

RESEARCH ARTICLE

CLIMATE-SMART AGRICULTURE TECHNOLOGIES AND PRACTICES IN NEPAL

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ABSTRACT

Climate change poses serious threats to agriculture, impacting food security and livelihoods globally. Nepal, one of the most vulnerable countries, faces challenges such as food insecurity in multiple districts, changing rainfall patterns, temperature variations, and the risk of glacial lake outbursts. To address these issues, Climate-Smart Agriculture (CSA) offers an integrated approach that combines eco-friendly practices like no-tillage, intercropping, integrated pest management, rainwater harvesting, and the use of ICTs to enhance productivity with minimal environmental impact. Climate-Smart Villages (CSVs) in Nepal serve as models for implementing these practices, fostering resilience among smallholder farmers and marginalized groups. This paper reviews the impacts of climate change on agriculture, discusses CSA practices, and examines ongoing programs and policies aimed at enhancing food security and adapting to changing environmental conditions in Nepal.

KEYWORDS

Climate Change, Climate Smart Agriculture(CSA), Climate smart villages(CSV), Adaptation, Policy

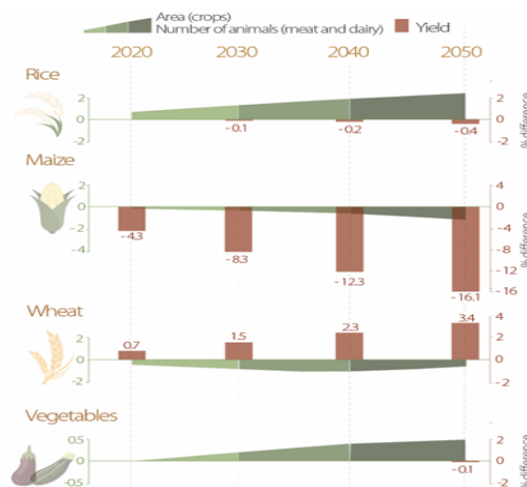
1. INTRODUCTION

Climate change, defined as long-term variations in climate attributed to natural factors or human activities (IPCC, 2007a). Key consequences include changes in rainfall, temperature variability, rising sea levels, salinization, water scarcity, and extreme weather events, which disrupt agriculture, forestry, and fisheries (Thornton and Cramer, 2012). The most visible effect is global warming, with South Asia projected to see up to a 10% reduction in rice yields and over 10% for maize and millet by 2030 (UNCTD, 2009; Lobell et al., 2008).

Nepal ranks as the fourth most climate-vulnerable country globally, facing disproportionately severe impacts (Dangal, 2012). With 42 of 75 districts classified as food insecure and 21 glacial lakes deemed hazardous, nearly 1.9 million people are considered highly vulnerable, signaling alarming

future risks (Lamsal, 2017). Nepal is experiencing an average temperature rise of 0.06°C annually with challenges like drought, severe floods, and landslides (Malla, 2008).

Nepal's agriculture, the backbone of its economy, faces declining productivity due to its heavy reliance on monsoon rainfall, compounded by limited irrigation facilities and erratic weather patterns (Bhujel and Ghimire, 2006). Delayed monsoons and insufficient water supply have left thousands of hectares of farmland uncultivated (Regmi and Adhikari, 2007). The impacts of climate change on agriculture are profound, including disruptions to agroecosystems, heightened risks of pests and diseases, and altered nutrient and soil moisture cycles (Fuhrer, 2003). Marginalized groups such as Dalits, Janajatis, and women are particularly vulnerable (Bhatta et al., 2015).

Climate change impacts on yield, crop area and livestock numbers in Nepal^[29]

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2. CLIMATE SMART AGRICULTURE

Climate-Smart Agriculture (CSA) represents a comprehensive approach to transforming agricultural systems in response to climate change (Lipper et al., 2014). The Food and Agriculture Organization of the United Nations (FAO) defines CSA as a strategy to sustainably increase agricultural productivity and income, enhance climate change adaptation, mitigate greenhouse gas (GHG) emissions where possible, and support food security under changing climate conditions (FAO, 2013). By sustainably increasing food production, strengthening farmer resilience to climate variability, and mitigating greenhouse gas emissions, CSA serves as a critical tool for addressing climate change (Aggarwal et al., 2018). CSA encompasses a range of innovative practices, institutions, and policies tailored to climate conditions, many of which may be unfamiliar to farmers (Papuso and Faraby, 2013).

CSA practices include conservation agriculture techniques such as minimum tillage, alternative crop establishment methods, integrated nutrient and irrigation management, and residue incorporation as it enhances crop yields, improve water and nutrient use efficiency, and reduce greenhouse gas emissions from agricultural fields (Sapkota et al., 2015). Other CSA technologies include rainwater harvesting, agricultural insurance, and the use of improved seeds, which help farmers cope with extreme climate events and enhance resilience (Altieri & Nicholls, 2013).

3. CLIMATE SMART AGRICULTURE PRACTICES

3.1 Weather Smart CSA Technologies

Table 1: Major varieties (rice, maize and wheat) having adaptive capacity on adverse climatic conditions in Nepal	
Character	Varieties
Rice	
Cold Tolerant	Lekali Dhan-1, Lekali Dhan-3, Chandannath-1, Chandannath-3
Drought Tolerant	Radha-14, Sugandhit Dhan-1, Sukkhkha Dhan-4, Sukkhkhadhan-5, Sukkhkhadhan-6, Barkhe-2014, Sukkhkhadhan-3, Sukkhkhadhan-2, Sukkha Dhan-1, Khumal-13, Khumal-10, Tahara 1, Hardinath-2, Ghaiya-1, Khumal-10, Tarahara 1, Hardinath-2, Ghaiya-1, Khumal-8, Barkhe-3004, Ram Dhan, Mithila, Hardinath-1, Radha-4
Water logging/Submergence tolerant	Celharang Sub-1, Swarna Sub-1, Samba Masuli Sub-1, Makawanpur-1
Disease/ Insect Pest tolerant	Lekali Dhan-1, Lekali Dhan-3, Sukkha Dhan-4
Maize	
High temperature tolerant	Rampur Hybrid-10 and Rampur Hybrid-8, Arun-6
Drought tolerant	Rampur Hybrid-6, Rampur Hybrid-4, and Khumal Hybrid-2
Lodging tolerant	Resunga composite and Manakamana-6
Disease/Insect pest tolerant	Rampur Hybrid-6, Arun-3, Arun-6, Khumal Hybrid-2, Manakaman-6
Wheat	
High temperature tolerant	Tilotloma, Danphe, Gaura, Vijaya, N1, 971, Aditya, Gautam
Drought tolerant	Banganga
Disease/Insect pest tolerant/resistant	Munal (UG 99 resistant), Chyakhura, Banganga, Danphe, Gaura, Vijaya (UG 99 resistant), NL 971, Aditya, Gautam

Source: SQCC (2017)

3.2 Soil Smart

Practices like no-tillage (NT) conserve soil organic carbon, especially in topsoil, improving soil quality while reducing costs, conserving moisture, and minimizing erosion (Lal et al., 2007). Higher levels of exchangeable nutrients like calcium, magnesium, and potassium in surface soils under NT compared to conventional tillage (Ismail et al., 1994). Innovations like Sloping Agricultural Land Technology (SALT) conserve soil and water on

slopes, stabilize land, and promote bio-terrace formation (Grogan et al., 2012). Similarly, agroforestry and integrated systems like agri-horticulture reduce erosion, improve soil health, and promote efficient nutrient cycling (Nair, 1984).

3.3 Crop Smart

Intercropping systems enhance ecological sustainability, output stability, productivity, and resilience to environmental disturbances (Vandermeer, 1989). Green manuring, a climate-smart practice, minimizes reliance on external inputs and is well-suited for smallholder farmers (Gurung et al., 2017). Similarly, mulching helps conserve water and reduce labor costs (Subedi and Basnet, 2016). The use of jholmal, an organic liquid fertilizer, improves crop yields by rapidly supplying nutrients to address temporary deficiencies, promoting plant growth (Gajjala, 2018). Water-efficient methods like alternate wetting and drying can cut irrigation requirements by 30% while maintaining rice yields (Bouman et al., 2007).

3.4 Water Smart

Water is the primary medium through which the impacts of climate change will be experienced by people, ecosystems, and economies (Stuart-Hill et al., 2012). The demand for safe drinking water is rising due to population growth, industrial expansion, intensive farming, climate change, and increased consumption (Bakkenes et al., 2002). Rainwater harvesting systems have emerged as a viable solution to address water scarcity. Globally, rainwater harvesting is being utilized to improve food security, encourage farmers to diversify their enterprises, create additional water sources, and complement conventional water supply systems (Maume, 2014). The efficiency of water use is particularly high with drip irrigation, which reduces evaporation, conveyance, and distribution losses (Dhawan, 2002). Fertigation ensures uniform nutrient application to the root zone, resulting in higher and quality yields along with savings in time and labor (Singh, 2002).

3.4.1 Water-Efficient Production Techniques

3.4.1.1 Direct Seeded Rice (DSR)

Direct seeding involves the establishment of rice crops from seeds sown directly into the field instead of transplanting seedlings from the nursery in traditional transplanting methods, (Farooq et al., 2011). It makes better soil physical conditions for the preceding crops mainly wheat and other winter crops (Bista, 2018)

3.4.1.2 System of Rice Intensification (SRI)

The System of Rice Intensification (SRI) enhances rice productivity by changing the management of plants, soil, water, and nutrients. SRI helps mitigate greenhouse gas (GHG) emissions, particularly methane (CH₄), which can be reduced by 22% to 64% through alternate wetting and drying practices (Jain et al., 2014). SRI plants thrive with 30-50% less irrigation water compared to flooded rice fields, exhibiting thicker tillers and deeper roots due to wider spacing (Styger and Uphoff, 2016).

3.4.2 Water-Efficient Irrigation Systems

Alternate Wetting and Drying (AWD): The AWD method, developed by IRRI, Philippines, reduces water use by up to 30% and cuts methane emissions by about 48% compared to continuous flooding (Richards and Sander, 2014). In Nepal's Terai region, AWD saves 54.5% of irrigation water compared to traditional systems (Yadav et al., 2012).

Drip Irrigation: Drip irrigation is a water-efficient and climate-smart system, delivering water directly to individual plant roots at low rates from emitters in small-diameter pipes. It is gender-friendly, suitable for smallholders (Adhikari et al., 2018).

Sprinkler Irrigation: Sprinkler irrigation waters plants by spraying water in the form of rainfall. Suitable for any topography, it's particularly useful on slopes or narrow terraces where water discharge is low. Sprinkler irrigation is adaptable to most soils and farmable slopes, allowing uniform water application (Howell et al., 2015).

Rainwater Harvesting (RWH): With irregular rainfall patterns and limited water resources in rainfed areas, RWH is vital for rural farmers in Nepal. RWH technology have 48% more income compared to non-adopters, benefiting from increased agricultural productivity (Adhikari et al., 2018).

Sloping Agricultural Land Technology (SALT): It involves planting hedgerows of perennial and annual crops along the contours to prevent soil erosion and maintain soil fertility. This system helps reduce runoff and soil loss while increasing crop yields, particularly maize, when integrated with nitrogen-fixing plants like *Alnus nepalensis* and *Indigofera dosua* (Lamichhane, 2013).

3.5 Livestock Smart

Livestock accounts for up to 18% of global greenhouse gas emissions (Thornton and Herrero, 2010). Climate change poses challenges to the livestock sector, including fluctuating feed prices, habitat changes, expansion of vector-borne diseases in warm climates, impaired reproduction, pasture quality and availability, and physiological heat stress (Thornton et al., 2009 ; Opio et al., 2013). Greenhouse gas emissions can be mitigated by improving feeding techniques, producing more from fewer animals with less feed (Blummel et al., 2010). Pasture land can be enhanced through the improvement of vegetation, such as planting high productivity, drought-tolerant, and deeper-rooted fodder grasses and/or legumes (Branca et al., 2011). Weather-indexed livestock insurance could also provide an effective safety net when preventive measures fail (Skees and Enkh-Amgala, 2002).

3.6 ICT Smart

A pluralistic approach involving telephone, television, printed media, radio, and internet networks significantly enhances agricultural production (Singh, 2014). ICT initiatives in agro-advisory services applicable in Nepal include telecommunication, media initiatives, printed media, and internet-based initiatives (Das, 2016). ICT empowers farmers by making them more innovative and capable, which helps in reducing risks and uncertainties (Abraham, 2007). Mobile applications contribute positively to technology transfer by offering cost-effective solutions and addressing field-based challenges faced by farmers (Wankhade et al., 2011).

4. ADAPTATION AND PRACTICES IN NEPAL

In Nepal, several adaptation initiatives and climate-smart practices have been implemented across various districts to help communities cope with climate change impacts and promote sustainable development.

- UNDP's Integrated Climate Risk Management Program (ICRMP) in Dolakha district, with financing from the Swedish Government and the Government of Nepal, provided training on off-season vegetable farming and plastic tunnel construction. This program aimed to strengthen risk management practices, improve resilience, and contribute to poverty reduction (UNDP, 2018).
- The Scaling-Up Climate Smart Agriculture in Nepal project, implemented in the Kaski, Lamjung, and Nawalparasi districts, focused on identifying, testing, and screening CSA technologies. This project involved poor farmers, extension agencies, and researchers to develop and implement champion CSA practices, with active participation from local and governmental stakeholders (Gautam et al., 2015).
- The 'Climate Smart Agriculture in the Himalayas – An Innovative Green Business Model for Food Security and Poverty Reduction of Mountainous Communities of Nepal' project worked in Bajura district. It aimed to transform traditional agriculture and forestry into socially prestigious and economically viable businesses (ANSAB, 2015).
- CIMMYT's flagship project on CSM focused on scaling up local CSM practices in Nepal, India, and Bangladesh (CIMMYT, 2015).
- ICCO's Climate-Smart Agriculture Project received the Adaptation at Scale Prize for its innovative efforts in the Karnali zone. Key initiatives included:
 - ✓ Agro-solutions in the Karnali zone to promote climate-resilient practices.
 - ✓ Subsistence farming in Karnali
 - ✓ Engaging 250 vulnerable households in solar pumping irrigation systems.
 - ✓ Initiating the sale of surplus food to international markets, thus improving food security and economic resilience (ICCO, 2017).

5. CLIMATE-SMART VILLAGES IN NEPAL

The Consultative Group for International Agricultural Research (CGIAR) and the Climate Change, Agriculture, and Food Security (CCAFS) are implementing a climate-smart village (CSV) approach across Asia, Africa, and Latin America (Aggarwal et al., 2013). This CSV approach is integrated into the agriculture research-for-development agenda and aims to tackle

climate change challenges to enhance food security (Campbell et al., 2016).

International Center for Integrated Mountain Development (ICIMOD), in partnership with Environment and Agricultural Policy Research, Extension, and Development (CEAPRED), developed the Climate Smart Village (CSV) approach. This initiative provides communities with tools to enhance resilience to climate change while promoting sustainable development (ICIMOD and CEAPRED, 2015). The CSV is a multi-stakeholder approach to local-level practices for promoting climate-smart agriculture. Key features of CSVs include: Nutrient Smart, Water Smart, Crop Smart, Future Smart, ICT Smart, Energy Smart (Aggarwal et al., 2013)

6. MAJOR PROGRAM AND POLICY

For the successful design of institutions and programs, the six "ins" of Climate-Smart Agriculture (CSA) are crucial: inclusive institutions for information, investment, innovation, and insurance (Meinzen-Dick, Bernier, & Haglund, 2013). Several institutional arrangements, policies, and strategies have been developed by the Government of Nepal (GoN) as well as various NGOs and INGOs to support adaptation initiatives in the country. These include:

- Climate Change Policy 2011 under Nepal Climate Change & Development Portal (Ministry of Environment, 2011)
- Climate Resilient Planning: A tool for Long-term Climate Adaptation under National Planning Commission (NPC, 2011)
- Agriculture Development Strategy (2015- 2035) under Government of Nepal (ADS, 2015)
- Irrigation Policy 2014 under Government of Nepal with support from The World Bank (GON, 2014)

DOMAIN	POLICIES	INSTITUTIONS
Agri and Food Security	Agriculture Development Strategy (2014), Agriculture Development Policy (2004), Agriculture Extension Strategy (2014), National Biodiversity Strategy (2014), Agro-biodiversity Policy (2014)	Agriculture Development Strategy(2015), Agriculture Development Policy(2004), Agriculture Extension Strategy(2014), National Biodiversity Strategy(2014), Agro-biodiversity Policy(2014)
Climate Change	Intended Nationally Determined Contribution to UNFCCC (2014), Climate Change and Risk Management Framework (2011-2022),Climate Change Policy,NAPA, LAPA, Low Carbon Economic Development Strategy (2015)	Respective Ministries, Local Government Bodies, Department of Hydrology and Meteorology, Research Institutions and Universities, I/NGOs

Source: Khari-Chhetri,(2017)

7. CHALLENGES

Despite the numerous benefits of Climate-Smart Agriculture (CSA), its adoption in Nepal remains limited. A key barrier is the lack of coordinated funding for adaptation and mitigation efforts, a challenge observed globally. In Nepal, factors such as farmers' socio-economic characteristics, agro-ecological zones, and the complexity of new technologies significantly influence CSA adoption (Cabell and Oelofse, 2012). Local institutions play a crucial role in transforming coping capacities into adaptive capacities and motivating smallholder farmers and marginalized groups (Berman et al., 2012). Achieving meaningful outcomes in Nepal requires collaboration across sectors, including agriculture, climate

change, food security, and policy programs, to ensure a holistic and coordinated approach.

8. CONCLUSION

Climate change presents significant challenges for Nepal's agriculture, including irregular rainfall, drought, and land degradation. Addressing these issues requires Climate-Smart Agriculture (CSA) practices that leverage local resources. However, effective implementation of government policies remains crucial. Successful adaptation and mitigation depend on coordinated efforts across planning, research, government, and NGO initiatives. Strengthening soil and water management, crop systems, and access to climate information is vital. Climate-Smart Villages (CSVs) provide models for integrating CSA practices that enhance resilience to climate change. A renewed commitment to sustainable practices and policy integration is essential to balance short-term food security with long-term climate risk management.

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