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Research Article

Behavioural science principles for scaling-up zero tillage wheat and maize in the Eastern Terai region of Nepal

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ABSTRACT

Farmers have a set of convictions and tend to do what their forefathers had practiced. By identifying their beliefs and designing appropriate ways of upscaling to convince them of new and improved practices, we can improve the adoption of zero tillage technology for maize and wheat. Small and fragmented landholdings that resulted from the cultural system of distributing land to heirs are diverse in their cropping requirements. Moreover, farmers are risk-averse and do not believe easily in new technologies. Traditional extension approaches have not been effective in upscaling these technologies. A new way of thinking based on behavioural science can provide some insights and guidelines for improving the effectiveness of technology adoption. Understanding farmers' socioeconomic circumstances and their decision-making system at the household and society level can help in designing upscaling approaches. Approaches such as capitalising on social bonding, use of established technology leaders, and use of farmers' organizations can improve adoption. Recommended strategies include encouraging a comprehensive contracting system of service provision, using active community influential local leaders in technology expansion, taking group and social identity approaches in technology extension, and capacity building programs for service providers/operators and farmers to help raise confidence and to remove perceived barriers to technology adoption.

Keywords: Behavioural science, extension approach, technology upscaling, zero tillage

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INTRODUCTION

Conservation agriculture-based sustainable intensification (CASI) combines the strengths of both conservation agriculture and sustainable intensification (Dixon *et al*., 2020). Compared to conventional practices, CASI approaches have improved the productivity and profitability of rice, maize, wheat, and lentil farming systems while at the same time reducing the amount of water, fuel, and labour needed to produce a crop in the Terai of Nepal (ACIAR/SDIP, 2018). CASI has shown great potential for food security and livelihood improvement, reduced

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production costs, improved returns to labor, expanded social capital, and strengthened system resilience at a small scale in the Eastern Gangetic Plains (EGPs) (Tiwari *et al.*, 2019; Dixon *et al.*, 2020). Many other studies have reported higher benefit-cost ratios from conservation agriculture in maize, wheat, and lentil compared to conventional agriculture in Nepal (Prasai *et al*., 2018; Shrestha *et al.*, 2018; Shrestha *et al.*, 2020; Karki *et al*., 2014). In addition to improving crop irrigation and nutrient management efficiencies, CASI technologies can also create a business environment for mechanized agriculture services and agrochemicals at the local level (Gathala *et al.*, 2020).

Among different aspects of CASI, zero tillage wheat and maize planting technologies were pushed by the government of Nepal through the Sustainable and Resilient Farming Systems Intensification (SRFSI) project in Sunsari and Dhanusha districts of Nepal. Zero tillage machines were used to plant rabi crops with a one-pass operation without tilling the soil and crop residue was left on the soil surface. Efforts included regular agricultural mechanization projects of the government, and other collaborative projects like the SRFSI project and the Cereal Systems Initiative for South Asia (CSISA). Upscaling approaches used included participatory technology trials, training, field demonstrations, and providing subsidies for seeds, fertilisers, and tillage machinery. Despite these efforts, the uptake of such technologies has been very low.

Recently, a collaborative project between NARC and the University of Western Australia and other partners, funded by the Australian Centre for International Agricultural Research (ACIAR) on "Understanding farm-household management decision making for increased productivity in the Eastern Gangetic Plains (FBIP))" that aims to identify and design ways of improving adoption using behavioural science insights is operational in the eastern Terai. This approach combines social science, economics, and psychology theories. An in-depth study was carried out by the project in 2019 to identify variables that influence adoption. The purpose of this paper is to present the constraints to upscaling ZT wheat and maize technologies in the eastern Terai and suggest possible improvements to the design of extension approaches based on principles derived from behavioural science.

Characteristics of farms and farming in Eastern Terai

The Eastern Terai region lies in the southern part of the country. It spans five districts out of 77 districts of the country. These are Jhapa, Morang, Sunsari, Saptari, and Siraha. The number of households are 80 016 with an average household size of 4.8. The total area in the eastern Terai is 7269 km^2 (CBS, 2017). The total number of farms in the region is 511 847, with an average number of parcels per holding of 2.54, and a total farm area of 440 232.1 ha (CBS, 2017). Because of the sub-tropical climate in the region, cereal food crops, vegetables, and fruits of tropical and sub-tropical nature are the main agricultural produce. The main crops are rice, wheat, maize, pulses, mungbean, jute, sugarcane, and tobacco. Two to three crops are harvested annually. Rice is the main crop in the monsoon season, while maize and wheat are grown in the drier periods before or after the monsoon. Maize is sometimes grown as an intercrop with legumes. Farming is mostly semi-subsistence, seasonal, and weather-dependent. Reports published by AITC (2018) have shown that major cultivable areas are still unused due to lack of modern farming equipment and technologies.

CASI technologies have the potential in the region to address sustainable intensification and labor shortages in cropping seasons. Emphasis on minimizing tillage operation by employing multi-tasking machines and equipment like seed drill tractor attachments which apply fertilizer with the seeds have proven useful (SARPOD, 2017). However, there is still a need

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to focus more on strengthening machinery service provision in the local context for the long-term sustainability of CASI practices among farming communities (Pokhrel *et al.,* 2018).

CASI demands mechanization, however, the machines are expensive and beyond the resources of most smallholders. Developing motivated, well-trained, and equipped CASI mechanization service entrepreneurs, preferably among farmers themselves is the best way to increase farmer's access to CA mechanization services to boost the adoption of CA in target regions (Sims & Heney, 2017). Similarly, a logical solution could be for CA mechanization services to be provided by private sector entrepreneurs. The continued availability of mechanization services is an important factor in making CA more sustainable through maintaining an assured machinery input supply chain (Keinzle & Sims, 2015). In Nepal, CASI mechanization is in the early stage and requires collective effort from the government, and public and private sectors and all stakeholders.

Existing extension strategies for scaling-up of CASI technologies in Nepal

The National Agriculture Policy (2004) recognized Nepal's extension system as pluralistic in nature. The Agriculture Extension Strategy (2006) focuses primarily on institutional pluralism, privatization and decentralization of extension services, group and cooperative formation, use of local SPs, redefining the role of the public sector, and use of ICTs. Agriculture extension strategies designed for upscaling CASI technologies are mostly conventional. These include providing subsidies for purchase of machineries, participatory research for testing and popularising the technology, training for farmers and service providers, and use of mass media. These strategies have not been effective (SARPOD, 2017). Kafle *et al*. (2018) reported that supply chain management, focus on the service provider, capacity building, agriculture credit, and effective service provision are crucial to the sustainability of farm machinery technologies. As socio-economic and psychological factors are important in the decision-making process to adopt CASI technologies, it can be facilitated by locally identified and specially trained group leaders or by promoters (Meena *et al.*, 2013). Existing extension strategies need revision to incorporate diverse issues from behavioural science principles explaining why farmers are not adopting CASI technologies.
Bottom-up farmer and researcher-driven experiments and demonstrations at the field level were used in the SRFSI project. The SRFSI project used existing but under-utilized institutional frameworks of farmer groups, which took responsibility for management of machinery and crops that helped to promote CASI practices at the farm level (Gathala *et al*., 2020). Moreover, they developed trust between project partners and communities and developed a positive relationship with village and leader farmers. Many different stakeholders were connected through the farmer groups to facilitate awareness of, uptake, and out scaling of CASI (Gathala *et al.*, 2020). The extension of CASI technologies in Sunsari district has been promoted through policy supported by NARC and the Department of Agriculture (DOA) which included farmers' visits to demonstration plots, training programs, field days, dissemination of leaflets, and distribution of pamphlets about the advantages of CASI technologies (Pokhrel *et al.*, 2018).

Innovation Platforms (IPs) were established in the SRFSI project sites to facilitate the adoption of CASI technologies in the EGP (Brown & Darbas, 2016). IPs are multi-stakeholder forums which aim to achieve institutional change by nudging stakeholders and organisations to solve a problem in a coordinated action and facilitate CASI adoption (Brown *et al*., 2017). Community Business Facilitators (CBF) were introduced by NGO International

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Development Enterprises (iDE) Nepal to strengthen links with service providers (Darbas, 2017).

METHODOLOGY

Focus Groups Discussions (FGD) were used for exploring issues with a community or group and to generate rich and detailed qualitative information on the factors, constraints, and opportunities to be used in assessing the strategies and options for upscaling Zero tillage wheat and maize planting. We carried out two FGDs on improved adoption of ZT wheat in Bhokraha of Sunsari district involving 10 male farmers and eight female farmers, respectively. Two other FGDs were carried out on improved availability of ZT services for wheat and maize planting attended by 12 male and one female farmers, and another attended by 12 service providers. While the focus group guides were developed in English, they were translated into Nepali.

Theoretical Framework

The designs of the instruments for the FGDs were guided by the behavioural theories. They were Early behaviour theories, Bounded rationality, Prospect Theory, Social Cognitive Theory, Social identity approach, Dual Systems Theory, Theory of Planned Behavior, and Nudge Theory. The rational choice theory assumes that human actors have stable preferences and engage in maximizing behavior. Kahneman and Tversky (1979) proposed Prospect Theory which shows decisions are not always optimal and our willingness to take risks depends on its context. The concept of bounded rationality was introduced by Herbert Simon (Simon, 1990) and it suggested people do not optimise but 'satisfice' when making decisions due to their limitations in dealing with the complexities of decision making. Dual-system theory was discussed by Daniel Kahneman (2011) in his book in which people combine automatic, fast and non-conscious processes (System 1) with controlled, slow and conscious thinking (System 2). Learning that occurs within a social context is focused by Social Cognitive Theory. Albert Bandura, who builds on the idea that people learn through the consequences of actions by proposing that people learn in two ways: by observing the behaviour of others and social modelling (Bandura, 2004). The Theory of Planned Behavior (Ajzen, 1991) has been used to predict behaviours based on attitudes toward the behaviour, subjective norms and perceived behavioural control leading to intention to perform a particular behaviour that are assumed to capture the motivational factors that influence a behaviour. Nudge theory explain the aspect of the choice architecture that alters people’s behavior in a predictable way without forbidding any options or significantly changing their economic incentives.

Our study began with a general discussion of their thoughts, perceptions, beliefs, and experiences of the CASI technologies for wheat and maize, followed by specific questions about their advantages for men and women. This was followed by discussion points and prompts related to social influences on their adoption and changes in attitudes and behaviours among adopters of the technologies. We also asked about their sources of knowledge and who they perceived as most reliable. For the provision of service, questions were also asked about the possibilities of offering discounts if farmers organised themselves to have the planting done at the same time or for offering a comprehensive contract service to farmers.

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Data collection

FGDs were conducted from December 28, 2018 to January 26, 2019. Before execution, a one-day training was conducted at the Regional Agriculture Research Station, Tarahara, Sunsari. The purpose of the training was to discuss the procedures for conducting the FGDs and to discuss, clarify, and refine the FGD guide questions.

The FGD began with an introduction of the facilitators and the participants to the group. The purpose of the project and the FGD activity were outlined to the group. The importance of the discussion and their contribution and information was emphasized as critical to the design and implementation of further projects to spread CASI technologies more broadly in other places of the country. Participant's permission was sought to participate, to take photographs, and to record their views. Confidentiality of the information was emphasized indicating that the researchers are the only people who will see the raw transcripts and that any published or circulated reports would not identify individuals.

Data analysis

Written notes were transcribed and then translated into English. Content analysis was used to identify themes from the raw data and the transcriptions were also entered into NVivo and coded. Each FGD was also classified by topic, the gender of participants, and their role (e.g. farmer or service provider). The codes were derived partly from the questions (e.g. perceptions of advantages and disadvantages) but also from behavioural science theories (e.g. heuristics, biases, social identity, norms and attitudes, risk aversion, and decision criteria).

RESULTS AND DISCUSSION

Here, we present the results of the FGDs and discuss these in relation to different aspects of behavioural theories. We covered two issues. First was in relation to the adoption issues and the second was the issue of access to zero tillage service facility. Then we discussed related behavioural insights and extension implications.

Improved adoption of ZT in wheat and maize planting

We discuss here about the i) perceived merits of the technology and ii) barriers to their adoption across dispositional, social and cognitive factors affecting adoption of the technology. Implications of behavioural insights for designing extension programs have also been discussed for each of these factors.

Perceived merits of the technology

Some perceived advantages of the CASI technology have been recorded. Seed requirement is low compared to conventional tillage by rotavator. It helped maintain proper plant population which caused low lodging. They could plant earlier as ZT can be used in optimum moisture and farmers need not wait until complete drying of land, unlike rotavator operation which needs complete drying of the soil. Adopter farmers were also of the view that roots spread well in ZT planting. It also increases the efficiency of fertilizer as it is applied with the seed. Moreover, it supports the following crops and they believed that after wheat, production and productivity of rice was increased.

The technology was regarded as highly gender friendly. Female farmers believed that the technology is helpful for them as it does not require much labor for land preparation and ploughing, hence they do not need to prepare tiffin/snacks and carry drinking water to the

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field labors, helping to reduce women's' burden. Using the ZT machine, farming can be done by female members even in the absence of a male counterpart in the family as it does not require more work to be done for the sowing. This is uniquely important in the district as many male members are working and living outside the village.

Perceived barriers to the adoption of the technologies

Despite the above merits, most of the farmers have not adopted the technology. Perceived barriers to the adoption and relevant behavioural insights for designing extension programs have been categorised and discussed below.

A. Dispositional factors

1. Risk tolerance: Planting wheat and maize by ZT machine in this area was a new practice. A majority of the farmers had a belief that crops cannot be grown without deep and multiple ploughings. Only such ploughing can make soil loose, fertile, and pulverised allowing root spread and maintaining the water holding capacity of soil. This perceived risk has limited the spread of the technology.

2. Gender and soil: While all the machinery service providers are male, women farmers do not feel uncomfortable to access them for machinery service hiring. Also, rotavator users and operators discourage use of ZT by suggesting that soil will spoil by the formation of a hard pan at the surface after some years of ZT use.

Implications of behavioural insights for designing extension programs

1. Increase risk tolerance through focussing on promoting skills of the ZT operators, and awareness of farmers to minimise perceived technical barriers to the adoption and increasing the awareness of farmers on the importance of agricultural insurance in distributing risk.

2. As the ZT intervention has been taken as a risk of employment loss by the service providers of rotavators, we can help them turn into service providers of ZT machines by giving training and by facilitating them as required to replace rotavator by ZT machine.

3. Use innovative farmers' cooperatives and women's farmers in social marketing. As technology highly benefits women farmers, they can play a crucial role in upscaling of the technology. Similarly, extension intervention through farmers' cooperatives seems useful.

B. Social factors

1. Effects of established norms in the society: Upscaling of ZT in maize and wheat planting have been affected by norms in society. Such norms include i) Descriptive norms i.e. practice of the people and ii) Injunctive norms i.e. what they think others expect of them. ZT machine works in stubbles of previous crops and the field looks untidy. Farmers like a clean field after planting. Therefore, farmers who are using ZT are discouraged by neighbours' views of their untidy fields. When farmers tested the ZT machine for wheat and maize the first time, their relatives and neighbors reacted negatively. They said that it is not a good technology as there will not be any production without tillage. Some neighbours annoyed tractor owners and operators by suggesting they are doing worthless

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work. Some of the neighbors said that it's only a way of getting subsidy from the government and some of them claimed you will be at a great loss from this work.

Farmers' cooperatives have been found to establish new norms in society, with technology adoption greater for farmers associated with groups. It is due to an increased relationship among the farmers. They also feel proud of being progressive farmers. Some of these farmers convinced their neighbors to use a ZT machine and to take the risk of failure. It has also increased interest in training and learning about it. Farmers from adjoining villages have come to see the technology and increased sharing and interaction about the technology in the village through their cooperative.

2. Signaling motives of an individual: Farmers feel privileged when their fields are visited by research scientists and other Governmental officials. They believe that this improves their social status. For example, Mr. Chandan Mehta of Bokraha village claims that he has earned status while working with 'Big shots'. He is serving as the technology facilitator in his village and has been able to expand the area under ZT wheat and maize in his village in the last four years.

Implications of behavioural insights for designing extension programs

1. Use farmers' cooperatives to establish new norms for the use of the technology in the society through building group efficacy to remove social constraints.

2. Use of influential local lead farmers in awareness programs can be helpful in scaling up of ZT technology in maize and wheat.

C. Cognitive factors

1. Awareness, knowledge, and skills

Out of 10 male farmers, three did not use ZT due to clogging of pipes that caused poor seed dropping, which required one assistant worker to look after when clogging occurs to stop the tractor and clean the clogged soil from the hose. This increased the seeding cost as they had to go for re-sowing/dibbling the seed manually. Others are of the view that ZT machine requires certain soil moisture unlike conventional tillage. Therefore, they could not use the machine in dry soil. Birds also picked seeds left uncovered while seeding. ZT machines cannot apply urea and potash as a basal application at the time of seeding, because these fertilizers get wet and lumpy in the box due to the hygroscopic nature of these fertilizers, so, only DAP can be used with the ZT machine.

2. Perceived behavioural control

The most pressing problem perceived by farmers is the lack of access to ZT services. Some of the farmers have limited access to the machine in scattered and small parcels. Moreover, service providers were unable to provide adequate and timely services in wider areas even though farmers were interested and booked in time. This is due to demand exceeding available services from the low numbers of service providers. They also prefer to provide service to wheat farmers as compared to maize growers.

Implications for behavioural insights for designing extension programs

1. Attention is required to awareness creation of farmers, fine tuning of tillage equipment, knowledge, and skills of ZT before the intervention of the ZT technology.

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2. Potential solutions for timely ZT services include providing a discount if farmers organize in a group which reduces the cost required to reach the small and scattered plots, and a comprehensive contracting service. With these in place, the service provider can do work for a long duration in the same area which increases their profit.

Improved availability of ZT services for wheat and maize planting
The price for ZT planting was reported to be NRs. 3000-4000 per bigha in 2019. Price is decided before service delivery. The mode of payment is cash immediately after service delivery while in some circumstances within a week depending upon personal relationship. They were providing services based on booking date and first-come-first-serve basis. They give a discount on a rate based on the size of the plot and nearness. For example, small parcels are charged higher per unit as compared to a large parcel of land and based on the distance of the plot from the location of SP. Service providers give more priority to neighbours, nearby farmers, and relatives.

Perceived barriers to service provisioning
limited availability of machines is a common problem. Moreover, sowing time of both maize and wheat coincides. SPs prefer to provide service to wheat farmers as compared to maize growers because farmers experience a decline in yield of wheat planted wheat after December. Wheat panted after December will be affected by heat wave in flowering time which reduces seed setting. Also, the cumbersome process to recalibrate the ZT machine from wheat to maize, which takes more than three hours, is a problem.

SPs are concerned with the size of the plot as small plot size is discouraging to them because it was difficult to turn the vehicle/tractor in the field and also takes more time. For example, two hours was required for sowing a one *Bigha* plot, whereas 2.5 hours was required for sowing one *Bigha* of land with small parcels. They also had the problem of standing crops in surrounding plots which affects machine movement that has been managed by paying damage compensation. Also, the availability of skilled operators is lacking in many places.

Implications for behavioural insights for improving service flow of ZT machine

1. Land consolidation and land levelling should be promoted through government policy for the promotion of ZT use. Currently, they have to go to India for repair and maintenance, so making this service available at the local level will improve the speed and quality of services. Custom hiring centres at the local level could be another option. Mini combine harvester and reaper and/or happy seeder should be promoted for paddy crops so that field is ready earlier for ZT machine in the Rabi season. SPs reported that a two-wheel tractor (mini tiller) operated ZT machine which could be operated by women increased the ability to provide timely and profitable service to women farmers.

2. Potential solutions for timely ZT services include: i) providing a discount by SP if farmers organize in a group which reduces the cost required to reach the small and scattered plots, and iii) a comprehensive contracting service

   Comprehensive contracting serviceThis system also solves the constraints posed by small and scattered holdings and allows movement of farm machineries across plots of individual farmers, thus saving time and fuel of machine operation. In this system, farmers pay the total cost of machinery operation, seed and fertilizer and wait for their turn of seeding. By sending money to SPs, land can be planted, even if the landowner

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stays out of the village addressing the problem of keeping land fallow due to labour shortage in the villages the This arrangement helps solve the lack of appropriate quality and quantity of seeds and fertilizers as the service providers can buy in bulk from reliable suppliers. This system also solves the constraints posed by small and scattered holdings and allows movement of farm machineries across plots of individual farmers, thus saving time and fuel of machine operation. In this system, farmers pay the total cost of machinery operation, seed and fertilizer and wait for their turn of seeding. By sending money to service providers, land can be planted, even if the landowner stays out of the village addressing the problem of keeping land fallow due to labour shortage in the villages helps solve the lack of appropriate quality and quantity of seeds and fertilizers as the service providers can buy in bulk from reliable suppliers.

CONCLUSION

Despite efforts to speed up the extension of zero tillage wheat and maize planting technologies, the technology has not reached most of the farmers. Some behavioural insights useful for scaling up of the technology have been identified in Focus Group Discussion carried out in Sunsari district of Nepal. Sims and Heney (2017) have suggested to develop motivated, well-trained, and equipped CA mechanization service, preferably from farmers themselves. The continued availability of mechanization service is also important (Keinzle & Sims, 2015). Farmers' decision-making systems involve the influence of society, family, risk-taking behaviour, and rewards for adopting technologies. These have reduced the effectiveness of traditional extension approaches in the case of ZT maize and wheat technology expansion. Extension approaches should involve the following:

a. Encourage a comprehensive contracting system between service providers and farmers for improving efficiency of SP, solving the problem due to small and scattered holdings and harmonising in cropping pattern for smooth flow of machines in the field.
b. Using active community influential local leaders, and successful CASI adopters as technology champions to lead technology expansion. These leaders will gain status and can work effectively as technology ambassadors.
c. Group approach of technology extension strategy can be effective where all individuals are socially strongly bonded.
d. Capacity building programs for service providers/operators and farmers help raise confidence and remove perceived barriers to technology adoption decisions.

Field experiments considering different behavioural implications should be conducted to validate these findings before making a final recommendation.

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necessarily reflect the official position any organization.

Authors' contributions

Y.N. Ghimire and K.P. Timsina conceptualized and drafted the paper. S.P. Adhikari, K.P. Shrestha and S. Gairhe conducted field study and contributed in drafting the paper. Y. Acharya, D. Devkota, N. Upadhyay, M. Kharel and H.K. Poudel drafted the article. R.M. Prior and F.R. Rubzen critically revised and edited the paper.

Conflict of Interest

The authors declare that there are no conflicts of interest in this paper.

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