruit trees, mitigation measures are difficult to apply after the establishment of orchard. Proper management of existing technologies, adoption of new technologies, variety selection matching with changing climate change is the key measures to overcome climate change impacts on fruit production.

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**Abbreviations:** GDP, gross domestic production; USNAS, united states national academy of science; TSS, total soluble

## Introduction

### Background

Nepal is a mountainous country with different agro-climatic zones where different types of fruit crops can be grown. Most of the Nepalese land is in hilly area where cultivation of other crops like cereals, pulses etc. is difficult. Fruits trees can be grown easily in such sloppy land with minimum damage to soil which is highly prone to erosion. Fruit trees don't require any tillage operation and irrigation can be done effectively in sloppy land also. These fruit trees also help to conserve the soil by minimizing erosion. Varieties of fruits can be grown in different agro-climatic zones. The main climatic zones are tropical, sub-tropical, mild-temperate and temperate. The major fruits grown in Nepal are Mango, Banana, Guava Apple, Citrus, Pear, Peach, Papaya, Pineapple, Litchi which has their own growing environment i.e. temperature, humidity, precipitation, solar radiation etc. but due to changing climate their production decreases day by day. Global warming causes rise in temperature which leads to rapid shifting in climatic zones. This shifting causes serious problem in fruit production. Other serious problems of climate change are disease pest outbreak, drought, landslides, flood, erosion etc.<sup>1</sup> Fruit sector contributes a good share in total agriculture GDP. The demand of fresh fruits in daily consumption is very high. Domestic production can't meet the market demand so we have to import fruits from neighboring countries like China, India. The domestic production decreases day by day due to serious damaging diseases, pest, lack of proper management practices, uneven precipitation, which all are the result of climate change. It is a serious problem which is mainly due to emission of greenhouse gases from industries, deforestation and urbanization resulting changes in solar energy, temperature and rainfall intensity. Climate change cause shift in climatic zone due to which positive effect seen on some tropical fruits because they can be grown in higher altitude also. The production of temperate fruits is decreasing due to rise in temperature and lack of proper chilling temperature for growth and breaking of dormancy.

### Statement of problem

The study about climate change is very important for fruit production nowadays. We should have good knowledge of climatic zones and their shifting pattern in response to climate change for the

better production of fruits. Most of the researches on climate change are done on cereal crops and other annual crops only due to their short growing season. There is not enough research done in Nepal about the effect of climate change on fruit production. Fruit growers are not aware about the effect of climate change and their production is declining day by day. We should adopt some improved production techniques for the fruit production that can cope with the climate change. Climate change has some positive effects so we should work on to minimize climate change effect by using its positive side.

## Objectives

- To study about the climate change pattern and its causes.
- To study about the effect of climate change on fruit production and ways to minimize it.

## Major findings

### Climate change

The amount of greenhouse gases on earth surface is increasing day by day. These greenhouse gases like carbon dioxide (CO<sub>2</sub>) absorb infrared radiation (heat) emitted from surface of earth. The more emission of these greenhouse gases causes the earth to warm up quickly and result in climate change. Since 1900, the global average temperature of earth increased by 0.8°C (1.4°F).<sup>2</sup> The average temperature in Nepal is rising in faster rate than the global average. The rate is higher in Himalayan region. Due to this climatic change, precipitation is becoming unpredictable and uneven, resulting in extreme environmental conditions. Climate change mostly affects poor people in their livelihoods and their lifestyle.<sup>3</sup> Nepal is one of the most vulnerable countries of the world towards changing climate. Nepal is suffering from climate change-led impacts like depletion of snow cover, glacier retreat and flood outburst from glacial lake. Other problems like erratic rainfall, water stress, and vector borne diseases are affecting at the community level. Early flowering and ripening of fruits or crops and shifting seasonal weather pattern are the major impacts on agriculture sector.<sup>4</sup> The earth is warming continuously due to which climatic zones are shifting.

The effect of global warming can be seen on higher Himalayas of Nepal in terms of glacier retreat and significant increase in size and volume of glacial lakes, more prone to outburst flooding. This type of flooding mainly affects the agriculture sector by degrading agricultural land.<sup>5</sup> Although Nepal does not produce much of

greenhouse gases as compared to industrialized countries, it has facing serious consequences of climate change. Exploitation of natural resources, deforestation, population growth are the major causes of climatic degradation in Nepal which lead to pollution, declination water quality, drought, landslide, flood, land degradation and other environmental problems. These events lead to losses in agricultural productivity.<sup>6</sup> Due to climate change temperature and precipitation pattern changed. The changes in temperature and precipitation will result in changes in water regimes and land which ultimately affect the agricultural productivity. The tropical regions of the poorest countries affected more than the other parts with low level of technologies, wide pest range, weeds, diseases; land degradation, rapid population growth etc. For the mitigation of climate change some adaptation measures should be carried out like improving water management practices, modernization of agriculture, utilizing new techniques like changing crop types and location etc.<sup>7</sup>

### Climate change effects on fruit production

Horticultural crops are more sensitive to climatic variability as they heavily rely on adequate water supply and proper amount of daily energy like temperature, solar radiation. That's why a small rise in temperature may cause serious damage to horticultural crops like fruits and vegetable. Most important effect of the climate change on fruit crops is shifting of climatic zone. Due to climatic zone shift the climatic suitability changes. The percentage change in climatic suitability is not same in the case of all fruits. The following figure shows the changes in climatic suitability of some fruit crops along with other horticultural crops. The figure shows that the change in climatic suitability of a crop also reduces the suitable cropping area. In the figure among the fruits Bananas shows the higher percentage of decrease in suitable cropping area (68%) and also the high negative change in climatic suitability over a period of time (1961-1999) followed by apple (58%), oranges (47%), and coconut (40%). Mango showed the lower variation in climatic suitability change with more positive effect along with low decrease in suitable cropping area (28%) (Figure 1).

In high hills like Manang and Mustang district the climate change especially rise in temperature has some positive effect in agriculture sector. In fruit farming, bigger and testy apples can be grown at higher

altitudes also which can't be grown in past years due to freezing temperature.<sup>6</sup> Tropical countries have great diversity among fruit trees. Over 1000 species of tropical fruits in America, 1200 in Africa and 500 in Asia including 300 species in Indian subcontinent are reported but only small portion of that are cultivated commercially. Most of the tropical fruits are benefited by the climatic change like mango, coconut and banana production area is increases due to increasing temperature and they can be grown in higher altitudes also. In some fruits quality traits like coloration, spottiness, fruit texture and taste can be altered by the change in temperature, precipitation and rainfall etc. and it also affects the phenological stages (such as flowering, growth flushes etc.) of some tropical fruit (e.g. mango). Conservation of genetic resources of fruit trees in changing climate is quite difficult task. Unlike cereals and legumes, fruit trees may not have seeds or seeds may be recalcitrant or may be the varieties need to be propagated vegetative. In this case ex situ conservation in field gene banks should be done. These ex situ (on field) conservation of germplasm are highly affected by the changing climatic condition and incur significant establishment, management and maintenance cost.<sup>8</sup> Perennial fruits like mango, guava, jackfruit, grapes bear only in a year but the temperature and precipitation that the tree exposed throughout the year determines the quality and quantity of produce. Since, fruit trees has longer flowering period, the temperature regime in the soil as well as the outside temperature determine the fruit set by changing the level of hormones required for the growth and development. In temperate fruits, temperature plays a key role in breaking dormancy, while in sub-tropical and tropical fruits; it plays an important role for fruit bud differentiation and fruit set. Different fruit require different temperature regimes for their better growth and development but due to global warming the fruit trees doesn't get the required temperature and hence the production decreases. Climate change has different type of effects on different fruits. Tropical fruit trees don't grow continuously i.e. the apical bud spend most of its time in rest. The new vegetative as well as reproductive flushes appear only after the end of this rest period.<sup>9</sup> In tropics where temperatures are already high, further rise in temperature will affect adversely the yield and quality of fruits while in areas with already cold temperature as a limiting factor for growth, increase in temperature will be beneficial factor. So, the rise in temperature in the areas already with high temperature, there will be shifts in growing areas.<sup>10</sup>

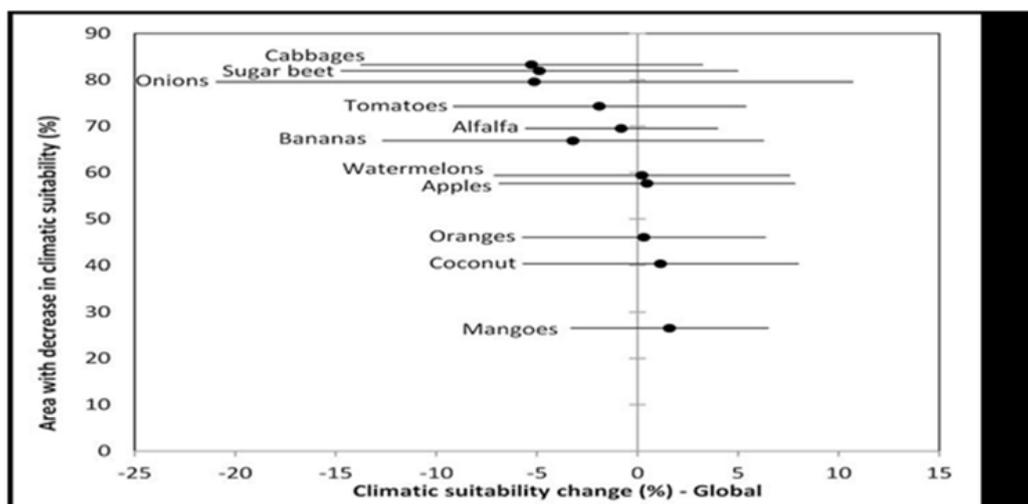


Figure 1 Percentage of global suitable cropping area decrease vs. percentage of climatic suitability change (Global) over a period of time (1961-1999).<sup>20</sup>

Climatic shift affect the flowering date in mango (both delay and early), resulting in poor quality of fruit. Variation in temperature, unseasonal rainfall and higher humidity cause altered flowering trends, delays in panicle emergence and fruit set in case of mango. Low night temperature and unseasonal rains in sub-tropics may result in low fruit set while low day temperature reduces the pollination activities. High temperature during panicle development in mango speed up the growth due to which less number of days available for effective pollination which may lead to low production. Unseasonal rain coupled with varied temperature may induce the off season flowering of mango in some cases but the fruit setting will be poor. High temperature causes desiccation of pollen and poor activity of pollinator resulting in poor fruit set. Increase in carbon dioxide concentration alone increase mango production but when it is combined with high temperature and changes in solar radiation cause decrease in production.<sup>11</sup> Climate change causes abrupt change in night temperature which will cause asynchronous flower production in sub-tropics and result in poor productivity. Flower buds that exposed to cold temperature during night time may change into vegetative ones under warm night conditions. In tropics cool winter days followed by hot summer days may result in poor flowering. Cool temperature at the time of inflorescence growth reduces the perfect flowers number.

Inflorescences, which emerges during late and mid flowering time results in more number of perfect flowers due to rise in temperature at the late flowering season. In sub-tropical climate, temperature is important environmental stimulation of flowering in mango and other fruit trees also.<sup>12</sup> (Figure 2) In papaya, higher temperature has resulted in flower drops as well as sex changes in male and hermaphrodite plants along with promotion of stigma and stamen sterility. In case of grapes, variation in temperature cause alterations in developmental stages and ultimately the ripening time. Higher temperature increases number of cluster per shoot but reduce no. of flower per cluster. Higher temperature causes reduction in photosynthetic rate due to wilting of leaves by high evapotranspiration rate. In case of fruits like pineapple, flower induction takes place at reduced temperature, short day or both conditions while long day with high temperatures results in irregular flowering.<sup>13</sup> In case of mandarin low temperature helps in releasing bud dormancy and vegetative buds and flower initiation occurs before the winter season.<sup>14</sup> Higher temperature also has effect on fruit maturation and quality. In grapes high temperatures result in delay in fruit maturation and reduction in fruit quality. The total soluble solids, fruit firmness and percentage dry mass were also affected by higher temperature during fruit growth.<sup>15</sup> In Guava red color development in peel requires cool nights but due to rising temperature the color development is affected. The areas suitable for red colour development are reducing.<sup>16</sup>

In case of pear, the size and appearance, total soluble solids, total sugar, total acid and water content were greater and acid to sugar ration and vitamin C content were found lower in fruits collected from low temperature regions compared to high temperature regions of China.<sup>17</sup> In Naval oranges acidity content was affected by low temperature leading to low TSS content. Rainfall during September-October had an obvious effect on the total soluble solids while low rainfall at that time increased the soluble solids.<sup>18</sup> In papaya, high temperature and high moisture content will bring about higher TSS. This is also observed in case of mango and guava. Rainfall during maturity period may cause blackening of fruit while reduced winter rains will increase the irrigation requirement as well as poor crop production. In sub-tropical fruits temperature has direct effect on maturity and

ripening. When sufficient moisture is available TSS increases with increase in temperature while in some fruits like passion fruit, TSS do not increase. Most of the fruit trees are heterozygous in nature and the genotype and environment interaction (G×E) is very high. So, the effect of different temperature regimes has different on different fruits. Color development in fruits also affected by environmental conditions, like in pomegranate, certain gene only expressed colour development under certain environmental condition. The aril colour changes from red to pink under a suitable environmental condition only because it is governed by gene expression under matching environmental condition. In Cavendish banana, golden yellow colour development is affected under high temperature. From these conditions we can say that climate change is one of the major factors that affects the gene expression for certain traits. So, the genotypes should perform well under different climatic conditions.<sup>19</sup> High temperature along with high rainfall and humidity help in making suitable condition for the development and spread of a number of diseases and pests which are harmful to fruit crops. Most of the diseases and pest infestation occur at high temperature and humid condition. High temperature and intense radiation had negative correlation while minimum temperature, humidity and wind speed had positive correlations with the disease development.



**Figure 2** Pseudo-fruit setting in mango due to climate change

Fruits harvested during humid conditions were more infested by the fungal diseases. In case of mango and Guava the incidence of fruit fly is low at higher temperature (Diedhiou et.al, 2007). In grapes downy mildew develop easily under warm, humid conditions. High temperature coupled with unseasonal rainfall during vegetative phases result in damage due to this disease (Pearson and Goheen 1988). In case of apple appropriate soil moisture is very important factor for good production. Excessive moisture may lead to ideal condition for development of crown and collar rots, while insufficient moisture leads to drought, stress and poor quality fruit (Black et.al, 2008). Postharvest quality of fruits is also affected by the changing climate. Immediately after the harvesting of fruits rapid cooling is done to reduce the temperature. High temperature after harvesting may cause high respiration rate and enzyme activity which reduce the self-life of fruits. Rapid cooling also helps in slow ripening, maintenance of firmness, inhibition of pathogenic activity and minimum water loss (Talbot and Chau, 2002).

### Climate change adaptation

To overcome the effects of climate change we have to adopt various management practices suitable to changing climate, using suitable varieties according to the changing climate or changing climatic zone

and the current production system should be made environmentally and economically sustainable. Selection of appropriate rootstock is also an important factor to suite the changing climatic condition. Some of the species can adapt themselves to the new climatic condition and become more tolerant to the climate change like fig has sunken stomata, thick cuticle and waxy coating on the leaves which help to tolerate high temperature. Indian gooseberry or aonla have adapted by reducing the leaf area which reduce the transpiration area. Pomegranate is winter hardy as well as drought tolerant. Papaya can be grown well under both tropical and sub-tropical conditions. Through good management practices like pruning and cultural manipulations grapes, basically a temperate fruit can be grown well under tropical conditions. Also, to mitigate the effects caused by diseases and pest we should have the information of specific climatic condition and interaction with diseases and pest development conditions. Climate change makes it possible to grow crops of lower altitude in higher altitude but we have to consider the cost and benefit analysis before replacing old crop with the new one.<sup>20</sup>

Diversification is an important strategy used for minimizing risk of climate change. A sole crop can give bumper production during a favorable climatic condition but diversity can bring stability in production system, lowers the diseases and pest infestation. To deal with the uncertainty and variation in production, farming communities around the world use diversified cropping system and fruit trees provides important option in diversifying crops. Fruits add resilience to farming systems as they can withstand climate adversity better than the annual crops. Fruit trees provide multiple use values in addition to fruits, such as timber, firewood, fodder, windbreaks and atmospheric nitrogen fixation. Reproductive stages of fruit trees are most susceptible to climate change with the effect on quality and quantity of produce. Temperature and moisture stress mostly affect at the time of flowering and fruiting. After the establishment of fruit orchard it is difficult to change the varieties unlike the cereal crops which can give production in short period and variety change wouldn't be difficult. In fruit orchard we can change the variety by using grafting techniques. New varieties can be grafted to the old already established rootstocks by top working, side grafting etc. In this way we can maintain large amount of diversity in small area. Selecting a resilient rootstock and grafting it to the varieties that bears at complementary times may ensure production even in erratic climatic conditions.<sup>21–26</sup>

## Conclusion

Fruit production is a long term investment. After the crop establishment only few adjustments can be done. So, adaptation measures towards climatic change should focus on improvement of existing technologies for creating appropriate production environment for current as well as future conditions. Fruit trees have some advantage of being more resilient of climatic variation. Choice of variety is one of the important processes while establishing new orchard because variety suitable for current climatic condition can't be suitable for the future climatic condition in long term. Thus, farmers need those crop varieties which can tolerate greater stress like heat, drought as well as photo and thermal insensitive varieties. Although, fruit farming is important in Nepal, only few researches are done in relation with climate change till now. Most of the researches related to climate change are targeted to annual crops like serials and pulses. The perennial nature of fruit trees makes it difficult to do research on them. Researches on fruit trees should done for 5-8 years for the more relevant data.

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## Conflicts of interest

The authors declared there is no conflicts of interest.

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