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Climate Change: It's Causes, Inflicted Hazards, Adopted Strategies and Opportunities in Agriculture of Nepal: A Detailed Review

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ABSTRACT

The greatest threat of 21st century, climate change is being deeply studied for its adverse effects and coping strategies by almost all nations of world. Although, detailed studies in developed nations are most common, Nepal lags in its own research and studies for understanding this change. With great geographic, altitudinal, socio-economical and biological variation in Nepal, the need for study of climate change has grown mandatory since farmers are experiencing peculiar unusual cases different from past. Farmers perception and studies remark the changes in temperature, rainfall, weed dynamics, insect, pest and disease outbreak, hazardous events, duration of a season, unpredictability in weather, loss of production and productivity, food insecurity, degradation of soil physical and chemical status, biological losses and alterations. Many adaptive strategies have been put forward locally and from government level that have shown different efficacy in different environment. Simply put, local site-specific adaptive strategies must be given more importance and prioritization. Financial cringe to tackle climate change must be sorted out and available resources must be put to use by NAPA. Modifications in farm operations, time adjustment and use of modern technology in practices, crop selection, improvement and their cultivation, detailed weather forecasting, soil and water conservation practices, agroforestry, crop rotation, share cropping and off farm engagements have been highlighted. Factors that influence the rate of adoption include age, gender, education and outreach of house head, financial liquidity, size of farms and availability of resources. New opportunities and prospects though revealed, it is still to be utilized.

INTRODUCTION

Climate change, an emerging global issue, is the prime talk of the century caused due to release of GHGs via anthropogenic activities namely fossil fuel combustion, deforestation, unplanned urbanization & industrialization and livestock (Paudel 2012; Panday 2012; Steinfeld et al. 2006). This change is supposed to bear social, economic and political dimensions (Reilly, 2001) with influences in marine, fresh water and terrestrial ecosystems (IPCC, 2007). Different countries show different response (positive/negative) to the climate change however, most affected countries are the developing nations dependent on agriculture with lack of appropriate infrastructure and adequate finance (Gebreegziabher et al. 2011; Mendelsohn et al. 2006; Anttila-Hughes and Hsiang 2013; Rayamajhee and Bohara 2019a). Nepal, a landlocked country having interface with Tibetan Plateau and plains of Northern India, bear diverse biogeography and eco-climatological conditions (S. Manandhar et al., 2010). Altitude ranges from Mt. Everest (8848.86 masl) to flat plains in Terai (64 masl). It extends to Saara jungle in the west. Country is divided into 5 major physiographic regions: Terai plains (up to 700 masl), Siwalik Hills (700- 1500 masl), Middle mountains (1500- 2700 masl), High Mountains (2000- 4000 masl) and High Himalayas (4000- 8848 masl) (Anuska Joshi et al., 2019). Climate ranges from sub-tropical in south to arctic in north (Shrestha and Aryal, 2011). Our complex topography, unstable geology, fragile ecosystem (MOHA 2013; Rangwala and Miller 2012;

Saito 2012), rainfed agriculture (MoAD, 2012), illiterate farmers and their social vulnerability (Adger et al. 2003; Aryal et al. 2014, 2016; Huq et al. 2004; Islam et al. 2016; Morton 2007; Agarwal et al., 2014; Awasthi et al., 2002; Eriksson et al., 2009; Karki and Gurung, 2012; Maskey et al., 2011; Nyaupanea and Chhetri, 2009; Rai, 2007) helped securing 4th rank in vulnerability to climate change in world (Maplecroft, 2011) posing great risk to agriculture, forestry & biodiversity, water resources and human health (Maharjan et al., 2009). More than 1.9 million people are considered to be extremely vulnerable to climate change, with another 10 million at risk (GoN 2010, p. 11).

Prime effects seen in Nepal that threaten traditional agriculture include temperature increase, erratic rainfall, unpredictable monsoons, decreased length of winter, hailstorms, increased hazardous events like: drought, landslide, mass movement, edge cuttings, glacier lake outburst floods (Aryal et al. 2014, 2016; Devkota et al. 2013; Khanal 2014; Shrestha and Aryal 2011; Bajracharya et al. 2007; Timsina 2011; Sharma and Dahal, 2011; Holmelin and Aase 2013; Im et al. 2017; Janes et al. 2019). Studies provide adequate evidences of increasing temperature especially in recent decade (Shrestha and Nepal, 2016). The annual rise of temperature 0.040C per year in Nepal, is greater than the world average and more prominent in mid hills and mountains (Baidya et al. 2007; Shrestha and Aryal 2011). Western and Central Nepal are expecting greater temperature increase than Eastern

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Nepal (Timsina, 2011) and level of impact is dependent on local biological conditions and management practices (Parry et al. , 2005). MoE-Nepal (2010, 2012) showed loss of nutrients, biodiversity and water resulting decline in livestock productivity. Upstream climatic hazards have affected downstream areas immensely via increase in pressure on natural resources and increased competition for food, shelter and income (ICIMOD 2008; Rasul and Hussain 2015; Hussain et al. 2016). Likely, alterations in soil physical and chemical properties would influence the quality of soil (Aydinalp et al. 2008; Khanal 2009; Lohani 2007). Spread of pests and hyper pests in crop have been rising (Panday, 2012). If not the main cause, climate change acts as catalyst to trigger these adverse effects (S. Manandhar et al., 2010). Seen impacts are intense at smaller scale (sub basin level) than at larger scale (Basin level) (Bharati et al. 2016; Hussain et al. 2016). Increasing food and livelihood insecurity outcome via failure of crop production, productivity and loss of local landraces (Regmi and Adhikari 2007, Malla 2009, Ministry of Environment (MOE) 2010, Hussain et al. 2016, IPCC 2018; Kohler et al., 2010; Macchi, 2011; Marston, 2008) are yet to be analyzed in Nepal (Morton 2007; Schlenker et al. 2006; Schlenker and Lobell 2010; Fisher et al. 2012; Lobell et al. 2014; Moore et al. 2017; Baldos et al. 2019) evidenced by fact that 50.67% Nepalese have not even heard of climate change (CBS, 2017). The lag is mainly due to difficulties in gathering meteorological evidence however, several investigations have been conducted (Aryal et al 2014; Becken et al 2013; Chaudhary and Bawa 2011; Maharjan et al 2011; etc). IPCC (2014) confirms extension of poverty and creation of new pocket areas in both the developed and developing countries; primarily in rural mountain of Nepal (Hunzai et al. 2011; Gerlitz et al. 2012, 2015; MOEST/UNDP 2008; CBS, 2011; Dulal et al. 2010; Bhatt et al., 2013; Malla, 2008)

Adaption to climate change means being able to cope with the consequences, moderate the hazards and take advantage of prospects if any with modifications in agricultural practices and capital investment (Joshi et al., 2017; Easterling et al. 2007) however, they must be location specific (Chhetri et al., 2012). Annual adaptation cost is expected to be in order of US \$20,000 (about US \$70 per targeted household) at village level in Nepal (IIED, 2011). Commonly found response included drip irrigation, engagement in off farm activities enhancing migration, alterations in cropping calendar, use of biopesticides, soil and water conservation practices, share cropping, regulation of fertilizer application, improved varietal development and adjustment, agroforestry (Hussain et al. 2018; Below et al. 2012; Deressa et al. 2009; Harmer and Rahman 2014; Yila and Resurreccion 2013; Bryan et al., 2013; Pradhan, Khadgi, Schipper, Kaur, & Geoghegan, 2012; Reid & Schipper, 2014).

Probability of adaptation seemed primarily influenced by age, gender and education of family head (Deressa et al. 2009; Sarker, Alam & Gow 2013). Size of farm, financial liquidity, involvement in community level organizations,

resource availability and institutional activities of support service also played determining role (Asfaw and Admassie 2004; Legesse et al. 2013; Gbetibouo 2009; Ndambiri et al. 2013; Mulatu 2013; Tesso et al. 2012; Tiwari et al., 2014; Bahinipati, 2015; Sarker et al., 2013; Piya et al., 2013). Establishment of National Adaptation Programme of Action (NAPA) by the government to identify, prioritize and resolve these problems has laid a foundation however lack of fund paralyzes its scope (OXFAM, 2009; NAPA, 2010). Climate Change Policy and Local Adaptation Plan of Action (LAPA) framework in 2011 has promoted the participation of people in planning and implementing adaptive measures (MoE, 2011).

METHODOLOGY

Literature review was done through a comprehensive search of articles from Google Scholar based on keywords strictly in context of Nepal. Papers with correlation between agriculture and climate change were prioritized. Also, reference section of each article was searched in order to find additional related articles. The search process uncovered 45 research and review articles summarized contextually in this paper.

DISCUSSION

Causes

Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, persistent unsustainable anthropogenic changes and enormous greenhouse gases (GHGs). The major force in causing accelerated climate change is Greenhouse gas emission. Since the pre-industrial era, anthropogenic greenhouse gas emissions have increased largely by unsustainable human-centric activities, which are now higher than ever. Anthropogenic causes such as deforestation, overgrazing, and unscientific farming on steep slopes of Nepal and other developing countries have resulted in the loss of flora and fauna. They have caused soil erosion, landslides in the hills, and flooding in the plain areas as well. Their effect, together with those Greenhouse gases emission from industries is extremely likely to have been the dominant cause of the observed warming since the mid-20th century (Netra et al. 2012). Agriculture is one of the important contributors to GHG emissions on a global scale. Agricultural land use in the 1990s was responsible for approximately 15% of all GHG emissions (Organic Consumer Association, 2008) and another report produced by OECD (2001) stated that agriculture contributes to over 20% of global anthropogenic greenhouse gas emissions (Food and Agriculture Organization, 2008). Agriculture contributes about half of the world's emissions of two of the foremost potent non-carbon dioxide greenhouse gases: methane and nitrous oxide (World Bank, 2008). Livestock manure, nitrogenous fertilizers and irrigated paddy are said to be liable for producing most agricultural non-carbon GHGs which have more powerful greenhouse effects and have greater longevity than CO₂.

Hazards Influencing Agriculture of Nepal

Climate change broadly, will force the irrational changes on locally available natural resources, biodiversity and environment thereby alternating biological, geophysical and socio-economic elements (Lybbert et al. 2012; Bartlett et al. 2010; Sambridhi 2011)

A study conducted in Koshi River Basin (KRB) showed prevalence of small holders (avg 0.98ha) (Hussian et al., 2018) who had great contribution of agriculture to their food security and livelihood in the past, however, both the production and income has markedly declined over time (ISET 2008; Hussain 2016). Climate change has been pointed out the key aspect of this change supported by 80% of surveyed households who perceived effects as drought, floods, livestock diseases, insect and pest outbreaks (Hussian et al., 2018). Bharati et al. (2012) on this very region expected the temperature to rise by 0.79–0.86 °C till 2030 compared to 1976-2005 which supports the claim of frequent and intense drought and dry spells due to enhanced evaporation (Devkota and Gyawali, 2015). Temperature rise combined with irregular patterns of rain and unpredictable moisture favors livestock, plant diseases and pest outbreak were also supported by (Singh et al. 2000; Basu and Bandhyopadhyay 2004; Sirohi and Michaelowa 2007).

Household surveys and focused group discussions conducted in Lamjung district showed community perceptions regarding rainfall, 90% respondents claimed increasing erratic rainfall and 65% claimed decreased frequency (Joshi et al., 2019). Data from meteorological station showed increasing monsoon, pre monsoon and post monsoon rainfall but decreasing winter rainfall. Standardized Precipitation Index (SPI) of 1981-2010 confirmed increasing risk of drought in post monsoon and winter season from 2001-2010 thus drying up the sources of drinking water. In addition to this 80% perceived increase in flood, 60% in drought, 80% in no. of hailstorms, 55% in summer temperature. Notably, 100% claimed to have experienced decrease in production

similar to Tharus of Western Terai (Maharjan et al., 2011), 68% in biodiversity and 65% in forest products (Joshi et al., 2019).

Based on the cross-sectional survey data collected from 120 households in 2009 in Rasuwa, 40.8% felt decreasing rain in rainy season, 78.3% felt decreasing rain in winter, 60% felt drier every year, 51.7% felt increasing outbreaks and infestations and 41.7% felt increasing cost of food. Also, potato and maize harvest was delayed by a month while that of wheat was 1 month early in Syaphru and Daibung. However, Dhunche showed delay in harvesting time of potato and wheat by 1.5 month and of maize by 1 month; in Laharepauwa, all wheat, maize and rice were delayed.

As stated by Practical Action (2009) annual mean temperature trend of Nepal varies from -0.04 to 0.06°C in the far-western region, 0.02 to 0.04°C in the mid-western region, 0.02 to 0.08°C in the western region, -0.04 to 0.08°C in the central region, and -0.06 to 0.09°C in the eastern region. Also, it stated trend of annual precipitation from -10 to 20mm in Nepal's eastern region, -40 to 20mm in the central region, -30 to 40mm in the western region, -20 to 10mm in the mid-western region, and -10 to 20mm in the far-western region. Warming in irrigated systems is beneficial however, Nepal having rain fed farming, this is harmful (Mendelsohn, 2009)

Education, (EQ) of future medical students. *International Medical Journal*, 18, 293-299.

With increasing temperatures, outburst of invasive weed species as Banmara (*Chromolaena odorata*) has limited the fodder availability for domestic animals forcing people to give up livestock rearing. Also, their aggressive nature outsmarts other crops in competition mostly medicinal herbs in forests (Kunwar 2003; Barik and Adhikari 2011). Recent years show reduction in potato production due to a disease associated with change in soil moisture (Gautam et al., 2013). People claim increase in population of mosquito and early flowering of Kaphal (*Myrica esculenta*) year after year in these regions.

Table 1: House hold surveys and community perception

Parameter	Remarks
Rise in Temperature	0.5 to 2.0°C by 2030
	1.3 to 3.8°C by 2060
	1.8 to 5.8°C by 2090
Change in annual mean precipitation	-34 to +22% by the year 2030
	-36 to +67% by the year 2060
	43 to +89% by the year 2090
Change in monsoon precipitation	-14 to 40% by the year 2030
	-40 to +143% by the year 2060
	-52 to +135% by the year 2090
Runoff	Greater downstream flows at first, reduced over a long time; snow replaced by rain in winters; Frequency and intensity of natural disasters increase

Source: (IPCC 2008; Bates et al. 2008; NCVST, 2009; ISET-N, Kathmandu and ISET, Boulder, Colorado 2009; Erikson et al. ICIMOD 2009; McSweeney et al. UNDP 2008)

Table 2: NAPA (2010) ranks districts of Nepal according to vulnerability index as

Vulnerability index	Districts
Very high (0.787- 1)	Kathmandu, Ramechhap, Udayapur, Lamjung, Mugu, Bhaktapur, Dolakha, Saptari, Jajarkot
High (0.61- 0.786)	Mahottarari, Dhading, Taplejung, Siraha, Gorkha, Solukhumbu, Chitwan, Okhaldhunga, Achham, Manang, Dolpa, Kalikot, Khotang, Danusha, Dailekh, Parsa, Salyan
Moderate (0.356-0.6)	Sankhuwasabha, Baglung, Sindhuli, Bhojpur, Jumla, Mustang, Rolpa, Bajhang, Rukum, Rautahat, Pan-chthar, Parbat, Dadeldhura, Sunsari, Doti, Tanahu, Makawanpur, Myagdi, Humla, Bajura, Baitadi, Rasuwa, Nawalparasi, Sarlahi, Sindhupalchok, Dar-chula, Kaski
Low (0.181- 0.355)	Nuwakot, Dhankuta, Kanchanpur, Bardiya, Ka-pilbastu, Terathum, Gulmi, Pyuthan, Surkhet, Ar-gakhachi, Morang, Dang, Lalitpur, Kailali, Syanja, Kaverpalanchok
Very low (0- 0.18)	Ilam, Jhapa, Banke, Palpa, Rupendehi

Major rivers of Nepal are supplied by over 3000 glaciers from high Himalayas and feeds different needs of people living downstream. Climate change will cause disproportion river runoff due to its impact in precipitation. Also, runoff will increase with glacier melt and decrease later as the process advances (Agrawala et al., 2003).

With the impacts upon the water sources, GLOF, glacial fluctuation and alterations in hydrological regime has become common. With temperature rise seen (Chaudhary and Bawa, 2011) significantly greater than the global average and more significant in Himalayas (Pokhrel and Pandey, 2011) ranging from 0.029 °C per year at Meghauli in the Terai (Pandey 2016b) 0.07 °C per year in the Middle-Mountains at Daman and 0.27 °C per year in the high Himalaya at Langtang (Chaulagain 2006), plains in monsoon get vulnerable as intense rainfall coincides with downstream flows from mountains (Bartlett et al. 2010; Leduc et al. 2008; Malla 2008; Dulal et al. 2010; NCVST 2009). Increased concentrated rain during a time of year has increased incidences of flood, hailstones, landslides, mass movements, soil erosion and avalanche mostly affecting rural people due to their socio economic and dependency in environment factors (Lohani 2007; Aydinarp et al. 2008; Khanal 2009; CBS 2011; MOEST/ UNDP 2008). OXFAM (2009) highlighted the financial limitation of country and ineffective coordination between environment ministry and ministry of forest to brew even more impacts.

In drier regions, salinization and desertification is expected due to the change in soil physical and chemical properties: loss of organic matter, leaching of soil nutrients, increased evaporative losses etc. In addition to this, decline in crop production has been correlated with increased unnecessary transpiration losses from plants and environment conducive for insects, pests and diseases (Aydinalp et al. 2008; Khanal 2009). Timsina (2011) showed increased mass movement and edge cutting tragedies of Nepal due to change in frequency, intensity and form of precipitation.

A questionnaire survey in 720 households covering 6 districts of Nepal revealed increase in summer (95%) and winter season (41%) temperature, weather unpredictability (56%), reduced precipitation (58%), draught (85%), natural disasters (78%), infestation in crops (83.1%),

invasive weeds (75.3%), soil degradation (81.6%), reduced productivity (73.6%) (Khanal et al., 2017). In another paper regarding the same survey published by Khanal et al. (2018), he highlighted the decreased frequency and increased intensity of rainfall facilitating flood and landslide and late start of monsoon in Nepal.

Increase of 20C temperature seems to increase yield of crops in Nepal (Malla, 2008). A time series regression model analysis (1978-2008) of effect of climate on major food crops of Nepal (paddy, maize, millet, wheat, barley and potato) was done. With increase in summer temperature and rainfall, only paddy seems to be benefitted and yield increase was noticed. In case of potato and maize that are staple diet of mid hills and mountains, increased temperature in summer outweighed positive influences of summer rain and minimum temperature making people vulnerable. Although rainfall is seen in decreasing trend in winter, significant temperature than in summers has increased yield of winter crops (Maharjan and Joshi, 2013).

Comparative study done in Terai and Mountain of western development region reported farmers in lowland didn't experience Loo, big storms and western winds of February as in the past; while farmers of lower Mustang confirmed presence of mosquitos and other insects associated with unusual summer and winter temperature rise, decrease and changed timing of snowfall. Dhaulagiri and Annapurna ranges also showed less snow cover, Muktinath experienced frost delayed by 2 weeks occurring only from October, Marpha stated increased rain and fog (Manandhar et al., 2010). Increased winter rainfall in western Nepal during winters is also stated by Ichiyanagi et al. (2007).

Highest mountain areas are to be most affected and precipitation in these areas is likely to increase by 5% by 2050s considering huge variations in river basins (Shrestha et al., 2015). This increase in precipitation is caused due to decline in snowfall and rapid melting of glaciers mostly affecting Nepal eastern Himalayan glaciers (Wiltshire, 2014), found consistent to other mountainous regions of world. Degradation of rangelands and forests (Bolch et al. 2012; Immerzeel et al. 2013) was noted. Poverty being higher in mountains and rate of poverty reduction lower than in lowlands specifies the difference between the two areas and clarifies their vulnerability to crisis (Hunzai et

al. 2011; Gerlitz et al. 2012, 2015).

No snowfall in last 10 years in Chilime and only two in last 18 years, hotter summer and colder winter perceived in Chilime, Thuman, Gatlang and erratic rain felt in all study sites of Grey, Gojlung, Chilime, Thuman and Gatlang. Particularly due to change in rainfall, productivity of potato decreased from 2010-2014 however, increase was noticed in 2015 and 2016 in Gatlang; increased foggy days contributed decreased productivity of potato in remaining areas. Also, increased water availability in micro irrigation systems in April and May was noticed due to snow melt in hotter summers (Merrey D.J. et al. 2018).

APN report shows, rise in temperature by 10C, positive influence is seen in maize productivity throughout the ecological zones. Rise by 20C causes doubling of CO₂ concentration, yield declines in Terai but Hills are less affected. In case of rise up to 40C, mountainous regions are benefitted esp. in rice by 7%, however, 25% yield reduction in Terai is noticed esp. in maize (OXFAM, 2009). Increased problems of grain weevils have been observed as major storage pests of maize in Nepal. High rainfall and humidity due to unpredicted conditions of climate change has increased incidences of Turccicum blight, BLSP thereby decreasing maize production (Nayava and Gurung 2010).

At present condition of climate change and doubling of CO₂, positive influence to wheat yield in all agroecological regions has been observed (Nayava et al., 2009) which has been consistent with findings of other researches carried out. However, among rice, wheat and maize, wheat shows maximum variation thus it is regarded to be the most insecure crop (Pallazzoli et al. 2015). Even if positive influences of CO₂ are taken into account, by mid 21st century, crop yield may decrease upto 30% in S. Asia (Cruz et al. 2007; Aggarwal and Sivakumar 2011)

Increased crop canopy temperature, unwanted evapotranspirative losses, impaired physiological

functioning, clogged soil, disruption of micro and macrobial activity, loss of fertile top soil, elimination of local landraces eg. basmati rice, Thapa Chini, Kalanamak, Jhinuwa, Kanak Jira, Chananchura, Tunde Masino, Anandi (red and white), Ghaiya, Jund, Marshii, wheat, maize (Sathiya, Murali, Dhinde, Sete, Panheli), finger millet (Okhle, Dalle, Paundure, Jhapre, Mutthe) (Paudel, 2012), unusual rain, fewer rainy days but with higher intensity has been mentioned prime noticed impacts in Nepal (Panday, 2012).

Nepal though rich in policy with over 10 policies, 18 acts, 9 regulations and 8 orders talking about agriculture, implementation has severely failed and every new policy formed repeat the previous set objectives and indicators even of completed already (Pandey, 2017). Crop pest interaction, alterations in distribution and development of pests and plant resistance (Lal 2011a; Macchi 2011; Pruneau et al. 2012; Ramirez-Villegas et al. 2012; Paudel et al. 2014; Bhatta et al. 2015; Coakley et al. 1999; Schmidhuber and Tubiello 2007). Farmlands left fallow is seen as common outcome of climate change in Nepal (Paudel et al. 2014; Chapagain and Gentle 2015).

Case study of farmers in Lumle, Kaski mentioned hailstorms even in night and winter, winter rain getting heavier and shifted to early spring and post monsoon, decreased flood but increased intensity, change in phenology of plants esp. rhododendron (2-3 weeks earlier), Kafal, Tote, Amba, Amp, Darim, Timila, Chutro, Aaru (Thapa et al. 2015); invasion of Banmara reduced availability of high valued MAPS like Chiraito (Swertia chirayita), Panchaunle (Datylorhiza hatageria) and Satuwa (Paris polyphylla), reduced infiltration and ground water recharge, increased population of harmful ants, moths, leech, cutworms, hoppers, aphids, stink bug, big horns bug, wood ants, snail, slug and diseases like Phytophthora, fungus in potato, "rate" in rice (Pandey, 2017)

Indicator based vulnerability assessment developed by

Table 3: Potential cost of climate change to farmers includes

Direct cost	Indirect cost	Cost of adaptation
Decrease in gross returns from crops	Costs of Land degradation	Costs of technological adaptation
Additional costs of crop production	Costs of agro-biodiversity loss	Costs of behavioral adaptation
Decrease in gross returns from the livestock production	Costs of uncertainties	Costs of managerial adaptation
Additional costs of livestock and poultry production	Costs of food security	Costs of compliance to policy options
Costs due to increasing risks of natural hazards	Costs of conflicts over scarce resources	

Source: (Pant, 2011)

Hahn et al. (2009) has been used by Aryal et al. (2014); Etwire et al. (2013); Pandey and Jha (2012); Shah et al. (2013). In 543 household studied from Dhading, Syangja and Kapilvastu representing all 3 ecological regions showed, Livelihood vulnerability index (LVI) of Dhading and Kapilvastu higher; Vulnerability index: IPCC indicated Dhading agro-livestock holders to be most robbed; NAPA lists Syangja into 'high landslide risk

zone' (Panthi et al., 2015).

Sherpa (2010) reported no snow in Kapi Himal of MWDR at 15000 feet. Stream was found flowing at the top of Everest by melting ice (Shrestha, 2009). Club roots of crucifer, blight of Solanaceous crops, rust of wheat, blast of rice, leaf spot of maize has been increasing at present scenario of change (Paudel, 2012).

Farmers from Indrawati Basin of Nepal noticed more

Table 3: Study in Kailali district of FWDR noticed following change in natural community influenced by climate change

List of plants decreased		
Name of plants	Local name	Family
Calotropis gigantea	Ank	Asclepiadaceae
Artemisia indica	Titepati	Asteraceae
Anaphalis busua	Buki	Asteraceae
Cannabis sativa	Bhang	Cannabaceae
Cuscuta reflexa	Akas Beli	Convovulaceae
Asparagus racemosus	Kurilo	Asparagaceae
Smilax	Kukurdaino	Smilacaceae
Viscum album	Hadchur	Loranthaceae
Thysanolaena maxima	Amriso	Poaceae
Cynodon dactylon	Dubo	Poaceae
Imperata cylindrica	Siru	Poaceae
Urtica dioica	Sisnoo	Urticaceae
Tinospora cordifolia	Gurjo	Menispermaceae

Source: (Thapa et al. 2015)

List of plants increased:

Name	Local name	Family
Ageratum conyzoides	Gandhe	Asteraceae
Ageratina adenophora	Banmara	Asteraceae
Spilanthes calva	Marathi	Asteraceae
Parthenium hysterophorus	Badmas Jahr	Asteraceae
Cyperus rotundus	Mothe	Cyperaceae
Cyperus iria	Chhatore	Cyperaceae
Cassia tora	Chhinchhine	Fabaceae
Argemone mexicana	Thakalikada	Papaveraceae
Lantana camara	Kuri	Verbenaceae

Source: (Thapa et al. 2015)

warming effect in the daily minimum temperature than maximum however, their monthly mean difference was same. Winter and spring crops are most vulnerable due to this trend mostly in the lower elevations and in places are already grown today at threshold level (Sivakumar & Stefanski, 2011). In the basin, annual average rainfall was projected to decrease by 0.9% of baseline in the 2020s, 1.4% in the 2055s and 3.0% in the 2080s. Clear increase in rainfall during the early winter months (120% of baseline for November and 102% for December by the 2080s), and a small increase in spring and early summer was seen, but decrease in late winter, mid-to-late summer, and autumn is also taken into consideration. Pulses e.g., grey pulses (gahat), black gram (mas), common beans (bodi), brown pulses (mashyang), and soya beans (bhatmas) seem to be the most affected crop in this region. Barley (phaper), tuber (pidalu), sweet potato (shakkarkhanda) has been stopped to cultivate (Pradhan et al. 2015).

Drier soils, loss of top soil by erosion, leaching of nutrients by rain and increased temperature has forced farmers to increase use of chemical and organic fertilizers

to keep up the productivity (Shrestha and Nepal, 2016). Quantitative data analysis done by Aryal et al. (2016) and Sujakhu et al. (2016) showed similar impacts consistently. Study shows that an increase in temperature has a positive impact on the production of rice. Rice production may uplift by 0.09% to 7% in the case when precipitation is increased by 20% and temperature is increased up to 4°C (MoPE, 2004)

If agricultural production in Nepal is adversely affected by climate change, the livelihoods of two-thirds of the labour force, particularly of the rural poor will be at risk (FAO, 2006). Eastern Terai faced a rain deficit in the year 2005/06 by early monsoon and crop production reduced by 12.5% on a national basis. Nearly 10% of agri- land was left fallow due to rain deficit but midwestern Terai faced heavy rain with floods, which reduced production by 30% in the year (Regmi, 2007)

Several studies show that livestock and poultry production is adversely affected by climate change (Hertel and Rosch 2010, Kabubo-Mariara, 2009). This change also increases the mortality and morbidity of animals, particularly from

climate-sensitive infectious diseases (Patz et al., 2005b). Increases in zoonotic diseases among the animals also increase the risks of transmission of such diseases in human beings and increase the costs of veterinary medicines. Increased temperature and relative humidity are said to increase the risks of aflatoxin development in feedstuffs thereby increasing the risks of poisoning among animals (Pant, 2011).

Local Adaptation Measures by Farmers of Nepal

IPCC (2018) proclaims the impact of climate change in the livelihood depends entirely on the time and type of adaptation practices adopted. Adaptation should consider short term and long-term basis (Adger et al., 2003; Eriksen et al., 2011; Pittock and Jones, 2009) and its theory considers that all systems and individual can and will adapt to changing situations (Smithers & Smit, 2009). If appropriate, they help to cope, moderate and take advantage of situations (Joshi et al. 2017; Tesso et al. 2012). Type and degree of adaptation in agriculture is influenced by climate, biophysical, socio-political and environmental factors (IIED, 2011; Keane et al. 2009; Khanal et al. 2018b).

Adaptations might be planned by government or autonomously exercised by households (Stage, 2010).

KRB showed change in cropping patterns, high water demanding crops as cereals to fruits and vegetables (esp. potato, onions and garlic) with low water demand and high market value (Gurung and Bhandari 2009; GWP-JVS 2014: p. 21; Dixit et al. 2009; Hussain et al. 2016). Utilization of improved seeds, resilient varieties, water conserving techniques of irrigation, reserved investment in irrigation projects, replacing larger ruminants with more hardy smaller ruminants like goat has been noticed (Hussain et al. 2016; Manandhar et al. 2011; Bartlett et al. 2010; Shafiq and Kakar 2007). Credit and agricultural insurance facility, technology transfer, market access, extension services via field schools and demonstrations for new adaptive practices by the government has been presented as a significant approach as well (Surminski 2010; Hussain et al. 2018).

Literate family head adapted quicker since decision in rural families relied solely on them (Dhakal et al. 2015), larger family had resourceful labors available anytime improving their coping ability (Ndambiri et al. 2013; Deressa et al. 2009; Tesso et al. 2012; Hussain et al. 2018; Quayum and Ali, 2012; Vijayasarithi and Ashok, 2015) however, smaller families were found to undertake soil, water & fertilizer management and off farm adjustments more (Khanal et al. 2018; Deressa et al. 2009; Hassan and Nhemachena 2008). Joshi et al. (2017) found, with increase in a unit of schooling, adoption of new climate friendly technologies increased by 13% and 26% reduction in ability of adaptation in female headed families than male headed. Also, he found 24% increase in adaptation practices exercised by families earning more part of income from non-agriculture source when compared to the same income level agricultural family. Likely, larger holdings increased the prospect of income and provided

liquid finance to adopt mentioned practices (Hussain and Thapa 2015; Mulatu 2013; Knowler and Bradshaw, 2007), also prospect of taking chance in one of the plots by farmer trying something new is higher (Khanal et al. 2018a). Local opportunities e.g., bee keeping, handicraft, medicinal and aromatic plants, ecotourism etc. should be strengthened via institutional prospects to reduce out migrants and improve ability of food purchase (Hussain et al., 2018).

Adoption of different agroforestry practices according to suitability of location has increased and help immensely e.g., Elainchi farming in agroforestry is increasing in Lamjung. Climate smart policies targeting the higher altitudes should be formulated by the government with effective implementation (MOE 2009; Joshi et al. 2019). Diversification of crop species, adoption of soil and water conservation practices and manipulation of timing in operations is hyping up (Asseng and Pannell 2013; Devkota et al 2017). VDCs of Rasuwa responded to this change via integration of agriculture and livestock, involvement in off farm activities, rain water harvesting techniques and mulching (Merrey et al. 2018; Joshi et al. 2017). Gentle et al. (2018) observed 4 VDCs of Lamjung and saw use of consumption loans, alternative energy source, bio-pesticides, sharecropping and widespread migration as a response. All these similar responses were experienced by Chalise et al. (2015) in farmers of Central Region.

Joshi et. al (2017) found 24% higher adaptation rate to families that consider food security threat consistent with Kurukulasuriya and Mendelsohn (2006); Deressa et al. (2009); Apata et al. (2011). In his study in Rasuwa, higher northern villages (Syaphru and Dhunche) showed 32% less adaptation rate than lower southern villages (Daibung and Laharepauwa). He focused widespread awareness campaigns utilizing government and local level development actors with training sessions to help cope with the changing climate.

Nepal signed UNFCCC in 1994 and have introduced National climate change policy 2076 (2019) whose goal is to prosper socio-economic prospect of country by creating climate resilient system (National Climate Change Policy 2019_Public Health Updatepdf, n.d.). National Adaptation Programme of action (NAPA) has been created which aims to asses and prioritize vulnerabilities, identify adaptations, develop priority proposals, provide learning and management platform and finally develop multi stakeholder framework of action against the change (National Adaptation Programme of Action (NAPA) Ministry of Environment, n.d.). Even with the establishment of NAPA, lack of financial supply to it cripples its activity (OXFAM 2009; Pokhrel and Pandey 2011). Chapagain et al. (2009) concluded that people are more inclined to utilize the innovations easily available at their disposal.

In survey of six districts regarding effectiveness of CBOs, majorly employed adaptation practices were varietal adjustment (53.21%) followed by soil & water

management (50.07%), fertilizer management (45.15%) and timing adjustment (43.49%). 91% had followed at least one adaptation measure and many (62%) were found to be involved in community-based organizations (CBOs) that promoted smaller household size, higher education for househead & crop diversification supporting claim of Conley and Udry (2010), Kassie et al. (2013) and Wossen et al. (2013) that farmers help and teach others in their network (Khanal et al. 2017; Binam et al. 2004).

Data collected from focus group discussion, stake holder workshop and household surveys from 6 districts representing all 3 agroecological regions of Nepal showed 24 practices common to local as adaptation: Crop/ varietal adjustment, Grow diverse crops/varieties, Grow drought tolerant crops/varieties, Grow short duration crops/varieties, Grow insects/diseases resistant crops/varieties Grow less water intensive crop/varieties, Crop rotation, Intercropping/mixed cropping, Change planting locations of crops , Farm operations time adjustment, Change planting date/ harvesting date, Adjustment in time of weeding, pesticide application , Soil and water management, Mulching, Cover crops, Reduce tillage, Fallowing, Terrace construction, Agroforestry, Rain water harvesting, Flood control, Improve/increase irrigation, Fertilizer management, Improve/increase chemical fertilizer use, Improve/increase farm yard manure use, Off-farm adjustment, Keep more livestock, Weather forecasts, Livelihood diversification (Khanal et al., 2018). Among the practices, soil and water conservation was found to show excellent results to uplift food productivity. Average Adaptation index of 99.1, 115.3 and 56 was seen for terai, hills & mountains and households that exercise adaptations were found 10, 9 and 16% more effective than non-adapters respectively. Mean Technical efficiency (TE), derived from stochastic frontier analysis framework, was 0.72 while the value ranged widely from 0.14 to 0.93. This stated that on an average, 28% increase in production can be made using the same input level with practice of adaptation practices. TE in larger scale with greater no of practices was found 13% in average greater than employing fewer practices on smaller scale (Khanal et al., 2018).

Study from rice fields of Nepal by Khanal et al. (2018) show adjustment in timing of operations is most commonly practiced against climate change impacts while fertilizer management is least preferred. This is the result of lower cost and minimal effort associated with the first measure. Records show that adopted households would have lost 648kg/ha if they had not adopted and those who didn't adopt would have gained 241kg/ha rice more in case of practice of adaptive measures.

Young aspiring farmers seem to adopt the change in practices very well with changing climate. Autonomous adaptation practices must be focused and prioritized for extension in Nepal to gain success in undermining climate change (2018)

Household affected by disasters were more likely to employ adaptation than non-affected e.g., drought in an

area forced people to consider supplementary means of irrigation or crop shift to less water demanding ones. Areas closer to market show people engaging in off farm employment more as an adjustment (Khanal et al. 2018). Adhikari et al. (2017) proposed the use of more hardy crops like barley, beans in the high altitudes to tackle issues of climate change.

In paper presented by Manandhar et al. (2010), zero tillage and surface seeding, driving rickshaws, working as porters or in factories, off season vegetable production was noticed locally in western Nepal. In the same paper, possible strategies for upland were presented which included: crop diversification, kitchen waste and water harvesting technologies, extension of apple production between elevations; and for lowlands included: promotion of IPNM, introduction of early maturing, drought and flood tolerating varieties, fish farming in flood prone areas. Indigenous knowledge of Lamas in Mustang was presented as an example who focused that all crops should be sown by every farmer synchronized which will share the damage in crop thus pin pointed the incorporation of local ancient knowledge into principles of adaptive practices for site specific dissemination and success.

Released and registered varieties of rice adopted by farmers in Nepal in terms of moderate- high drought tolerance include Masuli, loktantra, Mithilia, Radha-4, Barkhe 3004, Ghaiya-2 etc. (MoAC, 2007) and improved varieties from India in terms of drought tolerance are Ram dhan, Gorakhnath Gold (moderate flood tolerance as well), Mayur, Sarjubaun, Sarju-49, Bajigar (moderate flood tolerance as well), Motisava (moderate flood tolerance as well), Panta-10 , Golden mansuli (moderate flood tolerance as well), Sundar Sabha (moderate flood tolerance as well), Gauri, Sava Mansuli, Saba (Field survey, 2008).

Climate resilient traditional crops rich in micronutrients such as local maize, millet, buckwheat, local beans, lentils and barley can be an effective coping strategy to evade food crisis in mountains (Adhikari et al. 2017). Selling milks of Chauri, yak and live sheeps can be a way for living as well. Start of off farm activities: tourist guides, opening of resorts, migration to cities, weaving of woolen jackets, caps, carpets etc. has been studied in Grey, Gojlung, Chilime, Thuman and Gatlan (Merrey D.J. et al. 2018; Hussain et al. 2016, 2018; Rasul et al. 2014).

Projection of climate change in future will be determined by change in agriculture with time thus technical change, increased capital, improved access and possible policy change must be well processed. Irrigation is the best option to sort problem in warming as well as in drying (Mendelsohn, 2009).

With increasing threat of maize grey leaf spot in mid hills of Nepal recently, Manakamana-3, Shitala, Deuti, Ganesh-1,2 varieties have been introduced to eastern and central hills. Researchers are focused in developing varieties with less anthesis silking interval (ASI) to overcome drought. Updating the Monitoring and Evaluation of Ministry of Agriculture has been targeted

(Nayava and Gurung 2010).

Adoption of heat tolerant varieties of wheat will increase production of wheat in today's doubling rate of CO₂ content. Improved seeds use to tackle climate change and sustain productivity is also highlighted as a better option (Nayava et al., 2009). Irrigation is also presented as adaptive measure to tackle this problem by Pallazzoli et al. (2015).

Participatory promotion of local genetic resources via seed banks, reduced pesticide use, soil conserving tillage, carbon sequestration, integration of farming systems, improve soil OM, rain water harvesting, conservation agriculture (no till, mulching), green manuring, identifying and uplifting local technologies via R&D (e.g., use of animal urine, plant extracts etc.), community based biodiversity management, home gardens in cities etc. has been presented very effective means of mitigating climate

change effects (Panday, 2012).

Drip irrigation in Kapilvastu, rain eater harvesting for Dhading and bioengineering methods of erosion control in Syangja has been presented as best adaptive measures by Panthi et al. (2015). In his paper, he mentioned social forestry approach, insurance, community cooperative and other formal and informal groups to link and strengthen social capital.

Promotion of Slope Agriculture Land Technology (SALT) and hedge row cropping for mid hills, tunnel/ plastic house farming, community centered small scale storage facilities, germplasm conservation has been put forward as necessary measures to tackle climate change (Paudel, 2012). A 10-point "Everest declaration" to contribute 1.5% GDP to climate fund for reducing GHGs has been made (Shrestha, 2009).

Need of weather information system targeting rural

Table 4: Nepal's effort to climate change

Crops	Varieties	Purpose
Rice	<ul style="list-style-type: none"> Lalka Basmati, Ghaiya 1 & 2, B-6144, Sukhha Dhan-1, 2, and 3, and IR-44535-5 Sworna, IR-64, and Sanwa Mansuli 	<ul style="list-style-type: none"> Drought Tolerant Submergence tolerance
Maize	Manakamana-5 (white), Manakamana-6 (yellow), and Deuti (white)	For mid hills, tolerant to lodging and remain green after maturity; fodder to animals and intercropping suitability
Wheat	<ul style="list-style-type: none"> Aditya (BL-3264) NL-971 WK- 1204, Pasang Lahmu, and Gautam 	<ul style="list-style-type: none"> high temperature and hot wind tolerant, leaf rust and yellow rust resistance resistant to leaf rust, moderately resistant to yellow rust and Helminthosporium leaf blight, and tolerant to high temperature tolerant to yellow rust
Tomato	Srijana and Bishesh	Off-season production, tolerant to blight, high yielder.

Source: (Paudel, 2012)

farming community via TVs, radio, mobile phones to help them adjust their farm operations has become mandatory to support them. Farm ponds, surface/ sub surface dams, tanks for supplementing irrigation can help in dry periods since agriculture is rainfed (Pradhan et al. 2015).

Community based management of common resources have been positively considered by local farmers throughout the country (Kunwar et al. 2020) and local institutions working with bottom up approach seem to be best suited in context of solving environmental problem (Benjamin et al. 1994; Ostrom et al. 1994; Varughese and Ostrom 2001; Shivakoti and Ostrom 2002; Rayamajhee and Joshi 2018; Rayamajhee 2020; Rayamajhee et al. 2020a; Rayamajhee et al. 2020b; Rayamajhee and Paniagua 2020). Easing Indo-Nepal trade of food commodities can be beneficial as well (Rayamajhi et al. 2020).

Another study done in Makwanpur, Nepal regarding risks to food security due to climate change showed vegetable-based enterprises to be more efficient than cereal based because of diversity and regular income flow (Shrestha and Nepal, 2016). Participatory forest management is worth citing (Ojha et al. 2009; Niraula et al. 2013).

A report estimated that a 20% increase in soil organic matter as a result of organic agriculture would result in a

decrease of about 9 tons of carbon emission per hectare (Food and Agriculture Organization, 2008).

Organic agriculture helps in better management of soil and water, promoting biodiversity and strengthening community knowledge systems which increase the resilience of farming systems. Organic agriculture emits less N₂O because of a systemically lower N-input from organic manure, a higher C/N ratio in applied organic manure and low available mineral N₂ in the soil for denitrification, the persistent plant cover in organic systems which results in more efficient uptake of mobile nitrogen in soils, thus reducing the potential risk for N₂O emissions (Khanal, 2009)

Recent studies on Northern Kenya and Southern Ethiopia reviewed by Morton (2001) have focused on the coping strategies used by pastoralists during recent droughts and the longer-term adaptations are: Engage in herd accumulation, in which pastoralists cope by systematically selling livestock during drought or drought-onset; Keep multispecies herds to take advantage of different ecological niches and the labor of men, women, and children; Use purchased feed or lopped fodder from trees as supplementary feed for livestock, which can be taken as a coping strategy; Livelihood diversification away

from pastoralism in the form of shifts into low-income or environmentally sustainable occupations.

The practices provided by FAO (2009) to cope with climate change hazards align with the practices put forward by various authors with a new prospect of Community-centered small-scale fruit production (apple, apricot, walnut, and mandarin orange).

In view of climate-sensitive agriculture, use of timely weather and seasonal climate forecasting, to adjust their farming practices to minimize adverse impacts on rural livelihoods, and food security (Powell et al., 1998)

For high hill and temperate conditions (2500m and above), cold-tolerant rice varieties of Chandannath-1 and 3, others have been developed and popularized especially in the Jumla and Karnali regions (Paudel, 2011) where around 3.9 million people in the area suffered from hunger and malnutrition due to acute shortage of food (Paudel, 2010).

Use multiple sowing dates, thereby decreasing the chance that the whole crop will be at a critical stage during an extreme weather event (Food and Agriculture Organization, 2008) has been put forward with encouragement in genetic diversity of both crops and livestock, save their local landraces that are highly adaptable, making them self-sufficient and self-reliant.

Opportunities

Though opportunities prevail, we are not being able to grasp this and utilize for our benefit since we require external assistance and support (Gawith et al., 2015). Several cash crops like potato, garlic, onion, vegetables showed increase in productivity therefore, prioritization of these crops formulating proper national policies and institutional priorities can help gain profit as well (Hussain et al., 2018).

Despite the impacts, opportunities of cereal cultivation in Mustang, Manang has grown. Rise of temperature in higher altitude has allowed earlier planting and harvesting prospects thus cropping intensity can be increased (Pant, 2011). Melting of glacier, snow and ice with summer monsoon has made water available for farming. Natural decomposition of OM has increased with rising temperature and favored nutrient uptake mechanisms can be of great significance (Bartlett et al. 2008; Khanal 2009; Lohani 2007; Malla 2008).

Value chain development of handicrafts, traditional crops and vegetables will be greatly helpful. Formalization of existing and expanding irrigation systems can be done to lower conflicts at local level. Prospect of introducing and expanding plastic tunnel cultivation and solar pumps in mountains through government aid will be a great achievement and has immense prospect as well (Merrey D.J. et al. 2018).

Carbon fertilization in atmosphere can help to boost the production of C3 plants however, the effect is nonlinear (Pant, 2011).

CONCLUSION

Nepal is rich in biodiversity which ranges from tropical

to tundra hence called the micro-museum of world climate. Therefore, vulnerability of climate change to Nepal is immense although its contribution to global GHG is minimal. Climate awareness among the farmers has been seen mandatory. The common effects of this change experienced in Nepal includes temperature fluctuation, erratic rainfall, outbreak of insect, pest and diseases, increased hazardous events of flood, landslide, edge cutting, bank erosion, mass flow, glacier lake outburst, hailstorms etc., proliferation of invasive weeds, livestock complexities which deteriorate status of food production and questions food security. To tackle these adversities, local adaptation plan of action is suitable. Blanket recommendation will be inappropriate for Nepal due to its diversity thus, essentiality to exploit site specific local traditional knowledge is mandatory. Commonly practiced adaptive strategies include: varietal adjustment, diversification of crops, planting resistant and improved varieties, crop rotation, Intercropping/mixed cropping, farm operations time adjustment, mulching, cover crops, reduced tillage, Fallowing, terrace construction, agroforestry, rain water harvesting, flood control, Improve/increase irrigation, fertilizer management, improve/increase chemical fertilizer use, improve/increase farm yard manure use, Off-farm adjustment, keep more livestock, weather forecasts and livelihood diversification. Soil and water conservation practices have been promising for many farmers, management of crop calendar and timing of farm operations if promoted can be crucial.

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