



Qualitative Evaluation of Cropping System Intensification in Coastal Saline Zone of West Bengal, India

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Agricultural research and extension projects aimed at socio-economic and ecological development in the coastal saline zone (CSZ) often face serious operational challenges. Crop management practices in these stressed ecosystems confront stiff climatic (cyclonic storms, extreme high and extreme low rainfall, prolonged hot dry spells), edaphic (soil salinity during winter and summer months, excess soil moisture in rainy season and lack of soil moisture in summer season), production (growing long duration rainy season paddy varieties and consequent delay in sowing dry season crops) and socio-economic (resource-poor farmers, lack of credit and market infrastructure, migration of human labour) constraints. Any intervention in such systems, thus, needs critical empirical examination, not only in terms of concrete numbers but in terms of human experience for whom the interventions are made. During 2016 to 2020, a team of researchers and development workers, as part of a donor-supported project, aimed at standardizing and disseminating a suite of climate-smart, farmer-friendly technologies in Rangabelia and Jatirampur villages under the Gosaba Block of South 24 Parganas district, which comes under the CSZ of West Bengal. The interventions envisaged were - sowing date alteration of rainy-season rice to fetch good return from post-monsoon relay-sown lathyrus, intensification of rice-fallow areas with green gram, implementing water-saving technologies like drip irrigation with straw mulching for higher profit in tomato cultivation, and growing potato and onion under zero tillage and straw mulching conditions. The present study qualitatively examined the outcomes of these cropping system intensification interventions to capture the experience of the adopters of these technologies. Our thematic analysis identified field management, farmers' difficulties in coping with adverse agro-climatic and edaphic situations, barriers and drivers of technology adoption, and women's participation in agriculture as core areas of concern. Among the technologies introduced, zero tillage potato cultivation was the most adopted technology, followed by relay sowing of lathyrus and drip irrigation technology in tomato. Problem of salinity and water scarcity was widely reported, where higher crop yield was the predominant driver of technology adoption. Notably, women farmers received benefits from several technological interventions. Outcomes of the study provide a first-hand knowledge of farming situations, the problems associated with adopting innovations, and major factors that shape their adoption in the study areas. These qualitative insights can be amalgamated with formal quantitative studies and inform extension workers for sustainable implementation of future projects.

(Key words: Technology adoption, Smallholder farmers, Saline soil, Qualitative analysis)

The coastal saline zone (CSZ) of West Bengal state covers a major portion of South 24 Parganas (14 out of total 29 blocks) district (Govt. of W.B., 2022), and is marked by acute poverty, food and nutritional insecurity, and risks of disasters, among others. Crop production is primarily constrained by soil and water salinity and the non-availability of good quality irrigation water. Deep

submergence during the monsoon and drying of soil and water bodies from late winter to summer season become defiant to remunerative crop cultivation in these areas. Apart from all these well predicted situations of the CSZ, the unprecedented weather calamities during the past few years (*Aila* in 2009, *Bulbul* in 2019, *Amphan* in 2020, and *Yaas* in 2021) caused huge destruction of

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agricultural lands, houses, livestock and fish ponds, making the farms of the zone extremely vulnerable to climatic perturbations. Despite numerous socio-economic constraints, recurring disasters, and soil salinity, the place has consistently revived and restored its potential for development in the crop, livestock, and fisheries sectors through collaborative interventions. In the face of each calamity, farmers have honed their skills and expertise through new experiences, challenges, and the adoption of contingent technologies.

West Bengal is the largest rice producer in India, producing 25.35 million tonnes rice from 5.58 million ha area (Govt. of W.B., 2021), and the crop occupies an integral part in the state's agricultural scenario. One can find numerous cropping systems in the state involving rice as the central crop. However, in the CSZ of West Bengal, nearly 6.02 lakh ha area out of total 9.07 lakh ha cultivable area *i.e.*, 66.67% of total agricultural land is rice mono-cropped (Brahmachari *et al.*, 2017). Here, rice is the only crop grown in the rainy season (*Kharif*), rainwater being the only source of irrigation, and there is hardly any winter or summer crop grown due to constrained irrigation. Non-remunerative agriculture often leads to labour migration from the villages (Saha and Goswami, 2020). Many of the male residents of the villages of CSZ go outside for months, or even for years to earn money to sustain the livelihood of their families. Apart from climatic and edaphic problems of the area, the pandemic COVID-19 has also jeopardized the livelihood options there (Goswami *et al.*, 2021). Restricted movement of farm labourers and transport of farm produce, lack of buyers in the local and distant markets, ailment and deaths of farmers put a question on the resilience of this region's farming systems.

The problems of CSZ are deep-rooted, and they cannot be surmounted within a few days' or months' or even years' interventions, rather need a redefined sustainability regime for the regional socio-ecological systems. There must be various possible agricultural options for the farmers so that one technology can be alternatively taken as insurance against loss in another technological option. Most importantly, there is a need to bring sustainable intensification (SI) in the cropping systems of the CSZ, as it will not only help in improving productivity and profitability but also reduce the

economic and environmental risks in producing crops in these areas (Ray *et al.*, 2020).

With an aim to intensify the cropping systems in the Sundarbans part of CSZ, we conducted research trials on a series of improved technologies from 2016 to 2020. Our project had some unique features that appreciate farmers' participation, focus on location-specific technologies, and long-term target of improved technological interventions. A quantitative impact study of the intervened technologies on the end users have been studied (Ray *et al.*, 2019), followed by a techno-economic assessment of the existing as well as potential cropping systems (Ray *et al.*, 2020), and their associated economic risk under different market situations (Ray *et al.*, 2023).

Qualitative analysis of narratives generated by in-depth interviews with respondents is a powerful and comprehensive tool for agricultural researchers. It allows for the systematic organization, coding, and analysis of qualitative data, such as interview transcripts, field notes, and audio/video recordings. Researchers can easily extract key themes, identify patterns, and explore relationships within their data. Use of qualitative analysis software like Atlas.ti offer a range of analytical features, including the ability to annotate and link different data sources, conduct inter-coder reliability checks, and generate visual representations of the data (Hwang, 2008). Such analysis simplifies the inert process of adoption or diffusion of any technology, enabling researchers to gain deeper insights and produce rigorous and meaningful findings. To realize the processes of adoption, these analyses are required to understand the nature and strengths of the variables and the interactions among them. Thus, apart from merely adopting a simplified view of the subject to measure and count the occurrences of events, it takes a holistic perspective to understand the complexities of human behaviour (Black, 1994). Till date, qualitative analysis has been used to evaluate/estimate farmers' perception about in-vitro cell culture techniques in animal farming (Räty *et al.*, 2023), factors affecting the adoption of innovative agricultural practices (Pignatti *et al.*, 2015), farmers' participation and challenges in farm entrepreneurship and value addition (Gulsia and Yadav, 2023) and factors influencing farmers' participation in

the development of e-commerce (online selling of farm products) (Gao, 2022).

In the present study of evaluating the impact of different crop management interventions in the context of cropping system intensification, we performed qualitative data analysis to reveal the opinions, thoughts and feelings of respondents while adopting or refusing technological interventions. This approach focused on the after-intervention issues with the people to understand their thought process, and perception about technologies, among others. Such perceptions cannot be expressed quantitatively but rather understood better through in-depth interaction with the people. Considering the above things, we framed our study objectives to identify: a) how do farmers adapt to soil and climatic constraints with reference to the adoption of sustainable intensification technologies? b) what are the issues related to the adoption of technologies? c) what are the perceived benefits of adopting cropping system intensification in the study areas? and how much is the adoption or adoption pattern of different interventions? and d) what are the gendered outcomes of the technological intervention?

MATERIALS AND METHODS

Rangabelia and Jatirampur villages of Gosaba Block, in South 24 Parganas District, West Bengal were purposefully selected as the study area, where a donor-supported cropping systems intensification project was being implemented during the research. In these two villages, agriculture was the primary occupation for 88.5% of households, and a little more than half of the farmers (55.8%) had access to irrigation water (Brahmachari *et al.*, 2020). We conducted in-depth interviews with project beneficiaries using a checklist to evaluate the adoption, dissemination and impact of introduced technologies, namely showing date alteration of rainy-season rice to fetch good return from post-monsoon relay-sown lathyrus, intensification of rice-fallow areas with greengram, implementing water saving technology like drip irrigation with straw mulching for higher profit in tomato cultivation, and growing potato and onion under zero tillage and straw mulching situations. The data collection instrument consisted of general information about

the farmers, agricultural land holding, cropping systems of the last 5 years, technology adoption and the associated factors, and participation of women in agricultural activities (Table 1).

The field enumerators collected data from 1st March to 31st July, 2020, during the restrictions of COVID-19 pandemic and super cyclone Amphan. Due to the restrictions in holding face-to-face interviews with farmers, telephonic interview was the only way to collect data. A total of 10 farmers were interviewed in 16 days (20th June to 6th July, 2020) with a pre-tested, semi-structured interview guide. The small sample size is very common in qualitative research and it is determined by information saturation instead of working with a pre-determined sample size. Among the farmers surveyed, seven were male farmers and three were female farmers.

The interviewer established rapport with the respondents and minimized interviewer bias by using probing questions, managing transitions, and deciding to move to the next question upon reaching information saturation. The interviewer guaranteed the respondents that personal information and information confidentiality would be strictly maintained. Interviews generally ranged from 30 to 40 minutes and these were audio taped with due permission. Phone recordings were transcribed verbatim, and then translated from vernacular language into English. Transcriptionists and translators had prior training in agriculture, rural development and qualitative research. The basic steps in qualitative data analysis *viz.*, collecting and organizing the data, coding of the database, describing key findings and forming themes, representing and reporting findings, interpreting the meaning of the findings, and finally validating the accuracy of the findings were followed as suggested by Cresswell (2012). Transcripts from the present study were coded using the qualitative data analysis software ATLAS.ti 8 for Windows and were analyzed using an inductive thematic analysis approach. In our study, a total of 10 documents (transcripts of 10 interviews) were analyzed. These 10 documents were then coded leniently, the number of codes being 25. Codes are

Table 1. Variables considered during the study

Sl. No.	Variables	Description
1.	General information about the farmers	a) Whether he/she (respondent) belongs to scheduled caste (SC) or scheduled tribe (ST) or other backward class (OBC) or unreserved category? b) How many members are there in his / her family? c) Up to which class did the respondent complete his / her study? d) What is the total land area (inclusive of the house, cultivable land and others) and total cultivable area of the respondent? e) Is the soil fertile or medium fertile or non-fertile in nature? Whether he / she experienced any kind of problem in the soil (saline or acidic or acid-sulphate soil)? f) Is there any irrigation facility available with the respondent? If yes, then what is the source of irrigation water?
2.	Basic information about the cropping systems	a) What are the cropping systems being followed during past five years? b) Differences among cropping systems in terms of rice equivalent yield, system productivity and profitability. c) How much of the total produce is used for household consumption, and how much is being sold in the market? d) Total expenditure incurred for cultivation of crop
3.	Adopted technologies	a) What are the technologies that have been adopted by the farmers for improving system yield and profit? b) From where did the farmers come to know about these technologies? c) How many farmers have indirectly adopted the technologies from the direct respondents? d) What are the factors determining the direct and indirect adoption of these technologies? e) What are the different purposes of the household being served from the addition income from using improved technologies?
4.	Risk management	a) What are the precautionary measures taken after disaster being forecasted? How did the farmers manage the farming activities after cyclone is over? b) What were the impacts of COVID-19 pandemic on agriculture? How did they cope with the situation?
5.	Women participation	What is the level of participation of women members in agricultural activities? What are the experiences the women gained while taking key part in farming operations?

basically small meaningful and reasonable word (s) representing any selected quotation from the text which can justify the quotation succinctly. For example, if we write #1:2 against any quote, it means the quote was from the code number 2 of the 1st document (*i.e.*, first farmer). Simultaneously, memos were also written along with the coding process. While coding the transcripts, we took notes in the form of these memos from different intriguing aspects. It includes both the farmers' perceptions and

the researchers' views on the topic. These memos are the perceptions or feelings or even any kind of memories or research questions or comments that were felt to be important by the researcher while interviewing the interviewees.

RESULTS AND DISCUSSION

Socio-demographic and physiographic features

The basic information about the farmers and farming situation is listed in Table 2, covering gender,

Table 2. Basic information about the farmers and farming situations

Farmers	Gender	Education	Age	Caste [†]	Members in family	Land holdings [§]	Source of irrigation	Problem in soil	Perception about soil fertility
Farmer 1	Male	Higher Secondary	65	General	5	T: 3 bigha; C: 2.5 bigha	Pond Water	Salinity	#1:2: The soil has a problem of salinity (2.3 mili-mhos cm ⁻¹) ...The acidity is 5.6 (pH) #1:3: The soil was once very fertile but the continuous erosion of the stream bank has lowered the soil fertility level.... As per my knowledge including the occurrence of super cyclone <i>Amphan</i> , it has been eroded for total 6 times #2:3: Soil tests are done for my field under Rangabelia project...The problem of salinity prevails in soil as the area is prone to flooding (<i>i.e.</i> , erosion of stream bank and intrusion of salt water) in every 2 -4 years... It happened in 2006, in 2009, and again in 2020 #3:3: I have my soil tested under TSRD....There is no problem of salinity in the field.... However, in this year (2020), I guess there has been the intrusion of salt in soil during May month (due to Amphan)...I am not sure about that, and I will wait for soil test results #4:2: There exists problem of soil salinity...The soil is not much fertile #5:2: The soil is saline and also not much fertile... This year there was salt intrusion #6:2: Every year, due to flood situation, there is intrusion of saline water which increases soil salinity, but I hope the rainwater during monsoon period will mitigate the problem to some extent #7:2: I have my soil tested on regular basis from TSRD centre under ACIAR project, and the TSRD people suggests me how to treat the soil #8:2: Once upon a time the soil was in good condition.... But after cyclone <i>Aila</i> in 2009, salinity of soil increased and growth and production of pulse crops reduced drastically....After that I only cultivate rice....However, recently pulse crops are being grown in the soil...Except salinity, there is no other problem in the soil #9:2: In general, there is no problem in soil but when saline water enters into the field, multifarious problem occurs #10:3: I have my soil tested under ACIAR project... Presently only banana grows well in the low land of our villages
Farmer 2	Female	Class IX and below	42	General	7	T: 10 bigha; C: 10 bigha	Pond Water	Salinity	
Farmer 3	Male	Higher Secondary	45	General	3	T: 5 bigha; C: 5 bigha	Rain Water, Pond	No Such Problem	
Farmer 4	Male	Class IX and below	41	SC	5	T: 2 bigha; C: 2 bigha	Pond	Salinity	
Farmer 5	Male	Class IX and below	62	General	6	T: 3 bigha; C: 3 bigha	Pump	Salinity	
Farmer 6	Male	Secondary	62	OBC	4	T: 4 bigha; C: 4 bigha	Pond	Salinity	
Farmer 7	Male	Class IX and below	39	General	4	T: 1.5 bigha; C: 1.5 bigha	Pond	No Such Problem	
Farmer 8	Female	Class IX and below	46	OBC	5	T: 8 bigha; C: 7 bigha	Pond	Salinity	
Farmer 9	Female	Secondary	38	General	4	T: 4 bigha; C: 4 bigha	Pond	Salinity	
Farmer 10	Male	Class IX and below	63	OBC	4	T: 7 bigha; C: 7 bigha	Rain Water, Pond	Salinity	

[§]T, Total land; C, Cultivable land. [†]SC, Scheduled Caste; OBC, Other Backward Class. 1 ha = 7.5 bigha

education, age, caste, household size, availability of irrigation facilities, and perception of soil fertility. Out of the 10 respondents interviewed, four farmers were above the age of 60 years. The highest land holding was 10 bigha (1 ha = 7.5 bigha), while the lowest was 1.5 bigha. The last column of the table shows the farmers' perception of their soil condition. Based on their comments, it is evident that they are all concerned about soil salinity. Additionally, most of them expressed worries about natural disasters that worsen the soil condition. Their traditional practices to improve soil conditions take at least 2-3 years, resulting in significant losses in agricultural production. Most farmers are aware of soil testing and got their soil samples tested by Tagore Society for Rural Development (TSRD). Farmer 1 even had knowledge of the soil test results, including the electrical conductivity (EC) values. Many of them clearly indicated that the soil was once fertile, but continuous saltwater intrusion, soil erosion, and floods have drastically affected its condition. They believed that the soil was no longer suitable for cultivating major field crops. Table 3 provides details of the crops cultivated in the fields and homestead land. Overall, the system includes rice in the rainy season, rice/potato/lathyrus/onion/tomato/other vegetables (knolkhol, chilli, etc.) in the winter season and greengram/onion in the summer season.

Contingency measures to alleviate/escape soil and climate-related problems

The farmers delayed the transplanting of rice seedlings until August to coincide with the onset of monsoon rain, which helped in removing soil salinity before sowing. Additionally, they utilize green manuring with *Dhaincha* plant (*Sesbania aculeata* Pers.) to ameliorate soil salinity issues. The roles of green manuring in improving soil properties by reclamation of saline and sodic soils are also scientifically proven (Pawar *et al.*, 2020).

Some farmers grew rice seedlings in wooden frames placed on mud soil, resembling the "Dapog" method of preparing rice seedlings (Bhakta *et al.*, 2021). In response to the question regarding contingency measures for salinity problems caused by cyclones or salt intrusion, one respondent shared their approach:

#3:17: This year in the *Kharif* season, I am experimenting

with preparing rice seedlings in thin cloth sheets framed with bamboo poles at the nursery, given the saline situation in the fields. Many neighbours believe the seedlings will not emerge this year, but I remain hopeful based on my previous experience after the Aila situation in 2009.

Furthermore, as a traditional practice to address salinity after floods or cyclones, farmers remove the pond water and mud, treating the pond with lime. The same farmer shared their process:

#3:17: Due to the occurrence of *Amphan*, saltwater entered the ponds. I removed the water and mud from the ponds to eliminate salts. Then, I applied lime, bleaching powder, and other substances. I know that if the field is wet and cow dung is spread over it, the salinity problem will be alleviated to some extent.

The study areas experienced recurrent natural calamities, causing significant losses to agricultural crops and household properties. However, the farmers made efforts to reconstruct and restore everything. In response to questions about their actions after such devastation, one respondent stated:

#3:16: In my area, we faced floods in 2006, *Aila* in 2009, and *Amphan* in 2020. Each time, salt intrusion damaged our crops, and it takes considerable time to restore normal soil fertility. In recent years, I have been growing lathyrus, but I'm uncertain if it will be possible to grow in the upcoming *Rabi* (winter) season in 2020 due to the salinity problem.

Besides, demonstrations on home-yard rice nursery was conducted in farmers' household premises (Fig. 1) in both the study villages of Gosaba block for promotion of earlier rice seedling transplanting as a contingency measure for the villages (Brahmachari, 2022).

Issues regarding adoption of technologies

The quoted farmers in this analysis have mentioned several limitations and challenges related to technology adoption in their agricultural practices. These include difficulties in growing winter and summer crops, limitations in zero tillage onion production, problems with potato storage, and the age of the farmers. Although zero tillage potato production has gained immense popularity because of its higher productivity and profitability (Sarangi *et al.*, 2021), there are still some problems regarding storage and marketing of

Table 3. Details of crops cultivated throughout the year

Farmers	Kharif (Rainy) season		Rabi (Winter) season		Pre-Kharif (Summer) season	
	Crop	Area	Crop	Area	Crop	Area
Farmer 1	Rice (var. MTU 7029, Jatayu, Varshadhan, Dudheswar etc.)	2.5 bigha	Lathyrus Potato (var. Kufri Pokhraj)	0.1 bigha 0.1 bigha	Pumpkin Bitter gourd Ridge gourd Greengram	In kitchen garden In kitchen garden In kitchen garden 0.25-0.3 bigha
Farmer 2	Rice (var. CR Dhan 1017)	8 bigha	Boro rice Lathyrus Potato Onion	1.5 bigha 0.1 bigha 0.3-0.35 bigha 0.25-0.35 bigha	Green gram	0.75 bigha
Farmer 3	Rice (var. CR Dhan 1017)	4 bigha	Potato Pointed Gourd Lathyrus	0.25 bigha 0.25 bigha 0.25 bigha	Green gram Onion	1 bigha 0.25 bigha
Farmer 4	Rice†	1.5 bigha	Lathyrus Potato Okra Bitter gourd	2 bigha 0.2-0.25 bigha In kitchen garden In kitchen garden	-	-
Farmer 5	Rice (var. CR 1018, Santoshi, Jatayu etc.)	2.5 bigha	Potato Lathyrus	0.1 bigha 0.1 bigha	Green gram Onion	0.25 bigha 0.25 bigha
Farmer 6	Rice (var. CR 1017, CR 1018, Jatayu etc.)	3.5 bigha	Potato Chilli Tomato Capsicum knolkohl	0.2 bigha In kitchen garden 0.15 bigha In kitchen garden 0.05 bigha	Okra	In kitchen garden
Farmer 7	Rice (var. CR 1017, Jatayu etc.)	1 bigha	Lathyrus Potato Vegetables	0.15 bigha 0.075-0.1 bidga In kitchen garden	-	-
Farmer 8	Rice	7 bigha	Lathyrus Potato Cauliflower Cabbage Knolkohl	4.5 bigha 0.25 bigha In kitchen garden In kitchen garden In kitchen garden	Chilli Ginger	In kitchen garden 22 jute bags were planted
Farmer 9	Rice	3.5 bigha	Lathyrus Potato Onion	0.2 bigha 0.2 bigha 0.075 bigha	Bitter gourd Ridge gourd	In kitchen garden In kitchen garden
Farmer 10	Rice (var. CR 1017, Jatayu)	5 bigha	Lathyrus Potato Brinjal Beetroot Coriander leaf	0.15 bigha 0.15 bigha In kitchen garden In kitchen garden In kitchen garden	Okra	In kitchen garden

†If there is no mention of variety after the name of the crop, it can be understood that the farmers could not mention the names of the varieties; 1 ha = 7.5 bigha



Fig. 1. Home-yard rice nursery at Rangabelia village of Gosaba block, West Bengal

potato. At the time of potato harvesting, the market value of potato was lower than 10 Indian Rupees (INR) to a maximum 16 Indian Rupees (INR) only. The market value reached 24 to 25 Indian Rupees (INR) during July or even after July. However, after August, the potato tubers started rotting, and there were no cold storage facilities available for farmers to preserve the potatoes. This lack of storage options also prevents the farmers from exporting potatoes to other places where they could fetch higher prices. Farmer 3 pointed out:

#3:10: After August, the stored potato does not remain in good condition to be consumed...So in any way, potato is kept till August for own consumption.

Farmer 4 mentioned:

#4:7: At the time of harvesting of potato, I received about 15-16 Indian Rupees (INR) per kg, and now *i.e.*, during month of July, it is sold at 23-24 INR per kg

Farmer 7 said:

#7:8: When we harvest the potato, the market value is not more than 10 INR per kg... As there is no cold storage facility and also no way to export to another place from our area, we have to sell potato at a lower price...However, onion has no problem of storage, and that is why we don't sell it and store it in our house for family consumption throughout the year.

Limitations of knowledge of onion cultivation exist in the villages. Farmer 10 only mentioned about this thing:

#10:10: I also tried to grow onion and garlic... But I did not know that garlic takes more time than onion for maturity; however, the yield of the former was good... Other people also tried onion but the size of the bulbs were smaller in size.

Another important concern mentioned by the farmers is their age. The older farmers were interested in agriculture but faced physical limitations that prevented them from working continuously in the fields. Some of them also expressed regret that their sons were not interested in agriculture, considering it as a profession lacking prestige.

Table 4 further highlights the most adopted technologies in the area, as well as the drivers and barriers behind their adoption. The most frequently mentioned technologies include zero tillage straw mulched potato cultivation, zero tillage in lathyrus, and drip irrigation in vegetables. The least mentioned technology is the cultivation of lentil for rice-fallow intensification. The main barriers to technological adoption, as reported by the farmers, are salinity and water scarcity in the area, natural disasters, and the engagement of farmers in non-agricultural activities

or work. Some farmers also mentioned their age and sickness as barriers. On the other hand, the drivers of technology adoption mentioned by the farmers are increased yield, reduced use of inputs and labour, and

the ability to use the extra income for various family expenses. The least mentioned drivers include reduced pest attacks, solving soil-related problems, and the non-migration of rural youths to urban areas.

Table 4. Rankings of different technologies adopted, major barriers and drivers of adoption

Major technologies intervened	Major barriers of adoption	Major drivers of adoption
1. Zero tillage and straw mulching technique in potato and onion 2. Relay cropping of lathyrus 3. Drip irrigation of vegetables 4. Rice-fallow intensification with greengram	1. Problem of salinity and water scarcity 2. Natural disaster 3. Otherwise engagement – less time for farming 4. Market price fluctuation 5. Lower soil fertility 6. Storage of potato 7. Continuous erosion of stream bank 8. Problem of rodents at tuber development stage of potato 9. Sickness 10. Over age	1. Increased yield 2. Requirement of lesser agri-inputs (water, fertilizer, etc.) and lesser labour engagement 3. Use of extra income for family expenditures like education of children, buying new clothes, purchasing medicines, etc. 4. Purchase of agricultural machineries 5. Women empowerment 6. Share of women in the profits earned 7. Timely sowing and harvesting 8. Non-migration of youths to the urban areas 9. Solving soil related problems 10. Lesser pest attack

Perceived benefits from the technologies

The word cloud analysis of farmers' perceived benefits of drip irrigation and zero tillage potato cultivation technologies provides valuable insights into their motivations for adopting these technologies (Fig. 2). For drip irrigation, the farmers emphasised the importance of water in vegetable cultivation. They mentioned the need for a water source, such as a pond, and highlighted the benefits of drip irrigation in ensuring a continuous supply of water to their crops. The use of terms like "scarcity" suggests that water scarcity is a significant concern in the area, and the farmers view drip irrigation as a solution to address this issue. The mention of "bottles" and "drops" indicates the farmers' awareness of the technical aspects of drip irrigation, where water is provided in controlled amounts directly to the roots of the plants. Mandal *et al.* (2020) identified the scarcity of good quality irrigation water and soil salinity during the dry (*Rabi*) season as major constraints of agricultural cropping options in saline areas.

In the case of zero tillage potato cultivation, the farmers highlighted vermicompost and straw mulching as important components of this technology. They mentioned the positive outcomes of using these practices, such as increased yield and income. Comparisons with conventional cultivation methods also indicated that the farmers perceived zero tillage potato cultivation as a more efficient and productive approach. The mention of "timely" suggests that this technology allows for proper timing of planting and harvesting, which is crucial for successful potato cultivation. The mention of "rotting" may be an indication of the storage issues that the farmers face with potato cultivation, as discussed earlier.

By analysing the words quoted by the farmers, researchers could gain a better understanding of the reasons behind technology adoption. The recurrent themes of water scarcity and the desire for increased yield and income indicated that the farmers were motivated by the potential benefits of these technologies in addressing their specific challenges and improving their livelihoods.

#2:16: In our villages, the female farmers spend more time than male members in the homestead or field...I, along with my husband, take decisions on farming...The extra income belongs to me only and is further used for family expenses as per my discretion.

This compulsion stems from the outmigration of the male family members to distant places for earning cash. A male farmer shared:

#4:13: Women of our houses are involved in paddy harvesting, threshing, lathyrus picking, potato planting etc...Male members often go outside (Bangalore, Andhra Pradesh, etc.) for job.

We draw support from the comment of another male farmer:

#5:19: In my family, 2-3 of the women members are involved in farming...In our villages, contribution of women is more in the field...We the male members contribute less in the field as we work in some other places.

However, even in families where men are not migrating, the work burden needs to be shared:

#6:26: Women in this area also take part in agricultural activities as it is impossible to accomplish the huge farming operations by male members alone...In my family, I and my wife only do such works as our son stays in the town.

Also, in extended families, women farmers help their in-laws during the absence of their husbands to save money needed to hire external farm labour.

#8:10: Me and my daughter-in-law, we do all the laborious work in field...We don't hire any labour.

Apart from the male members, the female members also shared the profit from farming to meet personal needs. When we analysed the gendered benefits of new technologies we found that monetary benefits were an important aspect of technology adoption, but there were other reasons for "happiness" of these women. The technological intervention arguably reduced male outmigration, and many of the male members started living with their families and sharing field activities with their wives. It lowered the requirements of hired labour, thus reducing the cost of cultivation. The women could manage time for engaging in other activities, could even take some rest after hard work, and participate

in community affairs. They expressed that the lower water requirement was a very good opportunity for marginal and small farmers to cultivate more crops, thus empowering the women members by instilling the right to access and benefits from agriculture. It could be considered as one of the important achievements of this project. An observably delighted woman expressed:

#2:15: Earlier, the young male members of the family used to go outside the village for hard work, avoiding farming as a profession...But, as they have observed more income after adopting the new technologies, they have started staying at home and working in their own fields (comment of the interviewer: "she was very happy!!!")...It is a big gain for me.

The small interventions could trigger unanticipated positive gender outcomes, such as reduced hassle of pumping irrigation water when water use efficiency is increased by bottle drip irrigation:

#5:20: The women are happy after adopting the bottle drip irrigation technology as they need not to pump water anymore...The extra income from farming is also used by the female members (comment of the interviewer: "he delivered a light smile!!!").

The male members are also happy that the women have become experts in their own rights and carry out certain activities on their own:

#6:27: Women are becoming more intelligent now, and they don't need to ask anything regarding the use of drip irrigation as they cultivate vegetables in the house premises and use the extra money for the family needs.

This confidence is also translated into the perceived empowerment of women as expressed by a woman farmer:

#9:12: Now I need not to depend on my husband...I am independent now...I think I am the owner of the profit, and I also make decisions in the absence of my husband as most of the time he stays out of the village...Now I am not worried about my children's studies as I can make enough profit from farming.

CONCLUSION

Overall, the study demonstrates the importance of capturing the voices and perspectives of farmers, particularly women, to better understand the challenges they face and the impacts of agricultural technologies.

The findings highlight the nuanced ways in which these technologies can benefit farmers and improve their livelihoods which, we believe, might be difficult to report otherwise through reductionist approaches. Although the qualitative analysis was primarily aimed at generating insights into the technology adoption processes, the present study's methodology can be replicated to explore various other aspects in similar agro-ecological situations.

CONFLICTS OF INTEREST

There exist no conflicts of interest among the authors.

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