WORLD AGRICULTURE

Associate Scientist, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Borlaug Institute of South Asia (BISA), International Maize and Wheat Improvement Centre (CIMMYT), New Delhi, 110012, India.

[2]Regional Program Leader, CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS), Borlaug Institute of South Asia (BISA), International Maize and Wheat Improvement Centre (CIMMYT), New Delhi, 110012, India.

Summary

South Asia[SA] is very vulnerable to current as well as future climatic risks owing to its large population, food demand and poverty. There is an urgency to increase the adaptive capacity of the region's agriculture to a changing climate.

This paper highlights a wide range of Climate Smart Agriculture options undertaken to address the risks and challenges faced by farmers in the region. Climate Smart Agriculture (CSA) helps to improve farm productivity and income, increase adaptation and resilience to a changing climate and reduces greenhouse gas emissions.

CSA options include *water, energy, nutrient, carbon, weather and knowledge-smart* technologies, practices and services suitable for various crops and cropping systems in the region. The paper also summarises a meta-analysis of climate- smart agricultural technologies adopted in South Asia.

The implementation of a range of CSA technologies can improve yield of rice from 0.5 to 2.5 tonne per hectare and wheat yield from 0.2 to 2.8 tonne per hectare (33-64). Our primary study of three agri-business companies outreach areas showed that the involvement of agri-business companies has significance for the adoption of CSA technologies in their outreach areas.

Depending on the type of CSA technology, the CSA technology adoption rate in the industry's outreach area was 50-60% in rice, 60-70% in maize and 80-90% in sugarcane farmers. The average farm income has increased by 20% following CSA interventions in all crops.

This paper also discusses the key challenges and enabling factors that can accelerate CSA adoption and potential use of new information and communication technologies (ICTs) for scaling-out a range of CSA technologies. The paper concludes by discussing public sector and private sector strategies to scale-up adaptation options depending on the nature of climatic risks and investment requirements.

Key words:

Climate Smart Agriculture (CSA), Information and Communication Technologies (ICT), Adaptation, Scaling, Agricultural Extension System **SA** South Asia countries: India, Pakistan, Afghanistan, Bangladesh, Nepal, Sri Lanka, Bhutan and Maldives.

1 Introduction

The majority of land in South Asia is used for agriculture. Currently, more than 260-million-hectare land is used for it and it contributes about 15% of the total Gross Domestic Product (GDP) and employing more than 50% of the population in the region (1).

In some countries, such as in Bangladesh and Nepal, more than 65% population is engaged in the agricultural sector. The region has made tremendous progress in last four decades in food production and availability, yet a quarter of the world's hungry and 17% of the world's undernourished population lives there (2).

Total population in the region is expected to grow to 2-2.68 billion people by 2050 (3). This, accompanied with rising per capita income, and urbanisation will lead to an increase in demand for grain and a gradual shift of expenditure from cereals to meat, milk, fish and other animal products.

Therefore, the monetary value of agricultural production must increase by more than 75% from the 2005/07 level in order to meet the increased food demand in 2050 (4).

The frequency and severity of extreme climatic events such as droughts, cold and heat waves, floods, storms and cyclones have increased across all countries of South Asia in the last few decades (5-7). These events are leading to considerable production variability across the region.

Several studies have shown that, unless we start adapting now, South Asia could lose 10-50% of crop production by the end of the century due to global warming, despite the beneficial aspects of increased atmospheric CO_2 (8-11). Projections indicate the possibility of losing of 4-5 million tons of wheat production with each increment of 1^{o}C temperature throughout the crop growing period (12). Recent simulation analysis has also indicated that rain-fed maize, sorghum and paddy yields are likely to be adversely affected by the increase in temperature (13). Moreover, the projected increase in drought and flood events could result in greater instability in food production and threaten the livelihood security of millions of people in the region (14).

A wide variety of CSA options has been proposed to reduce the negative impacts of climate change, build climate resilient agricultural production systems, and harness the benefits of global warming. These options range from a simple adjustment in crop management practices to transformation of agricultural production systems to adjust with new climatic conditions in a particular location (15,16).

Several studies have shown that there is a large potential for improving crop yields, input use efficiency and reduction of greenhouse gas (GHG) emissions by implementation of various practices and technologies in diverse cropping systems in the South Asia region (17-20).

Therefore, the objectives of this paper are: (i) to outline adaptation options suitable for different crops and cropping systems in South Asia, (ii) to assess the benefits of a single option, or a portfolio of adaptation options based on a literature review, and (iii) to present strategies to disseminate adaptation options in agriculture to reach the required scale. The paper also discusses public and private sector strategies for a more effective uptake of adaptation options depending on the nature of climatic risks and investment requirements.

2 Adapting agriculture to changing climate

Agricultural production systems in all South Asian countries are well known to be sensitive to long-term climate change and short-term (annual and seasonal) weather variability (9,11).

Consequently, the production systems in the region need to be adjusted. focusing on effective management of current as well as future climatic risks. Recent research in South Asia identifies a range of options that can minimise climatic risks and build a resilient agricultural production. Depending on their appropriateness for a particular location, these options include, *water, energy, nutrient, carbon, weather and knowledge smart* technologies, practices and services (Table 1).

Change in precipitation pattern and atmospheric temperatures create water and heat/cold stresses in many crops. Several practices and technologies such as water conservation and harvesting measures, and low water requirement technologies and practices, can help to overcome the water related stresses in agriculture and improve water use efficiency.

Crop yield improvement potential of these technologies under water deficit conditions has been adequately established through experimental studies and on-farm trials in a number of locations in South Asia (e.g. 21, 22).

There are a number of technologies and practices that help to improve energy and nutrient use efficiency under changing climate. For instance, minimum tillage, use of crop residues, change in crop sowing methods, and site specific nutrient management can significantly improve energy and nutrient use efficiency and reduces carbon emissions (e.g. 17, 18, 23). In many locations of South Asia, farmers experience large crop yield losses due to severe drought or flood events.

A non-structural intervention to reduce production losses and stabilize farmers' income (24-26) exists to contain climatic risk management by dissemination of ICT based climate information through agro-advice services, together with weather-based insurance.

These *weather smart* interventions aim to improve farmers' capacity to adopt other climate smart technologies/practices and enhance farm productivity under a changing climate.

A meta-analysis of adoption benefits of climate smart technologies and practices was conducted based on experimental and on-farm research (33-64 in Appendix 1). Interventions, related to nutrient, water, and energy were examined across South Asia.

Adoption of a single technology or a combination of them for rice and wheat crops had a significant impact on yield. Table 2 presents change in rice yield from the adoption of different technologies. Average increase in rice yield from the use of nutrient and water management technologies was 83% (2.42 tonne/ha) and 23% (0.19 tonne/ha), respectively.

Use of zero-tillage in rice may reduce its yield, but a combination of minimum tillage with other technologies such as nutrient and water management has been shown to improve rice yield by 6.9%.

Similarly, use of a leaf colour chart (showing the greenness of the crop leaf, indicating nitrogen requirement of the crop) and GreenSeeker (to measure vegetative index to determine nutrient requirement for the crop) to manage nutrient application through split dose in rice crop can improve average yield by 39% or 1.73 tonne/ha. Also, laser based land levelling improves water and fertilizer distribution in rice field resulting in yield improvement by 13% (0.55 tonne/ha).

Similarly, Table 3 presents change in wheat yield from the adoption of different climate smart technologies. Average improvement in wheat yield from the use of nutrient and water management technologies were 85% and 24%, respectively.

In wheat crop, both minimum tillage and combination of tillage, nutrient and water management technologies have positive impacts. Minimum tillage alone can improve wheat yield by 5.8% (0.25 tonne/ha) and combination with other technologies by 8.8% (0.35 tonne/ha). In both rice and wheat crops, water and nutrient management have a large impact on yields.

3 Challenges introduced by the adoption of new technologies

Despite evidence from successful pilot programmes and on-farm studies, the uptake of many CSA practices and technologies is not adequate to achieve their full potential in agricultural production in the South Asian countries (27). For instance, the uptake rate of new water management practices in India in last 40 years is only about 12% (28).

There could be many barriers, including lack of financial resources, policy and institutional bottlenecks, and lack of coordinated actions by different stakeholders to the uptake (29, 30).

Table 4 presents key challenges, inhibiting and enabling factors and stakeholders in adapting agriculture to changing climate. Farmers need to make a substantial level of investment in different forms to adopt CSA technologies. But given the uncertainty of climate change impact and constraints on resources, smallholder farmers focus more on current farm income and food security than investment for future adaptation benefits.

Their transaction cost in accessing technologies, services, finance and insurance is very high owing to small and fragmented land holdings. Transaction costs of financing and insurance institutions are also too high to deal with marginal/small holdings/credit/insurance.

These dilemmas point to a need for viable business models around adaptation options at local and national levels. Similarly, farmers’ awareness, accessibility and affordability to adaptation options are major issues in many South Asian farm communities. The promotion of private sector and farming system based adaptation options is a key enabling factor for adoption of CSA technologies and practices.

In South Asian countries several institutional and policy interventions have been initiated for adaptation to changing climate. National Adaptation Plans of South Asian countries outline existing and future policies and programmes to address climate change adaption in agriculture.

The sub-national level climate change adaptation plans also focus on addressing the existing as well as future challenges of climate change and taking required steps to reduce the associated risks and vulnerabilities. For the successful implementation of national and sub-national adaptation plans for climate change, South Asian countries need to integrate several CSA options in current policies and programs relating to agricultural development.

This requires engagement and networking with a multitude of stakeholders in policy design and implementation process and development of science-based complete package of adaptation options.

Another key challenge in adapting agriculture to changing climate is to include socially and economically disadvantaged groups e.g. gender and marginalised farmers in the climate change adaptation process. Women account for up to 60% of the agriculture workforce in South Asia.

In some countries, such as Bangladesh and Nepal, the figure is even higher as men continue to migrate in search of off-farm work. Women and marginal farmers face specific barriers in adapting to changing climate due to lack of access to information, low literacy levels and social inequalities. Mainstreaming gender and social inclusion in adaptation policies and institutions, and training and capacity building activities can enable this group of farmers to adapt to climate change.

4 Scaling adaptation options

4.1 Public sector strategy

In South Asian countries, agricultural technologies and knowledge are predominantly created and disseminated by public institutions. The public institutions are largely responsible for mobilizing available CSA technologies to meet farmers' needs.

Thus, integration of climate smart technologies, practices and services with existing agricultural extension programs is vital to scale up adaptation options to large areas and farmers. In all South Asian countries, agricultural extension systems are well established and governments are investing huge amount of financial resources to develop infrastructures, human resources and technologies.

Some modification in these systems can promote adaptation options in agriculture. Figure 1 presents four possible combinations of CSA technology dissemination through agricultural extension systems. The existing agricultural extension systems include direct technology transfer to farmers, provision of advisory services through extension staff, human resource development for service provision and farmers' empowerment.

Supply of improved seeds resilient to climatic stresses, precision nutrient and water management technologies, and farm machinery for tillage, intercultural operation and crop harvesting can be integrated with the existing technology transfer mechanism.

Similarly, advisory services can include provision of CSA implementation guidelines and ICT based climate information and agro-advisory services to the farmers. Use of ICT based tools such as mobile phones, televisions and radios have proven to be efficient in agricultural extension and advisory services.

The dissemination of agromet information through ICT based tools combine research-meteorology-extension and farmers' continuum. Inclusion of CSA knowledge into the course curriculum of agriculture universities and technical institutes promotes human resource development.

Experimental learning and farmer-to-farmer exchange of knowledge can also encourage farmers to implement adaptation options in their farms.

4.2 Private sector strategy

a. Business opportunity

The role of private sector in climate change adaptation is becoming more prominent. Over the last few decades, advances in science have enabled rapid development of climate smart technologies and services for adapting agriculture to changing climate.

Many technologies and services that exist are marketable products, such as improved seeds, agrochemicals, farm machinery, water management system and ICT based climate and agro-advisory services. Table 5 presents technologies and services in which the private sector can invest to promote their business in the climate risk management sector. The business opportunities for private sector range from supply of machinery and agricultural inputs to service provision.

b. Ensure supply of raw materials

An important area of consideration for the agri-business industry is securing supply chains to ensure availability of production inputs under increasing climatic risks. In the agri-business sector, unpredictability of availability, quality and prices of raw materials could be prompted by climatic risks (31, 32).

Climatic risks such as extreme weather events, prolonged period of drought, floods and heat stresses can severely reduce local food production. The management of existing and of potential climatic risks in their input supply chain requires supply by a sustainable and economically viability local industry.

The increased climatic risks also offer agri-business industries a motivation to strengthen supplier relationship with producers. The agri-business industries can directly (in tightly-coupled supply chain) and indirectly (in loosely-coupled supply chain) promote CSA technologies, practices and services that minimize a range of climatic risks in a particular crop.

Table 6 presents results of a case study of private sector conducted in Nepal. Three agri-business industries were chosen to promote CSA technologies in their local command areas.

The first agri-business industry is procuring rice from local farmers, the second and third are procuring maize and sugarcane respectively. In rice and maize crops, the supply chains are loosely coupled and agri-business industries purchase crop from collectors and wholesalers.

For the sugarcane crop, there is a tightly-coupled supply chain and the sugar industry directly procures sugarcane from the farmers. This industry has sugarcane purchasing agreements with farmers. These three industries are promoting many CSA options listed in Table 1 above. The CSA technology adoption rate in the industry's command area was 50-60% in rice and 60-70% in maize, within three years, depending on the type of CSA technology. This adoption rate was up to 90% by sugarcane farmers. Similarly, the average farm income has increased by 20% following CSA interventions in all crops. The average benefit-cost ratios under CSA intervention for farmers were 1.3, 1.4 and 1.8 for rice, maize and sugarcane, respectively. These results indicate that the agri-business industries may play a crucial role to promote CSA options in agriculture.

5 Conclusions

South Asian agriculture is one of the most vulnerable sectors to changing climate owing to high exposure to climatic stresses and low adaptive capacity. A range of adaptation options are available at the farm, community and landscape levels. Climate-smart agriculture (CSA) can offer a variety of schemes for adaptation options to increase agricultural production and income sustainably, to increase adaptation and resilience, and to reduce GHG emissions from agricultural activities.

This paper presented a range of adaptation options to mitigate moderate to extreme climatic risks. These include water, energy, nutrient, carbon, weather and knowledge-smart technologies, practices and services. The range for use locally will depend on their climatic risks and agricultural production system. The meta-analysis of CSA studies conducted in South Asia indicates that there is a large potential to improve crop yields from the adoption of nutrient, water and tillage management options.

However, the adoption of these technologies at farm, community and landscape level has many challenges. Farmers' investment capacity for CSA technologies and opportunity costs of investments for several adaptation options are key challenges in adapting agriculture to a changing climate.

Similarly, integration of CSA into current agricultural development policies and gender and social inclusion are other testing factors. But there are many enabling factors and game changers that can help to promote CSA technologies in vulnerable areas. Hence, more science-policy dialogues, engagement with policy makers, and development of CSA evidence, need to be considered.

Strengthening the public sector for promoting CSA options through existing agricultural extension systems is a key to success. Simple modifications in current technology transfer, advisory services, human resource development and farmers' empowerment activities can scale wide range of CSA technologies, practices and services in agriculture. Similarly, the private sector can promote many adaptation options through business in CSA technologies and services. Agri-business industries dedicated to maintaining a high-quality and stable supply of agricultural products can enhance their supply chain management strategy by investing more in CSA technologies and farmers' capacity building.

Acknowledgement

We acknowledge the support for this work provided by the numerous donors contributing to the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

The authors would like to thank Ritika Khurana (Consultant Researcher) and Milan K Joshi (PAC-Nepal) for their support in information collection. We also thank anonymous reviewers and editors for comments on an earlier version of the manuscript. The views expressed in the paper are the authors' alone.

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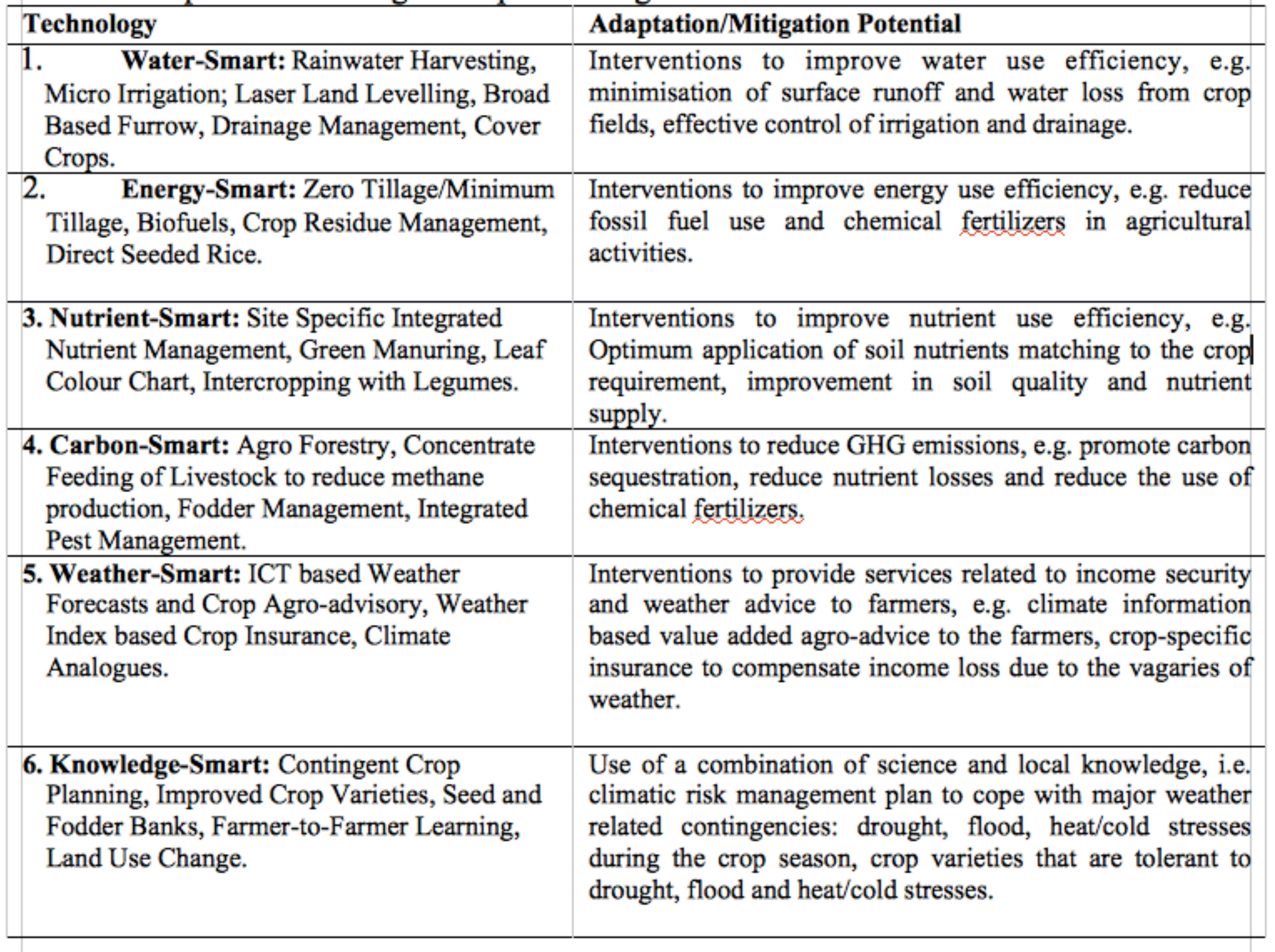
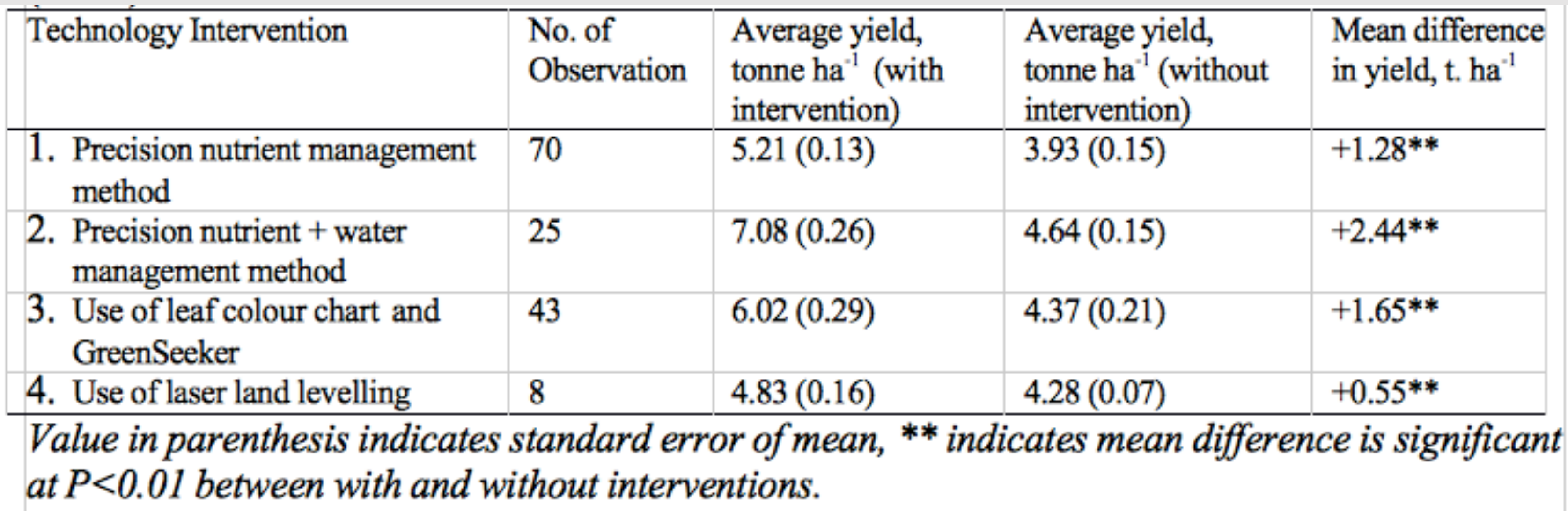
Figures



Technology	**Adaptation/Mitigation Potential**
1. **Water-Smart:** Rainwater Harvesting, Micro Irrigation; Laser Land Levelling, Broad Based Furrow, Drainage Management, Cover Crops.	Interventions to improve water use efficiency, e.g. minimisation of surface runoff and water loss from crop fields, effective control of irrigation and drainage.
2. **Energy-Smart:** Zero Tillage/Minimum Tillage, Biofuels, Crop Residue Management, Direct Seeded Rice.	Interventions to improve energy use efficiency, e.g. reduce fossil fuel use and chemical fertilizers in agricultural activities.
3. Nutrient-Smart: Site Specific Integrated Nutrient Management, Green Manuring, Leaf Colour Chart, Intercropping with Legumes.	Interventions to improve nutrient use efficiency, e.g. Optimum application of soil nutrients matching to the crop requirement, improvement in soil quality and nutrient supply.
4. Carbon-Smart: Agro Forestry, Concentrate Feeding of Livestock to reduce methane production, Fodder Management, Integrated Pest Management.	Interventions to reduce GHG emissions, e.g. promote carbon sequestration, reduce nutrient losses and reduce the use of chemical fertilizers.
5. Weather-Smart: ICT based Weather Forecasts and Crop Agro-advisory, Weather Index based Crop Insurance, Climate Analogues.	Interventions to provide services related to income security and weather advice to farmers, e.g. climate information based value added agro-advice to the farmers, crop-specific insurance to compensate income loss due to the vagaries of weather.
6. Knowledge-Smart: Contingent Crop Planning, Improved Crop Varieties, Seed and Fodder Banks, Farmer-to-Farmer Learning, Land Use Change.	Use of a combination of science and local knowledge, i.e. climatic risk management plan to cope with major weather related contingencies: drought, flood, heat/cold stresses during the crop season, crop varieties that are tolerant to drought, flood and heat/cold stresses.

Figure 1.

Table1: Adaptation and mitigation options in agriculture

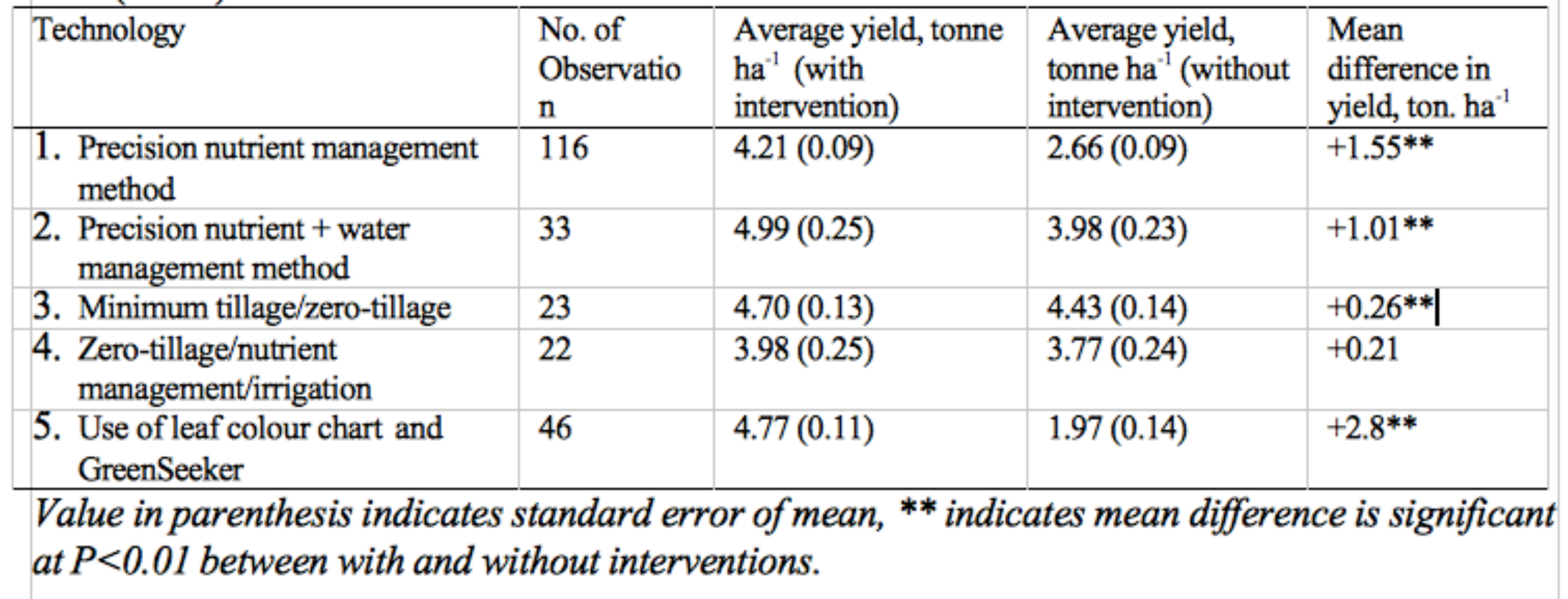


Technology Intervention	No. of Observation	Average yield, tonne ha^{-1} (with intervention)	Average yield, tonne ha^{-1} (without intervention)	Mean difference in yield, t. ha^{-1}
1. Precision nutrient management method	70	5.21 (0.13)	3.93 (0.15)	+1.28**
2. Precision nutrient + water management method	25	7.08 (0.26)	4.64 (0.15)	+2.44**
3. Use of leaf colour chart and GreenSeeker	43	6.02 (0.29)	4.37 (0.21)	+1.65**
4. Use of laser land levelling	8	4.83 (0.16)	4.28 (0.07)	+0.55**

*Value in parenthesis indicates standard error of mean, ** indicates mean difference is significant at P<0.01 between with and without interventions.*

Figure 2.

Table 2: Change in rice yield after climate smart interventions in different locations of South Asia (33-64)

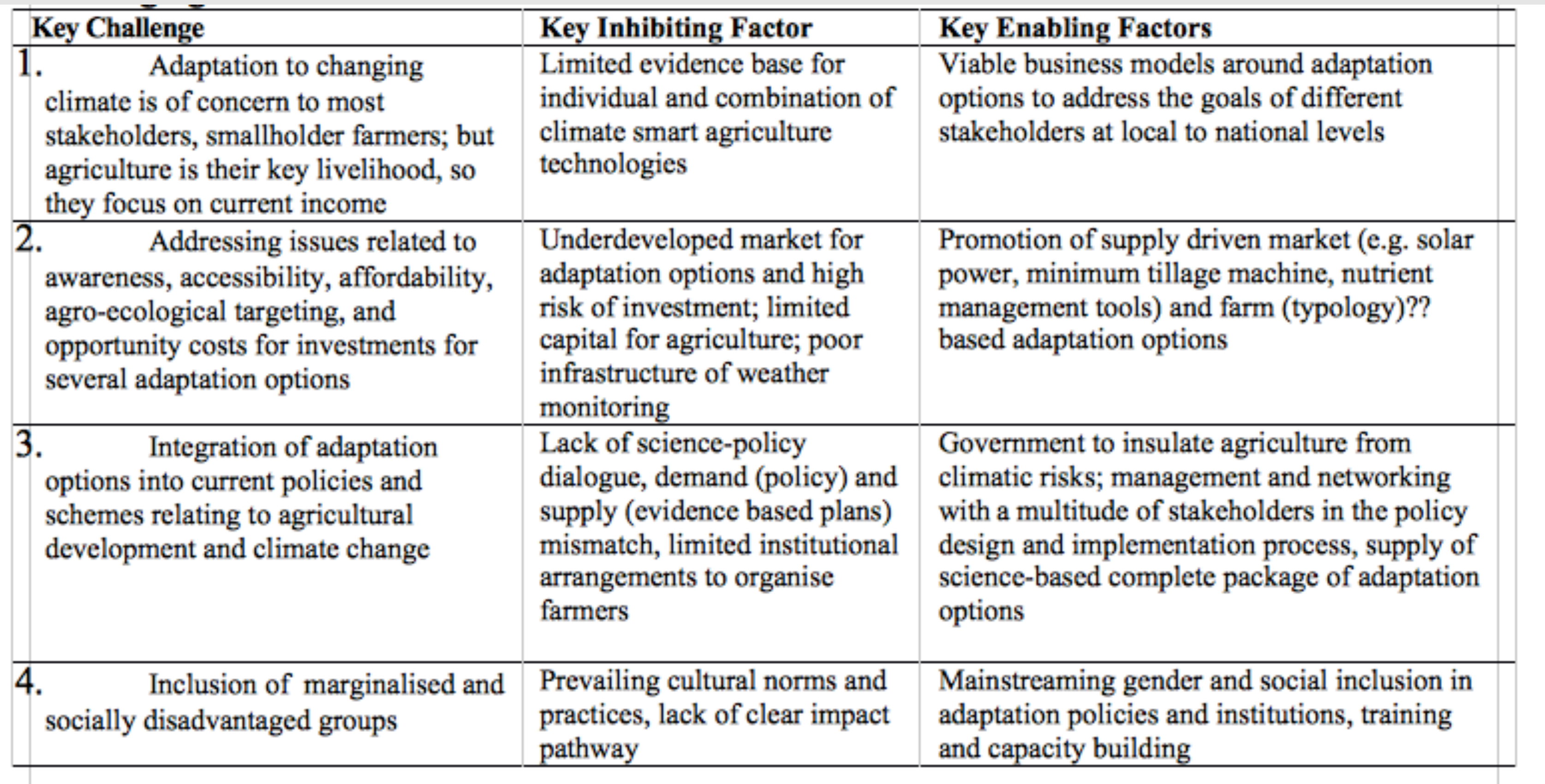


Technology	No. of Observation	Average yield, tonne ha^{-1} (with intervention)	Average yield, tonne ha^{-1} (without intervention)	Mean difference in yield, ton. ha^{-1}
1. Precision nutrient management method	116	4.21 (0.09)	2.66 (0.09)	+1.55**
2. Precision nutrient + water management method	33	4.99 (0.25)	3.98 (0.23)	+1.01**
3. Minimum tillage/zero-tillage	23	4.70 (0.13)	4.43 (0.14)	+0.26**
4. Zero-tillage/nutrient management/irrigation	22	3.98 (0.25)	3.77 (0.24)	+0.21
5. Use of leaf colour chart and GreenSeeker	46	4.77 (0.11)	1.97 (0.14)	+2.8**

*Value in parenthesis indicates standard error of mean, ** indicates mean difference is significant at P<0.01 between with and without interventions.*

Figure 3.

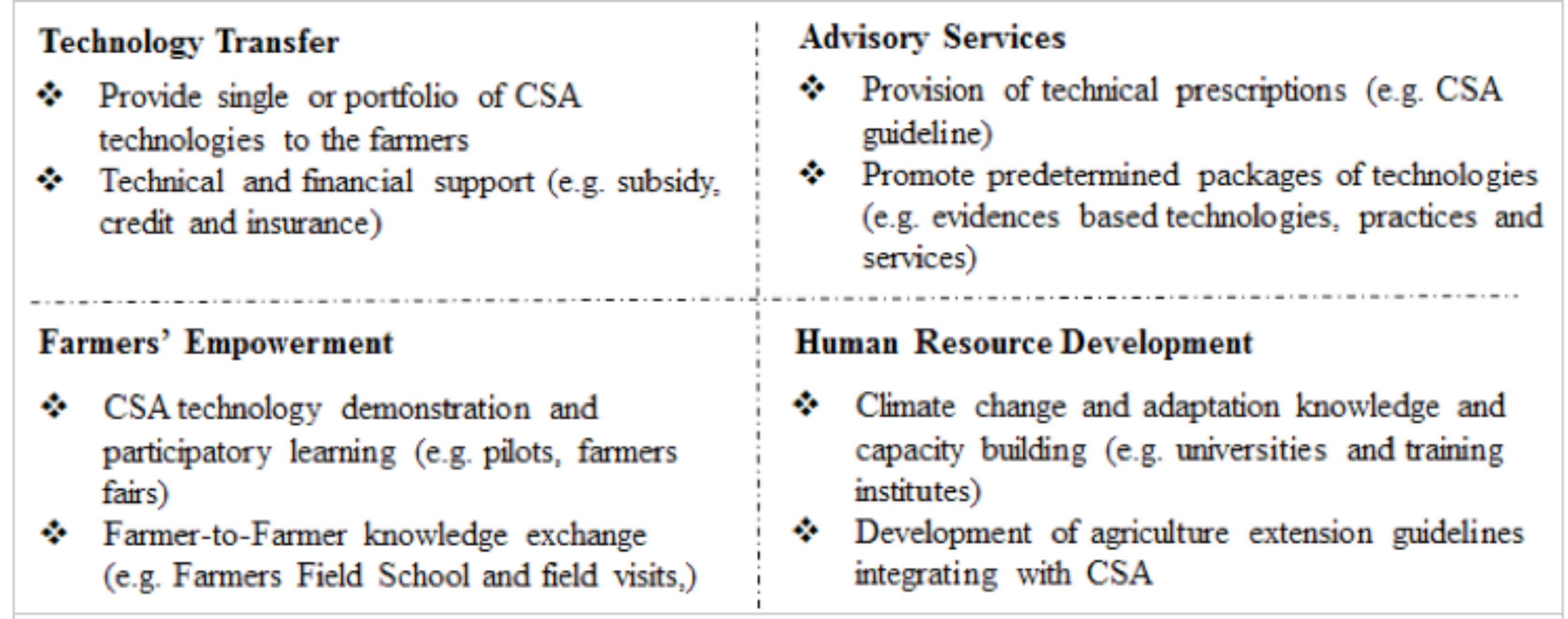
Table 3: Change in wheat yield after climate smart interventions in different locations of South Asia (33-64)



Key Challenge	**Key Inhibiting Factor**	**Key Enabling Factors**
1. Adaptation to changing climate is of concern to most stakeholders, smallholder farmers; but agriculture is their key livelihood, so they focus on current income	Limited evidence base for individual and combination of climate smart agriculture technologies	Viable business models around adaptation options to address the goals of different stakeholders at local to national levels
2. Addressing issues related to awareness, accessibility, affordability, agro-ecological targeting, and opportunity costs for investments for several adaptation options	Underdeveloped market for adaptation options and high risk of investment; limited capital for agriculture; poor infrastructure of weather monitoring	Promotion of supply driven market (e.g. solar power, minimum tillage machine, nutrient management tools) and farm (typology)?? based adaptation options
3. Integration of adaptation options into current policies and schemes relating to agricultural development and climate change	Lack of science-policy dialogue, demand (policy) and supply (evidence based plans) mismatch, limited institutional arrangements to organise farmers	Government to insulate agriculture from climatic risks; management and networking with a multitude of stakeholders in the policy design and implementation process, supply of science-based complete package of adaptation options
4. Inclusion of marginalised and socially disadvantaged groups	Prevailing cultural norms and practices, lack of clear impact pathway	Mainstreaming gender and social inclusion in adaptation policies and institutions, training and capacity building

Figure 4.

Table 4: Key challenges, inhibiting and enabling factors and stakeholders in adapting agriculture to changing climate



Technology Transfer

- ❖ Provide single or portfolio of CSA technologies to the farmers
- ❖ Technical and financial support (e.g. subsidy, credit and insurance)

Advisory Services

- ❖ Provision of technical prescriptions (e.g. CSA guideline)
- ❖ Promote predetermined packages of technologies (e.g. evidences based technologies, practices and services)

Farmers' Empowerment

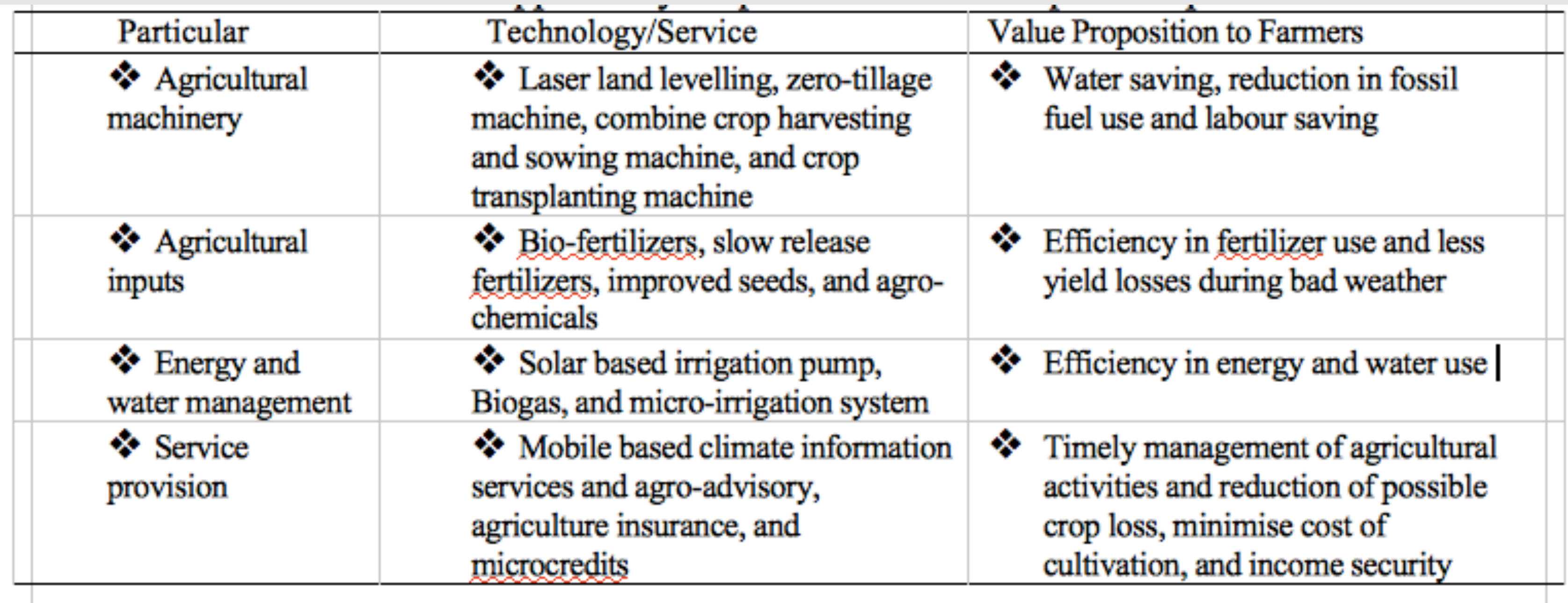
- ❖ CSA technology demonstration and participatory learning (e.g. pilots, farmers fairs)
- ❖ Farmer-to-Farmer knowledge exchange (e.g. Farmers Field School and field visits,)

Human Resource Development

- ❖ Climate change and adaptation knowledge and capacity building (e.g. universities and training institutes)
- ❖ Development of agriculture extension guidelines integrating with CSA

Figure 5.

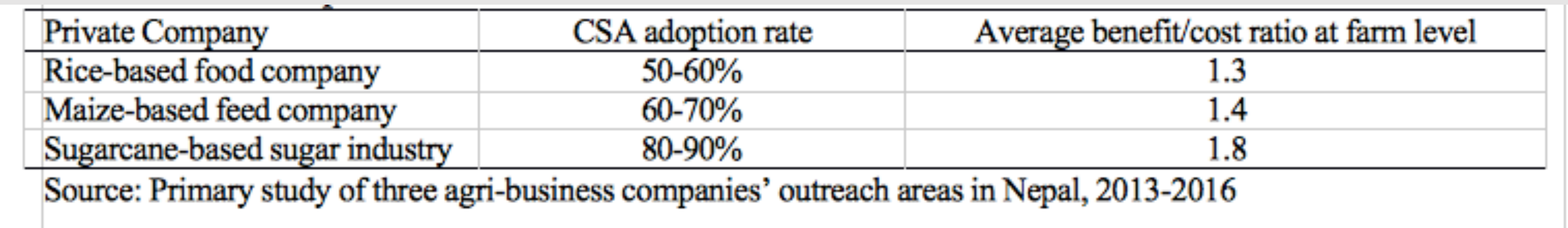
Fig 1 Integration of CSA into the four concepts of agricultural extension



Particular	Technology/Service	Value Proposition to Farmers
❖ Agricultural machinery	❖ Laser land levelling, zero-tillage machine, combine crop harvesting and sowing machine, and crop transplanting machine	❖ Water saving, reduction in fossil fuel use and labour saving
❖ Agricultural inputs	❖ Bio-fertilizers, slow release fertilizers, improved seeds, and agro-chemicals	❖ Efficiency in fertilizer use and less yield losses during bad weather
❖ Energy and water management	❖ Solar based irrigation pump, Biogas, and micro-irrigation system	❖ Efficiency in energy and water use
❖ Service provision	❖ Mobile based climate information services and agro-advisory, agriculture insurance, and microcredits	❖ Timely management of agricultural activities and reduction of possible crop loss, minimise cost of cultivation, and income security

Figure 6.

Table 5: Potential investment opportunity for private sector in adaptation options



Private Company	CSA adoption rate	Average benefit/cost ratio at farm level
Rice-based food company	50-60%	1.3
Maize-based feed company	60-70%	1.4
Sugarcane-based sugar industry	80-90%	1.8

Source: Primary study of three agri-business companies' outreach areas in Nepal, 2013-2016

Figure 7.

Table 6: CSA adoption rate and benefit-cost

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Dr Arun Khatri-Chhetri,

Professor Pramod K Aggarwal

19th July 2017

Comments