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Farmer Perceptions, Behaviour, Investment Needs and Policy Changes for the Adoption of Conservation Agriculture

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ABSTRACT

The green revolution has transformed India from a food deficit to a food surplus country. The over-exploitation of natural resources along with climate change has posed a greater challenge for agriculture than ever before. In the context of sustainability of natural resources and increasing farmer's income, conservation agriculture (CA) practice has been emphasised. CA has been advocated primarily for the rainfed areas although in India, it has largely been applied in irrigated areas, mostly in the Indo-Gangetic plains (IGP). Though the outcomes of CA are not realized in its initial years, but can be highly promising and profitable in the long run. This paper is an attempt to reveal farmers' perceptions about CA, adoption issues of CA and puts forth a few suggestions that maybe considered during policy formulation for enhancing the adoption of CA.

Key words: Conservation agriculture, farmers' perceptions, adoption, policy formulation

Introduction

Increasing population, urbanisation, mass scale deforestation and pollution are just a few factors to quote responsible for global warming and climate change, which in turn, is directly affecting the agriculture and indirectly the human life. Natural resources degradation has been a great concern to meet the future demand for food, feed, fodder and fibre. The food security as well as sustainable farm livelihoods are threatened by decline in productivity, soil erosion, nutrient deficiencies, depletion in groundwater, decrease in biodiversityand increase in environmental problems all over the world. In India, especially in the western Indo-Gangetic plains which happened to be the land of green revolution, the production system is facing serious challenge of landandwater scarcity, soil health degradationand rising production cost. Groundwater use increased by 500% over past 50 years; 15% of the blocks in India extract more water than is replenished (CGWB, 2014); generous electricity subsidies and flat monthly power tariff has incentivized over-extraction of groundwater. Therefore, it is important to look for appropriate technologies to prevent degradation of soil and water resources, while maintaining sustainable agricultural production (Joshi, 2011). Crop residue burning (about 140 M tonnes) has become a serious issue in the IGP after harvest of rice to deal with leftover stubbles and timely sowing of wheat (Somasundaram *et al.*, 2020), which affect the air quality over the vast North-West region of India.

The role of conservation agriculture (CA) is well recognised to meeting aforesaid agrarian challenges in many developed and developing

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countries. The area under CA has been showing an increasing trend all over the world (Mishra *et al.*, 2018). In 2015–2016, adoption of CA has been in 180 M ha that was about 12.5% of the total global crop land (Somasundaram *et al.*, 2020; Chatterjee and Acharya, 2021). USA has been the pioneer country in adopting CA systems followed by Brazil, Argentina, Australia and Canada (FAO, 2012). According to Kassam *et al.* (2019), no till practices are adopted by the farmers mostly in the rice-wheat cropping (<5 M ha) and in cultivation of maize, cotton, pigeon pea and chickpea crops in rainfed upland areas of India. CA is mostly practiced in areas under rice-wheat system and is estimated to cover ~13 M ha in South Asia (10 M ha in India).

Concept of CA is based on the principles of no/minimal disturbance to soil, permanent cover on soil using cover crops, mulch, crop residues, and diversified crop rotation. CA prevents the loss of arable land by maintaining of a permanent soil cover, minimum soil tillage, crop residues management and crop diversification, and improves biodiversity and regenerate the degraded soils (FAO, 2016). Minimum or no soil tillage and optimum use of external inputs including the agrochemicals do not hamper the biological processes (Abrol and Sangar, 2006; Friedrich *et al.*, 2009). Thus, CA is referred as resource efficient or resource effective agriculture and its aim is not only to conserve but also to efficiently use the soil, water and biological resources combined with external inputs through integrated management (Bhan and Behera, 2014). Adoption of resource-saving agricultural crop production strategies aim to accrue profit together with increased and sustained production levels with environmental conservation (FAO, 2009).

The application of CA has potential in different agro-ecological systems and soil types. It is virtually possible in all the crops; however, more popular in case of cereal crops like rice, wheat, and maize. The conservation agriculture practices provide a range of technology and management options going beyond the zero-tillage along with crop residue retention and mixed crop rotations, which are neutral to size of holdings offering multiple benefits. Adoption of CA practices is urgently needed by small farmers to increase their income through reduced cost of cultivation, enhanced production and saving of resources (Derpsch, 2008).

Farmers' Knowledge and Perceptions on CA

CA is knowledge-intensive and complex technology involving changes in farming operations, and success of it rests on what the farmer does, thus farmer driven (Patrick, 2007). Effective implantation of CA technologies at the farm level is influenced by the perceptions and views of the farming community. Due to perceived benefits of CA, it is increasingly being adopted by the farmers. However, progress is slow due to small land holdings (<1 ha), lack of appropriate farm implements for small holders, low technological reach to farmers, and the farmers mind-set towards conventional/ traditional farming (Somasundaram *et al.*, 2020).

Owing to the advantages of CA on reducing drudgery of women farmers, the farmers in Bihar state of India are accepting the technologies in a rapid scale since last 8-10 years (Singh *et al.*, 2014). Due to resource saving and higher net return, zero-tillage technology is recommended as a potential option for sustainable crop production, saving resources and increasing income of the farmers (Tripathi *et al.*, 2013). Farmers' perception about adoption of CA in Bihar was documented where several benefits were perceived by the farmers in adoption of zero-tillage direct seeded rice (ZTDSR) viz., saving in resources like labour, water and time, timely seeding, increased yield, lesser tillage cost, reduction in drudgery, etc. (Kumar, 2018). A total of 75% farmers mentioned of achieving higher yields by adoption of ZTDSR. According to all the sampled farmers (both male and female), saving of labour is one of the significant drivers of ZT technology adoption. Although associated problems of this technology were weed infestation, poor germination, low yield, and ununiform seeding, a majority of the farmers (86%) perceived that limited knowledge on herbicide use has restricted the adoption of

ZTDSR. Farmers opined that use of mechanical paddy transplanter provided advantages like line sowing, labour saving, reduction in input cost and drudgery, and increased yield. Preparation of mat-type nursery, uneven sowing/ ununiform transplanting and gaps were perceived as major disadvantages in case of rice cultivation on an uneven land condition. Most of the farmers mentioned that non availability of trained tractor drivers for operation impedes the adoption of ZT machines.

Delay in sowing of wheat after mid or late November in the IGP used to result in grain yield losses of 1-1.5% per day of delay (Somasundaram *et al.*, 2020; Hobbs *et al.*, 1997). The CA has primarily considered use of zero till seed-cum fertilizer drill for timely sowing of wheat after harvest of rice in rice-wheat system (Hobbs *et al.*, 2008); accordingly, it is being promoted (Mehla *et al.*, 2000). ZT wheat area has been increasing and presently occupying about 30% of rice-wheat growing areas in India's Indo-Gangetic plains (Kumar, 2018). Similar to the ZTDSR, application of zero tillage in wheat has provided similar advantages like saving of labour, inputs including water and cost of tillage, as well as timely sowing and increased yield. The major limitations in using ZT in wheat crop are lack of trained tractor drivers for machine operation, required soil moisture condition during sowing, poor germination and weeds infestation. According to Kumar *et al.* (2016), the probability of adoption of ZT technology has increased with the increase in farm size in Haryana and main drivers of adoption are increase in yield effect and saving of cost. Farmers' knowledge on ZT technology was assessed as 63% in Haryana (Kumar and Godara, 2017). Majority of farmers in rice-wheat cropping had favourable attitude towards ZT, however, they had limited knowledge on ZT (Kumar and Kumar, 2018). Another study has revealed that farmers have preferred to continue the adoption of ZT in wheat in Haryana. According to the farmers, the germination of seeds and yield of wheat are better in case of ZT compared to conventional tillage with the completion of sowing operations by 10 to 15 days in advance. They, however, mentioned the problems of weeds in ZT wheat. According to many farmers, lack of availability of ZT seed drill machines limited the adoption of ZT in their area. Kumar and Godara (2017) mentioned that farmers with higher socio-economic status farmers were having higher knowledge level on ZT.

Most of the farmers cut a portion of crop residues for animal feed or household fuel and burn the rest for field preparation of next crop in IGP in India. In order to overcome/stop residue burning, efficient residue management strategies/ techniques are needed (Singh *et al.*, 2005). To create awareness and knowledge of farmers on harmful effects of crop residue burning, anti stubble burning movement has been initiated in India. In the state of Punjab, government has made the school students ambassadors of anti-stubble burning campaign in rural areas to create awareness among the farmers regarding harmful effects of crop residues burning and necessity of environmental conservation. Under another anti-stubble burning campaign 'Happy Seeder, Happy Lungs', students in Delhi donated a happy seeder to a women self-help group in Haryana and created awareness and knowledge on CA. November 4 is declared 'anti-stubble burning day' by West Bengal government to generate awareness among the farmers regarding detrimental effects of the stubble burning (Chatterjee and Acharya, 2021).

Information Needs of Farmers for Adoption of CA Technologies

Information is the most prerequisite element for an action to take place. Most farmers keep on using a particular technology either because of its profitable performance or their low risk-taking ability to switch to a new technology, or both. Lack of information and possession of a minimal vision often make them fail to take a right decision before the occurrence of an unforeseen ill event. So, the dissemination of right information to the right people at right time is of utmost importance. In the present changing climatic scenario and natural resources degradation, the priority should be given to awareness generation among the farmers about the consequences that they may face in the upcoming years because of their existing farming practices. Once they are made aware of their inadvertent exploitation of the natural resources, they will look for possible solutions where the extension professionals (information sources) can suggest alternatives stressing on CA technologies. As their awareness is aroused and interest created, the information goal is accomplished posing way for the action to take place. Now the trial decision of a technology will take place whose results will end up in the form of adoption or rejection of that technology.

A farmer will require a plethora of information regarding CA. Farmers need to be made aware that how land is prepared with no/ minimum soil disturbance, slashing/rolling of weeds or previous crop residues and use of herbicides. They need information on direct seeding, zero tillage/direct drilling of seeds, etc. It is important to know the method of planting in CA and application of fertilizers. The farmers need to grow cover crops during fallow season as well as follow crop rotation to protect soil, improve soil structure and soil microbial activities, mobilize nutrients, and controlling weeds and pest. The effectiveness of information sources proportionately affects the adoption of technologies (Singh and Mukherjee, 2018).

Factors Affecting Adoption of CA Technologies

The fundamental definition of adoption advocates it as 'a decision to make full use of an innovation as the best course of action available' which points out: the individual, the technology and the environment, as the three factors responsible for adoption of a technology.

Singh and Mukherjee (2018) grouped factors affecting adoption of CA technologies undervarious broad categories viz. economic factors, characteristics of farm & farmer family, communication &information sources used, biophysical & technical factors, and social factors. Thecost of technology, increase in yield, higher profit and re-duced cost of cultivation are considered as economic factors influencing the adoption rate of CA technologies. The minimum tillage technology saves the labour, machinery and fuel cost. CA technologies haveshown a limited increase in yield compared to conventional system in the long run. The farmers' characteristics are the inherent abilities possessed by an individual and varies from farmer to farmer. CA adoption is commonly found to be positively associated with farmer knowledge or perceptions of soil problems in the field. Farmers' educational levels, agricultural experience, and in some cases, age may influence their decision to adopt or not to adopt a technology. The size and prevailing soil-associated problems in a farm are important for adoption of CA technologies. The frequency and ease with which various communication and information channels are used by the farmers make them more aware of the benefits of CA and ultimately helps in adoption of technologies. They consider rainfall, soil type, wind direction, topography, etc. as the biophysical factors influencing adoption of CA technologies. The availability of CA machineries, their spare parts, access to maintenance services, etc. are the technical factors correlated positively with its adoption. The membership or association of a farmer with social institutions viz. SHGs, cooperatives, etc. are the social factors positively influencing the adoption of CA technologies. A technology may not be profitable but still it may be implemented on a large scale to improving the soil health, which is a reflection of adoption due to social interest.

Multidimensional impact assessment of ZT technology on wheat productivity in Haryana suggested the farmer's participatory approach as the accurate guide for adoption of ZT technology by farmers (Kumar *et al.*, 2016). Majority of adopters were in the age group of 30-50 years and they identified literacy as an important factor for CA adoption. An increase in farm size reflected increase in adoption of the technology. An obvious reason behind this behaviour could be increase in risk-taking ability due to larger farm size. The other driving force of change to switch from conventional practices to ZT technology were attitude, knowledge and satisfaction of the respondents. The main driver of rapid and widespread acceptance of ZT in Haryana is happened to be the effects on yield combined with cost-saving.

Crop residue management poses a series of challenges and limitations such as crop establishment, fertilizer application and weed management. These constraints have been partially overcome by the innovative latest version of the Turbo Happy Seeder (THS) - a tractor-mounted no-till with residue management device/equipment that has the capability to cut and shred the previous crop (rice straw) and plant a succeeding (wheat) crop and the left-over residue act as mulch in sown area. This is recognized as an important technological intervention for in-situ residue management (Sidhu *et al.*, 2009, 2015). The socio-economic factors that influence farmers' decision making on crop residues management are poverty, small land holdings, inability to hiring machines like happy seeder/no-till seed drill, etc. for residue management (Somasundaram *et al.*, 2020).

Other than the knowledge and perceptions of the farmers, feasibility and appropriateness of CA technologies with respect to several attributes like simplicity/ complexity of technology, relative advantage, observability, need of the technology, physical compatibility, cultural compatibility, sustainability, economic viability (cost, profitability), etc. influence the adoption phenomena. There are other factors like socio-personal, socio-economic, communicational and psychological attributes of the farmers and various technical, social, economic and infrastructure constraints, which also have relationship with farmer's adoption/ rejection of CA technologies. On the basis of the lessons drawn from past studies a conceptual model is presented here that indicates different factors influencing adoption dynamics of CA (Fig. 1).

Investment Needs for CA

Most studies on CA in India have been conducted in rice-wheat cropping systems in the IGP. Friedrich *et al*. (2009) mentioned the universal applicability of CA principles and reported that all crops including root and tuber crops can be grown adequately in CA. Therefore, it is worth mentioning that there is great opportunity for research and promotion of other

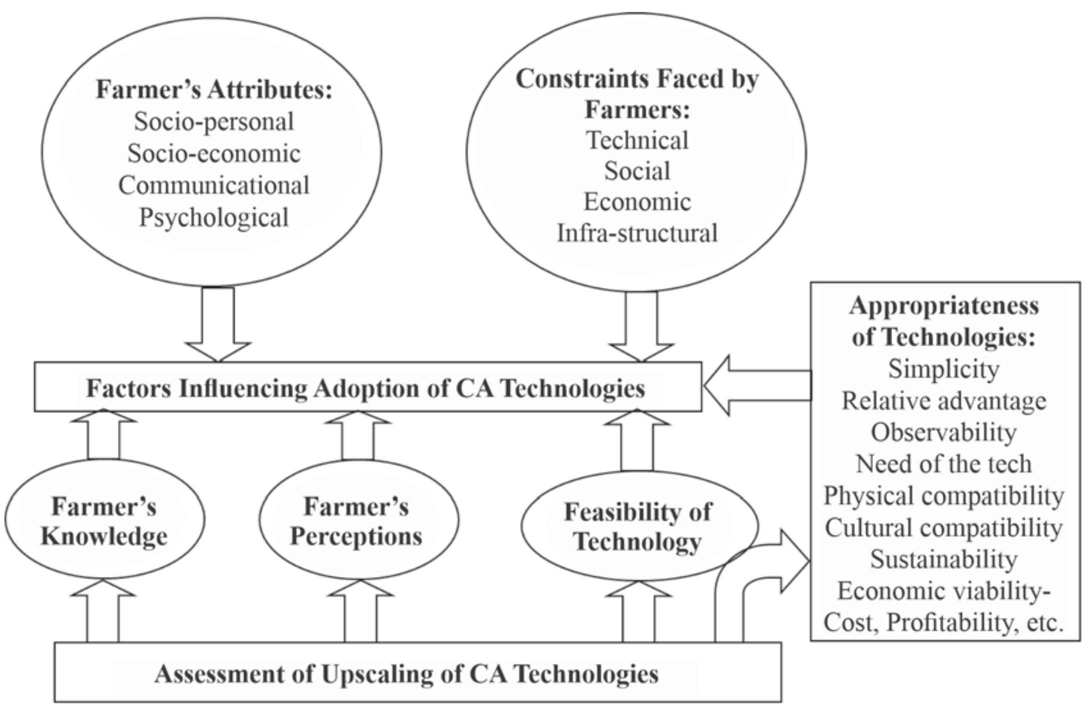

Fig. 1. Conceptual model indicating factors influencing adoption dynamics of CA

more valuable and marketable crops at different new avenues. It will add to knowledge domain, create opportunity for employment and overall improve the socioeconomic condition of farmers in particular and whole nation in general.

At present, only a very few countries produce CA equipment and cash their profit with larger scale export and import. It is important to ensure quality and availability of equipment through appropriate incentives. The development low-cost machines by the firms through subsidy support from national or local government will act as precursors for promoting CA technologies (Bhan and Behera, 2014).

Among all CA technologies, ZT has been adopted and practised on a greater extent as it is seen as a potential option to discourage reside burning practice. So, on one hand there is need to extend the adoption of this technology and on other hand, technologies related to crop cover and crop rotation are needed to develop, promote and diffuse in the social system. The new machineries viz. turbo seeder, happy seeder, laser land leveller, etc. are also potent options whose adoption can be enhanced by strengthening custom hiring centres (CHCs) and improving after sale services.

In a nutshell, there is a huge investment need for exploring new areas for adoption of already established CA technologies, comprehensive mass demonstration and training to provoke awareness and interest for other alternatives related to CA technologies. Indigenous production of machineries and setting up of a network of CHCs for their cheap and easy availability, accessibility and affordability to small and marginal farmers. Government investment on prevention and monitoring of crop residues burning is essential and a mechanism requires to be established for the farmers to get incentives on the basis of carbon storage and other ecosystem services through residues retention and crop residues management (Somasundaram *et al.*, 2020). Small and marginal farmers lack the resources to invest for CA, where government interventions are required to provide not only technology backstopping but also institutional and financial support mechanisms.

Policy Formulation for Large Scale Adoption of CA

The understanding of CA systems is much more complex than conventional cultivation methods (Bhan and Behera, 2014). Site-specific knowledge has been the main limitation of the spread of CA systems. The adaptation of conservation agriculture technologies requires the consideration of diverse resource base and location specificity (Bhan and Behera, 2014). The research and development wing of conservation agriculture should develop strategies accordingly. Jat *et al.* (2020) suggested the need for strengthening of CA by pursuing one or more strategies, including (i) increasing yields per hectare; (ii) increasing cropping intensity per unit of land and (iii) changing land use.

Conservation agriculture indicates a complete and drastic shift from traditional cultivation practices. For the effective implementation of conservation agriculture practices, the policy analysis should consider integrating CA technologies with other traditional technologies, CA's effectiveness in the long run, and focus on capacity building aspects that encompass developing institutions, stakeholders, etc. It should analyse how policy frameworks and institutional arrangements impact CA (Raina *et al.*, 2005). For this, the implementing agencies must orient all the stakeholders through a capacity building process.

The efforts of R&D and Extension agencies has resulted in increased adoption of zero-tillage of wheat crop that resulted in increased resource use efficiency and decreasing cost of cultivation. The adoption of CA technologies must address institutional, technological and policy-related issues (Bhan and Behera, 2014).

In India's eastern regions, state and central government's research & development institutions have put many efforts into promoting resource conservation technologies. The adoption of CA technologies started with zero-till wheat in the rice-wheat system. for effective scaling up, awareness and demonstration programs on CA technology usage is needed. Further, the government must involve multi-stakeholders to establish backward and forward linkage mechanisms for farming community to effectively adopt these technologies (Mishra *et al.*, 2018). In the IGP, a shift from food security to food-and-nutritional security to livelihood security encompassing policies and institutional arrangements to promote crop diversification is the need of the hour (Behera *et al.*, 2007).

For assessing the farmers' perception about CA, the framework should evaluate the outcomes like crop yields, input savings, soil fertility, water-saving and labour saving, reduction in pests/ diseases, socio-cultural acceptance, etc., under both non-adoption and adoption scenarios (Kumar, 2018).

Few other critical policy considerations for the promotion of CA (following Bhan and Behera, 2014) are mentioned below:

- Scaling up CA practice: The past bias and mindset of farmers on tillage practices have contributed to CA technologies' poor adoption (Hobbs and Govaerts, 2010). Farmers are used to follow tillage as one of the mandatory operations under land preparation since long time; therefore, changing mindset of farmers requires constant persuasion. Mindset will change rapidly when farmers are experiencing the benefits of CA (Patrick, 2007). Under such situations, technology assessment and refinement through farmers' participatory on-farm trails and large-scale demonstrations are needed.
- Complementary crop improvement: CA technologies give rise to significant changes in the microclimate around the root zone. Therefore, complementary crop improvement programmes need to be developed.
- Resource database on CA: The agencies involved in promoting CA must generate a reliableresource database by complementing each other's work. They also need to focus on the systematic monitoring of socio-economic, environmental, and institutional changes in CA projects.
- Capacity building on CA- The policymakers must incorporate capacity building of stakeholders through organized training on CA. Lack of trained human resources for imparting behavioural changes at the ground level is a significant constraint in CA's promotion. Hence, the government must support CA activities at all levels.
- Integration of CA technologies and services: The ministries, departments and institutions must integrate CA technologies and services so that farmers get adequate and timely services to adopt CA practices.
- Assistance for CA technologies' suitability in local environments: The government should collaborate with local communities and other stakeholders for initiating adaptive research and developing principles and practices suitable to local conditions.
- Support the development and ensure CA equipment availability: Most of the available CA implements and equipment are imported from other countries. Provisionally, importing CA tools and equipment can be removed or reduced to encourage and promote their availability. In the long run, large scale adoption is to be encouraged by enabling manufacturing at the local level. The establishment of local hire service centres (custom hiring centres) can help the users hire large, expensive, and more complex equipment and assist in training on machinery maintenance and business skills. At present, new machineries like laser land leveller, happy seeder, turbo seeder, etc., are more accessible for wealthy and medium to large farmers groups in India. These are found helpful for CA practices and need to be made accessible to small and marginal farmers through institutional innovations like farmers producer organisations, user groups, custom hiring centres, etc.
- Promoting fees for environmental services and fines for harmful practices: In the area of 13.5 M ha of IGP of South Asia, continuous tillage-intensive rice-wheat cropping system

has resulted in over-exploitation of natural resources and decreased productivity. It has led to the un-sustainability of agriculture. Additionally, crop residue burning has adverse environmental impacts. The incorporation of crop residues into soil improves the soil environment by contributing to microbial population growth and root activity, and subsequent nutrient conversions (Singh *et al.*, 2005). The adoption of CA technologies improves the environment through carbon sequestration, organic carbon built-up, soil erosion prevention, and groundwater recharge. Therefore, the government may consider rewarding such farmers who significantly contribute in environmental conservation and sustainable management of natural resources through CA technologies adoption, thereby making a positive impact on the quality of life.

- Building partnership: Challenges to CA can be addressed by adopting a systematic approach to efficiently understand and manage fundamental processes and component interactions. A system perspective can build an alliance with farmers and enable them to understand it. All the stakeholders, including scientists, farmers, extension personnel, policymakers at both government and private levels, must work in partnership mode to develop and promote new CA technologies.
- Credit and subsidy: Credit provision at the subsidized rates to farmers to buy the machinery, equipment, and inputs for adoption of CA need to be ensured through banks and credit agencies at reasonable interest rates.

The role of service providers and small-scale machine manufacturers as promoters and critical players in meeting and creating an increasing demand, has been identified (Laxmi *et al.*, 2007). It is pointed out that twin advantages of increased yield and cost savings resultsin profitable returns from ZT adoption with a reduction of adoption risks. However, knowledge gaps still exist that need to be unravelled through an assessment of degree of gains apprehended on the ground and the scope for scaling up the plot-level impacts.

The adoption of CA-based technologies in heterogeneous agro-ecological and socio-economic environments could be encouraged by organizing intensive demonstrations and awareness campaigns and farmers' skill development programs (Joshi, 2011).

The promotion of CA must become a global movement by involving institutions like the Food and Agriculture Organization (FAO) of the United Nations, International Fund for Agriculture Development (IFAD), the World Bank, Asian Development Bank, and African Development Bank. In India, an institutional agency like the National Bank for Agriculture and Rural Development (NABARD) may take the lead to make conservation agriculture a national movement by coordinating all the stakeholders of agriculture and allied sectors. Appropriate institutional arrangements are to be made to ensure the provision of machinery and technologies to small and marginal farmers. The Krishi Vigyan Kendras (KVK) may offer training programs for skill development and undertake demonstrations for diffusion of CA innovations (Mishra *et al.*, 2018).

In India, policy formulations must incorporate the CA Technologies by sensitizing policy advisors, financial contributors, and other stakeholders. The effective communication of benefits of conservation agriculture to all the stakeholders is important for its widespread adoption (Joshi, 2011). Judicious blending and implementing CA technologies in policy frameworks may help to achieve sustainability by conserving natural resources and increasing agricultural production and productivity.

Conclusions

Conservation agriculture is viewed as one of the potential options for sustainable agricultural system maintaining the soil health, conserving the environment, enhancing the resource use efficiencies, decreasing cost of cultivation, increasing the productivity and income of the farmers. However, area under CA remains low due to many agro-economic, socio-economic and institutional challenges in adoption of the technology. The traditional mind-set of farmers with conventional farming practices, poor socio-economic conditions, marginal and small farmholdings, weed management, location-specific crop residue management, lack of accessibility/availability of CA machineries are major impediments in adoption of CA practices in the country like India. An extensive capacity building programme through training, demonstration, exposure visits as well as institutional arrangements is required for upscaling the CA technologies with an increased adoption by the farmers.

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