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Visible evidence of climate change and its impact on fruit production in Nepal

Padma Nath Atreya[1,*] **Manoj Kaphle**[2]

[1]Ministry of Agriculture and Livestock Development, Kathmandu, Nepal
[2]Agricultural Development Bank, Agriculture, Small and Micro-enterprise division, Kathmandu, Nepal

[*]Corresponding Author: atreyapadma@gmail.com

Abstract

In recent years, Nepal is experiencing visible impact of climate change in agriculture. This review paper describes the recent climate change pattern and phenomenon with its impact on fruit production in Nepal. Various researches suggest that change in temperature has played vital to reduce the level of soil organic carbon, and soil micronutrients. With exposure to extreme temperatures, insects may produce heat shock proteins, cryoprotectants and osmolyte compounds within their bodies to survive, so these insects can exist in such environment. Most of the researches resulted that higher temperature induces early flowering under the subtropics may result in low fruit-set because of abnormalities arising from prevailing low night temperatures. Similarly, insufficient chilling greatly influences flower initiation and fruit coloration along with deterioration in fruit texture and taste. Besides the effect of high and low temperature, papers also claimed that decline in rainfall from November to April adversely affects the winter and spring crops that ultimately reduces food production. Hence, organization related to fruit research, education and development in Nepal have to run effective program to bring new genetic sources that can resist the adverse effect of climate and may bring some positive vibe to tackle the climate change.

Keywords: Climate change, Global warming, Fruit species, Sustainable agriculture

Introduction

Agriculture is a vital part of the Nepalese economy. It contributes to about a third of the country's GDP and involves about two-thirds of its population (SANDEE, 2014). Horticulture sector contribute 23 % in AGDP out of which fruit sector contribute half (FDD, 2015).An average size of ownership of agricultural land in Nepal is 0.85 ha per household, but majority (45%) owns less than 0.5 ha (Timsina, 2011a). Horticultural crops mainly vegetable, spices, fruit and flower are prime sector and ranked third after agronomical and livestock resources in farmer's preferences (MoAD, 2015). The unique agro-ecological zones favored by altitudes, topography, and aspect with in the country offer an immense opportunity for growing different types of fruit crops (Atreya and Manandhar, 2016).The current total area, productive area, production and productivity of fruits are are 1,50,387 ha, 1,10,802 ha, 9,92,703 mt and 8.96 mt/ha respectively in FY 2014/015 (FDD, 2016). Out of total cultivated area fruit covered 4.79% (MoAD, 2015).

In recent years, Nepal is experiencing visible impact of climate change on agriculture, biodiversity, health, tourism, infrastructure and water resources (Timsina, 2011b).The established commercial varieties of fruits, vegetables and flowers performed poorly in an unpredictable manner due to aberration of climate (Datta, 2013). Problem of frequent drought, severe floods, landslides and mixed type of effects in agricultural crops (Malla, 2008) and Increased risk of hailstorm, flooding, pest and diseases will also adversely affect farming because of climate change (Adhikari, 2014). It is likely that climate change and increasing variability will have both negative and positive impacts on production systems (LI-Bird, 2009). Effects of climate change on agriculture are particularly high as the agriculture produces food and provides the primary source of livelihood for large chunks of weaker sections of the society (Pant, 2012). Many studies so far have focused on the impact

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ORCID: Padma Nath Atreya: 0000-0002-5099-677X Manoj Kaphle: 0000-0003-1385-6441
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of climate change on cereals and major crops only despite the importance of fruits in terms of nutrition and food security (Sthapit and Scherr, 2012b), very little or no work has been done. As woody perennials, fruits trees are perceived to be less susceptible to the changing climate. The changes in climate in the form of erratic precipitation, increase in temperature, lesser days serving as the chilling period have started affecting the mountain agricultural production systems and ultimately the food security of the people (Datta, 2013).

Methodology

This paper was prepared based on review from different published and unpublished printed materials, books, research papers, reports of different organizations. Discussion was made with horticulturists, farmers, lecturers/professors of universities and indigenous communities involved in fruit production. Related different web sites also visit during reviewed period.

Result and Discussion

Fruit production status and climate change vulnerability

Status of fruit production in Nepal (2015/16)

Table 1. Area, production and productivity of fruits in Nepal

Fruits	**Area (ha)**	**Productive area (ha)**	**Production (mt)**	**Production rate(mt/ha)**
Summer fruits	84227	68691	641759	9.34
Citrus fruits	39035	25261	222789	8.82
Winter fruits	27125	16849	128155	7.61
Total	150387	110802	992703	8.96

Source: FDD, 2016

Major fruits grown in Nepal

Table 2. List of major fruits with scientific name and family which are grown in Nepal

English name	**Scientific name**	**Family**	**Nepali Name**
1. Tropical Fruits			
Mango	*Mangifera indica*	Anacardiaceae	Aanp
Litchi	*Litchi chinensis*	Sapindaceae	Litchi
Banana	*Musa paradisiaca*	Musaceae	Kera
Plantain	*Musa sapientum*	Musaceae	Tarkari Kera
Coconut	*Cocos nucifera*	Anecaceae	Nariwal
Pineapple	*Ananas comosus*	Bromeliaceae	Bhuin katahar
Mountain Papaya	*Carica candomarcensis*	Caricaceae	Pahari mewa
Papaya	*Carica papaya*	Caricaceae	Mewa
Jackfruit	*Artocarpus heterophyllus*	Moraceae	Rukh katahar
Date	*Phoenix dactylifera*	Palmae	Chhohara
Bael	*Aegle marmelos*	Rutaceae	Bel
Sapota	*Achras zapota*	Sapotaceae	Sapota
Cashew nut	*Anacardium occidentale*	Anacardiaceae	Kaju
Guava	*Psidium guajava*	Myrtaceae	Amba, Belauti
Avocado	*Persea americana*	Lauraceae	Ghew phal
Jujube	*Zizyphus mauritiana*	Rhamnaceae	Ber
B. Sub Tropical Fruit			
Lime	*Citrus aurantifolia*	Rutaceae	Kagati
Sour orange	*Citrus arantium*	Rutaceae	-
Pummelo	*Citrus grandis, C. Maxima*	Rutaceae	Bhogate
Rough lemon	*Citrus jambhiri*	Rutaceae	Kathe Jyamir
Sweet lime	*Citrus limettioides*	Rutaceae	Chaksi
Lemon	*Citrus limon*	Rutaceae	Nibuwa
Citron	*Citrus medica*	Rutaceae	Bimiro
Hill lemon	*Citrus psuedolimon*	Rutaceae	Pahari nibua
Mandarin	*Citrus reticulata*	Rutaceae	Suntala
Sweet orange	*Citrus sinensis*	Rutaceae	Mausam
Kumquat	*Citrus japonica*	Rutaceae	Muntala
Trifoliate orange	*Citrus trifoliata*	Rutaceae	Tinpate suntala
Nepalese Hog plum	*Choerospondias axillaris*	Anacardiaceae	Lapsi

English name	Scientific name	Family	Nepali Name
Pistachio nut	*Pastacia vera*	Anacardiaceae	Pesta
Indian hog plum	*Spondias pinnata*	Anacardiaceae	Amaro
Tea	*Thea sinensis*	Combretaceae	Chiya
Aonla	*Embilica officinalis*	Euphorbiaceae	Amala
Chestnut	*Castanea crenata*	Fagaceae	Katus
Tamarind	*Tamarindus indica*	Leguminosae	Imali
Grapes	*Vitis vinifera*	Vitaceae	Angoor
Fig	*Ficus carica*	Moraceae	Anjir
Mulberry	*Morus alba*	Moraceae	Seto Kimbu
Mulberry	*Morus Indica*	Moraceae	Kimbu
Pomegranate	*Punica granatum*	Punicaceae	Aanar
Coffee	*Coffea arabica*	Rubiaceae	Coffee
Coffee	*Coffea robusta*	Rubiaceae	Coffee
C. Warm Temperate Fruit			
Persimmon	*Diospyros kaki*	Ebenaceae	Haluwabed
Olive	*Olea europaea*	Oleaceae	Jaitun
Olive	*Olea cuspidata*	Oleaceae	Jangali Jaitun
Apricot	*Prunus armeniaca*	Rosaceae	Khurpani
Plum	*Prunus domestica*	Rosaceae	Aalu bakhara
Peach	*Prunus persica*	Rosaceae	Aaru
Pecan nut	*Carya illinoensis*	Juglandaceae	Chuche Okhar
Japanese plum	*Prunus salicina*	Rosaceae	Aalucha
Sand pear	*Pyrus communis*	Rosaceae	Naspati
European pear	*Pyrus pyrifolia*	Rosaceae	Bedeshi naspati
D. Temperate Fruits			
Apple	*Malus pumila, M. domestica*	Rosaceae	Syayu
Walnut	*Juglans regia*	Juglandaceae	Okhar
Crab apple	*Malus baccata*	Rosaceae	Mayel
Almond	*Prunus amygadalus*	Rosaceae	Badam

Source: Shrestha, 1998; Singh, 1969; Shrestha et.al., 2001; Regmi and Shrestha, 2005; Tomiyashu et.al.,1999

Vulnerable district with respect to climate change

Table 3. Vulnerability ranking of fruit growing districts of Nepal

Vulnerability ranking	Districts
Very high (0.787-1.000)	Kathmandu, Ramechhap, Udayapur, Lamjung, Mugu, Bhaktapur, Dolakha, Saptari, Jajarkot,
High (0.61-0.786)	Mahottarai, Dhading, Taplejung, Siraha, Gorkha, Solukhumbu, Chitwan, Okhaldhunga, Achham, Manang, Dolpa, Kalikot, Khotamg, Dhanusha, Dailekh, Parsa, Salyan,
Moderate (0.356-0.600)	Sankhuwasabha, Baglung, Sindhuli, Bhojpur, Jumla, Mustang, Rolpa, Bajhang, Rukum, Rauthat, Panchthar, Parbat, Dadeldhura, Sunsari, Doti, Tanahu, Makawanpur, Myagdi, Humla, Bajura, Baitadi, Bara, Rasuwa, Nawalparasi, Sarlahi, Sindhuplachok, Darchula, Kaski
Low (0.181-0.355)	Nuwakot, Dhankuta, Kanchanpur, Bardiya, Kapilbastu, Terathum, Gulmi, Pyuthan, Surkhet, Argakhachi, Morang, Dang, Lalitpur, Kailali, Syanja, Kavrepalanchok
Very low (0.000-0.180)	Ilam, Jhapa, Banke, Palpa, Rupandehi

Source: NAPA,2010

The ranking of the district shows that majority of the districts are vulnerable to climate change. The analysis suggests that 1.9 million people are highly climate vulnerable and 10 million are increasingly at risk, with climate change likely to increase this number significantly in the future. Figure inside parenthesis indicate climate change vulnerability index.

It is not always possible to determine which changes are due to environmental degradation and which are due to climate change. The important thing is to understand what is changing and to plan an appropriate response. Despite bestowedfavorable geographic and climatic factors for growing varieties of fruit, fruit industry in Nepal is constrained by a number of factors such as monsoon rains during the period of fruit development and maturation, uneven distribution of rainfall, dry springs and winters, spring frosts and winds, hailstones during fruit development and ripening are major (Acharya and Atreya, 2013).

Drivers of climate change and its impact

Impact of temperature

Increasing temperatures will directly impact crops by affecting their physiology. Higher temperatures will also indirectly affect crops through changes in the water regime and due to the increase in the intensity of pests and diseases, they will produce. The warming, moreover, is projected to be strongest in the Himalayan Highlands (including the Tibetan Plateau) and in the arid regions of Asia (Karn, 2014). Early greening of vegetation and early breeding of organism in response to warming (Adhikari, 2014). Higher temperature speed plant growth and development in annual crops (Bakshi, 2015). Mean annual temperature to increase by 1.4 degree Celsius by 2030, 2.8 degree Celsius by 2060 and 4.7 degree Celsius by 2090 (NCVST, 2009). The temperature is increasing in faster rate than the previous decades. Same studies show higher temperature increment for winter compared to the summer and monsoon seasons. In terms of spatial distribution, the NCVST (2009) study shows a higher increment in temperature over western and central region as compared to eastern Nepal for the year 2030, 2060 and 2090. As temperature increases, cropping pattern as well as disease of human and livestock's can be expected to shift in higher ecological zones. Similarly, increase in temperature may lead to reduce the level of soil organic carbon, soil micronutrients and accelerate decomposition by activating the microbial population in the soil (Malla, 2003). These findings are also supported by Timsina as he stated that increases in temperature may have impact on the changes in the timing, intensity and volume of rainfall and rising carbon dioxide levels (Timisina, 2011). In another hand, other researchers identified some positive vibe of higher temperature on fruit development considering the quantity and quality of fruits. Higher temperature at the fruit development stage speeds up maturity, fruit size and quality, Temperature also determines the number and quality of flowers, and thus directly influences the fruiting potential for the season (Dinesh and Reddy, 2012).

Impact of rainfall variation

Nepal is already a country vulnerable to natural disasters, particularly floods and landslides. Much of the population is relay on rain fed agriculture to feed their family which is vulnerable to drought and more variable precipitation. With increased intensity of summer monsoon, the risk of flash flooding, erosion and landslides are supposed to be increased (FAO, 2010). There has already been an increase in the frequency and intensity of rainfall events in many parts of Asia, which has been largely attributed to increasing temperature. Such changing climate changes have caused severe floods, landslides and mudflows (Karn, 2014). Which has supported by Shrestha et al. (2003) who suggested that the number of flood days and consecutive days of flood events have been increasing in Nepal where changes in amount and seasonality of precipitation have affected soil moisture and groundwater reserves. Furthermore, Dahal and Khanal have provided an evidence that high increases in summer river flow are witness of leading to faster glacial melt (Dahal and Khanal 2010). There have been frequent droughts, soil erosion and land degradation through landslides, river cutting and floods, all resulting in a decline in production of crops. Unpredictable rainfall pattern resulting in more in some place and less rain in others. Moreover, IPCC (2007) projected that there will be a general increase in the intensity of heavy rainfall and an overall decrease by up to 15 days in the annual number of rainy days over a large part of the South Asia. Crops are also affected by more intense rainfall and other extreme weather events (Karn, 2014). Decline in rainfall from November to April adversely affect the winter and spring crops that ultimately reduces food production and threatened to the food security of people .Koshi, Narayani, Karnali and Mahakali are four major rivers of Nepal flowing from the Himalayas, which are the main source of water of the whole country. Agricultural sectors: mainly crops, livestock's and horticulture largely depend on the surface water sources in the country (Malla, 2008), however, floods from these rivers have increased in each year and have taken lives, destroyed physical assets, displaced people and inundated and deposited sediments on agricultural land. Terai is the most prone area of the flooding (Timisina, 2011).

Impact of drought

During the summer and normally drier months frequency and intensity of droughts seems also to have increased (Karn, 2014). This will affect agricultural production with water and sanitation, leading to increase the levels of malnutrition and incidence of water-borne disease (FAO, 2010).Such drought has been another phenomenon of climate change and has affected both winter and summer crops (Timisina, 2011).

Impact of wind and hot/cold wave

Winter drought along with cold wave is responsible to cause widespread damage to agriculture in Terai and Mid-hills of Nepal (FAO, 2010).

Impact of greenhouse gases

Greenhouse gases (GHGs) like Carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) are the three main responsible for climate change. Among all greenhouse gases, CO2 can significantly stimulate the growth, development and reproduction of plants including fruits. (Sthapit and Scherr, 2012 a). C3 plants benefit much more from increase in CO2 than C4 which has beneficial effect on plants to increase productivity. Atmospheric CO2 found more hazardous which is increasing exponentially and will likely to double i.e. about 700 ppm within the next century (Bakshi, 2015).

Impact of air pollution

The findings from Datta, air pollution has significantly reduced the yield of several horticultural crops and increases the intensity of certain physiological disorders like black tip of mango, which is induced by coal fume gases, sulphur dioxide, ethylene, carbon monoxide and fluoride (Datta, 2013). 3.2.7. Severity of fruit insect and pest in changing climate It was observed that warmer temperatures generally lead to rapid development and survival of insects in mid to high latitudes, which can account for detectable and unambiguous shifts in a range of insect species over the past half century (Matthew P Ayres, 2010). Insect crop pests and their natural enemies may also have modified their physiological system to cope with warmer temperatures. With exposure to extreme temperatures (both minimum and maximum temperatures), insects may produce heat shock proteins, cryoprotectants and osmolyte compounds within their bodies to survive shortterm exposure to high and low temperatures (Colinet et al. 2015; Ghaedi and Andrew 2016).

Consequences of climate change

The rising temperature and emission of CO2 to some extent is helpful in production of major crops. For example, increase in agricultural production by enhancing photosynthetic processes, water use efficiency, shortening physiological period and soil microbial activities. Increase in respiration process, fertilizer use efficiencies, shift in agricultural zone, increase in insect pest population, desertification, increase in soil erosion, evapo-transpiration and cause malnutrition in a world overflowing with food due to reducing protein and decrease in mineral nutrients content in different crops are negative effects (Malla, 2008).In perennial crop, being grown in a climate near its optimum, a temperature increase of several degrees could reduce photosynthesis and shorten the growing period affecting the productivity e.g. banana (Bakshi, 2015). The positive effects of climate change such as longer growing seasons, lower natural winter mortality, and faster growth rates at higher altitudes may be offset by negative factors such as changes in established reproductive patterns, migration routes, and ecosystem relationships (Adhikari, 2014). As in many developing countries, concerns are increasing about the negative impact of climate change on agricultural yields and food security (SANDEE, 2014). Decline in biodiversity and bio-cultural practices one of the adverse impacts of modern agriculture and a likely outcome of climate change have also caused many problems, especially the food crisis (Adhikari, 2014). Increase in temperature and CO2 will lead to an increase in population of pests and severity of diseases in presence of host plant. It increases the rate of reproductive cycle of insect and pest. The increase in insect population leads to demand for more use of pesticide, which unknowingly causes lots of harm to ecosystem as well as human society (Malla, 2008). Severe droughts and intense flooding create problems for field operation, more compaction of soil, and possible crop losses due to lack of oxygen for roots and disease problems associated with wet condition and flooding (Bakshi, 2015). Insufficient chilling greatly influences flower initiation and fruit coloration along with deterioration in fruit texture and taste. Further, the lack of proper chilling is also posing serious problems like scab disease, premature leaf fall and infestation of red spider mite in apple.

Implication of climate change in fruit production

A large variety of fruits are grown in Nepal, of which Summer fruits: mango, litchi, banana, guava, papaya, jackfruit, pineapple, arecanut, coconut; Citrus fruits: mandarin orange, sweet orange, lime, lemon, ; Winter fruits: apple, pear, walnut, peach, plum, pomegranate, apricot,

persimmon, hog plum and kiwi fruit are widely cultivated (Atreya, 2014). As fruit crops are perennial moving production area is difficult. In areas where current temperatures are below optimal for specific crops, there will be a benefit, while in areas where plants are near the top of their optimal range, yields will decrease (Bakshi, 2015). A significant change in climate at global and national level is certainly impacting our fruit production and quality. Climate change is one major factor affecting the fruit crop. Fruit yield is a function of light interception, variety's photosynthetic efficiency and cost of respiration (Dinesh and Reddy, 2012). Various quality traits such as fruit coloration, spottiness, fruit texture and taste can be altered by change in temperature, humidity and rainfall (Dinesh and Reddy, 2012).Climate change is likely to increase the occurrence of pests and diseases affecting humans, crops, animals and forests (Shrestha et al., 2003). The development and spread of crop diseases, pests and weeds will also have an adverse impact on agriculture, human health, and the environment (Malla 2008).Overall, it is clear that, when all factors are taken into account, climate change is likely to have a negative impact on agricultural yields in South Asia (Karn, 2014).Climate change effects on horticultural crops are speedily becoming issues in the present situation. Tropical fruits (banana, mango, papaya) and other crop like (croton) has been adopted in mid hills and observed off-season flowering in high altitudes crops like peach, pear and apple (Malla, 2008).

Tropical fruits

Incidence of pest and diseases would be most severe in tropical region due to climate change (Malla, 2008). Even a minor climate shift of 1-2^{o}C could have a substantial impact on the geographic range of these crops. High night temperature reduces anthocyanin accumulation, increased humidity due to prolonged rainfall makes fruits tasteless and skin cracking, high temperature above 115°F causes thick skin similarly rainfall during flowering and fruiting is detrimental in grape (Bakshi, 2015).Early flowering under the subtropics may result in low fruit-set because of abnormalities arising from prevailing low night temperatures. Mango phenology is highly influenced by variations in temperature. Water stress is known to increase the fruit drop in mango. High humidity, rainfall and frost during flowering are harmful. High temperature by itself is not so injurious to mango, but in combination with low humidity and high winds affects the growth of the mango trees adversely (Bakshi, 2015). Rains during fruiting periods may blacken fruits in mango or prevent desirable fruit coloration in guava, making the produce less appealing for the consumers (Dinesh and Reddy, 2012). The unusual impact of climate change has been witnessed in litchi production system as noted in flowering pattern (shifted early), fruit growth and harvesting periods. The young plants of litchi require protection from frost and hot desiccating winds otherwise their growth and survival is affected (Bakshi, 2015).Due to high temperature physiological disorder of horticultural crops will be more pronounced eg. Spongy tissue of mango, fruit cracking of litchi (Datta, 2013). Increase in temperature at maturity will lead to fruit cracking and burning in litchi (Kumar and Kumar 2007). The climate change increases the atmospheric temperature and change of rainfall pattern, as a result, banana cultivation may suffer from high temperature, soil moisture stress or water logging (Datta, 2013).In papaya, higher temperatures have resulted in flower drops in female and hermaphrodite plants as well sex changes in hermaphrodite and male plants. The promotion of stigma and stamen sterility in papaya is mainly because of higher temperatures (Bakshi, 2015).

Sub tropical fruits

Pest and disease of plain ecosystem may gradually shift to hills and mountains (Malla, 2008).Some pathogens of important crops from Terai zones has adapted in hills and mid-hills that may adversely affect the fruit production for example Citrus psylla that once only populated below 1000 masl are now able to survive in mid hill up to 1500 masl. that is due to increase in temperature. Seventy-five percent increase in air CO_2 content increased sourness in orange . Vitamin C was increased approximately by 5 percent due to increase in carbon dioxide gas (Kimball and Mitchell, 1981) in citrus. High temperature and high evaporation during flowering and fruit set result in low yield due to flower and fruit drop. The fruits have poor colour if the temperature during fruit maturation is high. In Navel oranges the content of acidity was affected by low temperature leading to low TSS content (Bakshi, 2015). Low chilling fruits being cultivated in sub-tropics are also under the threat due to non-availability of required chilling hours which has adverse effect on their flowering and the abrupt rise in temperature after fruit set is causing excessive fruit drop as well as there is poor sugar accumulation in the fruit due to steep rise in temperature during fruit development. Fruit that are exposed to high sunlight and high temperature conditions near harvest may experience sunburn to the skin that can cause cracking. Severely stressed, because of high temperature and insufficient rainfall, premature fruit drop may occur in peach(Bakshi, 2015). Specific chilling requirements of pome and stone fruits will be affected hence dormancy breaking will be earlier. Delay in monsoon, dry spells of rains, and untimely rains during water stress period, supra-optimal temperatures during flowering and fruit growth, hailstorms are some of the most commonly encountered climatic conditions experienced by the citrus growers over the past decade (Datta, 2013). The stability of the genotype to perform under different environment is the ultimate deciding factor in the expression of any trait act fruit industry and region (Bakshi, 2015).

Temperate fruits

Climate change is likely to affect chilling requirement of temperate fruit crops significantly and therefore, the opportunity to meet this requirement will be reduced as the climate becomes warmer. Increase in average global temperature would move the existing plant species and varieties to new latitudinal belts with favorable climates. It is, therefore, possible that crops that are used to be productive in one area may no longer be so or the other way round. The resultant of these climate changes are clearly apparent in the shifting of apple cultivation from lower elevations to higher altitudes in India (Rai et. al., 2015). On set of early snow in December and January had occurred more infrequently overtime and extended through the months of Feb. and March. Early snow contributes nitrogen for plant use, replenish soil moisture and prevent humidity build up. Amount of snow determines the number of chilling hours and thereby the times of bud break (Bakshi, 2015).Cool temperatures in the winter are essential for fulfilling their chilling requirements to ensure homogeneous flowering and fruit set and generate economically sufficient yields. In order to escape the damage of sensitive tissues from winters, trees from temperate or cold climates have evolved the mechanism of dormancy.The climate change affects not only the winter chilling of fruit crops but it also affects the other aspects like increase in the incidence of physiological disorders, pollination failure and phenology. As global warming is considered inevitable, endeavor should thus be undertaken to manipulate the chilling requirements of the temperate fruit crops by various means, so that the effect of changing climate could be mitigated more efficiently (Rai et. al., 2015). High temperature and moisture stress also increase sunburn and cracking in apples, apricot and cherries (Kumar and Kumar 2007). Melting of ice cap in the Himalayan regions will reduce chilling effect required for the flowering of many of the horticultural crops like Apple (Datta, 2013). With warmer winters, particularly at higher altitudes, less precipitation will fall as snow, further accelerating glacial retreat but also reducing soil moisture and accelerating erosion and therefore impacting on winter crops (FAO, 2010). Vulnerability, rarity and rapid extinction of many species of temperate fruits will be among the other consequences of climate change . High temperature and moisture stress is increasing sunburn and cracking in apple, apricots and cherries in the higher altitudes . Insufficient chilling reduces pollination, fruit set and ultimately the yield in walnuts, pistachio and peaches. Advanced flowering has been found in olive, apple and pear. Reduced flower size and pedicel lengths were observed in cherry due to less chilling (Rai et. al., 2015).

Strategies for improving the fruit production

I. Assessment of the vulnerability and climate risks associated with fruit production in all agro ecological region

II. Conduct seminar, workshops, training and general awareness program regarding climate change and its effect in fruit production.

III. Active participation of Nepalese researcher and development workers in the international seminar/conference/ dialogue about greenhouse gas emissions management and global warming with respect to fruit species.

IV. Identification of present issues of climate change in fruit sector via research.
V. Strengthen Horticulture Research Station and Commodity Program to run effective researches.
VI. Develop smart Information Communication and Technology (ICT) system to transfer climate adaptation methods and technologies at farmer's field.
VII. Preservation of genetic materials to reduce extinction of biodiversity due to climate change
VIII. Develop genotypes having resistance to heat and drought. In vitro conservation of rare and useful fruit species for future use.

IX. Promotion of fruit crop insurances program for social security's and food securities targeting commercial fruit growers. • Change in national policies that emphasizes incentives to the farmers for agricultural inputs in fruit production.
X. Evaluate varieties and rootstocks to minimize of climate change hazard.
XI. Phenotyping of allimportant fruits genetic wealth to make tolerable to temperature and moisture stressWork on genetic enhancement for tolerance to biotic and abiotic stress.
XII. Integrated nutrient management, Integrated pest management, Integrated weed management, development of water harvesting techniques to cope climate change in fruit species.
XIII. Agronomic management strategies such as Agri-silvicultural system, Agri-horticulture system, Agri-horti-silvicultural system, Horti-pastoral system, Inter cropping annual crops under fruit trees, Integrated Farming system should be adopted.
XIV. Diversification of high value fruit crops like peach, apricot, walnut, kiwi and olive.
XV. Introduction of low chilling cultivars of temperate fruits like apple, walnut, peach and plum etc.
XVI. Crop phenology of all major fruit crops under changing climate will be monitored.

Recommendations

I. Proper management of irrigation infrastructure in both rural and urban area of fruit pocket to reduce drought hazards is essential
II. Develop and introduce heat and drought resistant verities/breeds.
II. Introduce insect and pest resistant varieties in coordination with national agriculture research center
IV. Focus on application of IPM (integrated pest management) in fruit production.
V. Train producer to use safe agrochemicals to minimize pest and disease damage in the fruit crops.
VI. Sharing workshop on good practices of adaptation and mitigation with neighboring country to cope with vulnerabilities would bring new result.
VII. Develop climate-forecasting system for reducing hazards.
VIII. Need to build capacity of government officials at central ministry, provincial ministry and local government levels to communicate climate concerns.
IX. It would be better to use machines operated from renewable energy during intercultural operation

Conclusion

Nepal with diverse soil and climate comprising several agro ecological regions provides ample opportunity to grow a variety of horticultural crops comprising of fruits, vegetables plantation crops, spices and tuber crops and flowers. Among all fruits play a unique role in Nepalese economy by improving the income of the rural people. Fruits are also rich source of vitamins, minerals, proteins, and carbohydrates etc. which are essential in human nutrition and assumed great importance in nutritional security of the people. Cultivation of fruits plays a vital role in the prosperity of the nation and is directly linked with the health and happiness of the people. The knowledge about the impact of climate change on fruit production is limited. Addressing problems of climate change are more challenging in fruit crops as compared to other cereals. Consequences of climate change are global warming, change of seasonal pattern, excessive rain, melting of ice cap, flood, rising sea level, drought etc leading to extremity to fruit production. The issue of climate change and solution to the problems arising out of it requires thorough analysis, advance planning and improved management. Fruits are grown from tropical to temperate region of Nepal. Climate change poses serious challenges to human and places unprecedented pressure on the sustainability of fruit industry. The most effective way is to adopt conservation agriculture; using renewable energy, forest and water conservation, reforestation etc. to sustain the productivity modification of present horticultural practices and greater use of greenhouse technology are some of the solutions to minimize the effect of climate change. Climate change will impact fruit production through; Changes in the distribution of existing pests, diseases and weeds and an increased threat of new incursions, Increased incidence of physiological disorders such as tip burn and blossom end rot, Greater potential for downgrading

product quality, Increases in pollination failures if heat stress days occur during flowering, Increased risk of spread and proliferation of soil borne diseases as a result of more intense rainfall events along with warmer temperature, Increased irrigation demand especially during dry periods of the year, Increased atmospheric CO_2 concentrations will benefit productivity of most fruit crops, although the extent of this benefit is unknown, Increased risk of soil erosion and off farm effects of nutrients and pesticides, from extreme rainfall events, Increased input cost especially fuel, fertilizers and pesticides. Experiments on varietal evaluation will also be conducted under natural conditions at different altitudes/conditions with natural variations in temperature and moisture falling under various agro-climatic zones of the countries. Hence there is a need to protect these valuable crops for sustainability against the climate change scenario. To sustain the productivity, modification of present horticultural practices and greater use of greenhouse technology are some of the solutions to minimize the effect of climate change. Development of new cultivars of horticultural crops tolerant to high temperature, resistant to pests and diseases, short duration and producing good yield under stress conditions, as well as adoption of hi–tech horticulture and judicious management of natural resources will be the main strategies to meet this challenge.

Compliance with Ethical Standards

Conflict of interest

The authors declare that for this article they have no actual, potential or perceived the conflict of interests.

Author contribution

The contribution of the authors is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

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