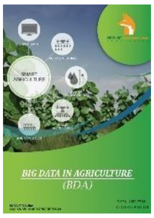
ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2682-7786 (Online)
CODEN: BDAIDR

Big Data in Agriculture (BDA)

DOI: http://doi.org/10.26480/bda.02.2025.93.99



CrossMark

REVIEW ARTICLE

# CLIMATE-SMART AGRICULTURAL PRACTICES IN THE NEPALESE FARMING SYSTEM

**Aashish Gyawali*, Akariti Gahatraj**

*Institute of Agriculture and Animal Sciences, Tribhuvan University, Rampur Campus, Khairahani, Chitwan, Nepal.*
**Corresponding Author's Email: aasishgyawali08@gmail.com*



**ARTICLE DETAILS**

***Article History:***

Received 23 March 2025
Revised 18 April 2025
Accepted 02 May 2025
Available online 17 June 2025

**ABSTRACT**

Climate-smart agriculture (CSA) is an innovation that calls for integrating agricultural development with climate resilience. In Nepal, the agricultural sector is significant for the country to achieve economic stability and food security; however, it has been suffering from adverse impacts of climate change and has most severely affected the smallholder farmers due to their limited adaptive capacity. This paper highlights the different practices of CSA already implemented in Nepal and their importance in addressing such challenges, improving agricultural productivity, resilience, and sustainability, and contributing to reduced GHG emissions. Key strategies include adopting drought-resistant crops, efficient water-use technologies, integrated nutrient management, renewable energy solutions, and agroforestry. However, fragmented institutional frameworks, and insufficient stakeholder coordination, hinder CSA adoption in Nepal and a lack of evidence-based knowledge tailored to local needs. The Climate-Smart Village (CSV) model demonstrates promise, utilizing participatory action research and community engagement to create localized solutions. Despite these challenges, CSA has immense potential to reduce climate risks, bolster food security, and promote long-term agricultural sustainability. Achieving these outcomes requires targeted interventions, enhanced policy support, and collaboration among government, private, and non-governmental sectors. By addressing these barriers, CSA can transform Nepal's agricultural systems, ensuring resilience and sustainability for future generations while advancing national and global development goals.

**KEYWORDS**

Climate change, Resilience, Synergy, Climate-smart village (CSV)

## 1. Introduction

Climate change is defined as a prolonged modification in climatic conditions, resulting from either natural cycles or anthropogenic influences, especially those linked to fossil fuel use. This activity results in heightened levels of greenhouse gases and a rise in global temperatures (IPCC, 2007a). Forecasts suggest that by the conclusion of the twenty-first century, global temperatures may increase by 1.8°C to 4°C (IPCC, 2007b). The rising temperature aligns with a projected population growth of almost one-third by 2050, requiring a 60% increase in food production to satisfy the escalating demand (FAO, 2009a; Conforti.,2011). The study recognizes Nepal as the fourth most vulnerable country to the impacts of climate change (Dangal.,2012). The agriculture sector, essential to the national economy, faces significant challenges due to changes in weather patterns and an increased frequency of extreme weather events (Malla., 2008; Bhujel and Ghimire., 2006). Agriculture must enhance its productivity on current land while concurrently adjusting to a changing environment. The sector must improve its resilience to hazards linked to extreme weather events, such as droughts and floods (Steenwerth et al., 2014).

Smallholder farmers, who are more exposed to climatic hazards and have little ability to adapt, suffer especially from the consequences of climate change on agriculture. With an average landholding of less than 0.5 hectares, smallholder farmers account for almost 80% of the agricultural industry, according to the Central Bureau of Statistics (CBS, 2022). Their poor adaptation strategies and great vulnerability to climate change help explain their sensitivity to changes in temperature. Reportedly less than half of the world average, national yields for important cereal crops like rice, wheat, maize, and millet (FAO, 2022). The people of Nepal are quite sensitive to the consequences of global warming. According to recent Asian Development Bank research, climate change is expected to cause Nepal to lose 2.2% of its yearly (GDP., 2025). With about 80% of the population at risk from natural and climate-related hazards, including excessive heat, flooding, and air pollution, Nepal ranks 31st on the 2019 INFORM Risk Index and is vulnerable to major disasters (CDCC., 2022).

The need for climate-smart agriculture (CSA) has grown due to the unpredictable nature of climate conditions, which pose considerable hazards to agricultural systems. A thorough transformation of the agricultural sector, including crop and animal production, fisheries, and forests, is urgently required to properly manage climate change while increasing agricultural productivity and income levels (Division., 2022). Climate-smart agriculture (CSA) is a method of reforming and reorienting agricultural growth in light of the new realities of climate change (Lipper et al., 2014). Climate-smart agriculture (CSA) refers to farming practices that boost food security in the face of climate change, improve farmers' adaptive capacity to climate change consequences, and mitigate climate change to the greatest extent possible. CSA tackles climate change and food security issues by sustainably increasing productivity, strengthening resilience, lowering GHG emissions, and improving national food security and development goals (FAO., 2010). Climate-smart agricultural methods promote sustainable food production, strengthen farmers' resilience to climatic variability, and reduce greenhouse gas emissions (Lipper et al., 2014; Aggarwal et al., 2018). It is worth noting that developing countries account for 74% of total agricultural emissions (Von Koerber and

| Quick Response Code | Access this article online | |
|---|---|---|
| | **Website:** www.bigdatainagriculture.com.my | **DOI:** 10.26480/bda.02.2025.93.99 |

Cite The Article: Aashish Gyawali, Akariti Gahatraj (2025).
Climate-Smart Agricultural Practices In The Nepalese Farming System. *Big Data in Agriculture, 7(2): 93-99.*

Kretschmer, 2006). Soil carbon sequestration can help to reduce around 89% of these emissions (Fischer et al., 2006a; FAO., 2009).

Through scientifically based projects, CSA stresses satisfying people's basic needs for food, energy, wood, and fiber. It is therefore very important for guaranteeing food security, reducing poverty, and promoting economic development. CSA also seeks to sustain and raise the resilience and production of agricultural and natural ecosystems, hence strengthening natural capital. The method tries to reduce the trade-offs involved in reaching these goals. To address the issues presented by climate change and so forward agriculture and food systems toward sustainability targets, it encourages a continuing, iterative collaboration among stakeholders, researchers, and legislators (Neufeldt et al., 2013). The climate-smart agriculture (CSA) strategy shows a dedication to improve the synergy between agricultural development and climate adaption. Its main goal is to guarantee food supply while also achieving more general developmental goals in view of a changing environment and growing food needs. CSA projects are meant to increase agricultural output sustainably, build resilience, and either reduce or eliminate greenhouse gas emissions (GHGs). To negotiate the trade-offs and synergies among its three basic pillars—food security, adaptation and mitigation—effective implementation of CSA depends on meticulous planning (FAO., 2010). Three pillars constitute climate-smart agriculture according to the Food and Agriculture Organization of the United Nations (FAO): (a) sustainably raising agricultural productivity and incomes (food security); (b) adapting and strengthening resistance to climate change (adaptation); and then (c) Wherever feasible, lowering and/or eliminating greenhouse gas emissions (mitigation).

Researchers have identified a multitude of actions that could potentially strengthen these three foundations. These encompass the creation of drought-resistant crops, the execution of integrated soil fertility management practices, the adoption of water conservation techniques, enhanced integration of livestock within smallholder mixed crop-livestock systems, and the rehabilitation of rangeland areas (Vanlauwe et al., 2010; Campbell et al., 2014; FAO, 2018; Rosenstock et al., 2019). Even with these things in mind, there are still questions about how to prioritize measures in certain situations and how to measure progress over time toward these goals. The absence of dependable baseline data for evaluating interventions exacerbates the difficulty. The lack of a focused strategy, wherein actions are customized to the individual situation, reduces the efficiency and efficacy of both national and international support programs. This reduces the likelihood of meeting important sustainable development goals (SDGs., 2030). These include ending hunger; making sure everyone has a decent standard of health and well-being; promoting responsible consumption and production; taking action on climate change; and protecting life on land (Van Wijk et al., 2020).

## 2. Core Principles/Pillars Of Climate Smart Agriculture (CSA)

Climate-smart agriculture (CSA) is founded on three interconnected objectives: promoting mitigation, fostering adaptation, and assuring food security. The development of resilient agricultural systems that can thrive in a changing climate is contingent upon the achievement of each objective.

### 2.1 Food security/Productivity

This pillar typically serves as a gauge of agricultural production, reflecting the criteria set by the Food and Agriculture Organization (FAO). But a focus only on output ignores two important aspects of food security. First, especially with regard to nutrition, which is a crucial gauge of food security, equating output with just food security is unduly narrow. Many studies show that improvements in crop yield could ironically lead to lower food security and more hunger. For example, a more efficient crop could cause crop diversity to decrease (Fraval et al., 2019). Contend further that Climate-Smart Agriculture (CSA) should concentrate other aspects of food security in addition to simple output. The second important consideration is food security's sustainabilit(Campbell et al.,2016) . Although the definition of this pillar specifies that developments in food security and production have to be sustainable, it does not provide particular criteria for assessing sustainability. There are several ways to describe sustainability (Pretty et al., 2011). Note approximately 100 different definitions common elements of sustainable agriculture, that underlie this research, however, include the provision of food and nutrition for both current and future generations, the ability to maintain production over extended periods, resilience to climate-related shocks, environmental stewardship concerning regional resources including biodiversity, water, and soil, and global concerns like greenhouse gas emissions (Schiere et al., 2002; Pretty et al., 2011).

### 2.2 Adaptation

Draw attention to important flaws in the study on climate change adaptation, most of which have to do with the inability of many studies to differentiate between the ideas of "coping" and "adaptation." (Wiederkehr et al.,2018). Regarding the difference between "short-term adaptation," which refers to immediate hazards like extreme weather events, and "long-term adaptation," which is focused on slow climate changes that call for systemic changes like crop variety choice or cropping system modification, they also demand clarity on this difference (Wiederkehr et al., 2018). They underline that standardized data on socio-economic variables, like household demographics, farm size, and economic status were of great relevance for forming adaptation methods required to improve the comparability of local case studies and to derive relevant lessons from them. They also demand the creation of strong "adoption indicators" to evaluate farms and households' capacity to implement important components in the development of climate adaptation strategies (Wiederkehr et al., 2018).

### 2.3 Mitigation

Mostly depending on GHG emissions from agricultural activities, the mitigating element of CSA focuses on reducing the environmental impact of food manufacturing. Most LMICs attribute the primary cause of anthropogenic emissions to the sector. Usually the most discussed environmental problems are GHG counts, including carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). (Pelster et al.,2017). Also discuss biodiversity and nutrient usage efficiency. Strategies to lower emissions will be based on emission factors, like those made under the IPCC Guidelines, because they help give a favorable idea of how much pollution different farming systems produce. These sometimes, however, depend on data from rich countries, which might not be pertinent in LMIC environments (Goopy et al., 2018). Recent developments in MRV systems make it simpler to monitor the outcomes of mitigating activities, which is seen to be crucial for future climate funding and pollution fines payable with money. Clear boundaries for evaluations at farm gates are vital and the first issue for a comprehensive review (Zhu et al., 2018; 2020).

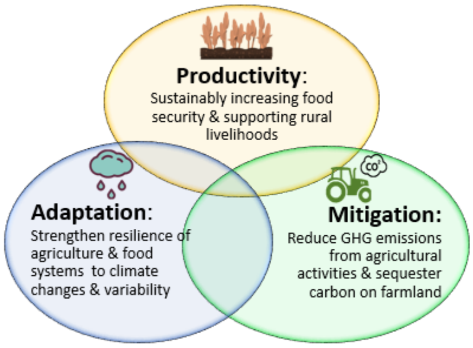



**Figure 1:** Principles of CSA (UC Davis, 2024)

## 3. CSA PRACTICES IN NEPAL

Climate-Smart Agriculture Practices in Nepal In Nepal, agriculture is a critical strategy for addressing climate change concerns, primarily within the agricultural sector, which greatly contributes to the nation's economy and food security. CSA practices are illustrated by the following:

### 3.1 Water smart

Water resources are essentially the foundation of agricultural output; hence, the growing problem of water shortage seriously compromises them. Smallholder farmers in rural Nepal especially depend on water-efficient agricultural methods. This strategy stresses the need to optimize water resource use while concurrently increasing crop yield and resilience (Haileslassie et al., 2022; Takeshima and Mano, 2023). Smallholder farmers often live in places with limited water supplies and erratic rainfall patterns, so facing different difficulties. The effects of climate change highlight the need of efficient water management techniques since they aggravate these problems even more.

One reasonable substitute for water shortage is rainwater collecting systems (Patil and Mali.,2013). Community ponds collect rainwater for use during dry times. Roof-to-root systems help gather rainfall for irrigation. Plastic ponds also help to capture greywater, which can be used for irrigation, so encouraging different water use. While sprinkler irrigation improves general irrigation efficiency, drip irrigation brings water straight to the root zone, so reducing water loss. Direct-seeded rice farming is another creative, water-efficient approach that uses less water than conventional transplanting techniques (Paudel et al., 2016). In rice production, the System of Rice Intensification (SRI) changes the management of plants, soil, water, and nutrients. While improving drainage and runoff, raised bed planting techniques and conservation furrows help save water.

Effective drainage management is the elimination of extra water by well-planned constructions. Cover crops help deposit nutrients into the ground and reduce soil water evaporation. Among the several cover crops used in Nepal are white clover (Trifolium repens), alfalfa (Medicago sativa), cowpea (Vigna unguiculata), and soybean (Glycine max).

### 3.2 Soil Smart

Soil is essential for providing food and fiber to an increasing global population. The characteristics of soil, encompassing its formation, development, and fertility, are affected by climate change factors including moisture levels, temperature variations, and carbon dioxide concentrations. The changes contribute to the increasing problem of global food insecurity (Navneet Parik.,2017). While adjusting to climate change, soil-smart practices seek to improve soil health, increase production, and assure long-term sustainability. To increase soil fertility and reduce nutrient depletion, integrated nutrient management (INM) is the combination of synthetic fertilizers with organic materials including compost, farmyard manure, and biofertilizers. Studies show that INM improves soil health in addition to crop output (Paudel et al., 2016).

Sloping Agriculture Land Technology (SALT) is a contour-based approach designed to conserve soil and, at the same time, to increase agricultural productivity on sloping lands. It significantly contributes to the conservation of soil and water resources, improves soil fertility, stabilizes slopes, makes agricultural activities on sloping lands easier, and gradually develops bio-terraces (Grogan et al., 2012). Conservation agriculture (CA) involves minimum disturbance of the soil, permanent soil cover, and crop rotation to reduce soil erosion and increase water retention under rainfed conditions (Khatri-Chhetri et al., 2017).

Agroforestry, agri-horticultural, and agri-pastoral systems enhance soil health by reducing erosion and runoff, improving soil properties, increasing nitrogen fixation, and promoting nutrient cycling. Mulching with organic or plastic materials retains moisture, suppresses weeds, and improves soil structure, a practice increasingly adopted in vegetable farming in Nepal (Paudel et al., 2016). Traditional practices like terracing and contour farming are effective in controlling runoff and soil erosion on slopes, and their integration with modern techniques further boosts efficiency (FAO.,2010).

### 3.3 Nutrient Smart

Nutrient-smart agriculture is an approach aimed at optimizing soil fertility in Nepal through integrated practices. It integrates organic and inorganic inputs to ensure an optimum nutrient profile and improved productivity (Paudel et al., 2016). Biofertilizers like Rhizobium, Azotobacter, and phosphate-solubilizing bacteria promote nitrogen fixation and phosphorus availability in the soil, which promote nitrogen fixation and increase the availability of phosphorus in plants, especially in leguminous crops (Khatri-Chhetri et al., 2017). Soil testing and fertility mapping allow for tailored fertilizer applications, which play a crucial role in minimizing environmental degradation (MoALD., 2020). Precision farming methods like fertigation make better use of nutrients. Crop rotation with legumes not only raises the nitrogen content but also lowers the number of pests and diseases that affect the plants (Paudel et al., 2016; Khatri-Chhetri et al., 2017). These affordable solutions are essential for the varied agricultural scene of Nepal since practices like vermicomposting and recycling of crop residues help to enrich organic matter and maintain soil health (Paudel et al., 2016; Khatri-Chhetri et al., 2017).

### 3.4 Crop smart

Nepal has developed climate-resilient crop varieties to solve the problems caused by drought, heat, floods, and disease ensuring agricultural productivity under challenging climatic conditions. Sukhha Dhan 1-5 developed by the NAARC are suitable for rainfed areas, while Swarna-sub 1 and Swarna sub-2 are rice varieties that thrive well in submerged conditions. Similarly heat tolerant wheat varieties, WK1204 and RR21 are released to ensure stale yields in rising temperatures. Short-maturity maize varieties like Rampur composite and Manakamana-3 are effective for unpredictable rainfall patterns. Climate-related diseases are less of a problem when you use disease-resistant varieties like Lumle Maize-1 and Radha-11. Also, vegetables that can handle cold temperatures let farmers in high-altitude areas grow crops outside of the growing season (Khatri-Chhetri et al., 2017; Paudel et al., 2016).

By overcoming transient nutrient shortages, jholmol speeds up nutrient availability, thus helping plant growth and increasing crop yields (Gajjela., 2018). To help plants grow better, growth-promoting bacteria in jholmol get rid of pathogens, improve soil nitrogen fixation, and make growth hormones (Rakesh et al., 2017). Made from homemade bio-fertilizer and bio-pesticide, Jholmal helps improve crop health and raise yields while lowering the cost of manufacture and application of dangerous chemicals.

### 3.5 Energy smart

Reducing reliance on non-renewable energy is the main objective of energy-smart agricultural practices and promoting renewable energy for sustainable farming. Solar-powered irrigation systems replace diesel pumps, enhancing resilience to drought and increasing productivity through cropping system intensification (Khatri-Chhetri et al., 2017). Zero and minimum tillage practices reduce fuel consumption, GHG emissions, labor, and water demands while improving energy efficiency and profitability (Paudel et al., 2016). Biogas systems utilize organic waste for clean energy, reducing firewood dependency, while agroforestry systems integrate fast-growing trees for biomass production, supporting renewable energy needs (ICIMOD., 2014).

### 3.6 Carbon smart

Reducing greenhouse gas (GHG) emissions and increasing carbon sequestration to support sustainability in the farming system are the primary goals of carbon-smart agricultural methods. These methods are absolutely essential in slowing down global warming and maintaining agricultural output. Directly helping in carbon sequestration and soil health improvement are methods like agroforestry, which mixes trees with crops and animals (ICIMOD., 2014). The zero tillage technique, an efficient carbon-smart method, reduces the use of fossil fuels and prevents the loss of soil organic carbon, thereby mitigating their impact (Khatri-Chhetri et al., 2017). Mulching, green manuring, and crop residue management, among other methods, raise soil organic matter and improve carbon sequestration. While offering resistance against seasonal weather fluctuations, perennial crops and plantations also greatly help to sequester carbon (Paudel et al., 2016). Green manuring is the technique whereby green plants used as bio-fertilizer, along with their parts (stem, leaves, twigs, or roots), are either incorporated into the soil or not to enhance soil health by adding nutrients contained in them. This method aids in raising the content of plant nutrients in soil such that crop yields and productivity will rise. Popular for green manuring techniques among Nepalese farmers, some plant species include Crotalaria juncea, Sesbania rolete, and Azolla (NARC., 2014). The pyrolysis of organic matter, a method that involves heating biomass in an oxygen-deprived environment, generates biochar, a carbon-dense substance (Gyawali., 2024).

The utilization of biochar in soils enhances soil fertility, augments carbon sequestration, and improves water retention. It presents a viable solution to two of the most urgent issues of our time: soil degradation and climate change (Gyawali., 2024).

### 3.7 Weather smart

A study by talks about how implementing weather-smart agricultural technologies in Nepal, such as building climate-resilient housing for livestock, has a big impact on protecting animals from sudden changes in temperature (Khatri-Chhetri et al., 2017). Access to climate data, encompassing both seasonal forecasts and real-time information, enables farmers to mitigate climate-related risks and make informed choices regarding planting and irrigation practices (Paudel et al., 2016). Additionally, crop insurance programs provide a financial safety net for farmers facing income losses due to erratic weather patterns, while weather-based crop advisory services from various governmental bodies deliver tailored recommendations (FAO, 2010).

### 3.8 Knowledge smart

Knowledge-smart agricultural technologies in Nepal focus on enhancing resilience to climate risks and improving productivity. Contingent crop planning helps farmers manage weather-related contingencies like drought, floods, and temperature stresses (Paudel et al., 2016). While fodder banks are very important for resource conservation for cattle, enhanced short-duration crop varieties that show tolerance to extreme environmental conditions offer practical answers to the problems presented by climate change. Established seed systems and banks help access climate-resilient seed varieties; high-yielding, stress-tolerant cattle breeds show better performance under climatic stress, improving general farm productivity (FAO., 2010). Furthermore, reducing the risk of income loss is diversifying methods of farming and fisheries. Particularly in view of abiotic stresses, the use of area-specific mineral mixtures and rotational grazing techniques improves the health of cattle (Paudel et al., 2016).

## 4. CSA: Policies, Institutions And Strategies In Nepal

With its wide spectrum of policy and initiative tools to reduce agriculture from this climate factor, the Government of Nepal has taken significant action in the field of climate change. Establishing a National Climate Change Policy in 2011, these are NAPA, or the National Adaptation Program of Action, and the LAPAs, or Local Adaptation Plans of Action, meant to support methodsologies creating climate-resilient agriculture. While some areas, depending on the type of climate vulnerabilities and agricultural systems, demand more investment, the ADS of Nepal gives capacity enhancement top priority. Although agriculture does not help to lower greenhouse gas emissions, several efforts are being made to combine CSA technologies into national and local levels in order to improve resilience in addition to achieving food security. Pilot testing and technical support for CSA have helped governments, LI-BIRD, CCAFS, Practical Action, and other non-governmental organizations to be supportive (Khatri-Chhetri et al., 2017). Particularly for the period 2017–2019, this 14th plan especially targets 150 communities where CSA has been encouraged. Making the CSV program, which just began in 2016, run efficiently depends on scaling up climate-friendly technologies in agricultural production and building an enabling environment (Adhikari et al., 2016).

The institutional environment for CSA implementation in Nepal is disjointed, with poor agency coordination, so slowing down development. Nonetheless, the recently developed federalist system of the nation is expected to enable more localized planning, so giving local governments more influence in the application and promotion of CSA methods. Leading the development of climate-related policies is the Ministry of Population and Environment (MoPE), working with other ministries including MoAD and MoLD. Moreover, by providing technical knowledge and financial support, international agencies including FAO and UNDP have strengthened Nepal's efforts at climate adaptation. Nepal has set goals for low-carbon development, such as promoting climate-friendly farming technologies, creating crops that can survive floods and droughts, and boosting the use of renewable energy sources, such as biogas plants for farm households (Paudel et al., 2016).

Government of Nepal is also implementing various policies and programs in the field of climate change and agriculture that are;

- Disaster Risk Management Strategy, 2009 2010 National Adaptation Program of Action Climate Change Policy (NAPA.,2011).
- Sustainable Local Government: Environment Friendly 2013
- Strategy and Action Plan for Nepal Biodiversity 2014–20
- Policy on agro-biodiversity; policy on irrigation; low carbon and economic development strategy (LCEDS); land use policy, 2014;2015:
- Nature Conservation: 2015–2030 National Strategic Framework for Sustainable Development
- Local Adaptation Program of Actions (LAPAs., 2015) Agriculture Development Strategy (ADS) 2015
- Draft Intended Nationally Determined Contributions (INDC., 2015)
- Nepal National REDD Strategy 2018

## 5. Climate Smart Villages (CSV)

A Climate Smart Village is a community or group of communities where farmers, government officials, agricultural research institutions, and non-governmental organizations work together to understand and use smart climate-friendly practices. Testing, demonstrating, and validating climate-friendly technologies at the local level is part of the CSV approach. Planning takes place at the village level, and local knowledge and institution involvement based on climate data are also used (Adhikari et al., 2016). Through cooperative research projects, the method uses Participatory Action Research (PAR) to enable community involvement, increase stakeholder engagement, and generate knowledge.

The structure of this model combines local-level testing and validation to support a portfolio of Climate Smart Technologies, or CSTs, along with methods. This model aims to scale up affordable and effective solutions that would allow local planning, integration of indigenous knowledge and institutions, as well as the use of climate data inside societies. CSV is created mostly using PAR also known as participatory action research (Adhikari et al., 2016). Not only shows the degree of central community involvement but also motivates stakeholders to participate in pragmatic projects whereby collective research generates knowledge. Several difficulties pertaining to climate-smart villages and farmers' adaptation to different climate-smart agricultural methods in Nepal consist of:

**Table 1:** Problems and CSA Practices in Nepal

| Districts | Problems | CSA Practices |
|---|---|---|
| Bardiya (Deudakala, Mohamamdpur, Belawa) | Rising average temperatures adversely affect the fruiting processes of solanaceous crops. Additionally, arid soil conditions hinder crop growth, shorten the grain filling duration, and diminish the yield of winter crops and fodder, as well as the emergence of new plants. Delayed arrival of rainfall further complicates timely crop cultivation. Furthermore, flooding events can lead to the accumulation of sand in agricultural fields, resulting in damage to the cultivated land. | Early-maturing hardinath combined with drought-tolerant rice varieties including sukha 1,2 and 3 are being used. Using water from a small stream plowing, planking, burning sick plants and groundwater. Use of the variant resistant to chickpea disease-abarodhi. High root cutting termite infestation forces one to turn from rice to banana. Developing dwarf tolerant varieties of crops (wheat, rice, maize) to fit storm |
| Dang(Rampur,Hekuli,Dhanauri) | Raised temperatures cause plants to wither. An insect pest invasion including powdery mildew and borer. Reduced rainfall influences panicle initiation, forced early maturity of crops, low production of late-planted rice, the spread of undesired weeds. Beginning and ending the monsoon, riverbank cutting resulting from flooding, landslip. | The establishment of gabion walls, alongside a prohibition on residential construction in the proximity of the river. The cultivation of alternative crops such as linseed, and the development of water harvesting ponds. Furthermore, the utilization of solar pumps for the extraction and distribution of irrigation water |
| Nawalparasi (Narayani, Rajahar, Tamsariya) | Rise in temperature an epidemic of illnesses, Increase the number of hot days; lower the rainfall; unable to raise the seedbed in time. | Organic farming and titepati application combined with neem leaves and cattle urine. Field hygiene and weed burning. Gabion, reforestation, bamboo, and Amriso Growing drought-tolerant varieties, adjusting planting time to get beyond floods. |
| Mahottari(Sarpallo,Hattisarwa,Rajbas) | Insect infestation prominent in mango production; very hot days hampered rice yield; the extra cost of water inputs; dry days affect cattle raising with sunstroke; less milk production. | Mostly Sukhha-4, bioengineering, damp building, and afforestation, drought is adapted via irrigation canal, drip irrigation, and growing a drought-resistant variety of rice. |

| Table 1 (Cont.): Problems and CSA Practices in Nepal | | |
|---|---|---|
| Gorkha(Ghyachock,Bhulmichock) | The increase in the frequency of insect pests combined with changes in rainfall, prolonged dry spells, and events of floods and landslides greatly affects livelihoods. | Extended dry spells force farmers to abandon their fields unkempt.<br>The difficulties given by changed precipitation patterns and soil erosion complicate their decision-making process. |

(Adhikari et al., 2016)

## 6. Challenges

Even if CSA techniques and adaptation have many advantages, they are rather rare in Nepal. Similar to Nepalese conditions, climate-smart agriculture faces significant obstacles due to uncoordinated funding for adaptation and mitigation (Buchner et al., 2011). Important determinants of the acceptance of CSA are socio-economic traits of farmers, agroecological zones, and the credit of new technologies. Thus, variations in climatic zones, socioeconomic features, and food production systems complicate CSA. A targeted parameter has to include young, female, and underprivileged farmers (Cabell and Oelofse., 2012). Local organizations greatly help to convert coping capacity into adaptive capacity and inspire smallholder farmers and underprivileged groups (Berman et al., 2012). To get desired outcomes in Nepal, several sectors of agriculture, climate change, food security, programs, and policy should cooperate. There is rather little evidence-based knowledge on CSA fit for Nepali farming conditions. The complicated and non-linear processes involved in the diffusion and scaling-up of CSA technologies are not well known to agricultural professionals or organizations at present. There is much room for development in institutional capacity and coordination among government agencies, corporate players, and non-governmental organizations engaged in CSA. Though several projects encouraged agricultural adaptation, most of them were unsustainable project-based solutions. Apart from that, policies and clauses do not particularly target the promotion of environmentally friendly farming methods (Paudel et al., 2017).

## 7. Pathways For Csa Scalability

Researchers have created three distinct models to meet specific needs, settings, institutional frameworks, and technological characteristics for advancing climate-smart agriculture solutions: Researchers have established three distinct models to address specific needs, settings, institutional frameworks, and technological characteristics for advancing climate-smart agriculture solutions: Targeting input-intensive or proprietary technologies, the commercial business model places great emphasis on private companies in scaling by providing required inputs. The policy incidence model addresses CSA options requiring the removal of policy obstacles or more government support to enable acceptance. At different program levels, scaling up CSA is a long-term, dynamic process involving many stakeholders and multidisciplinary approaches using several methodologies. By transcending conventional models for projects, the suggested routes will guarantee more general applicability and sustainable impact over time (Paudel et al., 2017).

## 8. Recommendation

The development of adequate and competent human resources in line agencies through the use of scientific knowledge and technology for risk monitoring and solution-oriented program implementation addresses CC challenges effectively. Improved access to quality local and worldwide climate data is essential to informed policy development. The strategy will enhance preparedness, CC adaptation, and access to CSA practices, which in turn will contribute to improved soil fertility and condition through strengthening institutional and technical capacities. Besides the creation of CC focal units with clear mandates, initiatives should focus on the enhancement of early warning systems in agriculture. Guided by the vulnerability and risk studies, the NARC should accord the highest priority to developing location-specific CSA technologies. Capacity building is also needed to assess financing gaps, develop plans, engage potential partners, and align initiatives with national and international commitments.

## 9. Conclusion

Climate-smart agriculture in Nepal can offer huge potential in mitigating the challenges brought forth by climate change to agriculture. Integrated into water, soil, crop, energy, and weather management, CSA helps in enhancing productivity, resilience, and sustainability. This includes drought-tolerant crops, renewable energy adoption, and efficient soil management methods that would help mitigate climate impacts and ensure food security. Despite its potential, CSA in Nepal faces several challenges. The complicated procedures involved in scaling CSA technologies are little known, and evidence-based knowledge of CSA practices as fit for Nepali agricultural systems is lacking. Furthermore, much has to be done with regard to capacity and coordination in government agencies, the business sector, and NGOs. Although different knowledge-transfer, commercial business, and policy incidence models have been developed to promote CSA, their implementation is plagued by sustainability challenges. The CSV approach has shown promise, particularly with its focus on participatory action research and community engagement, but better coordination and long-term commitment are needed. To reach the stated sustainable development goals by 2030 in Nepal, targeted, context-specific interventions and accurate baseline data are absolutely essential. Effective application of CSA will call for cooperation on government policies, planning, research, and NGO support. Additional effective elements of CSA are soil and water management, crop management, agroforestry, animal management, and access to climate information. For both the present and future, CSA would be important in reducing food insecurity and poverty in addition to lowering the risks from a changing climate.

## References

Adhikari, L.D., Paudel, B., Awale, P., Rasaili, S., Shrestha, D.K., Bhusal, A., 2016. Climate-smart villages in Nepal - Baseline report. Local Initiatives for Biodiversity, Research, and Development (LI-BIRD) and The Consultative Group for International Agricultural Research's (CGIAR) Research Program on Climate Change, Agriculture, and Food Security (CCAFS), Kaski, Nepal.

Aggarwal, P., Jarvis, A., Campbell, B., Zougmoré, R., Khatri-Chhetri, A., Vermeulen, S., Loboguerrero, A. M., Sebastian, S., Kinyangi, J., and Bonilla Findji, O., 2018. The climate-smart village approach: Framework of an integrative strategy. Ecology and Society, 23 (1), Pp. Article 15.

Aggarwal, P., Zougmoré, R., and Kinyangi, J., 2013. Climate-smart villages: A community approach to sustainable agricultural development. CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS).

Berman, R., Quinn, C., and Paavola, J., 2012. The role of institutions in the transformation of coping capacity to sustainable adaptive capacity. Environmental Development, 2, Pp. 86–100.

Bhujel, R.B., and Ghimire, S.P., 2006. Estimation of production function of Hiunde (Boro) rice. Nepal Agricultural Research Journal, 7, Pp. 88-97.

Bogdanski, A., Dubois, O., Jamieson, C., and Krell, R., 2010. Making integrated systems work for people and climate (pp. 1–136). Food and Agriculture Organization of the United Nations (FAO).

Cabell, J.F., and Oelofse, M., 2012. An indicator framework for assessing agroecosystem resilience. Ecology and Society, 17(1).

Campbell, B.M., Thornton, P.K., Zougmoré, R., van Asten, P., and Lipper, L., 2014. Sustainable intensification: What is its role in climate-smart agriculture? Current Opinion in Environmental Sustainability, 8, Pp. 39–43.

Campbell, B.M., Vermeulen, S.J., Aggarwal, P.K., Corner-Dolloff, C., Girvetz, E., Loboguerrero, A.M., 2016. Reducing risks to food security from climate change. Global Food Security, 11, Pp. 34–43.

Central Bureau of Statistics (CBS)., 2022. Nepal in figures .,2022. Government of Nepal.

Child-Centered D., R Reduction and C (CDCC) Consortium., 2022. Save the Children, UNICEF, Plan International Nepal, and World Vision International Nepal, Kathmandu, Nepal.

Conforti, P., 2011. Looking ahead in world food and agriculture: Perspectives to 2050. Food and Agriculture Organization of the United Nations (FAO).

Dangal, R., 2012. Country profile: Nepal. Asian Disaster Reduction Center (ADRC).

Division, R., 2022. Climate Smart Agriculture : A Key to Sustainability At a Glance. 4589.

FAO., 2009a. The state of food and agriculture: Livestock in the balance.

FAO., 2009. Agriculture and environmental challenges of the twenty-first century: A strategic approach for FAO (FAO COAG/2009/3, Committee on Agriculture Twenty-first Session, p. 11).

FAO., 2010. Climate-smart agriculture: Policies, practices and financing for food security, adaptation and mitigation. Rome

FAO., 2018. Upscaling climate-smart agriculture: Lessons for extension and advisory services (Occasional Papers on Innovation in Family Farming). Rome

FAO. 2022. World Food and Agriculture – Statistical Yearbook 2022. Rome.

Fischer, G., Tubiello, F.N., van Velthuizen, H., and Wiberg, D.A., 2006. Climate change impacts on irrigation water requirements: Effects of mitigation, 1990–2080. Technological Forecasting and Social Change, 74, Pp. 1083–1107.

Fraval, S., Hammond, J., Bogard, J.R., Ng'endo, M., van Etten, J., Herrero, M., 2019. Food access deficiencies in Sub-Saharan Africa: Prevalence and implications for agricultural interventions. Frontiers in Sustainable Food Systems, 3, Pp. 104.

Goopy, J.P., Onyango, A.A., Dickhoefer, U., and Butterbach-Bahl, K., 2018. A new approach for improving emission factors for enteric methane emissions of cattle in smallholder systems of East Africa – Results for Nyando, Western Kenya. Agricultural Systems, 161, Pp. 72–80.

Gajjela, S., Chatterjee, R., Subba, S., and Sen, A., 2018. Prospect of liquid organic manure on organic bitter gourd cultivation. Journal of Pharmacognosy and Phytochemistry, 7 (6), Pp. 189–193.

Grogan, P., Lalnunmawia, F., and Tripathi, S.K., 2012. Shifting cultivation in steeply sloped regions: A review of management options and research priorities for Mizoram state, Northeast India. Agroforestry Systems, 84 (2), Pp. 163–177.

Gyawali, A., 2024. Biochar for soil health and climate change mitigation: A sustainable approach. Ecofeminism and Climate Change, 5(2), 94–103.

Haileslassie, A., Mekuria, W., Uhlenbrook, S., Ludi, E., and Schmitter, P., 2022. Gap analysis and methodological framework to assess and develop water-centric sustainable agricultural intensification pathways in sub-Saharan Africa. Frontiers in Water, 4, Article 747610.

International Centre for Integrated Mountain Development (ICIMOD)., 2014. Agroforestry systems in Nepal: Enhancing resilience and soil health. ICIMOD.

IPCC. 2007. Climate change 2007: The fourth assessment report. Impacts, adaptation, and vulnerability.

IPCC, 2007b. Climate change: Physical change basis.

Khatri-Chhetri, A., Poudel, B., and Shirsath, P.B., 2017. Assessment of climate-smart agriculture (CSA) options in Nepal. CGIAR Research Program on Climate Change, Agriculture, and Food Security (CCAFS) and Local Initiatives for Biodiversity, Research, and Development (LI-BIRD).

Lipper, L., Thornton, P., Campbell, B.M., Baedeker, T., Braimoh, A., Bwalya, M., Caron, P., Cattaneo, A., Garrity, D., Henry, K., 2014. Climate-smart agriculture for food security. Nature Climate Change, 4 (12), Pp. 1068–1072.

Malla, G., 2008. Climate change and impact on Nepalese agriculture. Journal of Agriculture and Environment, 9 (5).

Nepal., A., R Council (NARC)., 2014. Green manuring for increased crop production. Communication, Publication, and Documentation Division.

Neufeldt, H., Jahn, M., Campbell, B.M., Beddington, J.R., DeClerck, F., De Pinto, A., Gulledge, J., Hellin, J., Herrero, M., Jarvis, A., LeZaks, D., Meinke, H., Rosenstock, T., Scholes, M., Scholes, R., Vermeulen, S., Wollenberg, E., and Zougmoré, R., 2013. Beyond climate-smart agriculture: Toward safe operating spaces for global food systems. Agriculture and Food Security, 2 (1), Pp. 12.

Pahl-Wostl., C., 2007. Transitions towards adaptive management of water facing climate and global change. Water Resources Management, 21, Pp. 49–62.

Pareek., N., 2017. Climate change impact on soils: Adaptation and mitigation. MOJ Ecology and Environmental Science, 2 (3), Pp. 136–139.

Pawar-Patil., V.S., and Mali, S.P., 2013. Watershed characterization and prioritization of Tulasi subwatershed: A geospatial approach. International Journal of Innovative Research in Science, Engineering and Technology, 2, Pp. 1230–1235.

Paudel., B., Bhatta, K.P., and Chaudhary, P., 2016. Climate-smart agriculture (CSA): Technologies and practices for Nepal. Local Initiatives for Biodiversity, Research, and Development (LI-BIRD).

Paudel., B., Khanal, R.C., K. C., A., Bhatta, K.P., and Chaudhary, P., 2017. Climate-smart agriculture in Nepal: Champion technologies and their pathways for scaling up. Local Initiatives for Biodiversity, Research and Development (LI-BIRD) CGIAR Research Programme on Climate Change, Agriculture, and Food Security (CCAFS).

Pelster, D.E., Rufino, M.C., Rosenstock, T., Mango, J., Saiz, G., Diaz-Pines, E., 2017. Smallholder farms in eastern African tropical highlands have low soil greenhouse gas fluxes. Biogeosciences, 14 (1), Pp., 187–202.

Pretty, J., Toulmin, C., and Williams, S., 2011. Sustainable intensification in African agriculture. International Journal of Agricultural Sustainability, 9 (1), Pp., 5–24.

Rakesh, S., Poonguzhali, S., Saranya, B., Suguna, S., Jothibasu, K., 2017. Effect of Panchagavya on growth and yield of abelmoschus esculentus cv. Arka Anamika. International Journal of Current Microbiology and Applied Sciences, 6, Pp. 3090–3097. https://doi.org/10.20546/ijcmas.2017.609.380

Rosenstock., T.S., Lamanna, C., Namoi, N., Arslan, A., and Richards, M., 2019. What is the evidence base for climate-smart agriculture in East and Southern Africa? A systematic map. In T. Rosenstock, A. Nowak, and E. Girvetz (Eds.), The Climate-Smart Agriculture Papers (pp. 141–151). Springer.

Schiere, J.B., Ibrahim, M.N.M., and van Keulen, H., 2002. The role of livestock for sustainability in mixed farming: Criteria and scenario studies under varying resource allocation. Agriculture, Ecosystems and Environment, 90 (2), Pp., 139–153.

Steenwerth, K.L., Hodson, A.K., Bloom, A.J., Carter, M.R., Cattaneo, A., Chartres, C.J., Hatfield, J.L., Henry, K., Hopmans, J.W., Horwath, W.R., Jenkins, B.M., Kebreab, E., Leemans, R., Lipper, L., Lubell, M. N., Msangi, S., Prabhu, R., Reynolds, M. P., Solis, S. S., … Jackson, L. E. ., 2014. Climate-smart agriculture global research agenda: Scientific basis for action (pp. 1–39).

Takeshima, H., and Mano, Y., 2023. Intensification of rice farming: The role of mechanization and irrigation. In K. Otsuka, Y. Mano, and K. Takahashi (Eds.), Rice green revolution in sub-Saharan Africa (pp. 143–160). Springer Nature.

University of California, Davis. Climate-smart agriculture policy. UC Davis Environmental Policy. Retrieved December 13, 2024.

Van Wijk, M. T., Merbold, L., Hammond, J., and Butterbach-Bahl, K., 2020. Improving assessments of the three pillars of climate-smart agriculture: Current achievements and ideas for the future. Frontiers in Sustainable Food Systems, 4.

Vanlauwe, B., Chianu, J., Giller, K. E., Merck, R., Mokwenye, U., Pypers, P., 2010. Integrated soil fertility management: Operational definition and consequences for implementation and dissemination. Outlook on Agriculture, 39 (1), Pp. 17–24

Von Koerber, K., and Kretschmer, J., 2006. Ernährung nach den vier Dimensionen: Wechselwirkungen zwischen Ernährung und Umwelt, Wirtschaft, Gesellschaft und Gesundheit. Ernährung and Medizin, 21, Pp. 178–185. Medizinverlage Stuttgart GmbH & Co.

Wiederkehr, C., Beckmann, M., and Hermans, K., 2018. Environmental change, adaptation strategies, and the relevance of migration in Sub-Saharan drylands. Environmental Research Letters, 13(11), Pp. 113003.

Zhu., Y., Merbold, L., Pelster, D., Diaz-Pines, E., Wanyama, G.N., and Butterbach-Bahl, K., 2018. Effect of dung quantity and quality on greenhouse gas fluxes from tropical pastures in Kenya. Global Biogeochemical Cycles, 32(11), Pp. 1589–1604.

Zhu, Y., Merbold, L., Leitner, S., Xia, L., Pelster, D. E., Diaz-Pines, E., 2020. Influence of soil properties on $N_2O$ and $CO_2$ emissions from excreta deposited on tropical pastures in Kenya. Soil Biology and Biochemistry, 140, 107636.