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Prioritization of Climate-Smart Agriculture Technologies in SAARC Countries

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Abstract

Climate-smart agriculture (CSA) is pivotal in combating the impacts of climate change on global agriculture and food security. It has increasingly gained prominence as an adaptation strategy against the adverse impacts of climate change on agriculture, particularly in South Asia. However, scaling up the adoption of CSA interventions becomes critical, due to predominantly small and marginal nature of landholdings in the region, various institutional and policy constraints, and trade regulations and barriers. Another significant challenge lies in categorizing and prioritizing the multitude of technologies considered to be climate smart. Therefore, this study attempts to explore the different CSA technologies within the socio-economic context of six South Asian countries: Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka, with the main objective of proioritization and scaling-up of these methods. The study begins by compiling an inventory of existing technologies and subsequently prioritizing them by using the World Bank (WB) CSA Technology Index. Secondly, the study tries to address the key challenges and propose policy measures to upscale the adoption of CSA technologies in these countries using participatory research conducted with the key stakeholders in these countries. The participatory research provided valuable insights, revealing critical policy and institutional barriers, and providing a basis for framing strategies and policy solutions to facilitate wider adoption of CSA technologies in the region.

Keywords: climate change, climate smart agriculture, prioritization, scaling-up, adoption, CSA tech index, South Asia

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Acronyms

AWD	Alternate Weting and Drying
BARI	Bangladesh Agricultural Research Institute
CSA	Climaet Smart Agriculture
CSFI	Climate Smart Feasibility Index
C-SUCSeS	Consortium for Scaling-up Climate Smart Agriculture in South Asia
DSR	Dirct Seeded Rice
FGD	Focused Group Discussion
FAO	Food and Agriculture Organization
GPS	Global Positioning System
GHG	Greenhouse Gas
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IFAD	International Fund for Agriculture Development
LSP	Local Service Providers
WB	World Bank
WTP	Willingness To Pay

1. Introduction

Climate change is a global phenomenon and increasing at an alarming rate. The agricultural sector has been influenced by the changes in the climate and it is estimated that more significant and negative impacts can be seen in the future. The challenges faced by agriculture sector are adaptation of agricultural systems to climate change and mitigating its causes and effects, improving combination of economic, social, and environmental preferences, and increasing degree of food autonomy of the regions (Selbonne, et al., 2022). One of the characteristic impacts associated with climate change is the increase in intensity and frequency of the occurrence of extreme events such as floods, droughts, heat waves, among others. Climate change acts as a stimulus as it has a destructive impact on the food systems, posing a threat to the population worldwide. Hence, before the challenges intensify, climate smart solutions need to be applied on a much larger scale. Therefore, climate smart agriculture (CSA) is one such strategy that aims to provide adaptation, mitigation, and resilience to agriculture and farmers.

CSA may be defined as an approach of transforming and reorienting agricultural development under the realms of climate change (Lipper, et al., 2014). The concept of CSA was developed by Food and Agriculture Organization (FAO) in 2008 who defined it as agriculture that sustainably increases productivity, enhances resilience (adaptation), and reduces/ removes GHG emissions (mitigation). It is the area in which there is triple win among adaptation, mitigation, and food security. CSA is neither a specific technology nor a set of practices that can be applied universally, but an approach to develop the technical, policy and investment profile to achieve sustainable agricultural development for food security under climate change scenarios (Selbonne, et al., 2022). CSA cannot be applied universally but involves elements embedded in local environment from actions on-farm and off-farm that incorporates technologies, policies, institutions, and investment to meet the local requirements. It is a holistic concept which includes environmental (water and energy) as well as social (gender) and economic issues.

Developing countries are more vulnerable to climate change than the developed nations and South Asia is the world's most vulnerable region to climate change (Abeysekara, Siriwardana, & Meng, 2023). South Asian countries are primarily dependent on agriculture, where 65% of the population, the majority of the poor are living in rural areas dominated by agriculture, which contributes 18% to regional GDP and 42% to total employment (Kuhn, 2019). The region is primarily dependent on agriculture for their livelihoods, but at a high risk of climate vulnerability. It is highlighted that in the absence of adaptation measures to climate change, South Asia may lose 1.8% of its GDP by 2050 and 8.8% by 2100 (Ahmed & Suphachalasai, 2014). The average economic losses are projected to be 9.4% for Bangladesh, 6.6% for Bhutan, 8.7% for India, 12.6% for Maldives, 9.9% for Nepal, and 6.5% for Sri Lanka (ADB, 2014). The negative impact of climate change in South Asia has been predicted to exceed the global average (7% loss of GDP), mainly due to the importance of agriculture in the region, with a projected loss of 18% in Bhutan, 13% in Nepal, 10% in India, and 10% in Pakistan by 2099 (World Bank, 2021a).

Porter, et al. (2014) anticipated negative impacts of climate change on crop yields in different parts which included 60% reduction in maize yield, 50% reduction in sorghum yield, 35% reduction in rice yield, 20% reduction in wheat yield, and 13% reduction in barley yield. Moreover, rain – fed crops are going to face a decrease of almost 50% in their yield (Okolie 2023). For instance, in India, a rise in temperature between 1°C to 3°C may reduce rice yield by 3% - 10% in Punjab (Hundal & Kaur, 2007). Other studies have shown that if adoption of CSA practices are not started immediately, then South Asia may lose 10 – 15% in food production by the end of the century (Knox, 2012). Climate change acts as an impetus, exerting a destructive impact on food systems and posing a global threat to populations. Therefore, proactive implementation of climate-smart solutions on a larger scale is imperative to counteract these challenges before they escalate further.

Mere incremental changes are deemed insufficient for fostering the societal transformations necessary to mitigate and adapt to climate change, and enhance food security. The need to drive tangible and impactful transformations that extend beyond individual plots or sites, encompassing a larger population across larger geographical areas, on institutions and policies, is what triggers the interest in scaling up. The concern here is how to expand promising pilot demonstrations that have had substantial impact on poverty. The key lies not in researchers themselves driving the scaling process, but in employing strategies that facilitate the involvement of future users through partnerships, engagement, capacity development, and learning to apply research results in non-research purposes and making future generations aware about the enabling environments conducive to scaling up (Westermann, 2015). Research on dissemination of agricultural technologies and practices is being conducted globally to raise agricultural production, improve farmers' livelihoods, and alleviate poverty of small-holder farmers (Kilima, et al., 2013). CSA interventions are knowledge-intensive, location- specific, and need substantial capacity development (Neufeldt, et al., 2013). Promotion of CSA practices happen within the overarching food systems; therefore, it is necessary to consider the effect over space and time along with issues like justice, equity, governance, trade, migration, demographic change, and behaviour (Selbonne, et al., 2022).

CSA involves various goals, but there are various trade-offs that need to be addressed simultaneously. These trade-offs arise because achieving one goal sometimes comes at an expense of other objective. Hence, it is important to identify and manage these trade-offs. Here we present a list of trade-offs along with their management resolution based on primary and secondary data (Makate 2019, Neufeldt 2015, Westermann 2015).

Short-term yield vs long-term soil health: Inorder to boost crop yield in the short-term, use of chemical fertilizers can degrade soil health over long period of time. Thus, integrated soil fertility management practices can be practiced to maintain productivity as well as soil health.

Equity vs efficiency: Efficient allocation of resources often reaches to a smaller section of farmers, focusing on small and marginal farmers. Therefore, to overcome these equity challenges in distribution of resources, policy and programs need to ensure more equitable distribution and access to resources such as credit schemes and subisides are targeted mainly for small and marginalized landholders.

Diversification vs specialization: Diversification of cropping systems can lead to resilience to climate change but may not be economically viable as compared to high-valued crops. Hence, developing markets and value chain systems for diverse crops can help in making diversification more economically lucrative. The markets through awareness should be wiling to pay for CSA products or could be regulated to do so.

Intensification vs conservation: In order to meet the growing food demands, intensification of agriculture can lead to deforestation and biodiversity loss. Thus, sustainable practices like agroforestry and conservation agriculture can help to mitigate this trade-off.

Innovation vs tradition: Introduction of new and modern methods of cultivation may conflict with the traditional practices, creating resistance among the farmers. Participatory approach involving farmers adopting new practices can help to educate and create awareness among other farmers to adopt innovative methods of cultivation.

Investment in sustainable practices vs immediate returns: Sustainable practices often involves investment in infrastructure, training, capacity building, technology, which may not provide immediate returns to the farmers. Hence, providing financial incentives, subsidies, low interest loans can encourage the farmers to adopt these sustainable methods by reducing their financial burden. Managing these trade-offs requires careful planning, stakeholder engagement, and development of context specific strategies that balance the immediate needs of the society along with creating a long-term sustainable environment.

Given this backdrop, IFAD developed and approved the Consortium for Scaling up Climate Smart Agriculture in South Asia (C-SUCSeS) with the objective of prioritizing and scaling up sustainable and resilient agricultural technologies in South Asia, primarily focusing on six countries, namely Bhutan, Bangladesh, India, Nepal, Pakisyan, and Sri Lanka. Therefore, to achieve the objective of the project, it requires constructing a prioritization framework for CSA technologies along with identifying various challenges and opportunities to scaling up these practices with reference to socio-economic, demographic, geographical, and topographical conditions of the country. Hence, this study aims to design a prioritization framework based on the World Bank technology index method and assess various pathways, constraints, and methods for scaling up CSA practices. All the results presented in this study are coupled with primary (participatory approach – FGDs with farmers, extension agents, and National focal point? .) and secondary data sources.

The rest of this paper is divided into four sections. Section 2 provides details about the prioritization framework used for selection of the top CSA technologies, section 3 highlights the scaling up process in the region, section 4 talks about the country-wise and technology-wise constraints and policy measures for adoption of CSA practices, followed by conclusion in section 5.

2. Prioritization of CSA technologies

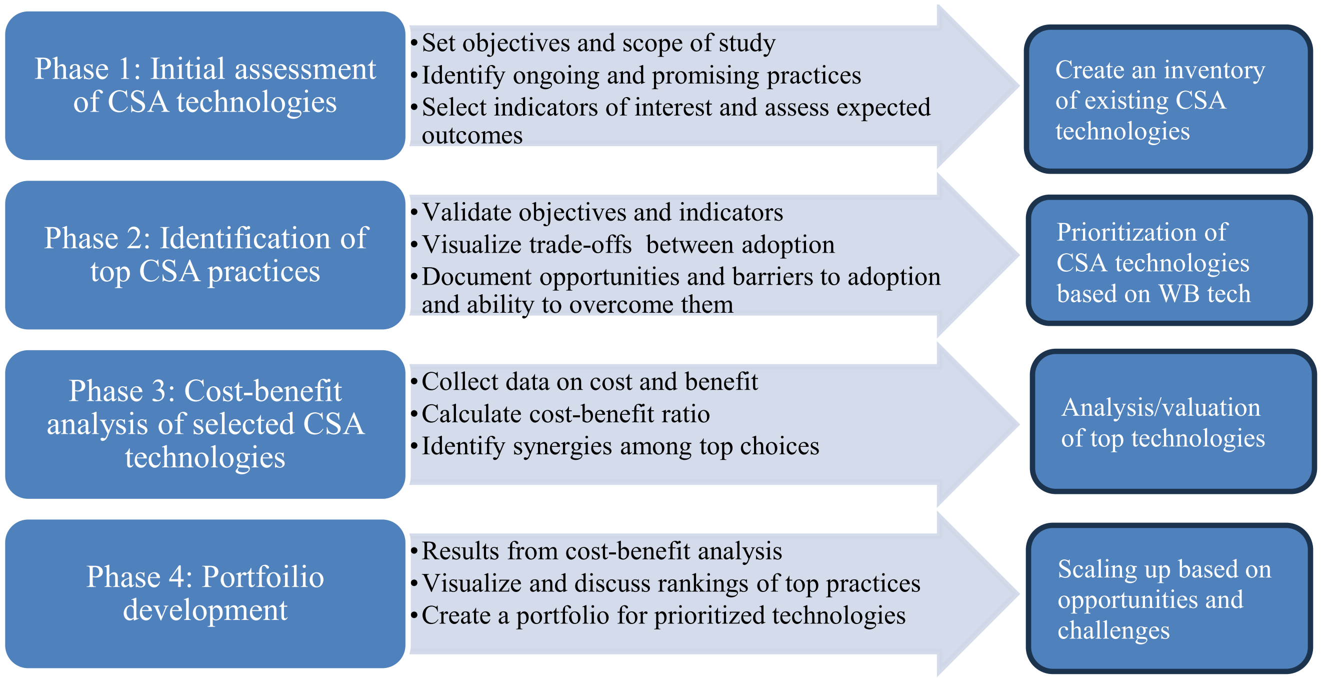
CSA comprises of range of practices like crop diversification, improved seed varieties, water conservation, effective water management techniques, and switching to advanced and more sustainable farm management methods. In the context of South Asia, adoption of CSA has become even more critical because of the vulnerability of the region to the adverse impacts of climate change and associated extreme events (Spijkers, M. A., 2011). These events pose substantial threats to agricultural production and food security. The adoption of CSA practices is likely to bolster resilience of farmers and protect them from yield losses (Berhanu, Ayele, & Dagnew, 2024). It will also ensure a stable food supply for the region's burgeoning population by ensuring stable crop yields. In addition, many parts of the south Asian region are prone to water scarcity or critical depletion of groundwater (Albinia & Hoffman, 2020). The range of effective water management practices under CSA, efficient irrigation methods, and drought-resistant crop varieties are critical to sustain agriculture production in this water-scarce region. Further, most of the farmers in South Asia are smallholders, with limited access to land and other capital resources. Various CSA practices, by virtue of being cost effective and smallholder friendly, can provide opportunities to the smallholder farmers in ensuring better livelihoods. Lastly, recognizing the critical role of women in South Asian agriculture and the increased feminization of agriculture, a range of CSA practices can empower women farmers and simultaneously enhance their resilience.

Given the broad scope of CSA, numerous agricultural technologies can qualify as climate-smart technologies. However, this wide-ranging inclusiveness has led to criticism, as it encompasses almost every new technology or innovation within the agricultural sector. Consequently, it is crucial to prioritize and shortlist specific CSA technologies from the extensive array available. This prioritization becomes particularly important in the context of public policy, where resources are limited and need to be allocated judiciously. Prioritization of CSA technologies support climate change adaptation planning in agriculture by designing an investment portfolio across various agro-ecological zones. This can result in large-scale implications of program design and implementation and climate change adaptation planning.

Various methodologies are used in the literature to prioritize and shortlist CSA technologies[1]. Under C-SUCSeS project, the World Bank (WB) CSA Technology (tech) Index methodology is used to provide relative scoring and ranking to all technologies. The World Bank has designed a CSA technology index, an unconventional approach constructed based on three parameters of CSA - productivity, resilience, and mitigation (World Bank, 2016). This index guides in thinking about the values of the technology, especially looking at the potential of improved decision making. It comprises of indicators with relative significance to productivity, resilience, and mitigation. The CSA tech index is composed of 27 indicators categorized into three components of key pillars of CSA. Given the contextual nature of CSA technologies, prioritization is essential, considering the diversity of farming systems. The development of this index was driven by specific criteria: measurability, acceptability to various stakeholders, and relevance and suitability to diverse farming systems. In essence, the CSA Tech Index is designed to be adaptable and applicable, meeting the needs of different agricultural contexts. The CSA technologies need to be context-specific and prioritized in different farming systems. The prioritization process and scaling-up of CSA technologies is summarized in Figure 1.

[1] Prioritization methodologies include: (a) willingness to pay (WTP) – the highest price that a customer is willing to pay for products/services. The two important approaches in WTP method are revealed preference and stated preference methods. (b) Climate Smart Feasibility Index (CSFI) – based on principal component analysis and is often used in combination with WTP method. (c) CSA Technology Index Method– an approach considering three parameters of CSA – productivity, resilience, and mitigation.

Figure 1: Process of prioritization and scaling-up of CSA technologies



Overview of the steps adopted for CSA technology prioritization in selected south Asian countries.

To generate a final score, we assign a raw score and target score based on whether an optimal condition is achieved or not. If the raw score is greater than the target score, we assign a score of 1 for that indicator, if equal then 0, and if it is smaller than the target score then -1 is assigned to it. We use Likert scale (1- Strongly disagree, 2- Disagree, 3- Neutral, 4- Agree, 5- Strongly agree) to determine the scores for 20 indicators and the remaining 7 indicators are based on actual numbers of raw and target scores. The Likert scale is used to rank the qualitative indicators like improvement in human capital of producers, promotion of crop diversification, etc. On the other hand, quantitative estimators like increase in yield (%), reduction in erosion (%), and others, a comparison is done between observed and expected values, then a score is assigned to it. Raw scores, also known as the actual scores, refers to the relative number assigned to an indicator based on evidentiary assessment. Target score is the aspirational number against which the raw score is graded. We have modified the indicators as per our project requirement and designed the index which is attached in the appendix (Table 2) below.

For the selected South Asian countries, a detailed inventory of CSA technologies was prepared by the national focal points (NFPs) and their teams in consultation with extension officials and farmers (SAC 2023). These inventories comprised technologies that are not only prevalent in these countries but are also supported through government programs and local research stations. From these inventories, a prioritization process was initated by IFPRI in consultation with the NFPs to shortlist three technologies in each country using the World Bank CSA technology index method described above. Table 1 provides the list of the outcome of this prioritization process undertaken for each member country. A detailed table providing the scoring of the CSA technologies in the respective countries is presented in appendix (Table 3).

Table 1: Prioritized CSA technologies of each country under the C-SUCSeS project

Member nation	Prioritized CSA technology (CSA tech index score)
Bangladesh	Zero tillage with mulch (4.61) Strip planting (4.39) Bed planting with residue retention (4.32)
Bhutan	Protected agriculture (3.7) Drip/ smart irrigation (3.6) Sustainable land management (3.36)
India	Zero tillage (4.5) Direct seeded rice (DSR) (4.1) Resilient intercropping using improved seed varieties (3.8)
Nepal	Drip irrigation (4.53) Alternate wetting and drying (4.36) Crop system {DSR in rice-wheat system + brown manuring} (4.23)
Pakistan	Zero-tillage wheat in rice-wheat cropping system (4.92) Zero-tillage/ happy seeder wheat (4.72) Resilient cropping system (sesbinia-wheat) in rainfed area (4.33)
Sri Lanka	Solar powered pumping coupled with micro irrigation system (4.6) Multi-purpose soil conservation bunds (4.2) Protected agriculture for high-value crops (3.8)

Source: CSA prioritization done by National Focal Points (NFPs) of each member country using WB CSA tech index

3. Scaling-up of CSA Technologies

Scaling-up is 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 2023). Scaling up brings in qualitative benefits to wider population over a broader geographical area, quickly, equitably,and lastingly (Franzel, et al., 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). Scaling up is rarely uni-dimensional, i.e., if programs scale up quantitatively and functionally, they need to also expand or- ganizationally and politically also (Hartmann and Linn, 2008). Moreover, it is a management issue about how to manage projects so that the positive impact is maximized (Pachico and Fujisaka, 2004). Scaling up requires a multi-dimensional approach involving policy support, capacity building, financial incentives, and collaborations with different stakeholders.

Since 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 fromlarge 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 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).

CSA scaling is the expansion of the adoption of proven and effective CSA technologies. Scaling-up CSA practices is non-autonomous but requires some facilitation in the form of conducive policy and institutional actions (Makate, 2019). Successful scaling up of CSA practices require identification and promotion of appropriate technologies, enabling environments constituting of suportive 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 altogetherimprove 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).

In this study, 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 on expanding proven technologies in the same area by increasing their adoption and expansion among farmers in that specific agro-climatic zone. The next section talks in detail about the key challenges faced and proposed policy measures to expand the adoption of CSA technologies in the member countries.

4. Constraints and strategies in scaling-up CSA technologies

For CSA to be more effective and efficient, coordinated actions are required from diverse stakeholders, including farmers, researchers, the private sector, civil societies, and policymakers. These actions should focus on four major areas: building evidence, enhancing the efficiency of local institutions, fostering coherence between climate and agricultural policies, and linking climate and agricultural financing (Lipper, et al., 2014).Hence, we present country-specific and technology-specific constraints in scaling-up of CSA practices and propose strategies accordingly. These constraints/policy recommendations have emerged from the discussions with different stakeholders involved in the process, including farmers, extension agents, agriculture divisions, and scientists.

- **Bangladesh:** The CSA technologies prioritized in Bangladesh are bed planting with residue retention, strip tillage, and zero tillage with mulch. Here, we discuss the constraints faced in scaling-up of these technologies and the proposed policy solutions for it.
  - **Bed planting with residue retention:** It is a modern version of conserving water for dry land farming (Talokar, Gabhane, & Umale, 2017). This method efficiently reduces the velocity of run-offs and sediment losses and leads to an increase in infiltration. The main function of this method is to control erosion and conserve soil moisture in the soil. The main advantages of using this practice are improvement in crop yield, reduction in labour requirement, cost-efficiency, and weed control. Miah et al. (2015) conducted a study in Bangladesh to understand the status of raised bed technology at farm level, assess the status of adoption of the technique at the farm level, factors affecting adoption and non – adoption, and evaluate farmer's perception on the impact of raised beds on input use and farmer's income. The study reflected that technology was adopted by 56% of the respondent farmers, the key factors influencing the adoption were extension contract, social membership, and number of male members in the family. Moreover, the study also concluded that the major crops cultivated through this system were wheat (97.95%), maize

(27.69%), onion (16.41%), and mungbean (12.31%). More than 82% of the farmers reported an increase in their incomes due to technology. The amount of food intake had also increased for some households. The majority of the farmers reported that raised bed technology reduced the use of seed (94.4%), fertilizer (73.3%), and irrigation water (61%). Although this practice has so many merits to be counted for, farmers face various challenges in the process of adoption of this technique. The main constraints reported by stakeholders involved in the scaling-up process are as follows:

i. Lack of availability and accessibility to bed planters due to its indigenous and novel design which is unpopular and not widespread among the farmer community.
ii. Ergonomics of the machine which requires the operator to walk behind the machine, and no provision for him/her to sit.
iii. Transportation over long distances is difficult.
iv. Inadequate availability of the planters during the short sowing period.
v. Lack of trained and skilled manpower to operate the machine effectively and efficiently.

To expand the adoption of the bed planting technology, it is essential to frame a comprehensive policy based on inputs from farmers, extension agents, and BARI officials. Initially, the priority is to enhance the availability and accessibility of machines through extension agents, local service providers (LSPs), etc. during the short sowing period on rental basis. Second, facilitating easy financing and credit options for farmers and LSPs to acquire bed planter machines is crucial for acquisition of the machines. Third, raising awareness among farmers about the technique and its benefits through advertising, training camps, and focused group discussions will help in popularizing the method of cultivation which will indeed help in promoting its adoption. Additionally, conducting field demonstrations and training programs at the village and farm level will raise awareness and equip the farmers with the necessary skills to operate the machinery. Finally, restructuring the ergonomics of the planter machine to make it user-friendly can help in encouraging wider adoption of bed planters in the region. These collective efforts can significantly enhance the adoption of bed planting techniques in Bangladesh's regions.

- **Strip tillage:** Strip tillage is a form of conservation agriculture involving minimal tillage. It combines the benefits of conventional tillage—soil drying and warming, and no tillage— preserve soil structure and reduce erosion by leaving some soil undisturbed. It is a type of precision farming where the crops are sown in narrow strips instead of broadcasting or drilling them across the field. It is often used in combination with other precision farming technologies, such as GPS-guided equipment and variable rate seeding, to optimize crop yields and decrease input costs. The key merits of using this practice are decline in wind and water erosion, improvement in water infiltration, retainment of soil moisture, decrease in sedimentation, appreciation in water quality, and boost in soil fertility (Sergieieva 2021, Masa 2023). Hossain et. al. (2021) showed that mechanized seeding of mustard and mungbean in strip planting with 50% residue mulching resulted in 62% higher profit in comparison to the broadcasted conventional tillage without residue. The strip planting technique also reduced the cost of land preparation by 68%, thereby leading to a decline in labour and fuel requirements by 30%. The challenges in scaling-up this CSA method are as follows:

   vi. Lack of awareness about the technology in the region.
   vii. Strip tillage machine is expensive and small-holder farmers do nothave affordability for this method.
   viii. Lack of training and skill to operate the till machine.
   ix. Inertia and risk are associated with adoption of this modern method of cultivation.
   x. Farmers perceive limited benefits in terms of yield as there is a lag of 2-3 years till the profits become apparent to the farmers.
   xi. Farmers also perceive that there is wastage of land area because of the excessive spacing between rows of strip planted.

Here, we present a few policy recommendations to facilitate the adoption of strip tillage in Bangladesh. First and foremost, raising awareness about the advantages of technology is crucial. This can be achieved through advertisement campaigns, training camps, and field demonstrations (at the farm level). Moreover, making strip tillage machines accessible at the village level is pivotal for increasing adoption. This can be facilitated through custom hiring centers, and rental services provided by extension agents and LSPs ensuring that small-holder farmers can benefit from this technique. Simultaneously, enabling easy credit and financial services for small-holder farmers is essential for acquisition of the machines. This will support them to invest in the technology and enhance their agricultural activities. Lastly, capacity building of the farmers through training programs, workshops, and field demonstrations is vital to equip them with knowledge and skills to effectively implement the strip tillage method of cultivation. This concentrated method will help in transforming agricultural practices and farmer's livelihood by enhancing the adoption of the technique in the Pabna regions of Bangladesh and pave the way for its adoption in other parts of the country.

- **Bhutan –** The CSA prioritized technologies in Bhutan are sustainable land management, protected agriculture, and drip/smart irrigation technologies. Below, we present the main challenges faced in upscaling of these techniques and prescribe policy recommendations.
    - **Protected agriculture:** Protected farming is a modern and scientific method of farming, under which the plants are protected from adverse natural conditions or unfavorable environments such as strong heat, strong cold, strong wind, strong light intensity, excessive rain, drought, etc. It is cultivation of high value vegetables and other horticulture crops in greenhouses that allows farmers to grow cash crops on small plots in marginal, water – deficient areas where traditional cropping is not viable. It refers to the use of technology to modify the natural environment of vegetable crops to extend their growing season and produce higher yields. The main merits of this technology are increase in yield and revenue, high water productivity, reduction in pesticide use, and year-round production, allowing

farmers to take advantage of market seasonality and higher prices. The main challenges faced in increasing adoption of this technology are:

i. Selection of the crop since all the crops are not suitable for cultivation in the polyhouses.
ii. The administrative procedure for acquiring a polyhouse is quite complex.
iii. High investment and capital cost.
iv. Discrepancies in the structure of the polyhouses lead to unfavorable temperature and humidity inside it.
v. Replication of the structure from hilly areas (protect from temperatures) in the north to southern foothills (protect from rainfall) is difficult.

The successful implementation of protected agriculture relies on a multifaceted strategy encompassing some of the crucial policy solutions. First, designing and construction of location specific polyhouse structure is vital for considering the micro-environmental characteristics essential for crop requirements. Along with this, a profound understanding of the crops suitable for a particular agro-climatic condition is essential to ensure optimal crop growth and yield with the protected environment. Secondly, establishing market linkages and robust value chains for the crops grown in polyhouse is pivotal to ensure market access and secure a consistent demand for the products. Capacity development remains a key factor is expansion of the adoption of any CSA technique. This can be achieved through training programs, workshops, exposure visits to successful polyhouses, and enhancing the skills and knowledge of the farmers. Moreover, a proper layout and design of the polyhouse is fundamental for efficient installation of the structures, ensuring efficient operation and maintenance. Finally, streamlining the administrative procedures for the installation of the polyhouses, reducing bureaucratic hurdles, providing financial incentives and subsidies will promote smoother adoption process for the farmers which is crucial for scaling-up the adoption of this method. Integrating all these measures will encourage the adoption of protected agriculture, creating a resilient and sustainable farming systems.

- **Nepal –** The prioritized CSA technologies in Nepal are alternate wetting and drying (AWD) method, direct seeded rice (DSR), and drip irrigation techniques. Here, we present the main constraints faced in scaling-up of these technologies followed by a few recommendations.
  - **Alternate wetting and drying (AWD):** Alternate wetting and drying (AWD) is a water management technique practiced cultivating irrigated lowland rice with less water than the usual system of maintaining continuous standing water in the crop field. It is a method of controlled and intermitted irrigation. This method reduces water demand for irrigation and greenhouse gas emissions without reducing crop yield. It is a cost-effective method capable of reducing water use by 25-30% (Rahman & Bulbul, 2015). 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). AWD is useful in maintaining water use efficiency by decreasing irrigation cost and enhancing efficiency (Ishfaq, et al., 2020). 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).The main constraints faced in upscaling the technology are as follows:
    - i. Lack of awareness and knowledge about the technique among the farmers.
    - ii. Lack of proper irrigation infrastructure for adoption of AWD.
    - iii. Insufficient technical support and training for the farmers.
    - iv. Farmers are hesitant to change from their traditional farming practices.

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 aware of 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. 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 to 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.

- **Direct seeded rice (DSR):** 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 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, more conducive to mechanization, and reduces GHG emissions that contribute to climate change. Past studies from Nepal on DSR has showed that this method of rice cultivation has been much more efficient in cultivating rice than the traditional puddled rice cultivation method. (Dhakal, Shah, McDonald, & Regmi, 2015) reported that the major challenges faced by the farmers in adoption of DSR method was high incidences of weed infestation, poor crop establishment, and reduced grain and straw yields, however, the benefit-cost ratio turned out to be higher in DSR (2.0) as compared to transplanted puddled rice (1.63) due to lower cost of production. (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 challenges faced by the farmers in the adoption of DSR in Nepal include:

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

To foster the expansion and scaling-up the adoption of DSR in Nepal, here are few policy recommendations. Empowering farmers with comprehensive education, skills, and training is fundamental for successful adoption of DSR. Field demonstration 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 the use of weedicides is important to ensure its use within the recommended quantities to reduce its harmful effect on crops as well as environment. Financial incentives and ease in credit services will play a crucial role in reducing the financial burden of the farmers and ensure a smoother transition to DSR practice from their traditional practice. Additionally, administered use of weedicides is essential to ensure adequate use within the recommended guidelines. Finally, an increase in extension services will ensure farmers with proper guidance related to agricultural activities. Hence, integrating all these measures will encourage widespread adoption of DSR in the country.

- **India –** The prioritized CSA technologies for India are direct seeded rice (DSR), resilient intercropping using improved seed varieties, and zero tillage. Simultaneously, we present the main restrictions faced in scaling-up of these technologies and suggest policy resolutions to them.

- **Direct seeded rice (DSR):** Direct seeded rice (DSR) is also one of the prioritized technology for India. However, the constraints associated with its adoption are slightly different from that of Nepal. A study conducted in Punjab (India) has shown that adoption of DSR reported lower cost of cultivation, higher revenues, and higher benefit-cost ratio of 4.78:1 in comparison to traditional method of 3.87:1 (Kamboj, Singh, & Kaur, 2022). Another study from India has shown higher crop yield of 3.74% in comparison to the traditional puddled rice, decrease in total cost by 7.51% on adopting DSR, and DSR adoption also led to reduction in fertilizer and land preparation cost (Mishra, Khanal, & Pede, 2017). The main constraints faced in scaling-up of DSR in India include:
    1. Rise in incidences of weeds leading to rise in use of herbicides.
    2. Irregular germination if sowing is followed by heavy rainfall.
    3. Delay in harvesting 3^{rd}/summer crop making the field unavailable for DSR.
    4. Marketing of herbicides in large quantities leads to excessive expenditure beyond requirements by the farmers.

For successful scaling-up of DSR in India, we present the following policy recommendations. Ensuring effective management of weedicides and herbicides requires a strategic approach to combat the excessive use and harmful impacts on environment and mankind. Secondly, monitoring the packaging, marketing, and sale of herbicides is crucial for controlled usage in the farms. Moreover, providing guidance and knowledge about the recommended limits of the use of weedicides is another important step towards controlling the unwarranted use. Additionally, increase in extension services about the sowing and germination of crops, harvesting of the crop, application of pesticides and weedicides, and weather updates is a crucial setup for ensuring proper execution and implementation of DSR. Therefore, these efforts combined in policy regulations will help in encouraging farmers to adopt DSR and upscaling the technology in the region.

- **Sri Lanka –** The CSA prioritized technologies for Sri Lanka are solar powered water pumps with micro-irrigation systems, multi-purpose soil conservation bunds, and protected agriculture methods. Now, we present the main constraints faced in scaling-up of these technologies and propose policy recommendations to them.
  - **Solar-powered water pumps coupled with micro-irrigation systems:** The main challenges faced in adoption of this technology are as follows:
    i. High capital cost of installation of solar pumps making it unaffordable for small-holder farmers.
    ii. The cost of pumping water is in addition to the cost of digging water source – ponds in the current scenario.
    iii. The cost of micro-irrigation system is an add-on.

Expansion of solar-powered micro-irrigation system involves community driven initiatives. One of the effective strategies involves fostering community ownership of pumps, leading to a cooperative effort among 5-6 farmers who share the common water pump. This will not only promote a sense of shared responsibility but also efficiently optimize the scarce resources. This will also lead to collaborative effort among the farmers, leading to satisfying individual farmer's needs effectively, enabling cooperation and mutual benefit among the community. Secondly, facilitating credit facilities to the farmers is crucial for the installation of solar-powered pumps. Access to credit facilities enhances the adoption among the community and investment in eco-friendly and cost-effective manner to harness the benefits of renewable energy efficiently. The combined efforts by the community and administrators will lead to scaling-up adoption of solar-powered pumps in the regions of Sri Lanka.

- **Multi-purpose soil conservation bunds:** The key constraints in the adoption of multi-purpose soil conservation bunds are as follows:

iv. Construction of bunds in small farms is difficult and of little use because the main purpose of bunds (reduce erosion and runoffs) is not met on fragmented lands.
v. High maintenance cost of the bunds creates a burden on small-holder farmers.
vi. Conflicting land use priorities between regular agricultural practices and need for soil conservation bunds hinder their construction.

The long-term sustainability of soil conservation bunds is essential for soil and water conservation. This is possible through plantation of horticulture crops like pomegranate, drumsticks, etc., ensuring stability of the bunds and a diversified income source for the farmers. The additional income will help the farmers in incurring the maintenance cost of the bunds. Hence, coordinated efforts will helps in upscaling construction of soil conservation bunds in the regions of Sri Lanka.

5. Conclusion

The development of effective adaptation and mitigation strategies is imperative to effectively address the extant and future risks stemming from adverse impacts due to climate change. Climate-smart agriculture (CSA) emerges as a transformative approach to realign agricultural development with the new realities of climate change (Lipper, et al., 2014). CSA aims to diminish farmers' exposure to short-term risks while bolstering their resilience by cultivating the capacity to adapt and thrive amidst shocks and long-term stresses. Essential components of this approach include identifying synergies, evaluating costs and benefits based on farmers' experiences, and crafting context-specific, socially applicable, and viable options. Consequently, prioritizing CSA technologies, followed by scaling up these methods, becomes indispensable. This study advocates for a prioritization framework grounded in World Bank indicators, concurrently identifying opportunities and challenges in the scaling up of CSA technologies.

CSA technologies offer numerous advantages, scaling them up in diverse geographical zones poses multifaceted challenges. Insights derived from primary and secondary sources reveal key constraints in adopting CSA technologies. These encompass farmer skepticism arising from delayed returns (sometimes up to two to three years), inadequate knowledge and technical skills, ergonomic concerns related to machinery, high equipment acquisition costs, limited awareness, restricted availability of machines and technical support, absence of formal credit sources, and unreliable climate information. To bolster CSA adoption and upscale these technologies, several policy interventions are recommended. These include augmenting formal credit availability for farmers, enhancing extension services, promoting awareness about CSA practices, integrating information and communication technology (ICT) with agro-advisory services, establishing dedicated green climate funds, fostering climate-smart value chains, implementing policy regulations featuring tax incentives and subsidies, aligning national agricultural policies with climate change, incorporating CSA into overarching policy frameworks, strengthening monitoring and evaluation systems, and cultivating robust institutional support through collaborative efforts among various government departments.

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Appendix

Table 2: Structure of the CSA tech index

Theme	Sub-theme	Indicator
Productivity	**Crop system**	• Increase in yield (%) • Reduction in land degradation (%) • Enhances soil health (%)
	Water use	• Saving in irrigation water (%) • Reduction in withdrawal of water for agriculture use (%)
	Energy	• Reduces energy use (%)
	Pest management	• Increases the share of agriculture land on which IPM is adopted (%)
Resilience	**Robustness**	• Improvement in human capital • Increase in stability of agricultural production needed to ensure own food security and income • Promotion of crop diversification
	Self-organization	• Facilitates cooperation and networking among producers • Contributes to gender inequalities
	Cropping system	• Increases the resilience of cropping system to adverse climate conditions (floods, droughts etc.)
Mitigation	**Emission intensity**	• Meets emission intensity targets
	Sequesters carbon	• Sequesters carbon in comparison with current intervention in similar farming system

Source: World Bank CSA tech index (World Bank, Climate-smart agriculture indicators, 2016)

Table 3: Detailed scoring of the CSA technologies based on the CSA tech index

Country	Technology (Score)
Bangladesh	Bed planting with residue retention (4.32) Integrated nutrient management (4.33) Strip planting (4.39) Zero tillage with mulch (4.61) Relay cropping (4.17)
Bhutan	Sustainable land management (3.36) Protected agriculture technology (3.7) Drip/Smart irrigation technology (3.6)
India	Improved seed variety (Foxtail millet) (3.5) Improved seed variety (Red gram) (3.5) Plastic mulching (4.1) Resilient intercropping (3.8) Direct seeded rice (4.1) Laser land levelling (3.6) Broad Bed Furrow (Soyabean) (3.8) Conservation agriculture (4.4) Zero tillage (4.5) Micro irrigation (4.2)
Nepal	Crop system (DSR in rice-wheat system + brown manuring) (4.23) Laser land levelling (4.06) Alternate wetting and drying (4.36)

Country	Technology (Score)
	Zero tillage wheat (4.36) Maize based intercropping (4.42) Drought tolerant rice varieties (3.94) Green manuring in rice (4.33) Flood tolerant seed varieties (3.78) Integrated nutrient management (4.17) Drip irrigation technology (4.53) Raised bed planting (3.77) Conservation agriculture (4.33)
Pakistan	Zero tillage wheat in rice-wheat cropping system (4.92) DSR in rice-wheat cropping system (4.06) Alternate wetting and drying (4.22) Mechanical transplanting rice (4.28) Zero tillage/happy seeder wheat (4.72) Raised beds/ridge planting wheat (4.17) Resilient cropping system (mung-wheat, soyabean-wheat) in rainfed area (4.06) Resilient cropping system (sesbinia-wheat) in rainfed area (4.33) Drought tolerant seed varieties (3.5)
Sri Lanka	Solar powered water pumping coupled micro irrigation systems (4.6) Multi-purpose soil conservation bunds (4.2) Application of biochar (4.2) Crop rotation with legumes in paddy fields (3.8) Protected agriculture for high value crops (3.8) Rainwater harvesting techniques (3.8) Cultivation of climate smart crops - Stress tolerant/ resistant varieties, short age crops/ varieties (3.7) Home gardening with organic manure (3.7) Alternative Wetting & Drying irrigation in paddy cultivation (3.6) 'Parachute" method of paddy seedling broadcasting (3.4) Climate forecasting based Agro-met advisory & alerts (3.3)

Source: Compilation of scores by NFPs of member countries

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