Effect of Climate Change on Horticultural Crops

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Abstract

Nepalese horticulture is at risk of changing climate as Nepal ranks the 14th most vulnerable country to the climate change in the world. Higher dependency on weather, fluctuating temperature ranges, changing rainfall pattern, increasing disease pest infestation, changing flowering and fruiting seasons of different fruit crops, drying up of water resources etc. are already being experienced by farmers. Alteration in temperature and precipitation has direct impacts on crop yield, food, and nutrition security. International Panel for Climate Change (IPCC) states that smallholder and subsistence farmers in developing countries have been affected the most from climate change impacts. This holds true for traditional farmers with small landholding and limited adaptive capacity. The impacts of climate change on the small landholder are localized and differ as per the region and specific climatic zone. Besides the physical factor, the social factor also contributes to farmer's vulnerability. When it comes to climate change related issues, the high dependence of small farmers on monsoon has increased their vulnerability to rainfall variation. The higher surface temperatures have led to the emergence of new weeds and pests posing new challenges to the entire farming system by increasing farm expenses and pollutants. Climate change is a big threat in producing quality and quantity fresh vegetables, vegetable seeds, fruits, cereal crops, and legumes as per the cropping calendar. The decrease in winter rainfall is causing prolonged drought between the months of October to May hindering the production of seasonal horticultural crops. The early flowering of especially the forest species as Rhododendron (Rhododendron spp.), Palash (Butea monosperma), Simal (Bombax mori) etc. are the proxy indicators of climate change. The temperate fruit plantation has shifted up from normal altitude. Nevertheless, farmers are gradually adopting alternative practices to cope with the abnormal climatic condition. They grow short duration summer crops so that harvesting can be done in October or early November and immediately sow winter crops while the soil still has the monsoon moisture. Farmers are also harvesting monsoon rainfall and using water-saving technologies such as drip irrigation. Documentation of these local knowledge and adaptation practices has been felt necessary to benefit farmers, develop climate-related policies, adopt climate resilient agriculture technologies and fight against climate change collectively. Campaign plantation of horticultural crops like fruits, plantation crops, ornamental plants and spices in degraded forest, abandoned marginal lands, road corridors and terraces of hills will avail mitigate climate change vulnerability and also prevent further environmental degradation.

Keywords: *Climate change, fruits, dormancy, mitigate, vegetables, vulnerability.*

1. Introduction

Nepal has very diverse climatic conditions ranging from tropical in the south to alpine in the north. The diversity in Nepal's climate is affected by the diversity of its multiple ecosystems and orography. The mountain, hill and plains landscapes also support highly diverse precipitation dynamics. The country's three distinct geographies-the snow-covered mountains, the mid-hills and the plains embody this diversity. Its hydrology is fed largely by the South Asian Monsoon System) SAM (but the relationship between the timing, volume of monsoon rainfall and the mountain landscape is diverse and complicated to understand. The dramatic variation in altitude over a short distance and its aspect (facing, lee-warding and wind warding) has resulted in pronounced orographic effects, effects which severely limit our ability to explain precipitation dynamics. The rainfall pattern in the plains that stretches from east to west varies with frequent flooding and drought. There have already been alarming signs of sharp and sustained decline in food security in Nepal and shifting of tropical and sub-tropical fruits to higher altitudes and so to temperate fruits as well.

Agriculture and climate change are inseparably linked—crop yield, biodiversity, and water use, as well as soil health are directly affected by a changing climate. Continued changes in the frequency and intensity of precipitation, heat waves, and other extreme events are likely, all will impact horticultural production. Furthermore, compounded climate factors can decrease plant productivity, resulting in price increases for many important agricultural crop (Relli, 1994).

2. Climate Change in Nepal

Climate change is global, but its nature, extent and magnitude are variable in different regions and locations. An analysis of trend of temperature in 49 stations in Nepal from 1977 to 1994 indicates a consistent and continuous warming at an annual rate of 0.06ºC. (MoE, 2010)

Another analysis by Practical Action (2009) on data from 45 weather stations for the period 1976-2005 indicated a consistent and continuous warming of maximum temperatures at an annual rate of 0.04ºC. Temperature has a positive impact on farm value in the alpine and temperate zones and a negative one in the sub-tropical zone. The Initial National Communication (INC, 2004) of Nepal to the United Nations Framework Convention on Climate Change (UNFCCC) and a range of recent studies show that Nepal is highly vulnerable to the potential negative impacts of climate change. Globally, Nepal ranked fourteenth in Climate Risk Index (CRI) in 2016 alone and twenty-sixth in the average CRI in twenty years between 1997 and 2016. These studies also indicate that the observed warming trend in the country is spatially variable. The scenarios of climate change indicated warming at higher elevations, the reduction in snow and ice coverage, loss of arable land to flood and erosion, erratic changes in monsoon, water shortages and droughts, threats of glacial lake outburst, disappearance of forests and indigenous horticultural crops, invasion by exotic weed species, outbreak of diseases and pests, sharp decline in food security and threats to biodiversity. The climate-induced risks and hazards can have wide-ranging, often unanticipated, effects on Horticulture, food security, biodiversity, water resources, energy, human health, urban settlement, terrestrial and aquatic ecosystems. Poor and vulnerable farming communities of Nepal, therefore, face possible dramatic impacts on their livelihood and well-being. Due to its higher dependence in weather Nepalese farmers with small land holding and limited adaptive capacity are likely to be hit the hardest. A study on the impact of climate change in vegetable seed production in some selected vegetable seed producing districts of Nepal conducted by CEAPRED in 2014 found that monsoon rainfall has delayed by a month in mid hills. Monsoon that used to start by the mid-June have begun from the end of June and last till September. Winter rainfall that was frequent in the past have decreased prolonged drought hindering the production of winter vegetables. Certain forest species as Rhododendron (*Rhododendron* sps.), Palash (*Butea monosperma*), Simal (*Bombax mori*) have begun to flower earlier than usual. Several local landraces and indigenous species have gone extinct mainly due to the climate change.

Reduction in yield of temperate fruits may occur due to shortening of growing periods, decrease in water availability and poor vernalization. There is a need to quantify the impacts of climate change on horticultural crops especially fruits. Indeterminate crops are less sensitive to heat stress conditions due to extended flowering period compared to determinate crops. The temperature rise may not be evenly distributed between day and night and between different seasons. In tropical regions even moderate warming may lead to disproportionate declines in yield. In high latitudes and altitudes, crop yields may improve as a result of a small increase in temperatures.

In perennial crops like mango and guava, temperature is reported to have influence on flowering. Mango has vegetative bias, and this becomes stronger with increase in temperature, thus influencing the flowering phenology. The percentage of hermaphrodite flower was greater in late emerging panicles, which coincided with higher temperatures, reported in different studies. During peak bloom period, high temperature (35ºC) accompanied by low relative humidity (49%) and long sunshine hours resulted in delayed flowering, multiple reproductive flushes, variations in fruit maturity, abnormal fruit set and transformation of reproductive buds into vegetative ones. Excessive transpiration and dehydration injure panicles. Leaf scorching and twig dying are common symptoms of heat stroke in bearing and non-bearing mango plants. Major observed effects of climate change on mango include early or delayed flowering, multiple reproductive flushes, and transformation of reproductive buds into vegetative ones and variations in fruit maturity, abnormal fruit set and premature ripening of mango. Increase in temperature during fruit maturity on litchi leads to fruit cracking and burning. Untimely winter rains promote vegetative flushes in citrus instead of flowering flushes. Dry spell during flower emergence and fruit set affects flower initiation and aggravates incidence of pest (Psylla).

High air temperatures (greater than 38°C) coupled with bright sunshine causes sunburn damage on exposed fruit. High temperatures (above 38ºC) and drought also Chokes the banana bunches. The low chilling temperature requiring crops like apple, peach, plum etc. have declined in productivity. High temperature and moisture stress increase sunburn and cracking in apples, apricot and cherries.

The slow-growing fruit orchard establishments need heavy investment and changing of fruit species or varieties in short duration would be difficult and painful loss-bearing exercise to mitigate the adverse effect of climate change. Growing suitable cultivar that can cope of the climate change has been practiced in apple in India where farmers have even shifted from apple to potato cultivation. Since many crops with chilling requirements are tree species, moving their production areas or changing the crop species is difficult. Thus lower-chilling requiring types may be replanted in orchards and plantations over the next decade. Grapes (*Vitis vinifera*) originated in temperate regions when at higher temperatures (42°C) vines are not capable of utilizing radiant energy possibly because of degradation of enzymes and chlorophyll exceeds rate of photosynthesis. In wine grapes anthocyanin development is influenced by difference between day and night temperatures with high variation (15-20ºC) promoting color development which could be affected by the changes in the climate.

3. Vegetable Crops

Monsoon, responsible for most of the region's precipitation, poses excess and limited water stress conditions. Succulent vegetables are generally sensitive to environmental, temperature and moisture extremes are the major causes of low yields. Soil water stress during growth stages of onion crop caused small bulbs and 26% yield loss.

Onion is sensitive to flooding during bulb development with yield loss up to 30-40%. In tomato, water stress accompanied by temperature above 28°C induced about 30-45% flower drop in different cultivars. Temperature above 33°C shriveled pollen and fruiting was reduced in all varieties of tomato in Sarlahi (Proceeding of Fresh vegetable and vegetable seed project 1987). Chili also suffers drought stress, leading to yield loss up to 50-60%. Most vegetables are sensitive to excess moisture stress conditions due to the reduction in oxygen in the root zone. Tomato plants under flooding conditions accumulate endogenous ethylene, leading to rapid wilting and leaf drop. In tomato high temperatures can cause significant losses in productivity due to reduced fruit set, smaller size and low quality fruits. Pre-anthesis temperature stress is associated with developmental changes in the anthers, particularly irregularities in the epidermis and endothecium, lack of opening of stromium and poor pollen formation . The temperature between 25 – 30°C is optimal for net assimilation rate in tomato , and the daily optimal mean temperature for fruit set in tomato is 21 – 25°C , . The pre-anthesis is a sensitive to climatic stress in tomato. Under climate change scenario the impact of these stresses would be compounded. These drought and salinity stresses are the primary causes of more than 50% yield losses worldwide. Post pollination exposure to high temperature inhibits fruit set in pepper, indicating sensitivity of fertilization process. Several connecting reasons, such as bud drop, abnormal flower development, poor pollen development, dehiscence and viability, ovule abortion and poor viability and other reproductive abnormalities, of fruit drop has been enumerated. In cucumber, sex expression is temperature-dependent. Low temperatures favors female flower production, which is desirable and high temperatures lead to production of more male flowers (Wien, 1997). Cauliflower varieties have specific temperature requirements. High temperature delays curd initiation in low temperature requiring cauliflower variety. In potato, high temperature and frost damage reduced tuber yield by 10-50%, depending upon intensity and stage of occurrence with reduction in marketable grade tuber yield to the extent of 10-20%. Plants respond accordingly to avoid one or more stresses through morphological or biochemical mechanisms. Aphids appear two weeks earlier with an increase in 1°C (Biotechnology and Biological Sciences Research Council, 2008). Cool night temperature favors induction of tuberization in potato. High night temperatures cause reduction in both the tuber number and size. Marked morphological changes and decrease in photosynthetic rate are caused by high temperature which drastically reduces tuber yield and biomass production.

Air pollution due to Sulphur dioxide, nitrogen oxide, hydro-chloride, ozone and acid rain cause adverse effects on growth, yield and quality of vegetable production. Many vegetable crops namely tomato, water melon, potato, squash, soybean, cantaloupe, peas, carrot, beet and turnip are more susceptible to damage from air pollution. Air pollution has been found to decrease the yield up to more than 50 percent in Brassica oleracea, Lactuca sativa and Raphanus sativus and 5-15 percent reduction in yield of vegetable crops has been reported when daily ozone concentrations reach to > 50 ppb.

Any soil warming would be advantageous for cucurbits, which are generally direct seeded and have a high heat requirement. Due to rise in temperature cultivation of these cucurbits are moving towards higher altitude in Nepal. Cucurbit cultivation has started even in Marpha/ Mustang. The rise in temperature influences survival and distribution of pest population; develops new equilibrium between alternate host crops and pests; hastens nutrient mineralization in soils; decreases fertilizer-use efficiency; and increases evapo-transpiration with reduced water-use efficiency. Thus, a net effect of climate change on horticultural crops will depend on interaction effects of rise in temperature and carbon monoxide (CO) concentration in atmosphere.

The perennial horticultural crop production is sensitive to temperature, water availability, solar radiation, air pollution, and CO_2. The value of perennial horticultural crops is derived from both the quantity and the quality of the harvested product.

4. Fruits Maturity and Quality

Higher temperature provokes faster tree fruit maturation which results in earlier harvest. On an average, fruits are harvested up to two weeks earlier. Fruits mature normally at temperature as high as 35°C. Elevated temperature and CO_2 level lead to a decrease in starch, soluble sugars, proteins and majority of minerals contents and increase in oil, phenols and ascorbic acid contents.

Higher day temperature and sunshine increases the process of photosynthesis and photosynthetic products in temperate vegetables. When night temperature is low the respiration rate also becomes low and in higher day temperature with full sunshine and lower night temperature will increase the net accumulation of photosynthetic products thereby giving higher yield.

Fruit trees from cold winter climates avoid the cold by going into dormancy. Period of dormancy enable fruit trees to tolerate freezing temperatures in their original habitats. Critical chilling requirements are crucial to select the right tree cultivar for a certain climatic zone. During that period any visible growth is suspended and most of physiological processes are stopped or slowed down. Growth resumes when cold season is over 32. Plants in general have mechanism to sense temperature during the whole season and thus modulate their physiology according to environment factors. Early blooming and harvest date for fruits around the world indicate that dormancy processes are changing. The plant phenology is significantly changed by photoperiod.

Climate change has adverse effect on insect activities, affecting pollination and fruit set. For cross pollinated fruits such as pistachios and walnuts, inadequate chilling can decrease pollination directly to reduced crop yields. Changes in rainfall supply can affect year-to-year differences at flowering quality and productivity in tropical fruits. In some cases, crop failures may frequently occur, and also observed lower yield and early senescence of trees. Fruit and vegetable growth and development are impacted by several environmental aspects. The biochemical reactions fundamental for normal cell function in plants will disrupts. It primarily affects the photosynthetic functions of higher plants. Maximum temperatures could cause significant losses in productivity of tomato, reduced fruit set, lower and smaller quality fruits.

Fruit quality and yield are influenced by global warming. Numerous factors are known to influence fruit development in orchard. Physiological processes in plants range from 0 to 40°C. However, temperature range for the development of fruits and vegetables is somewhat narrower. Temperature affects both photosynthesis and respiration and their ratio must be high in order to achieve high yield. Photosynthetic activity is in positive correlation with temperature until a certain threshold for each cultivar of a species. Higher temperatures inactivate enzymes and plants loose ability to cope with heat stress.

There is need for the identification of appropriate genetic resources for use in climate change areas. It might be better to develop good production systems, which can improve farmers' economic power. Farmers have important role in adaptation to changing conditions through natural selection or human interventions. It is very important to understand how climate changes will affect human interventions or vice versa.

5. Institutional and Policy Framework to Combat Climate Change

Agriculture Perspective Plan (APP), unveiled in 1995 with a 20 year vision, remained the main document referred to for Nepal's agricultural strategy, policy and programmes. The strategic focus of the APP was based on a vision of strengthening Nepal's regional economic linkages between the hills and the plain based on their respective comparative advantages – cereals in the plains and high-value fruits, vegetables, cash crops and livestock in the hills. It adopted a Green Revolution dependent approach based on massive investments on key inputs such as irrigation, fertilizers and rural roads to be focused on high potential areas, generating backward and forward linkages and multipliers across the economy. The APP is judged to be sound in design but suffered greatly in implementation.

National Agriculture Policy (NAP 2004) remains to date the main agricultural policy document for the sector as a whole. Its formulation was prompted by a number of new developments such as increasingly liberal policy environment, increased role for the private sector, MDG commitments, and Nepal's WTO membership and regional trading agreements. It set food security and poverty alleviation as the underlying goals to be attained through higher agricultural growth based on increased productivity and commercial and competitive agricultural system. It upheld the long term vision and strategy of the APP and gave continuity to its approach of pocket programmes. The NAP (2004) identified three core goals: i) increasing agricultural production and productivity; ii) making agriculture commercialized and competitive in regional and world markets; and iii) conserving, promoting and utilizing natural resources, environment and bio-diversity.

Agri-business Promotion Policy (2006) further elaborates on some of the policies in NAP (2004) focused on the promotion of agri-business through product value chains.

Three-Year Plan (2010/11-12/13) essentially continues with these goals and priorities, with emphasis on some additional priorities such as nutrition security, climate change, cooperatives and human resources development. Lastly, in this process, two new important policy documents were formulated in 2010 – the National Agriculture Sector Development Priority (2010) (NASDP) and the Nepal Agriculture and Food Security Country Investment Plan (2010). These documents contributed to further updating, fine-tuning and setting priorities in accordance with the above mentioned vision and policies.

Climate Change Policy (2011): The Government of Nepal through the Climate Change Policy (CCP 2011) expressed urgency to address the climate change by implementing relevant programmes to minimize the existing and likely impacts in different ecological regions. One of the goals of the CCP is to promote climate adaptation and adoption of effective measures to address adverse impacts of climate change through technology development and transfer, raising public awareness, capacity building and access to financial resources. The goals of the policy also includes development of a reliable impact forecasting system to reduce the adverse impacts of climate change in vulnerable areas in natural resources and people's livelihood.

Out of the seven objectives of the CCP, three are related to climate change adaptation and livelihood. First is to implement climate adaptation-related programmes and maximize the benefits by enhancing positive impacts and mitigating the adverse impacts. Second is to enhance the climate adaptation and resilience capacity of local communities for optimum utilization of natural resources and their efficient management. Finally, it is to improve the living standard of people by maximum utilization of the opportunities created from the climate change-related conventions, protocols and agreements.

Climate Resilience Planning (2011): Climate Resilience Planning is a tool for long-term climate adaptation. Enhancing the resilience of development plans to climate risk is a strategic and proactive move that requires assessment of anticipated climate threats and building measures to reduce the threats. This document describes community resilience and adaptation under sectoral vulnerability under the development scenario including agriculture. This also presents climate framework strategy and screening approach for development actions.

National Framework on Local Adaptation Plans for Action 2011 (LAPA Framework): LAPA Framework (2011) is developed to support operationalization of NAPA (2010), National Climate Change Policy (2011) and Climate Resilience Planning (2011) through integration of climate change resilience into local-to-national development planning processes. The Framework supports the Local Self Governance Act (1999) to integrate local adaptation priorities into village, municipality, district and sectoral level planning processes. The Framework adopts four principles, namely, bottom-up, inclusive, responsive and flexible to ensure the integration of climate change resilience into local-to-national planning. The bottom-up planning starts from the households and moves upwards to the Ward and rural municipality level and higher. The inclusiveness requires dialogue between diverse stakeholder groups in decision making including men and women of different ages, castes or ethnicities. To be responsive, the planning processes should focus on building resilience of the most climate vulnerable communities first. The principle of flexibility refers to the ability of the planning processes to be iterative in their approach. The units for integrating climate change resilient planning are at rural municipality and municipality level that capture location specific adaptation priorities within their territories.

The framework presents seven steps for LAPA development. The steps include details on climate change sensitization, vulnerability & adaptation, prioritizing adaptation options, developing an adaptation plan, integrating LAPA into local-to-national planning, implementing local adaptation plans and assessing progress through monitoring and evaluation.

United Nations Development Frameworks for Nepal 2013-2017: Government of Nepal and United Nations Country Team in Nepal developed United Nations Development Frameworks (UNDAF) for Nepal 2013-2017 in 2012. The Framework has proposed 10 outcomes divided into three components, namely; advancing equality through equity, protecting development gains, and creating an enabling environment for enhanced international cooperation. The 7th outcome falling under the second component states that "People living in areas vulnerable to climate change and disasters benefit from improved risk management and are more resilient to hazard-related shocks". The proposed project will help to achieve this outcome. The project is also somehow assist to the first component second outcome "vulnerable groups have improved access to economic opportunities and adequate social protection".

Agriculture Development Strategy (ADS) 2013: A full document of ADS 2013 is available for review in agricultural ministries' webpage. Considering the changed national and international contexts Government of Nepal has developed ADS. The main objective of the ADS is to succeed the Agriculture Perspective Plan (APP) and give long term strategies for agricultural development in the country. The scope of the ADS is very wide including food security, agricultural productivity, connectivity and resilience; sustainable production and resource management through climate change mitigation; adaptation and improved land and water management and water allocation; increased private sector development including cooperative sector), delivering fair reward to all stakeholders in the value chain; and policies, institutions, and investments. The policy options of the ADS support the LAPA as an implementation tool for the NAPA for climate change adaptation.

Mapping of agencies involved in climate change adaptation in agriculture. Different agencies are putting efforts in climate change adaptation in agriculture in Nepal. The agencies and their major roles relating to climate change adaptation are elaborated below:

Agency	Major functions related to the project activities
MOALD	Environment Section established in the departments. Budget programme guidelines for the coming year include programming for climate change adaptation. GIS section implements PPCR project to develop agriculture marketing information system (AMIS) web portal and meteorological and hydrological facilities for weather forecast and rainfall predictions based on information from DHM.
DOA	Transfers crop and fisheries production technologies to the farmers through a nation-wide network of regional and district level offices and service centres.
DLSO	Provides diseases treatment services and transfers technology for livestock and poultry production through a nation-wide network of regional and district level offices and service centres.
NARC	It will obtain real time data from 3 stations in Kathmandu, Nepalganj, Lumle and will develop agro-advisory package bulletin under PPCR. The package will be disseminated through printed matter, SMS notice board service, FM channel, agro-call centers and digital display.
MOSTE	It is working as the national focal point for all climate related activities
DHM	This department provides hydro-meteorological information for AMIS under PPCR, but the parameters are yet to be identified.
Practical Action	Working in the areas of resilient agriculture concept and vulnerability since 2005. It's developing a climate smart village in Nawalparasi district. Rainfall forecast information is provided to the community and helped in preparedness and management.
World Bank	Related projects of the World Bank include: PPCR, AMIS- data collection, information, AFSP – for technology development for adaptation and technology transfer, IWRMP – for modernization and rehabilitation of irrigation structures; institutional strengthening; and agriculture, FFS, climate smart agriculture- demonstration. Not much different between regular, PACT-- based on value chain, business incubation center in process, climate forecast can be helpful for commercial farms, PAF-livelihood, but weak in technology and Heifer International – livestock development.

Agency	Major functions related to the project activities
ICIMOD	Implementing HICAP (High Himalaya Climate Adaptation Programme) for hydrometeorology and climate management. Koshi Basin Project- Udayapur is overlapping district. The main issue is how to take the regional climate prediction models to the household level .HIMALICA (Rural Livelihoods and Climate Change Adaptation in the Himalayas) aims to support poor and vulnerable mountain communities in the Hindu Kush Himalayan region in mitigating and adapting to climate change. Adapt Himal focuses on livelihoods and ecosystem services in the Himalayas through enhancing adaptive capacity and resilience of the poor to climate and socioeconomic changes. This is to assess the impacts of climate and socioeconomic changes on the poor and identify adaptation and coping mechanisms. Drought monitoring and prediction through SERFVIR Himalayas, good for planners. Synergies can be in piloting climate smart village, mainstreaming CCA at district level planning and developing training modules for climate adaptation
Climate Change Network Nepal	Its scope covers informing, influencing, empowering and to some extent influencing. It develops common understanding and prepares positions for global Climate negotiations. It assists the government before the COP about how to negotiate. At sub national level it has partners NGONCC (NGO network in climate change) with secretariat in LIBIRD, Pokhara. Key lessons from the district level include: i) very low level of awareness about what happening at the central level; ii) people interested to work; iii) coordination mechanisms are not enough .Coordination is necessary and it can be done by DDC supported by MOFALD.
EC Delegation	Nepal climate Change Support Programme in 14 districts, rural Development, Food Security IDE implementing CCA in Nawalparasi, USAID: Climate change adaptation and technology transfer in Mid and Far Western Development region, started in 2013 for 3 years
MOFALD	LAPA Process and CRMP lead to Disaster Risk Reduction Centre (DRRC). Developed 14 steps local government planning process. LAPA implementation started in 69 VDCs but have practical problems.
RRCN	Risk Reduction Consortium Nepal is for all the hazards and climate change as a part of DRM. Among the five flagship programmes flood risk management in Koshi River Basin and community based disaster risk management are concerned with climate change adaptation.
NPC	13th plan has incorporated food security and climate resiliency in agriculture.NPC is ready to help for the project and coordination among cross cutting ministries. It has developed Climate Change Resilient Planning Framework that gives some questions helpful in risk ranking .Also developed a separate budget code for climate change research budget
MOHA	Constituted Central Disaster Rescue Committee. Designated the Chief District Officer in the districts as the Chief of DDRC.It also works for food security during disaster (drought, flood, fire.
DOI	Provides irrigation to increase resiliency.

Agency	Major functions related to the project activities
DAT/ DOA	Directorate of Agriculture Training has incorporated one session in climate change in its training. Each RATC organizes 10 to 12 training in a year for Junior staffs, farmers and even private sector/NGO. It also provides 51 working days Village Agricultural Workers training with objective of covering all 3915 villages.
IDE Nepal	IDE is implementing Initiative for Climate Change Adaptation 2012- 2017
USAID	funded by USAID. The $ 2 million project is to improve climate change planning and develop resilient income streams for 20,000 households in 8 districts Nawalparasi, Rupandehi, Kapilbastu, Dang, Kaski, Parbat, Syangja and Rolpa) in western and mid-west development region of Nepal.

6. Agricultural Impacts and Trade-offs

The net effect of climate change on world agriculture is likely to be negative. Although some regions and crops will benefit, most will not. While increase in atmospheric CO2 are projected to stimulate growth and improve water use efficiency in some crop species, climate impacts, particularly heat waves, droughts and flooding, will likely dampen yield potential. Indirect climate impacts include increased competition from weeds, expansion of pathogens and insect pest ranges and seasons, and other alterations in crop agro-ecosystems.

Remaining barriers to address threats of climate change vulnerabilities

The baseline projects will make a significant contribution to addressing issues described above. However, these do not adequately address the following barriers to climate change adaptation in agriculture and livestock sub-sectors and management for food security and environmental sustainability:

i. Insufficient institutional and technical capacity for adaptation to climate change in agriculture sector.
ii. Inadequate data and information on vulnerabilities, risks and lack of communication of timely risk information to users at all level (including farmers).
iii. inadeqaute awareness rising and knowledge management at all levels, and
iv. lack of enterprise diversification and inadequate linakges with supply chains and loss of livelihood activities due to climate related extremes.

7. Research and Development Needs

I. Development of drought/heat resistant crops that have been tested for high yields when subjected to periods of extended water shortage.
II. Improvements in plant nitrogen and water use efficiency and development of cost-efficient nitrogen uptake delivery systems and low-cost, high efficiency irrigation techniques.
III. Development of eco-zonal testing sites, efficient management and use of horticulture farm/ centres for research and data collection and dissemination efforts, using standard data protocols, to assess the performance of existing and new genetic material and management systems in today's range of agro-climatic conditions

IV. Continuous field testing to track climate change, breeding for resistance to new diseases and pests and to address changes in pollinator distribution have been identified as avenues to confront adaptation of crops in the face of climate change.

V. Development of assessment tools that incorporate the biophysical constraints that affect horticultural productivity and include climate and socioeconomic scenarios, including improved characterization of policy and program environment.

8. Way Forward

Adaptation strategies are short and long-term changes to human activities that respond to the effects of changes in climate. In horticulture, adaptation will require cost-effective investments in water infrastructure, emergency preparation for and response to extreme weather events, development of resilient crop varieties that tolerate temperature and precipitation stresses, and new or improved land use and management practices.

Focus should be given to participatory research and development so as to: identify and develop drought, flood, pest and/or disease tolerant crops varieties; strengthen on-farm in-situ conservation and utilization of plant genetic resources, including improved home garden diversification; strengthen farmer seed systems; enhance access to a larger portfolio of germplasm through promotion of community resource centres, multipurpose nurseries, local seed banks; promote and strengthen capacity for grassroots and participatory plant breeding to broaden the genetic base for secured nutrition and food production; and develop improved measures for conservation-based ecological farming, including sustainable soil and nutrient management practices. The participation of civil society and of rural communities in national and international negotiations and decision-making is crucial.

The constitution has provisions for allowing local governments to implement agriculture related-programs. Additionally, they are also empowered with authority to formulate rules and regulations to suit the local context. Once the local governments and regulations for operationalizing the constitutional provisions are in place, the federal government's role will be supportive — such as making necessary arrangements to place agricultural/horticultural technicians and providing federal funds for agriculture/horticulture. The local governments also have authority to generate resources for implementing local-level activities.

Because climate impacts are more visible locally, the local governments will have to focus more on adaptation measures. This would require them to include climate-resilient activities to support livelihoods of vulnerable communities. Such activities could include, i) promotion of organizations for commercial use, ii) increased participation of agribusiness, cooperatives and horticulture based industry, iii) reform of the land use policy to support commercial horticulture (fruits, vegetable, potato and spice crops based on comparative advantage, iv) rainwater harvesting and water conservation for horticulture, v) promotion of horti-forestry, reforestation and bio-resources conservation promoting suitable horticultural crops, climate-resilient horticulture such as crop diversification, introduction of drought tolerant crop varieties like Dragon fruits, evergreen fruits like avocado, and farming practices, and vi) introduction of new technologies in water management.

The local efforts can be complemented and supported by the federal government and development partners to promote climate change-adaptive new technologies, innovation and knowledge production at the local level. Good practices of demand-based programs in small irrigation, cooperative and family farming that have proven their effectiveness also need to be up-scaled.

Generation and sharing of data and on time publication of results and reports for public awareness and early preparedness will help in combating adverse effects of climate change as well as to take advantage of the effects for better production of certain horticultural commodities.

Conclusion

The inevitable global warming that affects many aspect of life on earth will certainly affect fruit production system than other agriculture systems. Symptoms like earlier blooming and harvesting have become common phenomenon. Negative consequences like deprivation of required winter chilling and changed content of bioactive compounds are most often reported changes due to global warming. Hence, the issues of climate change and solution to the problems arising out of it requires local analysis, planning and management. There is need to analyze and understand about climate change at regional and agro-ecological levels in relation to both annual and perennial horticultural crops, which could be managed through innovation, technology evaluation and timely dissemination to provide effective solutions to the problems. Climate change is already affecting the biodiversity and weakening the livelihood assets of poor and marginalized communities. The preparation of the National Adaptation Programme of Action (NAPA) is the latest official initiative to mainstream adaptation into national policies and actions so as to address the adverse impacts of climate change and reduce vulnerability to changing climate and extreme events. The Ministry of Environment signed the contract in November 2008 with UNDP to officially start the NAPA formulation process in Nepal, the Ministry completed the NAPA by April 2010 with some progress in terms of initial understanding on vulnerability context and identified preliminary sectorial issues through the mobilization of thematic working groups. The effective implementation of this action plan in horticulture sector is still awaited. Adaptation to climate change should be considered from the long-term planning process perspective. Adaptation in the agricultural sector can be seen in terms of both short-term and long-term actions. There is a need for provision of new irrigation schemes and local management strategies, as well as collaborative research, capacity building at different levels, inter-ministerial and inter departmental coordination and focused policies. Particular attention should be paid to building on existing local knowledge, practices and innovation, including good practices on agro-biodiversity management and related sectors.

The role of the local governments would also include policy intervention, based on data and context-specific peculiarities. This is where the local adaptation plans can help as they can provide a basis for the interventions. The local governments would also have to encourage continuous participatory research and involvement of community in local planning as these can assist farmers to identify appropriate adaptation strategies and actions in horticulture.

The integration of adaptation practices in horticulture sector will include adjustments that have to be made by households, firms, farms and institutions. These comprise activities such as managing natural resources for supporting local horticultural produce, input mixes in production, and changing laws, programs, and policies to incentivize adaptation practices for farmers, communities and firms. The challenge now is that despite having the mandate to lead local adaptation efforts, both the capacity and resources of local governments for planning and implementing climate-smart horticultural practices are low. Therefore, there is a need to build awareness about climate risk at local level alongside efforts to invest on capacity enhancement of front line extension employees and communities.

Lastly, documenting and disseminating successful initiatives in climate change adaptation and environment-friendly development can help promote effective implementation of climate-smart horticulture by integrating it in the local development plans.

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