ISSN: 1991-0037 (print), 2710-3285 (online)
SOUTH ASIAN JOURNAL OF AGRICULTURE
www.saja.edu.bd;https://www.banglajol.info/index.php/SAJA
Agrotechnology Discipline, Khulna University
www.ku.ac.bd

OPEN ACCESS | South Asian J. Agric.

Research Article | Vol. 9, No. 1& 2, 2022-'23:52-63

Title: Farmer Insights Regarding Zero Tillage Systems Against Weeds in the Eastern Gangetic Plains of South Asia

Authors: Bhavya Suri[1], Pragya Timsina[1*], Anjana Chaudhary[2], Emma Karki[2], Akriti Sharma[2], Rama Sharma[2], Hom Nath Gartaula[1,4], Brendan Brown[2,3]

[1]International Maize and Wheat Improvement Center, New Delhi, India
[2]International Maize and Wheat Improvement Center, Kathmandu, Nepal
[3]CSIRO Agriculture and Food, Adelaide, Australia
[4]International Rice Research Institute (IRRI), Philippines

*Corresponding Author: Pragya Timsina Email: timsinapragya@gmail.com

Article Info:

Received:
June 30, 2023

Accepted:
September 8, 2023

Keywords:
Herbicides; Zero tillage; Farmer perceptions; Weed management; Conservation agriculture; Technology adoption

ABSTRACT

A large amount of literature has now proven that Zero Tillage (ZT) as a part of Conservation Agriculture-based Sustainable Intensification (CASI) practices has the potential to help smallholder farmers in the Eastern Gangetic Plains (EGP) of South Asia transition to more productive, profitable, and sustainable production systems. Despite this, changes in weed management under ZT are commonly identified as a constraint to wider adoption, based primarily on quantitative investigations. Yet the contribution of this to farmers' evaluation and adoption behaviour remains underexplored. To address this issue, we explore farmers' perceptions of CASI-based herbicide weed management systems using semi-structured interviews from six locations across the EGP. This study identifies a divergence in experiences with herbicides, both geographically (with Sunsari and Bihar more negative than other locations) and in terms of user typologies (where users are overwhelmingly positive, and non-users are overwhelmingly negative). This divergence suggests that an information void exists that has the potential to contribute strongly to the negative evaluation of CASI, as well as potentially negative changes in household labour dynamics. To overcome this, promotional efforts should target education and training programs that address how to effectively spray, potentially with increased emphasis on use of weather forecasting. This would ensure equitable outcomes for household members, and increased interest and use of CASI could be promoted.

DOI: https://doi.org/10.3329/saja.v9i1-2.69749

To cite this article: Suri, B.,Timsina, P., Chaudhary, A., Karki, E., Sharma, A., Sharma, R., Gartaula, H.N., Brown, B. 2023. Farmer insights regarding zero tillage systems against weeds in the eastern gangetic plains of South Asia, South Asian Journal of Agriculture, 9 (1 & 2): 52-63.

INTRODUCTION

The Eastern Gangetic Plains (EGP) of South Asia encompasses a rain-dependent agroecology characterized by small average landholdings and limited access to agricultural inputs and outputs (Jat et al., 2020). In the future, the EGP will be further challenged with an expected worsening of climate change induced changes in precipitation, rising temperatures, and water scarcity which are likely to negatively impact the overall productivity of farming systems (Jat et al., 2020). In the face of climate change, high poverty rates intertwined with the social fabric of caste and gender dynamically impact vulnerable populations including women and marginalized groups (Yadav and Lal, 2018; Patel et al., 2020). Zero Tillage (ZT), as a part of conservation agriculture-based sustainable intensification (CASI) practices, aims at reducing input usage while improving soil quality through crop residue retention (Islam et al., 2019), lending the potential to alleviate the worsening impacts of existing issues.

ZT is implemented through three interrelated core principles: (a) minimal soil disturbance; (b) maintenance of soil cover; and (c) crop rotation (Erenstein et al., 2012). It has been shown to improve farm productivity and profitability and reduce labour requirements (Hobbs, 2007; Bell et al., 2019; Islam et al., 2019). It also offers socio-economic benefits such as improved food security, reduced drudgery and saved time from reduced labour requirements which can be used for leisure and alternative work (Brown et al., 2021), and stronger agricultural systems resilience to climate change (Dixon et al., 2020). These have together driven the adoption of ZT in many parts of South Asia, primarily the north-western Gangetic Plains (Dixon et al., 2020). Weed control in ZT systems is done by following standard protocols and managing specific herbicide applications for example in the pre-planting period. Thus, herbicide-based weed management is a significant component of CASI.

Herbicides are cost-effective alternatives to conventional weeding methods that require less labour and time and work well on weeds that are difficult to manage manually (Farooq and Siddique, 2015; Singh et al., 2015). In addition, as labourers have become increasingly expensive and scarce (Bajwa, 2014), herbicides are a more convenient alternative to manual weeding. Despite evidence on herbicide effectiveness in CASI (Erenstein et al., 2012; Pokharel et al., 2018), change in weed management has been often associated with limited uptake and negative evaluations of CASI practices in South Asia (Bajwa, 2014; Harman Parks, Christie and Bagares, 2015; Sims et al., 2018). This becomes an important study area in the EGP because herbicides have been used extensively in the region, and there is less existing documentation that looks at the relationship between herbicide use and ZT system, especially considering perspectives of farmers (Chauhan et al., 2012).

As such, changes in weed management alter household labour arrangements. Intra-household labour is an integral resource for smallholder farmers, and CASI systems invariably re-allocate men's and women's resources and further alter gender aspirations (Farnworth et al., 2016; Brown et al., 2021). Women in this region are often marginalized and have limited control over and access to resources like land, information, and extension services (FAO, 2019). The involvement in and impact of herbicide use for weed management is likely to be experienced differently by men and women, but culturally, men are the primary decision-makers. The important question to ask is whether ZT contributes to inclusive outcomes that benefit both men and women in the given social norms of the region.

So far, the transition to ZT systems has been explored nearly exclusively from a technological perspective and farmer's experiences, perceptions, and labour arrangements around herbicide use in the EGP have been overlooked (Bellinder et al., 2002; Shekhawat et al., 2020). Few studies, such as Chaudhary et al.'s (2022), investigate possible associations between herbicides and ZT uptake in the EGP, but very few have investigated comprehensive evaluations of the effects of changing weed practices on decision-making, specifically using qualitative research methods, that address the "why" and "how" of decision-making. Based on the farmer's own experiences, this study uses in-depth qualitative data to determine whether and how weed management performs (positive or negative) in farmer evaluation and outcomes related to CASI adoption. It achieves this by answering two research questions: [a] how do perceptions of herbicides impact the decision to implement ZT? and [b] does using herbicide within a ZT system lead to non-inclusive outcomes within households? In answering these questions, this study will help programs consider the role and implications of herbicides in the promotion and extension of CASI systems in the region, and the importance of farmer perceptions in deciding factors in herbicide use within ZT systems.

METHODOLOGY

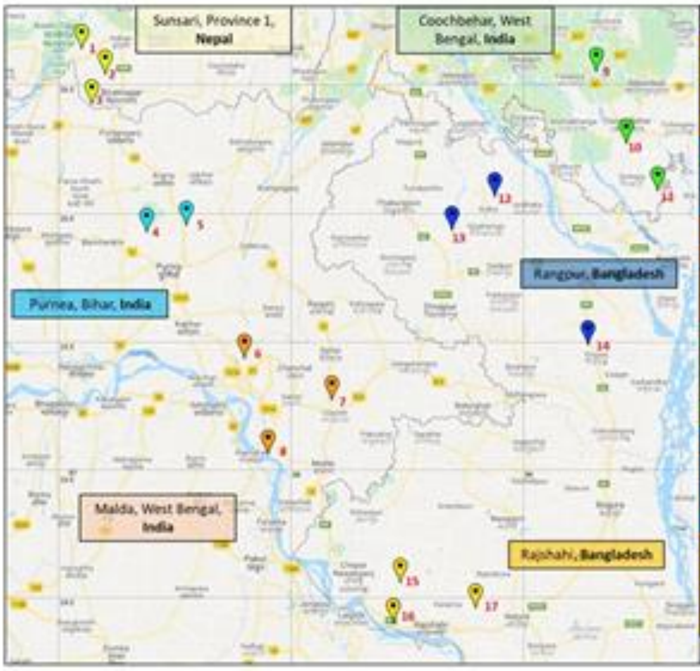
Study Design

This study is part of a larger study that applies the Decision-making Dartboard (DmD) qualitative framework (Brown et al., 2021) to explore the overall decision-making processes of farmers when evaluating different agricultural practices. The DmD framework builds on previous participatory qualitative analysis of the decision-making process in the EGP, as well as in various population subsets in Eastern and Southern Africa using the Livelihood Platforms Approach (LPA) (Brown et al., 2017a). The premise of both frameworks is to query the contribution in the evaluation process of various resource types (physical, financial, human, and informational) at different levels to determine key drivers of decision-making by individuals.

The DmD framework underpins this research and is applied to develop the question schedule which consisted of seven modules. Module One used KoboCollect software to gather basic pre-screening and demographic data to identify respondent typologies. Modules Two through Seven were open-ended questions that were digitally recorded for later transcription. Modules were designed to adjust to the respondent's type of CASI adoption status to determine why they chose to use or not use CASI. Module Two focused on their agricultural identity and ambition, while Module Three explored how they learn about new technology and subsequently how they may learn about ZT. Module Four explored their financial constraints, while Module Five explored how they opted to analyze and implement ZT. Module Six explored the background of ZT adoption in the community, whereas module Seven explored the consequences and implications of ZT implementation, as well as what more was required to achieve success. The question schedule covered all 24 aspects of the DmD framework.

Study Locations

The study was conducted in six districts across three countries of the EGP- Rajshahi and Rangpur districts in Bangladesh, Cooch Behar, Malda, and Purnea districts in India, and Sunsari district in Nepal (Figure 1). These locations were selected for their concentration of farmer population that covers different typologies of ZT use (non-user, dis-user and current-user) that have been enabled through ongoing promotional efforts to catalyze CASI uptake across the study locations since 2014 (Gathala et al., 2021). To generate respondent IDs in the results section, location codes, and household serial numbers are used together. For example, B16 indicates a respondent in Bihar, J36 indicates a respondent in Rajshahi, and [f] indicates a female respondent.



ID	Community	Type	Total
1	Bhokhara	High Adoption	21
2	Chitaha	Recent Adoption	12
3	Kaptangunj	Low Adoption	16
	S set - Sunsari, Province 1, Nepal		49
4	Udayanagar	Low Adoption	24
5	Kathaily	High Adoption	24
	B set - Purnea, Bihar, India		48
6	Sadilchak	Recent Adoption	14
7	Gorangapur	Low Adoption	20
8	Ugritola	High Adoption	15
	M set - Malda, West Bengal, India		35
9	Alipurduar	Recent Adoption	14
10	Ghugumari	High Adoption	22
11	Dinhata	Low Adoption	13
	C set - Coochbehar, West Bengal, India		49
12	Nilfamari	Recent Adoption	14
13	Dinajpur	Low Adoption	10
14	Pirganj	High Adoption	63
	R set - Rangpur, Bangladesh		87
15	Nobin Nagar	Low Adoption	15
16	Premtoli	High Adoption	18
17	Dharampur	Recent Adoption	15
	J set - Rajshahi, Bangaldesh		15
	Total		288

Figure 1: Map of study locations color-coded by country. Note: Purnea (B) is in the state of Bihar, India; Malda (M) and Cooch Behar (C) are in West Bengal, India; Rangpur (R) and Rajshahi (J) are in Bangladesh; Sunsari (S) is in Nepal.

Survey Implementation

As part of a selective sampling process, a snowball method was employed to capture a diversity of decision-making and experiences around CASI implementation, as outlined in Chaudhary et al. (2022). To capture this, various types of users and non-users were sorted based on the Stepwise Process of the Mechanization framework (Brown et al., 2021). This dataset is not representative but instead is intended to capture a diversity of experiences and perspectives. The snowball sampling methodology was applied as in Chaudhary et al. (2022) where initial interviews were held with project-aligned farmers and snowballed to capture diverse typologies depending on status of CASI adoption. Around fifteen to twenty respondents were identified and interviewed in each surveyed community based on the different typologies. Interviews were conducted in regional languages and ranged from thirty minutes to one hour. With prior consent of the participants, interview audios were recorded on mobile devices while maintaining confidentiality and respondent identity. In total, 288 semi-structured qualitative interviews were conducted with the household heads.

Analysis Process

This study is placed within the larger body of analysis a part of which has been used in Chaudhary et al. (2022) and Chaudhary et al. (2023) with the specific objective to explore the importance of herbicide perceptions and experiences in CASI decision-making, and a few adaptations were made to analyze the dataset. Firstly, while the larger study captured nine different typologies, this study simplified them into three broad categories: non-users (38 respondents), dis-users (73 respondents) and current users (101 respondents). First, 73 negative evaluators who are farmers who discontinued ZT use in the last 12 months, it also includes those who are not interested in ZT; second, 38 interested users are farmers who are interested in starting to use ZT in the future but have not acted on that intent; and third, 101 current users are farmers who have been implementing ZT for at least the last 12 months either using their own investments in ZT machinery or agricultural inputs or those who have increased area under ZT crops in the last 12 months.

All English transcripts were analyzed in Dedoose qualitative software (Dedoose.com) and thematically coded using the DmD framework. The 24 DmD-related codes (six levels by four resource kinds) and an additional 20 child-themes made up the themes utilized for coding. This work focuses on specific child codes on weed management, agricultural labour, household labour, and gender. Quotations were retrieved from the dataset and examined to fully comprehend weed management experiences and perceptions across the three typologies. Of the interviews analyzed, these child codes were thematically allocated 600 times, and were a part of 175 interviews analyzed.

RESULTS

Two divergent regional experiences with herbicides emerged. In Bihar and Sunsari, herbicide use appeared limited compared to the other four locations which had substantial and widespread herbicide usage, regardless of the implementation of ZT or conventional tillage (CT) systems. In locations where herbicide application was common, particularly Cooch Behar, Malda, and Rangpur, many respondents identified an extended history of use (e.g., “It [herbicide] has arrived here long ago. Almost 15 to 20 years ago...It has been sprayed for many years.”- J17; “I was using herbicides previously, before ZT.” - B24). Yet, regardless of the duration and prevalence of herbicide use, both positive and negative perceptions of herbicides were expressed within both regional experiences.

Negative perceptions about herbicide use from non-users

Negative perceptions about herbicides tended to reflect three key themes, as below.

(a) Perceived crop damage and associated ineffectiveness of herbicides

Unexpected consequences of herbicide were often identified through previous experiences where respondents noted unintended crop damage (e.g., *“I had sprayed herbicides twice, but my wheat crop also got damaged” – S34)*, even though the herbicides themselves were effective *(“I have sprayed, I feel like some of the weeds are dying but the crops remain very short”- C28 [f]*). A perceived lack of herbicide effectiveness was frequently linked to additional time to manage weeds (e.g., *“The problem of herbicide is that it can’t kill the weeds completely…To kill the weeds, I have to use a spade, or I have to spray again which takes time.” – J9*). Some new users of ZT reported that herbicides did not clear off the field efficiently, and additional labourers were hired to clear out the weeds left from the perceived ineffective performance of the herbicides (e.g., *“It [herbicide] controls weeds to some extent and I hire some workers to handpick them [weeds]”- S8*).

Consistently mentioned was the frequent re-emergence of weeds after the initial treatment, and crop-weed competition was yet another concern (e.g., *“Months later the grasses would grow even after applying herbicides in CASI, the growth rate of the grasses is quicker than the crop…But, under the conventional method, the growth rate was reduced”- S34*). In response, respondents mentioned the need for frequent repetitive applications of herbicides under CASI systems because of the proliferation of weeds (e.g., *“We are sowing with the help of zero tillage, but there is a lot of problem of weed in the field…So, we need to use herbicide frequently”- B3*). Furthermore, the weather frequently affected the effectiveness of the herbicides for the farmers, reducing their perceived benefit (e.g., *“We sprayed herbicides, but it was not effective. When there was rain, the herbicides were of no use. Sometimes the fields were filled with water” – S1*).

(b) Preference for conventional weeding practices

For non-herbicide users, there was a preference for the existing CT method even after observing benefits (e.g., *“I think conventional farming requires more effort... but even then, I prefer tillage farming to* *prevent weed growth."- M36),* citing learned experiences in contrast to perceived concerns for the effectiveness of herbicides *(e.g., "When the soil is tilled [CT], the weeds are uprooted from the soil so they cannot grow. If the soil is not tilled [CASI], then the weeds keep growing in the soil, especially in the presence of water"- J31 [f]*). The preference for conventional ponding-based weed management also emerged from the non-users of herbicides (e.g., *"Under conventional methods, we use the rotting water technique to kill the grasses. We use this technique as the weeds are smaller in size than the crop. Pesticide can damage the wheat crop as the height of the grass and wheat is the same when the zero-tillage machine is used."- S34*).

(c) Limited understanding

Based on the efficiency of herbicides with a particular crop, respondents frequently assumed that herbicides cannot be used for all types of crops (e.g., *"When there is a crop like maize… herbicide spraying is impossible, if sprayed then it will affect maize, so you have to do manual weeding." – R35*). Such assumptions were stronger for crops that are meant for human consumption (e.g., *"I spray on the jute crop when there are a lot of weeds… but we do not spray the herbicides like this on edible crops. – M31*), and livestock fodder (e.g., *"Weed which is controlled with herbicide is not used to feed livestock" – B16*) based on their conviction that herbicides were detrimental to health. Aside from the aforementioned challenges, the usage of herbicides and ZT frequently clashed with farmers' understanding of the perceived causes of weed emergence (e.g., *"Weeds die when you till the land by going under the soil, it gets rotten. But with zero tillage, they stick with the land and when water is given again, the number of weeds increases as it does not die."- But with zero tillage, they stick with the land and when water is given again, the number of weeds increases as it does not die."- J6*).

Positive perceptions about herbicide from herbicide users

A divergent view was provided by herbicide users often with many years of experience, who were nearly unanimous in their positive perception of its use that primarily related to reduced time, cost, and associated farm drudgery, as summarised in Table 1.

Table 1: Positive perceptions and benefits of herbicide use

Benefit	Quotations
Reduced weed occurrence with successive use of herbicides	*"When you cultivate with a tractor it produces weed 100%...zero tillage only produces 20% to 25% of that weed [after consecutive use of herbicides]"- M42* *"Zero tillage produces more weeds. But they are killed by spraying herbicides" - M30*
Time saving	*"If we try to do it ourselves manually instead of using herbicides, then it may take 6-7 days and it leads to late sowing, and it will impact the crop"- B31*
Reduced drudgery	*"The hard work has become easy now...There is no manual weeding work...we just have to apply herbicides…in the previous method we hired five to seven labors for weeding 2 bigha field for 4-5 days yet it did not suffice" - J18*
Reduced labor requirement	*"Earlier, we weeded 2-3 times to remove weeds. Sometimes 20-25 laborers were required in a bigha land. But in zero tillage, spraying the field once is sufficient" – M27*
Reduced labor cost	*"I started using herbicides to reduce the cost. The cost for hiring laborers is more to remove weeds"- M42* *"Earlier, we had to spend INR 1500-2000 [approx. USD 20-26] to remove weed with labor for 1 acre, and now we can do it with herbicide for just INR 200 or 300 [approx. USD 3-4]" – B21*

Labor scarcity	*"Laborers for weeding are not available now" - C30*

Gender dynamics and weed management

Different gender roles were identified by respondents across locations with respect to weed management. While some women's roles were pre-defined, others were more flexible and responded to changing labour requirements depending on whether they used herbicides or did manual weeding.

Spraying of herbicides as a man's domain

In households that used herbicide sprays, men were almost always tasked with spraying of herbicides. This was in part due to the perceived design and feasibility of carrying a spray tank on the back by both men and women (e.g., *"It is not possible for us [women] because the spray pump needs to be tied on the back and sprayed in the whole field... I can't carry that much load for the whole day"- B29 [f]).* In terms of gendered roles in weed management, the abundance of weeds determined who managed the weeds; if there are more weeds, then the male member was expected to spray the herbicides *(e.g., "When we see that there are a lot of weeds, then I request my husband to spray herbicides on the weeds." – C8 [f]*) and if, fewer women do manual weeding (e.g., *"When there is more fieldwork [weeding], then we hire labourer, and if there is less work, then family women do it" - B26*). Even in cases of male out-migration where women become the de-facto decision makers of the agricultural plot, men returned to the field to spray herbicides (e.g., *"My husband has to go away for 3 or 4 months…There are some things like spraying which I can't do so he does that work when he is here"- C16 [f]*).

Women's role in herbicide-based weed management

Under conventional weeding systems, women were directly involved in manual weeding in addition to their household responsibilities (e.g., *"After finishing cooking and other work, if she [my wife] has time, then she helps in weeding activity."- B16*). In herbicide-based weed management, weeding tasks involving mechanized spraying mostly shifted to men. Instead of using spray tanks on their own, women usually helped with manually handpicking weeds where necessary (e.g., *"The women cannot take the load of the tank on their back…so they help by plucking it with their hands" - C38*). Women also assisted men in the preparatory process of herbicide spraying (e.g., *"I help my husband in the spraying by bringing him water for the tank" - B29*).

DISCUSSION

This study proposed to explore two questions: [a] how do perceptions of herbicides impact the decision to implement ZT? and [b] does using herbicide within a ZT system create non-inclusive outcomes within households? These are answered in this section.

How do perceptions of herbicides impact the decision to implement ZT?

Perception of herbicides appeared strongly based on how prevalent their use has been in different communities. Where herbicide use appeared more constrained (e.g., Sunsari and Bihar), perceptions were mostly negative, while in other locations with longer experience with herbicides, this was not the case. Such a divergence is not uncommon and has also been found in the ZT experiences of farmers in Eastern and Southern Africa, where Brown et al., (2017b) found that smallholder farmers who used herbicides listed CASI as convenient while the farmers who did not use herbicides listed CASI as laborious.

Negative perceptions of herbicides appeared central to why users either practiced or did not practice, ZT. Yet while users were overwhelmingly positive about herbicides, negative evaluation tended to reflect experiences related to ineffectiveness and associated additional costs, impacts on primary crops, and health concerns. These concerns were not present with herbicide users. Such a divergence in options suggests that with targeted information provision and training, the hesitancy towards herbicides, and in turn ZT, could be reduced. For instance, issues with ineffectiveness, timing or spraying, and health concerns could be resolved with training on what, how, when, and where to spray herbicides. Given the mechanisms through which herbicides function, such pieces of training would also address the overall hesitance to embrace ZT and would help transition community perception.

A deeper effort to educate may also help explain known trends in ZT implementation, for example, the reduction in weed load in successive seasons. Recent research shows that ZT weeds are known to reduce over the years with successive application of herbicides (Nandan et al., 2020), but the findings show that farmers without adequate CASI and herbicide knowledge were unaware of long-term results. This could act as a deterrent to overall ZT adoption, particularly in the initial years when weed pressure and resistance were the highest (Bajwa, 2014; Sims et al., 2018).

Such arguments are in line with the broader ZT literature. For example, Erenstein et al., (2012) highlighted that the scaling of ZT needs to focus more on the transformation of farmer perceptions and mindsets rather than a singular focus on the technology itself, also considering ZT systems are known to be knowledge and management intensive and require proper agronomic knowledge transfer among and within farming communities (Wall, 2007). Supplementary activities and promotional efforts may also aid this process. For instance, proper dissemination of weather forecasts and herbicide application timing, especially during the rainy season, could help farmers plan their spraying schedules.

Overall, our findings suggest that hesitance to use herbicides does impede wider scaling out of ZT, particularly in locations that have more constrained uptake driven by negative perceptions of herbicide (e.g., Sunsari and Bihar). To address this, information systems that focus on herbicide use need to be targeted to bring user and non-user experience in line. Herbicides involve a system of application and could be complex in themselves but if used in conjunction with robust information flows, their application can help farmers derive larger benefits via CASI. How varying forms of information related to herbicides are communicated and interpreted play a decisive role in perceptions about herbicides in particular and in the uptake of ZT technology in general (Hermans et al., 2020). Innovative and continuous efforts on the part of government and partner organizations to control information flows need prioritization. The transition to ZT might require stronger support systems in the form of extension services and multi-stakeholder adaptive learning, as also suggested by other studies (Erenstein et al., 2012), that help farmers understand CASI and supporting activities, including weeds and their sustainable management (Sims et al., 2008).

Does using herbicide within a ZT system create non-inclusive outcomes within households?

Weeding burden has conventionally been more for women compared to men (Burman et al., 2020), but extensive use of herbicides tends to change a household’s internal labor allocation. Results indicate that herbicide-based weed management under CASI may contribute to a reallocation of family labour from conventional weeding primarily performed by women (Akter et al., 2017) to herbicide-based spraying, commonly performed by men. This is primarily driven by the weight of knapsacks and their incompatibility with perceptions of the physical abilities of women, also found in Zambia (Nyanga et al., 2012). This is consistent with the findings of Brown et al., (2021) that highlighted that the labour savings of ZT-based systems in the weeding period were more favourable in reducing women’s weeding responsibilities as compared to men.

However, that conclusion made would need to be moderated on two fronts. Firstly, it is clear that when herbicides are implemented ineffectively, women are still required to fulfill their conventional weeding roles. Based on these findings, herbicides may have frequently been applied ineffectively, increasing women's physical labour in addition to increasing unfavourable perceptions of CASI's performance for the community. This indicates that without enabling conditions, inequitable and unproductive practices may continue and calls for a focus on education and training programs that ensure correct and effective herbicide spraying practices.

Secondly, women appear to be allocated to aligned roles such as water fetching and additional weeding on areas that are not sprayed with herbicides. For example, Johnson et al. (2004) highlight that filling knapsack sprayers also tend to be labour-intensive and require recurrent mixing and filling up of the tank water which women would conventionally need to source. We also did not explore if that freed labour is allocated to additional chores or other tasks, so we cannot fully conclude that this leads to positive outcomes for women, but this would need additional in-depth studies.

CONCLUSION

While the literature has identified that changed weed management practices as a contributor to the low uptake of CASI across the EGP, little exploration has been done to understand how strong that contribution is to the overall CASI evaluation, nor to how the gendered implications of herbicide use impact household labour. This study identifies a divergence in experiences with herbicides, both geographically (with Sunsari and Bihar more negative than other locations) and in terms of user typologies (where users are overwhelmingly positive, and non-users are overwhelmingly negative). This divergence suggests that an information void exists that has the potential to contribute strongly to the negative evaluation of CASI, as well as potentially negative changes in household labour dynamics. To overcome this, promotional efforts should target education and training programs that address how to effectively use herbicides potentially also focusing on new technologies like information and communications technology (ICTs) on weather-forecast. This will ensure equitable outcomes for household members, and increased interest and use of CASI can be enabled.

DISCLOSURE STATEMENT

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

DATA AVAILABILITY STATEMENT

Anonymized Data can be made available on reasonable request.

FUNDING STATEMENT

This study was supported through the Australian Centre for International Agricultural Research (ACIAR): (WAC/2020/148 and CSE/2011/077).

ACKNOWLEDGEMENT

First and foremost, we would like to thank the farmers who agreed to take part in this research and share their knowledge and experiences with us. The transcribers are also appreciated for their assistance throughout the transcribing process. The members from the following partner organisations are thanked for their contribution during data collection-Uttar Banga Krishi Vishwavidyalaya, Satmile Satish Club O Pathagar, Department of Agriculture, Sabuj Mitra Krishak Sangha and Sabuj Bahini, Gourangapur Farmers Club in West Bengal; Bangladesh Agricultural Research Institute (BARI) and Rangpur Dinajpur Rural Service (RDRS) in Bangladesh; Bihar Agricultural University (BAU) in Bihar; Nepal Agricultural Research Council (NARC) in Nepal.

INFORMED CONSENT

The studies involving human participants were reviewed and approved by Gideon Kruseman, Head of CIMMYT Internal Review Ethics Committee (Ethics approval number: IREC-2019.020). The participants provided their informed consent to participate in this study.

REFERENCES

Akter, S., Rutsaert, P., Luis, J., Htwe, N.M., San, S.S., Raharjo, B., Pustika, A., 2017. Women's empowerment and gender equity in agriculture: A different perspective from Southeast Asia. Food Policy 69, 270–279. https://doi.org/10.1016/j.foodpol.2017.05.003

Bajwa, A.A., 2014. Sustainable weed management in conservation agriculture. Crop Protection 65, 105–113. https://doi.org/10.1016/j.cropro.2014.07.014

Bell, R., Haque, Md., Jahiruddin, M., Rahman, Md., Begum, M., Miah, M., Islam, Md., Hossen, Md., Salahin, N., Zahan, T., Hossain, M., Alam, Md., Mahmud, M., 2018. Conservation Agriculture for Rice-Based Intensive Cropping by Smallholders in the Eastern Gangetic Plain. Agriculture 9, 5. https://doi.org/10.3390/agriculture9010005

Bellinder, R.R., Miller, A.J., Malik, R.K., Ranjit, J.D., Hobbs, P.R., Brar, L.S., Singh, G., Singh, S., Yadev, A., 2017. Improving Herbicide Application Accuracy in South Asia. Weed Technology 16. https://doi.org/10.1614/0890-037X(2002)016[0845:IHAAIS]2.0.CO;2

Brown, B., Karki, E., Sharma, A., Suri, B., Chaudhary, A., 2021. Herbicides and Zero Tillage in South Asia: Are we creating a gendered problem? Outlook on Agriculture 50, 238–246. https://doi.org/10.1177/00307270211013823

Brown, B., Nuberg, I., Llewellyn, R., 2017a. Negative evaluation of conservation agriculture: perspectives from African smallholder farmers. International Journal of Agricultural Sustainability 15, 467–481. https://doi.org/10.1080/14735903.2017.1336051

Brown, B., Nuberg, I., Llewellyn, R., 2017b. Stepwise frameworks for understanding the utilisation of conservation agriculture in Africa. Agricultural Systems 153, 11–22.https://doi.org/10.1016/j.agsy.2017.01.012

Brown, B., Samaddar, A., Singh, K., Leipzig, A., Kumar, A., Kumar, P., Singh, D.K., Malik, R., Craufurd, P., Kumar, V., McDonald, A., 2021. Understanding decision processes in becoming a fee-for-hire service provider: A case study on direct seeded rice in Bihar, India. Journal of Rural Studies 87, 254–266. https://doi.org/10.1016/j.jrurstud.2021.09.025

Burman, R.R., Joshi, P., Sharma, J.P., Sharma, N., Mahra, G.S., Sharma, S., Kumar, R., Singh, R., Chahal, V.P., Singh, A.K., 2020. Quantification of drudgery and ergonomics assessment of weeding activity in vegetable production system. The Indian Journal of Agricultural Sciences 90, 634–638. https://doi.org/10.56093/ijas.v90i3.101505

Chaudhary, A., Timsina, P., Karki, E., Sharma, A., Suri, B., Sharma, R., Brown, B., 2023. Contextual realities and poverty traps: why South Asian smallholder farmers negatively evaluate conservation agriculture. Renewable Agriculture and Food Systems 38. https://doi.org/10.1017/s1742170523000066

Chaudhary, A., Timsina, P., Suri, B., Karki, E., Sharma, A., Sharma, R., Brown, B., 2022. Experiences With Conservation Agriculture in the Eastern Gangetic Plains: Farmer Benefits, Challenges, and Strategies That Frame the Next Steps for Wider Adoption. Frontiers in Agronomy 3.https://doi.org/10.3389/fagro.2021.787896

Chauhan, B.S., Singh, R.G., Mahajan, G., 2012. Ecology and management of weeds under conservation agriculture: A review. Crop Protection 38, 57–65. https://doi.org/10.1016/j.cropro.2012.03.010

Dixon, J., Rola-Rubzen, M.F., Timsina, J., Cummins, J., Tiwari, T.P., 2020. Socioeconomic Impacts of Conservation Agriculture based Sustainable Intensification (CASI) with Particular Reference to South Asia. No-till Farming Systems for Sustainable Agriculture 377–394. https://doi.org/10.1007/978-3-030-46409-7_22

Erenstein, O., Sayre, K., Wall, P., Hellin, J., Dixon, J., 2012. Conservation Agriculture in Maize- and Wheat-Based Systems in the (Sub)tropics: Lessons from Adaptation Initiatives in South Asia, Mexico, and Southern Africa. Journal of Sustainable Agriculture 36, 180–206. https://doi.org/10.1080/10440046.2011.620230

FAO, 2019. Gender and Work in Agrifood System. Food and Agriculture Organization. URL https://www.fao.org/3/cc5343en/online/status-women-agrifood-systems-2023/gender-work-agrifood-systems.html(accessed 7.27.23).

Farnworth, C.R., Baudron, F., Andersson, J.A., Misiko, M., Badstue, L., Stirling, C.M., 2015. Gender and conservation agriculture in East and Southern Africa: towards a research agenda. International Journal of Agricultural Sustainability 14, 142–165. https://doi.org/10.1080/14735903.2015.1065602

Farooq, M., Siddique, K.H.M. (Eds.), 2015. Conservation Agriculture. https://doi.org/10.1007/978-3-319-11620-4

Gathala, M.K., Laing, A.M., Tiwari, T.P., Timsina, J., Rola-Rubzen, F., Islam, S., Maharjan, S., Brown, P.R., Das, K.K., Pradhan, K., Chowdhury, A.K., Kumar, R., Datt, R., Anwar, M., Hossain, S., Kumar, U., Adhikari, S., Magar, D.B.T., Sapkota, B.K., Shrestha, H.K., Islam, R., Rashid, M., Hossain, I., Hossain, A., Brown, B., Gerard, B., 2021. Improving smallholder farmers' gross margins and labor-use efficiency across a range of cropping systems in the Eastern Gangetic Plains. World Development 138, 105266. https://doi.org/10.1016/j.worlddev.2020.105266

Harman Parks, M., Christie, M.E., Bagares, I., 2014. Gender and conservation agriculture: constraints and opportunities in the Philippines. GeoJournal 80, 61–77. https://doi.org/10.1007/s10708-014-9523-4

Hermans, T.D.G., Whitfield, S., Dougill, A.J., Thierfelder, C., 2020. Bridging the disciplinary gap in conservation agriculture research, in Malawi. A review. Agronomy for Sustainable Development 40. https://doi.org/10.1007/s13593-020-0608-9

Hobbs, P.R., 2007. Paper Presented at International Workshop on Increasing Wheat Yield Potential, CIMMYT, Obregon, Mexico, 20–24 MARCH 2006 Conservation agriculture: what is it and why is it important for future sustainable food production? The Journal of Agricultural Science 145, 127. https://doi.org/10.1017/s0021859607006892

Islam, S., Gathala, M.K., Tiwari, T.P., Timsina, J., Laing, A.M., Maharjan, S., Chowdhury, A.K., Bhattacharya, P.M., Dhar, T., Mitra, B., Kumar, S., Srivastwa, P.K., Dutta, S.K., Shrestha, R., Manandhar, S., Sherestha, S.R., Paneru, P., Siddquie, N.-E.-A., Hossain, A., Islam, R., Ghosh, A.K., Rahman, M.A., Kumar, U., Rao, K.K., Gérard, B., 2019. Conservation agriculture based sustainable intensification: Increasing yields and water productivity for smallholders of the Eastern Gangetic Plains. Field Crops Research 238, 1–17. https://doi.org/10.1016/j.fcr.2019.04.005

Jat, M.L., Chakraborty, D., Ladha, J.K., Rana, D.S., Gathala, M.K., McDonald, A., Gerard, B., 2020. Conservation agriculture for sustainable intensification in South Asia. Nature Sustainability 3, 336–343. https://doi.org/10.1038/s41893-020-0500-2

Jat, R.K., Sapkota, T.B., Singh, R.G., Jat, M.L., Kumar, M., Gupta, R.K., 2014. Seven years of conservation agriculture in a rice–wheat rotation of Eastern Gangetic Plains of South Asia: Yield trends and economic profitability. Field Crops Research 164, 199–210. https://doi.org/10.1016/j.fcr.2014.04.015

Johnson, P. D., Rimmer, D. A., Garrod, A., Helps, J. E., & Mawdsley, C., 2004. Operator Exposure When Applying Amenity Herbicides by All-Terrain Vehicles and Controlled Droplet Applicators, 2004. The Annals of Occupational Hygiene. https://doi.org/10.1093/annhyg/meh073

Nandan, R., Singh, V., Kumar, V., Singh, S.S., Hazra, K.K., Nath, C.P., Malik, R.K., Poonia, S.P., 2020. Viable weed seed density and diversity in soil and crop productivity under conservation agriculture practices in rice-based cropping systems. Crop Protection 136, 105210. https://doi.org/10.1016/j.cropro.2020.105210

Nyanga, P.H., Johnsen, F.H., Kalinda, T.H., 2012. Gendered Impacts of Conservation Agriculture and Paradox of Herbicide use among Smallholder Farmers. International Journal of Technology and Development Studies 3, 1–24.

Patel, S.K., Agrawal, G., Mathew, B., Patel, S., Mohanty, B., Singh, A., 2019. Climate change and women in South Asia: a review and future policy implications. World Journal of Science, Technology and Sustainable Development 17, 145–166. https://doi.org/10.1108/wjstsd-10-2018-0059

Pokharel, D., Jha, R.K., Tiwari, T.P., Gathala, M.K., Shrestha, H.K., Panday, D., 2018. Is conservation agriculture a potential option for cereal-based sustainable farming system in the Eastern Indo-Gangetic Plains of Nepal? Cogent Food & Agriculture 4, 1557582. https://doi.org/10.1080/23311932.2018.1557582

Shekhawat, K., Rathore, S.S., Chauhan, B.S., 2020. Weed Management in Dry Direct-Seeded Rice: A Review on Challenges and Opportunities for Sustainable Rice Production. Agronomy 10, 1264. https://doi.org/10.3390/agronomy10091264

Sims, B., Corsi, S., Gbehounou, G., Kienzle, J., Taguchi, M., Friedrich, T., 2018. Sustainable Weed Management for Conservation Agriculture: Options for Smallholder Farmers. Agriculture 8, 118. https://doi.org/10.3390/agriculture8080118

Singh, A.P., Bhullar, M.S., Yadav, R., Chowdhury, T., 2015. Weed management in zero-till wheat. Indian Journal of Weed Science 47, 233–239.

Wall, P.C., 2007. Tailoring Conservation Agriculture to the Needs of Small Farmers in Developing Countries. Journal of Crop Improvement 19, 137–155. https://doi.org/10.1300/j411v19n01_07

Yadav, S.S., Lal, R., 2018. Vulnerability of women to climate change in arid and semi-arid regions: The case of India and South Asia. Journal of Arid Environments 149, 4–17. https://doi.org/10.1016/j.jaridenv.2017.08.001