

Agriculture and Engineering Interface to Cope Climate Change Effects in Nepal: A Review

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Abstract

This paper analyzes present energy consumption by industrial sector within Kathmandu Valley. Initially, author has gone through intensive literature review and prepare questionnaire. Kathmandu Valley is considered as hub of economic sectors. There are large numbers of industries therefore Sample Distribution method is applied to select location. Out of 1,372 industries, 239 industries have been visited to collect data regarding various energy sources available, technologies used, manufactured final products etc. Collected data is compiled using MS-Excel. It was found that total energy consumption by manufacturing industries in Kathmandu Valley is 16.4 PJ. Diesel is the main energy sources which contribute about 37.21% of total energy consumption. The energy demand is projected from base year 2019 to 2050 using MAED energy model tool. The energy demand for manufacturing industries in Kathmandu Valley is estimated to grow from 16.4 PJ in 2021 to 50 PJ at low growth rate (3.95%), 116 PJ at medium growth rate (7%) and 524 PJ at high growth rate (12.7%). However, the demand of diesel and electricity will increase from 38% and 6% in base year to 60% and 14% respectively by 2050. GHG emission in 2021 was 1,249.6 thousand metric tons and it is expected to increase by 2050 at low growth, medium growth, and high growth is 3842.8 thousand metric tons, 8890 thousand metric tons, and 40,043 thousand metric tons respectively.

Keywords

Agriculture, climate change, engineering, smart farming, sustainable agriculture.

1. INTRODUCTION

Agriculture is the front liner to national economy for most of the developing countries as reflected by its share in gross domestic product (GDP) and employment [1]. In the context of Nepal, agriculture and forestry sector jointly contributes 23.79% share to national GDP covering NRs. 822,686 million gross values in 2018/19[2]. This sector engages 65.6%[3] population with 83% of farmers doing agriculture as deriving primary source of income from agriculture[4]. Farming communities are dominated by subsistence and smallholders with limited commercialization. Majority farms face low productivity, less access

to improved technologies, limited skill and labor shifting to non-farm sector for livelihood[5]. In addition, farming is dependent on elements of weather like rainfall, temperature, sunshine, pressure, wind and humidity which are parts of ecological factors having permanent interactions and independency, where change in any of them imparts others[6]. The events of climate related changes such as rapid rise in temperature, erratic rainfalls, storms and increase in frequency of extreme events such as landslides, floods or droughts lead toward risker farming. The agriculture planning under these changes and advocating better integration of adaptation and

mitigation actions to support sustainable agricultural development for food security, the climate-smart agriculture (CSA) is an obvious option[7]. Contextualizing CSA in Nepal is highly complex due to multiple dimensions of the agriculture production systems in the country with diverse climatic zones and socio-economic conditions. Government of Nepal (GoN) has developed National Adaptation Program of Action (NAPA), enacted a national Climate Change Policy in 2011 (CCP), and implemented Local Adaptation Plans of Action (LAPAs) promoting climate-friendly practices in agriculture which is one of the strategies set out in Nepal's Nationally Determined Contribution (NDC). The Agricultural Development Strategy-2015 (ADS) of Nepal aims to promote green technologies and reduce carbon emissions. The ADS targets capacity strengthening of agricultural extension staff and farmers on CSA practices and technologies for improved resilience to climate change and variability. The CSA technologies are broadly grouped under four categories; (i) change in agronomic practices, (ii) use of modern technologies and equipment to increase water, nutrient or other input use efficiency, (iii) information-related interventions such as use of information and communication technology (ICT) to disseminate climate information from agro-advisories and weather forecast services, and (iv) practices that reduce or transfer risks associated with farming, such as weather-index-based agriculture insurance[8].

Advancement in engineering technologies has evolved in farming over time. The advancement is witnessed from subsistence farming mode

towards use of sophisticated technologies such as farm machinery, adapting protected hi-tech structures and developing suitable irrigation system to digital use of information, remote sensing, robotic, drones, cloud computing, big data analytics and artificial intelligence (AI). The new advancement has enabled farming towards precision or smart farming[9]. The integration of engineering has contributed farming to new advancement. Agriculture and engineering interface has enriched farmer-machine interaction in agriculture based on real time information. Some practices are witnessed on estimating agronomical parameters or crop's progression, digitalization of soil system, surge or risk of pest and disease, unseen state or risk associated with agriculture production and environmental impacts and enabling farmers to cope with them. Moreover, engineering component contribute agriculture to be efficient in terms of investment, return and technical aspects.

In line with these contexts, the global technology intervention needs to prioritize agriculture which is the major contributors of national economy. This review aims to come up with existing engineering interventions like protected structures, irrigations schemes, AI and ICTs in climate change scenarios and inspire stakeholders to develop and replicate joining hands by cross-sectoral and multifaceted support for ensuring integration in correct path to cope with effects of climate change dragging laggard agriculture sector.

2. METHODOLOGY

This paper is based on review of practice to cope climate change effects in Nepalese and global scenarios. The information was accessed mainly through review of existing policies, plans and programs, ongoing practices and the appropriate measures towards coping strategy for climate change effects in agriculture related to interventions.

3. RESULTS AND DISCUSSIONS

3.1 Agriculture mechanization situation and policies in Nepal

Mechanization broadly covers all levels of farming and processing technologies that ease and reduces hard labour, relieves labour shortages, improves productivity and timeliness of agriculture operations, increase resource-use efficiency, enhances market access and contributes to mitigating climate related hazards in sustainable way considering technological, socio-economical, environmental and cultural aspects from simple and basic hand tools to more sophisticated and motorized equipment. In this regard, mechanization is broadly including the application of tools, implements, powered machinery and equipment to achieve agricultural production, comprising both crop and livestock production as well as aquaculture and apiculture[10].

In Nepalese agriculture, mechanization is getting attention with labour shifting towards non-farm activities, increasing cost of production and market-oriented farming including demographic shift, socio-economic and policy changes in the country. The power-operated machineries like

water pumps, tractors, harrows, rotavators, seed drills, threshers, combine harvesters, processing machine, sprayers, shallow tube-wells, treadle pumps and laser land levelers are in operation in Terai and use of tractors, power-tillers, mini-tillers, pump-sets and threshers is increasing in rural hills and mountains[11]. In addition, mechanization in Terai includes direct seeding of rice and wheat by zero tillage four-wheel operated tractor, minimum tillage by power tiller, use of rice transplanter, mechanized irrigation, intercultural operation by power weeder, harvesting by reaper and combine harvester, threshing by multi-crop thresher, mobile thresher and laser land leveler in larger farm while in hills, seed sowing by power tiller with seed drill, mini-tiller seeder, potato planter, maize planter, lifting irrigation, inter-culture operation by power weeder, harvesting by mini tiller reaper, brush cutter, serrated sickle and solar dryer for post-harvest processing are increasingly been used[12].

Agriculture mechanization in Nepal has been viewed as farm implements and machinery accesses and adoption which is largely import dependent. It was departure with provision of more efficient farm equipment and tools promotion in the first Five-Year Plan (1956-1960 AD) of the government emphasizing to reduce the farmer's burden of hard labor. Then after, private sector introduced tractors for ploughing and pump sets for water-lifting in irrigation from late 1960s and throughout 1970s, tractors and motorized pumps importation and adaptation throughout the terai and power tillers and mini-tillers in the hills largely extended only after

2006[13], [14]. Institutional development for farm mechanization started with establishment of Agricultural Implement Research Unit, Birgunj in 1960. Formerly, the Agricultural Engineering Directorate and now known as Center for Agricultural Infrastructure Development and Mechanization Promotion (CAIDMP) under Department of Agriculture (DoA), Nepal has mandate to develop infrastructure, farm building, farm roads, irrigation facilities and promote while, National Agricultural Engineering Research Center (NAERC) of Nepal Agricultural Research Council (NARC) is engaged in designing, testing, modification and promotion of tools and equipment[13].

Earlier, Nepal's major agricultural development policies and program such as "Agriculture Perspective Plan 1995-2015" and "National Agricultural Policy-2004" ignore mechanization due to fear of labour displacement in addition with small farm size, fragmented land holding, geographical constraints and narrow terraces in hills and mountains. However, with economic liberalization and mechanization realization in agricultural development sector "Agricultural Mechanization Promotion Policy-2014" has been formulated by GoN aiming to promote agriculture mechanization and commercialization and reduce food production costs through improving mechanization efficiency[11]. It focuses on promotion provision of subsidy on purchase of farm machineries. Further, "Agriculture Development Strategy 2015-2030" has designed mechanization options accessible through information dissemination, improve customer access to finance, capacity building for service

and maintenance providers, enable the business environment for leasing agricultural equipment, revise regulation and taxes to support mechanization[15]. The promotional policy related to the availability, access and adoption of mechanization like liberal importing policy, tax exemption and low tariff in importation are found crucial as trigger in agricultural mechanization development. Other related policies focusing in related arena are "Rural Energy Policy-2006" with provision of subsidy in the use of rural renewable technologies such as solar dryer, solar pump, micro-hydro, cold storage facilities and machinery and equipment that run by renewable energy, low tariff rate for irrigation and "Industrial Policy-2010" emphasizing establishment of agro-based industries. Moreover, yearly credit policy, transport policy and subsidy policy of government have integral effect in favoring agricultural mechanization[11].

Next to present situation, optimized design of agricultural machinery in combine with digital data management will enable small-scale farmers to access atomized and semi-autonomous equipment and digital innovations in mechanization technologies which can make agriculture more attractive to rural youth towards the high-tech digitally supported machinery led farming ultimately viewed as smart farming where one can image the higher production and profitability in this competitive commerce led world. The possible application of agriculture technologies related to engineering like precision farming, AI, remote sensing, blockchain technology, internet of things (IoT), ICT and

LIDAR present the challenges to successful sustainable adoption[16].

3.2 Climate changes and its effects in Nepalese agriculture

Global climate has varied range of time and space scales due to various factors that are internal and external to the complex climate system. Human activities of industrial revolution have increased the concentration of greenhouse gases on atmosphere which essentially traps more heat in the global climate system and cause global warming[17]. The measurable elements of weather, rainfall (and other form of precipitation), temperature (heat level), sunshine (duration and intensity), pressure, wind (direction and velocity/speed) and humidity (absolute and relative) are part of ecological factors which have permanent interactions and independency, where change in any of them imparts others[6].

The 2021 United Nations (UN) Climate Change Conference (COP26) commitment for sustained progress toward the Paris Agreement and UN framework convention on climate change, by limiting increased global temperature to 1.5°C above pre-industrial levels encompasses the net zero global emissions by at least 2050 which can only be meet by technology innovations realized by societal and industrial level and governments, as well as corporations. Step with various options, digital technologies offer the potential solutions to climate changes where just by AI based systems could contribute to reduction of 4% in global emissions by 2030[18].

The climate change results variations in solar energy, temperature, precipitation, soil moisture and sea level [19], [20]. The rapidly retreating

glaciers (average retreat of more than 30 m/year), rapid rise in temperature, erratic rainfalls and increase in frequency of extreme events such as floods and droughts like situation are some of the effects in Nepa [21]. Hydrological and meteorological data from Department of Hydrology and Meteorology indicate the increasing temperature in Nepal in consistent and continuous manner after the mid-1970s with maximum temperatures at an annual rate of 0.04-0.06°C. The duration of summer monsoon originating from the Bay of Bengal and winter precipitation from western Mediterranean Sea are found to be longer than normal increasing trends and late onsets ultimately late withdrawals. High intensity rainfall continuous for several days lead to massive landslide and soil erosion in the hills and finally flashes riverine floods in Terai. The changes in the dates of onset and retreat of the monsoon, number and frequencies of extreme precipitation events, intermittent droughts like situation during the monsoon season increase significant cost in agriculture. The extreme topography of Nepal challenges to prepare and mitigate effects if possible and if not adapt to reduce impacts on lives and livelihoods [21], [22]. In contrast, droughts occurring from the end of March through until arrival of the monsoon season in hills and mountain of Sudurpaschim and Kamali Provinces and Terai of Province no. 1 and Madhesh Province[22]. The pre-monsoon drought coupled with high temperature could reduce soil moisture in many areas reducing the available water for irrigation thereby further reducing farming possibility in non-irrigated area[19].

Short-term extremes in temperature and precipitation are critical for crop growth coinciding with key stages of development. The yields of different crops and geographic limits has been altered by changes in soil moisture, temperature and precipitation. Increased temperature often results in steep drop in net growth and yield. Heat stress affects crop yield through impact on physiological development and crop maturation. Higher temperatures provide a conducive-environment for the majority of insect pests. Longer growing seasons, higher night temperatures and warmer winter help insect pests undergo multiple life-cycles and increase the chances of affecting plant production. Further, the pattern and extent of rainfall and evapo-transpiration processes affect soil moisture storage, run-off and water absorption by the plant which creates condition of excess or no water during different stages of plant production. Moisture stress during flowering, pollination and grain-filling stage is harmful to most crops. Increased evaporation from soil and accelerated transpiration in the plants themselves will cause moisture stress[23].

Therefore, the disaster like floods, landslides and droughts and their consequences are climate induced indirect effects related to extreme rainfall events or non-uniform distribution throughout the topography. Flood affect agriculture in the Terai region every year imparting standing crops in the field and landslide prone in hills and mountainous region. Excessive rain in some part and drought in other part triggering with increasing temperature challenges crop production and productivity.

The efficient mechanization to cope with ever-increasing demand in climate change scenarios will be sustainably managed with utilization, maintenance, co-ordination and control of resources use with precision farming aided by technologies. The primary intervention of new technologies to disseminate information and make aware of the successive effects through ICTs and engineering development in the aspect of protected high-tech structures and efficient irrigation schemes leads to the coping strategy towards climate changes vulnerability. The development of low-cost water efficient technologies and development of early warning systems related to drought, rainfall and flood forecasting are crucial to cope with inevitable climate change effects.

National Strategy for Disaster Risk Management (NSDRM)-2009, a basic reactive and relief guide to disaster risk reduction, preparedness and effective response and currently, Sendai Framework for Disaster Risk Reduction 2015-2030 targets and priorities for action to prevent new and reduce existing disaster risk aiming to achieve the substantial reduction of disaster risk and losses in lives, livelihoods and health [22], [24]. ADS-2015 has visioned about improved resilience of farmers through early warning system, climate information and weather indexation systems, pilot a farmers welfare fund, promote agricultural insurance, improve capacity of extension staff and farmers in CSA and establish a fund for preparedness and response. Functional agriculture risk information system for delivering information and services in coordination with multi-stakeholder such as local

level bodies, provinces, development partners, line agencies, response team and necessary investments in agriculture infrastructure and technologies generation are pre-requisites for supporting climate risk reduction functions in agriculture.

3.3 Intervention areas and technology option

Agriculture is benefitting from technological advancements globally. Technologies improvement in agricultural aims to optimize production efficiency, enhance quality, minimize environmental impacts and production-associated risks[16]. Appropriate invention can contribute to the precise use of resources, inputs such as fertilizer, seeds and pesticides and avoiding overuse and waste in the adverse climate changes impacts scenarios through eco-system-based approaches. In order for advancing technologies to make a difference, these need to be adopted and used in farms around the world which could be possibly with the private sector involvement in development and government formulating policies and regulations to create an enabling environment to flourish and reach the ultimate need ones [25]. Human intervention or technological options especially in the area of engineering are of major importance in coping with climate variations[26]. These interventions in farming include protected structures, precision farming, modern farm implements and machineries or automated equipment for farm operations, drip irrigation systems for optimizing production efficiency and quality, AI for pest and disease diagnostics and management options, remote sensing (satellite and drone imagery), and deploying of ground sensors (soil, crop or

meteorological stations) leading to early warning system for minimizing production-associated risks and environmental impacts.

3.3.1 Protected structures

Increasing pressure on natural resources and small land holdings demand agricultural production system to be shifted to suitable interventions that can cope with climate changes and addressing population growth. Protected cultivation involving the use of structures (like greenhouses, net houses, screen houses, tunnels) is one of the options. On this regard, low volume high value horticultural crops management tool under protected condition increases competitive quality produce and productivity by 3-5 folds over open field condition. Protected cultivation enhances crops growth environments, prolong the harvest period, manage pests with minimal pesticide, use water and fertilizer efficiently, increase yields, improve quality, enhance stable production and off-seasoning[27]. The farms using protected cultivation facilities has been benefitted with increased farm profit by 68-73% in Taiwan who have been suffered by natural disaster shocks [28] that gives subsidizing idea for adoption of protected technology to mitigate the risks resulting from natural disaster shocks. Relating this, Ministry of Agriculture and Livestock Development (MoALD) has developed guidelines and standard for hi-tech greenhouse program in 2014/15 AD. Bamboo plastic tunnel, GI poly-tunnel, naturally ventilated greenhouse, fan and pad cooling greenhouse, agri-net house, shade house, high-tech and semi high-tech greenhouses are being adopted as controlled environment agriculture [12] for production of

vegetables, flowers and fruit sapling. These structures are generally recommended for selected crop in the selected area for targeted market place to get better return from the interventions and investment. Many donors funded projects and government funded projects such as Prime Minister Agriculture Modernization Project (PMAMP) has implemented programs on construction of protected structures and cultivation support [29].

The frequency of extreme weather events like drought periods and heat waves are of major challenges of changes in climate. The protected construction and covers protect crops from wind or hail storms facilitating in controlling internal temperature, humidity and radiation. This advances to the independence from the open field production and powered towards coping with climate change impacts. Technical and conceptual innovations in greenhouse designs like cover materials, shading screens, semi-/closed ventilation and improved natural and additional light are valuable in innovation of the protected structures to cope with abnormal climatic alternation and extreme weather conditions associated with climate changes [30].

The greenhouse cultivation has been benefited in both the winter and the warm seasons. During the winter season, inside greenhouses more favorable temperatures may be reached to grow heat-demanding species while during the warm season, the high solar radiation and exceeding temperature effects are compensated by the shading effect and can be regulated to certain extend by proper ventilation and/or cooling of the

greenhouse. For the year-round use, instead of plastic films, greenhouses with screens (nets) have become common practice in recent years in some areas. The screens are permeable for air exchanges with the outside environment and transparent to very limited and reduced sunlight. Screenhouses can reduce the damage caused by the heavy rainfall and hailstones but cannot protect crop from rainfall. This can be said growing crop under high-tech greenhouses avoid strong dependency on the outdoor climatic effect [31]. In Nepal, recent increasing trends of cultivating ornamental plants and commercial vegetables under protected structures in terai and mid-hills to avoid frost and maintain required temperature during winter and escape rain in rainy seasons has made ensure of the high investment in farming. Besides this, fruit nursery and rice seedbeds under well-equipped protected tunnels ensure healthy sapling or planting material compared to outdoor otherwise affected.

3.3.2 Irrigation schemes

Drastic decline of rainfall pattern and increased temperature creates drought condition with decreased irrigation water and increased water conflict. Efficient water use technology is a major in coping with climate change where loss of water and cost involved are less. High efficiency irrigation (including drip and trickle irrigation) is the better option which save significant amount of water and increase area under irrigation that contribute to sustainable land management and relief to climate change effects. This leads to requirement of the innovative design of integrated water delivery and application schemes [32]. Micro irrigation (including drip irrigation, mini

sprinkler irrigation and bubbler irrigation) is being promoted throughout the world as a climate-adaptive technology that will reduce demand for groundwater and notably enhance the resilience of agriculture in light of ongoing groundwater overdraft and climate change-induced shocks [33], [34].

Next, the water harvesting technologies capturing small water resources and decentralized water management infrastructures are alternatives to improve rainwater use and climate resilience [35]. The invention of lift irrigation to augment water supply and water harvest technology as reservoir to store additional water in hills and deep tube-well and bore-well along with recharge technology in the flatland are crucial to capture the water stress or drought impacts [36], [37]. In addition, the sensor based digital equipment or technologies are helpful in combating the water or moisture stress or drought and act accordingly.

3.3.3 Artificial intelligence

AI technology makes agricultural practices more efficient, equitable and less damaging to the environment by helping farmers to improve crop yield, address the challenges of soil health and use resources more sustainably reducing the agricultural sector's greenhouse gas emissions [38]. Automated equipment AI having remote sensing in compliance with information and communication technology leads to digitalization. Camera or scanner sensors applied in the computer vision systems are used in different agricultural production systems has made a simple and objective analysis of the images, videos and machine learning and produce

adequate descriptive data for future analysis and automate laborious task in non-destructive way. Sensors monitor the soil or crop or meteorological parameter to generate data captured, processes by specific software and AI to provide intervention options go for proper decision to act on the crop [16]. It is estimated that AI-based advisories would be useful to increase production by 30% [39]. The development of intelligence devices that use computer vision, automation in the field and integration with agricultural machines can solve agricultural problems currently open [40]. Drones and robots are among these machines.

3.3.3.1 Drones

DRONE (Dynamic Remotely Operated Navigation Equipment), also known as UAVs (Unmanned Aerial Vehicles), is a flying device either with the help of autopilot or manually using the remote control or smartphone app that can significantly enhance risk and damage assessment and revolutionize the way to prepare for and response to disaster [41]. Drones in agriculture are used for soil and field analysis, planting, spraying crops, crop monitoring, irrigation, crop health monitoring and remote sensing which ensure permanent crop monitoring from planting to harvesting [42]. Added with the images and videos captured by special sensors of drones, farmers can view crop changes that are otherwise invisible to human eyes [43] irrespective to the physical geographical structure. Drones' application in disaster management and weather forecasting are valuable with respect to climate changes. Drones provide quick means after a disaster to gather

information and navigate the destruction by saving resources on manned or manual tasks. In addition, drones monitor dangerous and unpredictable weather using specialized sensors for weather parameters, collect data and prevent mishaps [44] delivering agricultural intelligence [45]. Drones do solve the difficulty of surveying and surveillance of disaster damage mapping by improving the speed of exploration work too [46] including insects and disease damage [47]. Crop insurers and insurance policy are benefited with the use of drone in assessment of crop losses after natural disasters for accurate and quick calculation of pay-out or detect the fraud [43], [48]. In Nepal, due to air safety and privacy rights reasons drone flights are restricted [43], [49]. However, drones are useful in monitoring the crops and plan the farms in climate changes inevitable effects scenarios with designing the proper legal regulatory policy.

3.3.3.2 Agricultural robots

Robotics can address the potential consequences of climate changes and increase efficient use of resources fighting their negative effects. Robotics has potential to make difference in scientific research, help in reducing emission of greenhouse gases and mitigating climate disasters. In terms of mitigating climate disasters, faster responses are possible assisting in rescuing victim and post disaster recovery. Robotics introduction in agriculture having combination of different intervention technology platform like sensor for monitoring, specific software as data processing, decision options for implementation and automated action on actualization give the real sense of complete AI [16]. Works on agricultural

robots are in the early stages with different concept on evolution for potential innovation, implication and advancing technology to newer area. With given versatility, agrobots could be vital in labour intensive farm works in increasing sustainable crop production and management contributing in livelihood of smallholder farmers in developing countries. Currently, agricultural robotics autonomously used in weeding, irrigation, guarding the farms, reporting, ensure the adverse environment condition for production, increase precision and manage individual plants in multiple angles. To address more frequent drought, robots collect data and process them to be used in drought tolerant crop development by understanding combat phenomena to grow during drought [50]. Smart irrigation system technology compliance with automatic plant irrigator ensures the soil fertility, moisture content and temperature with respect to better crop growth and apply water effectively in stress condition. Agrobots could be useful in predicting the weather and other conditions related to agriculture and helps in accurate projection or prediction of concerns of farmers [39].

3.3.4 Information and communication technology

Information related to climate, weather, precipitation, and disaster are critically important. Monitoring and data dissemination by typical ICT to access daily weather forecasts and long-range predictions for environmental protection and economic development imparts on preparedness of safety of life and property. ICTs play role in disaster prevention, mitigation, response and

recovery by timely, predicable and effective information as early warning and alerts community at risks [51]. Community risk knowledge is acquired through systematically collected data, conduct risk assessment and disseminate the information as early warning to the at-risk communities prior to the disasters strike [52]. Untimely rain, drought, hail storm and strong wind have been responded as primary climate related hazard and improving forecasting and dissemination of climate information and promotion of farm-level adaptation measure access through early warning are first step to improve community resilience to climate change [53]. Early warning (EW) is the provision of empowering communities or individuals in threat by hazards to act appropriately in time and finally reduce the possibility of injury, loss of life, damage to property and the environment, loss of livelihoods and enhance the resilience of a society. EWS is progressive in deploying international commitment, better forecasting techniques, improved technology for communication and sharing of information and provide climate change adaptation in disaster risk reduction [54]. A complete and effective EWS consists of four inter-related components (i) risk knowledge, (ii) monitoring and warning service, (iii) dissemination and communication, and (iv) response capability. In climate change scenarios with scarce financing resources, the EWS should address all components with well designed and implemented in accordance with local institutional capacity and participation to enhance the potential action upon an early warning [54], [55]. Major challenge remains in the operational ground to achieve the potential benefits from

communicating risk information by the concerned authorities and communities at-risk. The comprehensive, clear and concise messages must be accessible to all users to reduce economic losses to better protect their assets and livelihoods. The advances in science and technology have contributed to know vulnerability warning messages and building and mobilizing their response capability to reduce risk [29]. The long-term seasonal forecasting, such as weather, climate, drought, and land degradation trend is most successful EWSs while short-term imparts of floods, geologic hazard and water pollution are harder to predict [56]. The communication of early warning information tools like short message service (SMS) (cellular phone text messaging), email, radio, TV and web service are ICTs' key elements [57]. Remote sensing technologies, IoTs, ICTs based agro-advisory services, internet and network computer and e-adaptation and e-resilience are among developed ICTs' EWS technologies.

3.3.4.1 Remote sensing

Remote sensing a tool for monitoring the real-time reliable continuous stream of data on environmental and meteorological phenomena. The advancement and availability of automated sensors that capture, analyze and predict adverse impacts through remote data, enhance the setting up of effective EWS, especially on global scale phenomena where traditional in-situ monitoring may be very difficult and time consuming [6], [57].

3.3.4.2 Internet of Things

IoT refers to scenarios where network connectivity and computing capability extends to objects or sensors to generate, exchange and consume data remotely providing feedback and make decision [58], [59]. The IoT devices are designed for self-report in real-time, improve efficiency and bring important information to the surface more quickly than a system to allow worldwide web communicating with one another [60]. The successful combination of wireless sensor network and the mobile communication technology in digital agriculture make control in monitoring and faster reaction remotely [61].

IoT technology of real-time wireless sensor network as EWS, monitor temperature and humidity and GSM SMS will notify the user to take environmental regulation measures. Wireless sensor node collects soil moisture, nitrogen concentration, pH value, precipitation, temperature, air humidity and CO₂ concentration and wireless sensor network forward them to central control device. As soon as abnormalities are detected by analyzing the environmental factors, early warning function be enabled and GSM warning messages be sent to the system user to take decision at right time and reference [62]. In the greenhouses, the sensors are able to measure four parameters in climatic adjustment: temperature, relative humidity, light irradiance and air carbon dioxide content and leads to the greenhouse environmental control system which adjusted the ventilation, heating and misting [63].

3.3.4.3 ICT based agriculture extension and agro-advisory services

An integration of Android Apps and a web-based system is an alternative to enhance and improve the manual system of current advisory service in the agriculture development. The system is able to detect and record information and these data are used by the advisory team to measure risk factor and helps in alerting the farmers with advice to do necessary actions [64]. Smartphones, internet services, mobile networks, televisions and radio widespread has created opportunities to disseminate relevant information faster and rapidly covering larger mass than ever challenges the extension worker efficiency. The internet-based initiatives for knowledge sharing and weather forecast using geographic information systems (GIS), global positioning system (GPS) services in agro-meteorological initiatives through Android agricultural apps [65] that helps in reducing risk and uncertainties [66]. These apps reduce time delays between monitoring, problem detection and provision of recommendation [67].

3.3.4.4 Internet and networked computers

Cloud computing (Google, Yahoo and Microsoft) have started incorporating maps and satellite imagery for a near-real-time mode [57]. Big data analytics through historical agrometeorological datasets, regression methods and neural network methods are mainly used for forecasting data in different problems with the aid of ICT have remote sensing to generate collect, process and visualize large data for future predictions and make decisions for the management [68].

3.3.4.5 e-adaptation and e-resilience

ICTs-mobile phones have been diffusing information rapidly to strengthen the physical preparedness of livelihood systems, institutions and organizations and social networks for climate change related events through GIS, GPS and modeling application. The establishment of multi-sectorial alliances to implement ICT related solutions in the field and ICT entrepreneurs need the provision of technical and financial support as incentives to access and connectivity in climate change affected regions. ICT based national programs and strengthening the internal capacity to adjust, change and transform of nationwide organizations to provide service of local adaptive actions for recovering from adverse climatic events [69].

4. GAP ASSESSMENT

Based on above discussion, we identify some gaps. Firstly, we identify the need for hazard mapping that provides bases for identification for planning to reduce the impact of climate change. Secondly, a lack of country specific research on appropriate technology that support for adaptation and mitigation measures for climate change hazards for smallholder farmers. Thirdly, assessment of appropriate technology is needed including the sustainable utilization of these technology. Fourthly, an institution that looks after climate resilient technology including technological and economic aspects is lacking. Finally, a commitment for assurance of budget including the implementation for climate smart investment plan need to be assured.

5. CONCLUSION

This paper draws conclusions that has implications on integration of new innovation the research and also on policy measures in Nepalese agriculture. The short-term and long-term strategies need to be developed to mitigate the effects of climate change hazards and promote adaptations of suitable technology in agriculture sector. While a short-term mitigations and adaptations measures could be borrowed from outside, the medium- and long-term solution should be based on context specific assessment and research evidences. The government approach of handling climate change impacts through preparedness, rescue, relief and recovery could be better developed through innovative technology such as digitalization of data base and early warning system developed based on integrated data base. The new innovations that link agriculture and engineering should focus on cost effective measure and sustainability of the technology. Research on technology, its development and dissemination among farmers should be based on the assessment of data and evidences for greater reliability and also on assessment of gap that show difference between actual and desired condition. A digital based problem solution measure based on real time data would augment for the sustainable solution of the problem leading to development of climate resilient agriculture.

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