Scaling-up of climate smart agriculture technologies in Nepal: An assessment of policy and institutional constraints and strategies

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Abstract

Ranked the 10th most vulnerable country to climate change, Nepal has in recent years ramped up its efforts to adopt climate smart agriculture technologies, however, challenges remain. This strategy paper critically reviews the constraints for adoption and scaling up for three chosen CSA technologies: direct seeded rice, alternate wetting and drying, and drip irrigation based on available literature as well as consultations. While these technologies have proven to minimize use of scarce water resources, reduce GHG emissions, as well as improve yields, many factors – technological, institutional as well as resource-related - have constrained their uptake. Specialized extension support and availability of advanced inputs are important for the promotion of these technologies while it is crucial to counter the concerns relating to occurrence of pests, weeds, diseases or other novel conditions that sometimes emerge with the adoption of these technologies.

Introduction

Nepal is a landlocked country and diverse in terms of landscape, topography, altitude, and geography. The nation is divided into three sub-parts based on the agro-ecological zones: mountain, hill, and terai regions, covering land area of around 35%, 42%, and 23%, respectively and 21% of the land area is utilized for agriculture purposes (MoALD, 2022). Small-scale and subsistence farming is still a dominant source of livelihood in the rural areas of Nepal. According to National Population and Housing Census (NPHC) 2021, around 33% of the households reside in rural areas. Agriculture contributed around 22% to the country's GDP in 2021 (Statista, 2023). World Bank has estimated employment statistics based on ILO data that around 62% of the population is employed in agriculture (World Bank, 2021).

Nepal's distinctive topography and social vulnerability makes it highly susceptible to climate change. Nepal has been ranked as the 10th most vulnerable country to climate change between 2000 – 2019 in the global climate risk index (Eckstein, Kunzel, & Schafer, 2021). Additionally, Nepal has been ranked 128 out of 181 countries in 2020 ND-GAIN index[1] (Chen, et al., 2020). It is projected that warming in Nepal will be higher than the global average. It is estimated that by 2080, Nepal will be warmed by 1.2ºC – 4.2ºC under RCP 8.5, highest emission scenario, in comparison to the baseline period (1985-2005) (ADB, 2021). The country is highly vulnerable to geological and climate-related hazards due to its varied landscape, high rainfall during monsoon, and its position in the active seismic zone (NPC & WFP, 2019). Moreover, the country is highly vulnerable to climate change also because of its high exposure and low adaptive capacity as a result of hydro-meteorological hazards, dependency on agriculture, rapid population growth, shrinking farm size in the Terai region, and rise in unplanned agriculture in the areas prone to climate change (Selavaraju, 2014). The Government of Nepal has also estimated a decline of 2.4% in the current GDP per year due to climate change along with an investment of $2.4 billion in adaptation by 2030 (IDS-Nepal, PAC, & GCAP, 2014).

Given the high risk and danger posed by climate change in the county, Government of Nepal has implemented several policies and initiatives to mitigate the impacts of climate change and promote sustainable economic development. Some of the key initiatives are the National Adaptation Program for Action (NAPA), National Climate Change Policy (NCCP), and National Framework for Local Adaptation Plans for Action (LAPA) and many more. All these steps taken by the government focus on promoting the adaptation measures, building resilience, and mitigating the negative impacts of climate change on Nepal's agrarian economy. Climate-smart agriculture (CSA) is one of those measures that aims at maximizing crop productivity and developing climate resilience. Hence, scaling-up of CSA practices is essential to foster development and secure the future of all the sections of society.

Scaling-up can be defined as efficiently increasing the socio-economic impact from a small to large scale coverage, referring to the replication, spread, or adaptation of techniques, ideas, approaches, and concepts, along with increasing the scale of impact (World Bank, 2003). It brings about the qualitative benefits to a wider population over a broader geographical area, quickly, equitably, and lastingly (Franzel, Cooper, & Denning, 2001). It is a long-term and non-linear process combining generalized and context specific approaches, with a focus on activities integrating local and external knowledge and mainstreaming new principles and processes (World Bank, 2003). It requires a multi-dimensional approach involving policy support, capacity building, financial incentives, and collaborations with different stakeholders. Since it is a linear process, we assume it to be horizontal, vertical, and diagonal processes.

Horizontal scaling involves repetition of proven technologies in new geographical zones or target groups, for instance, a technology that has been proven successful on pilot farms can be scaled through farmer-to-farmer exchanges (World Bank, 2003). Vertical scaling-up necessitates driving institutional and policy transformations by showcasing effectiveness and efficiency of practices and technologies which entails eliminations of obstacles from large number of people (World Bank, 2003). It refers to increasing the production capacity and efficiency within a specific farming system. It comprises of methods to enhance output, improve processes, and maximize the limited resources optimally. Since scaling-up of CSA technologies is non-autonomous, there is a need for facilitation in terms of conducive policies and

[1] ND GAIN index ranks 181 countries based on scores which calculates country's vulnerability to climate change and other global challenges along with their readiness to improve resilience.

institutional/structural changes (Makate, 2019). Lastly, diagonal scaling-up involves adding more project components or modifying project configurations in response to the evolving realms of society, for example, extension services can be added (Neufeldt, et al., 2015). There are three main stages of scaling-up: effectiveness, efficiency, and expansion. These stages represent sequence of investments, transitions, and outcomes on the way to CSA adoption (Neufeldt, et al., 2013).

Scaling of CSA practices is the expansion of the adoption of the proven and effective CSA technologies. Successful scaling-up of CSA practices require identification and promotion of appropriate technologies, enabling environments constituting of supportive institutional arrangements, policies, and financial investments at local to international levels, along with recognizing probable bottlenecks and opportunities such as market and policy drivers will be central to implementing CSA activities at scale (Neufeldt, et al., 2015). Policy strategies are vital as they provide a clear framework that sets guidelines and responsibilities essential for scaling up (Makate, 2019). On the other hand, effective and complementary institutional actions towards scaling can reduce farmer challenges, adoption constraints, and improve sustainability in scaling process, which can altogether improve the impacts of CSA practices in the society (Makate, 2019). To make CSA more effective and efficient, coordinated actions are required from farmers, researchers, private sector, civil societies, and policymakers in four major areas – building evidence, increasing efficiency of local institutions, fostering coherence between climate and agricultural policies, and linking climate and agricultural financing (Lipper, et al., 2014).

Given this background, IFAD developed and approved the Consortium for Scaling-Up Climate Smart Agriculture in South Aisa (C-SUCSeS) with the objective of promoting sustainable and resilient agricultural intensification in South Asia. In this paper, we focus on studying the CSA technologies prioritized for Nepal. We describe each of the technologies and highlight the key constraints in adoption of these technologies and prescribe a few policy solutions to overcome them. These constraints and strategies have been computed through secondary literature along with primary survey and focused group discussions with farmers, extension agents, and other stakeholders in the value chain in the country. We focus on vertical scaling-up process of CSA technologies. While horizontal scaling-up involves replication of proven technologies in different areas, the efficacy of same technologies can vary in different agro-climatic zones in different regions. Hence, we emphasize expanding proven technologies in the same area by increasing their adoption and expansion among farmers in that specific agro-climatic zone.

The selected CSA technologies for Nepal are direct seeded rice (DSR), alternate wetting and drying (AWD) method, and drip irrigation. Below, we discuss technology-wise challenges and policy solutions.

Review of selected CSA technologies

1. Direct seeded rice

Direct seeded rice (DSR) is an alternative method to cultivate rice in which the crop is seeded directly into the un-puddled fields. Direct seedling is a crop establishment system in which rice seeds are sown directly into the fields as compared to conventional method of growing seedlings in a nursery and then transplanting them into the flooded fields. DSR (wet and dry direct seeding) is practiced in about 95% of the total rice grown in Sri Lanka and more than 90% in Malaysia, and it is proven to be sustainable and eco-friendly because it emits less methane than transplanted rice (Sharma, Sharma, Yadav, & Sodari, 2021). In Nepal, DSR is practiced in dry fields in the uplands, more prevalent in the hilly region, and in the eastern and western lowlands where water gets stagnated in the monsoons (Malla, 2021). DSR is assumed to be one of the most efficient, sustainable, and economically viable rice production systems. In comparison to the traditional transplanted rice method prevalent in Asia, DSR assures faster planting and maturing of the crop, conserves scarce resources, is more conducive to mechanization, and reduces GHG emissions that contribute to climate change. Moreover, mechanized DSR also creates opportunities for employment through new service provisions and is less labour intensive and free from drudgery which becomes more attractive to youth and female farmers.

Field experiments at different research sites have shown that DSR helps in saving irrigation water (Bista, 2018), reducing labour requirements (Bista, 2018), decreasing cost of production with higher net returns (Mishra, Khanal, & Pede, 2017) (Kumar, et al., 2022), reducing GHG emissions (Bista, 2018), and increasing crop productivity (Bista, 2018) (Mishra, Khanal, & Pede, 2017). (Kumar, et al., 2022) reported that adoption of DSR resulted in increase in net income, crop yield, and reduction in cost of production with a benefit-cost ratio of 2.95 as compared to 1.88 in traditional transplanted method. On the other hand, Kamboj et. al. (2022) reported a higher benefit-cost ratio of 4.78 for DSR as compared to 3.87 for conventional transplanting method. (Devkota, Devkota, Acharya, & McDonald, 2019) reported comparable yields and lower cost of production by $160 per hectare in DSR as compared to puddled rice cultivation in western Terai region of Nepal, along with a higher water productivity by 4-18%.The key constraints faced by Nepalese farmers in adoption of DSR are as follows:

a) Unavailability of DSR drills and their spare parts.
b) Lack of knowledge and training in operating the drills, leading to non-uniform distribution of seeds.
c) Excessive incidences of weeds.
d) Improper sowing time and irregular rainfall, leading to rise in risk of seeds getting washed away or buried deep after germination.

A major constraint reported by the scientists for the successful establishment of DSR method is weed management (Bista, 2018). High weed infestation is a major challenge in DSR, especially in dry soil conditions (Rao, Johnson, Sivaprasad, Ladha, & Mortimer, 2007). Water management practices in DSR directly affect the crop microclimate as well as the lifecycles of pathogen, and influences crop physiology and susceptibility. In dry-seeded rice it was observed that the weeds germinated simultaneously with rice because of absence of a water layer to suppress the growth of weeds (Farooq, Siddique, Rehman, & Aziz, 2011). DSR also shows growth of weedy rice as well as incidence of weeds becoming resistant to herbicides. Further, micronutrient deficiencies are common in DSR due to imbalances in nutrients likes Zn, Fe, Mn, S, and N often caused by improper and imbalanced application of nitrogen fertilizer (Sandhu, Yadav, Singh, & Kumar, 2021). Infestation of diseases, insects and pests, panicle sterility, lodging, and soil sickness can create further challenges in DSR (Farooq, Siddique, Rehman, & Aziz, 2011) (Bhatt & Kukal, 2015).

Choice of appropriate rice variety for DSR is also crucial. Better drought tolerance, and cultivars with short duration, short-statured, long-rooted, resistance-to-lodging and blast, and early vigor as well as improved resistance to adverse soil conditions such as mineral toxicity and deficiency, short mesocotyls for herbicide tolerance, and resistance to rice blast were identified as some important traits for suitability for DSR (Farooq, Siddique, Rehman, & Aziz, 2011). Absence of appropriate rice varieties has led farmers to increase the seed rates up to 2-3 times in DSR which is a very costly decision. In Nepal rice varieties such as Sona mansuli, Hardinath, Radha-4, Radha-11, Chaite-2 have been identified as suitable for DSR. Other major challenges faced by the farmers in adopting DSR is the unavailability of machines, lack of knowledge and training in operating the DSR machines, and high irrigation costs using diesel pump. Since traditional methods of land leveling left large variability on land, it led to challenges in uniformity in water distribution and caused yield variability; it was suggested to use laser assisted precision land levelling to address this problem under DSR technique (Kumar & Ladha, 2011). Multicrop planters with a precise seed metering system to achieve accurate and precise seeding were suitable for DSR. This is useful for achieving better yields through uniform crop emergence and optimum plant density in direct drill-seeded rice. Further, it also lowers the seed rate and achieves precise plant-to-plant spacing. However, unavailability of such a "complete DSR production technology" was identified as a major constraint of DSR adoption in South Asia. Import restrictions, prohibitive transportation costs, high maintenance costs of DSR machines with use of imported spare sparts, and lack of a supply chain for affordable, durable, light weight, compact, low-power, eco-friendly, multi-purpose and marketable machines that could meet farmers' operational need were also important challenges in DSR adoption (Sandhu, Yadav, Singh, & Kumar, 2021). ..

To foster the expansion and scaling-up the adoption of DSR in Nepal, here are few policy recommendations. Firstly, empowering farmers with comprehensive education, skills, and training is fundamental for successful adoption of DSR. Field demonstrations is an important step to equip the farmers with skills and training required for operating the DSR machines. Secondly, ensuring availability and accessibility to DSR machines is pivotal for adoption and reducing barriers of the farmers to adoption. Besides this, proper infrastructure is essential for smooth adoption of the DSR practice. Administering trainings on the use of fertilizers, pesticides and weedicides is important to ensure its use within the recommended quantities to reduce its harmful effect on crops as well as environment. Inability to follow the recommended fertilizer schedule and weed control package (choice of herbicide, time of application, frequency, volume and even selection of appropriate nozzle for dispersion can be detrimental to crop yields under DSR (Mahajan, Chauhan, & Gill, 2013). Further, the state also must control the adoption of low-quality inputs by monitoring the formulations, concentrations of active agents, product information and labelling (Bilal & Jaghdani, 2024). Poor quality herbicides can endanger the soil microorganisms, birds and other non-targeted organisms, endangering the ecosystem services. Financial incentives and ease in credit services will also play a crucial role in reducing the financial burden of the farmers and ensure a smoother transition to DSR practice from their traditional practice. Custom hiring center facilities to make appropriate farm machinery available such as seed drills, seed metering device, land levelling device, etc. can be an important determinant for adoption of DSR (Mahajan, Chauhan, & Gill, 2013).. Finally, an increase in extension services will ensure farmers with proper guidance related to agricultural activities in DSR such as effective water management, land levelling, ensuring good water drainage system and bund management (Kumar & Ladha, 2011). Hence, integrating all these measures will encourage a widespread adoption of DSR in the country.

2. Alternate wetting and drying

Alternate Wetting and Drying (AWD) is a method of water management practiced in lowland irrigated rice with less water than usual system of maintaining continuous standing water in the crop field. It is a method of controlled and intermitted irrigation. Under this method, the agricultural farms are subjected to alternate flooding and drying instead of continuous flooding throughout the complete rice cultivation cycle. Fields are re-flooded when soil surface attains aerobic state and water is allowed to subside via percolation and evapo-transpiration (Ishfaq, et al., 2020). The key three components of AWD are shallow flooding for the first 2 weeks after transplanting to help recovery from transplanting shocks and to suppress weeds, then shallow ponding from start to end of flowering stage, and AWD during all other periods with irrigation water applied whenever perched water table falls below 15cm from the soil surface (Bouman, Lampayan, & Tuong, 2007). It has also been observed that adoption of AWD method has significantly reduced global warming potential and water use (Mazza, et al., 2016). AWD is categorized into three groups, safe AWD, mild or moderate AWD, and severe AWD, based on the soil characteristics (Ishfaq, et al., 2020). This technique is used in both transplanted and DSR cultivation of rice crop (Kar, et al., 2018). (Lorica, Singleton, Stuart, & Belmain, 2020) has recommended this method to be climate smart as it does not enhance rodent attack. While AWD effectively controls the growth of golden apple snail, brown plant hopper, false smut, and algae, it faces problems with non-aquatic weeds, rice blast, bacterial leaf blight, and root-knot nematode (Allen & Sander, 2019). AWD can reduce some diseases due to lower humidity in the crop canopy and increased plant resistance. Improved knowledge of IPM is important in AWD. Currently, AWD has been accepted as the most promising practice to reduce GHG emissions from irrigation of rice because of its large methane reduction potential and multiple benefits (Richards & Sander, 2014).

AWD is a profitable method for rice cultivation. It is a cost-effective method capable of reducing water use by 25-30% (Rahman & Bulbul, 2015), decreasing irrigation cost and enhancing the efficiency (Ishfaq, et al., 2020). Studies have shown that adoption of AWD has reduced water input by 14-18% (Belder, et al., 2004), 20-23% (Hasan, Habib, Abdullah, Bhattacharjee, & Afrad, 2016), and 31-44% (Liang, et al., 2016) by either maintaining or increasing crop yield as compared to the traditional flooding method. Moreover, this method also helps in maintaining soil fertility by following soil mineralization (Ye, et al., 2013), reducing environmental risk by decreasing methane emissions (Chirinda, et al., 2017) (Alauddin, Sarker, Islam, & Tisdell, 2020), and improving social capital by resolving water conflicts (Palis, Lampayan, Kurschner, & Bouman, 2016). This system helps in improving the growth and development of root and shoot (Yang & Zhang, 2010) along with improving and maintaining grain yields in comparison to the continuous flooding system (Liang, et al., 2016) (Norton, et al., 2017). It has also been witnessed that AWD system reduces the incidences of diseases and insect pest attacks in comparison to the continuous flooding system (Umesh, Mallesha, Chittapur, & Angadi, 2017). A study conducted in Nepal found that AWD is an extremely water-saving irrigation technique without reducing the crop yield (Howell, Shrestha, & Dodd, 2015).

The key challenges faced in upscaling of this technology in the country are as follows:

a. Infestation of weeds
b. Lack of proper irrigation infrastructure for adoption of AWD.
c. Insufficient technical support and training for the farmers.
d. Farmers hesitant to change from their traditional farming practices.

Traditionally, flooding conditions help to control the growth of weeds, and AWD conditions are known to give rise to weeds, incurring higher weed control costs. Such potential expenses also discourage farmers from adopting water saving practices (Pandey, et al., 2020). AWD requires controlling the usage of water supply, however, existing pricing mechanisms for irrigation supply based on area of land irrigated and not volume of water used can also be a deterrent in the adoption of the techniques (Pearson, Millar, Norton, & Price, 2018). Challenges in irrigation scheduling to suit the timing of AWD for individual farms is found to be a major constraint in Nepal (Howell, Shrestha, & Dodd, 2015). Given the locally-embedded nature of irrigation systems that operate through group decision-making processes, ensuring the right intervals and amounts of irrigation water in the fields can be challenging. In case of the Philippines, AWD was found to be more successful in small-scale pump-based irrigation systems and not so much in the large gravity-based systems due to an interplay of several constraints such as institutional enforcement, economic incentives, and ability to exclude unintended users (Enriquez, et al., 2021).

We propose a few policy recommendations for upscaling the adoption of AWD technique in Nepal. Firstly, creating awareness about the technique is important to make the farmers informed about the AWD method and the benefits associated with its adoption. Ensuring capacity development is vital, which can be done through training programs, farm trials, and workshops aimed at imparting skills and education to the farmers. Secondly, an adequate infrastructural set-up is essential to promote smoother adoption and execution of the AWD method of cultivation. The government could consider developing irrigation pricing mechanism such that economic and efficient use of water can be encouraged. Thirdly, strengthening extension services is pivotal to provide continuous support to the farmers, offering guidance and assistance throughout the process. Additionally, continuous research and development are essential to tailor AWD practice for diverse agro-climatic regions, optimizing the scarce resources to suit different environmental conditions, soil composition etc. Finally, policy support is of utmost priority to facilitate implementation of AWD through supportive regulations and guidelines, thereby fostering wider adoption of AWD technique in the region.

3. Drip irrigation

Drip irrigation is a type of micro-irrigation system that is widely used across the globe to improve crop and water productivity. It is used as a surface and subsurface irrigation method, depending upon the geographical and agro-ecological conditions. In surface irrigation, water is distributed to the farm land through channels that flood the area to a depth determined by the amount of water required while in subsurface irrigation, water flows underground and nourishes the plant roots through capillary action (Jayant, Dahiya, Rukhiyar, Raj, & Meena, 2022). It is a technique in which water and fertilizer are applied simultaneously to the roots of the plant to reduce evaporation and seepage loss. This method is best suited for orchard crops like tomatoes, grapes, corn, cauliflower, cabbage, etc. This method has various advantages like less water requirement, low evaporation loss, wets soil surface in less amount of time, no need to level the land, less labour required, and no soil erosion (Kumar, et al., 2023). Drip irrigation technology has also helped in ensuring a more efficient use of water by reducing the losses from evaporation and surface run-off (ICIMOD and PARDYP, n.d.)

A study conducted in Pakistan to assess the farmer's knowledge about the technology and their experiences found the benefit-cost ratio for low-head drip irrigation to be 1.27 for dates/lemon orchards in Khyber Pakhtunkhwa and 1.73 and 1.32 for grapes orchard in Punjab and Baluchistan provinces, respectively

(Hussain, et al., 2022). A study has found that adoption of drip irrigation in cotton and onion could save 50% and 40% of water requirement, respectively and increase crop yield by 75% and 50%, respectively (Bandana & Patel, 2023). A research study on the impact of micro-irrigation (drip irrigation and sprinkler) on date palm production showed that drip irrigation used 80% of water as compared to 100% crop water demand from sprinkler irrigation, showing high efficiency of drip irrigation along with increasing crop yield (Ghazzawy, Sobaih, & Mansour, 2022). (Gebrehiwot, Makina, & Woldu, 2017) assessed the impact of micro-irrigation on household welfare and found significant impact on asset formation by 186% and income by 8.8% as compared to the non-adopters of micro-irrigation. Studies have revealed positive effects on women's economic empowerment as a result of participation of women farmers in drip irrigation technologies (Upadhyay, Samad, & Giordano, 2003) as well as notable improvements in the production of vegetables in the off-season (other than monsoon) (Shah & Keller, 2002).

Studies have found some challenges in the drip irrigation system like expensive method, extra training and knowledge required, as well as regular supervision and high skill requirement (Jayant, Dahiya, Rukhiyar, Raj, & Meena, 2022). Further, shared landownership issues may also be a source of conflict while adopting technology such as drip irrigation (ICIMOD, 2008). Since Nepal has diverse topography of land, the drip irrigation systems have required adaptation for slopy and hilly terrains. Evaluation by ICIMOD and PARDYP (n.d.) has shown that institutional efforts to seek feedback from farmers in order to customize the drip kits in the manufacturing process had helped in localization of the technology in Nepal's mountainous areas. Further, cost minimization in order to cater to resource poor farmers was also an important part of technological adaptation. A recent study in India has also found technological constraints such as clogging of drippers by suspended materials, difficulty in maintaining optimum pressure for discharge as well as need for using more expensive liquid fertilizers while using drip irrigation system (Rajaguru, Kalidasan, & Tamilselvi, 2023). Such challenges necessitate a provision of accessible extension services for farmers. Further, absence of network of local suppliers and fabricators had come up as a challenge for accessing timely repair and maintenance of these drip irrigation systems (Palada & Bhattarai, 2012). (Postel, Polak, Gonzales, & Keller, 2001) have highlighted that fostering of small-scale assembly and packaging plants in the form of a network of microenterprises would also require a precondition of a sufficient scale of use of the technology in certain local clusters.

Some recommendations to promote drip irrigation system include use of multi-sectoral collaborative effort by bringing together members from universities, local research centers, multiple line agencies as well as farmers to implement the technology (ICIMOD, 2008). Localizing targeted drip irrigation systems in specific area clusters could help in fostering a private-sector/ market-led supply system for spare parts, repair and maintenance services for the drip irrigation system. Technological innovation in the form of providing good quality and low-cost drip kits tailored to smallholder farmers can help in enhancing its adoption especially among vegetable producers. Seeking farmers' feedback in manufacturing process can help overcome local problems for adaptation of drip technology especially in the mountainous/hilly areas. Gender mainstreaming in evaluation studies so as to uncover the specific challenges faced by women farmers in technology adoption may prove beneficial.

Conclusion

The review has highlighted the constraints, performance and extent of use of three climate-smart agriculture technologies especially in the context of Nepal and South Asia. Contextual factors such as availability of necessary farm machinery and equipment, inputs such as right variety of seeds, quality of weedicides, herbicides and pesticides as well as the technological capacity of farmers are important in the scaling up of these technologies. Agro-ecological conditions, availability of irrigation water and nature of landownership systems as well as government and institutional mechanisms play a crucial role in shaping the utility and adoptability of each CSA technology in various sites across Nepal.

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