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Research Paper

Benefits of precision conservation agriculture practices as perceived by Indo-Gangetic Plain (IGP) community for climate-smart agriculture

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ABSTRACT

The study was conducted in 2019 to assess the benefits of Precision Conservation Agricultural Practices towards climate smart agriculture as perceived by purposively selected 180 farmers in India IGP. A descriptive statistics was employed in analyzing the data. The study's results show that most Haryana farmers who took part in the research believed that crop diversification provides benefits of up to 10%. Additionally, the majority of Haryana's participating farmers (83.3%) felt that employing recommended varieties helps them more than 25% of the time. In Bihar, almost 13% and 5% of participants, respectively, felt that adopting direct seeded rice and alternating wet and drying resulted in negative effects. This was linked to crop failure that occurred after direct seeding and alternating wet and drying methods were adopted. Based on observations made in the field, it has been suggested that agencies and stakeholders assisting farmers in scaling up the adoption of climate smart agricultural practices, like precision conservation agriculture, should develop a shared understanding and strategy for promoting these cutting-edge technologies within farming communities. This will enhance their perception of the advantages.

Key words: Climate smart villages, Indo-gangetic plain, perceived benefits, precision conservation agriculture, zero tillage

The food bowl for ages has been the fertile land of Indo Gangetic Plain (IGP). As the primary "food bank," it has supported the food security of around 40% of the population and contributed 50% of all food grain output (Pal *et al.* 2009). In addition to improving food security through higher yield and decreased price volatility of food grains, the Green Revolution in the IGP also showed that agricultural development offers a practical means of boosting economic growth and lowering poverty. The Green Revolution's outstanding success was mostly attributable to the application of chemical fertilizers, herbicides, irrigation, high-yielding cultivars, and agricultural machinery. Over time, the region's natural resources declined and the agri-environment deteriorated due to the unsustainable growth in agricultural productivity brought about by the careless use of inputs (Erenstein *et al.*, 2007). Moreover, climate change is posing a new wave of difficulties for agricultural output (Arunachalam R., 2023; Surendra Singh Jatav & Naveen Prakash Singh, 2023; Naik M. B *et al.*, 2023). Approximately 80% of food is produced by smallholder farmers, of whom women make up 43% of the labor force in agriculture (Morton, 2007). Due to their limited ability to adapt, these communities are extremely exposed to the effects of climate change (AFDB, 2015; Ramanjaneyulu, 2012; FAO, 2011; Ranger Nicola, 2012; Easterling et al. 2007). Along with socioeconomic difficulties, there are other issues like the depletion of water resources, soil degradation from fertilizer applied indiscriminately, fragmented land resources, declining underground water table, growing scarcity, and competition for resources like labor, land, and water. Important food crops have experienced stagnation as a result, resulting in decreased farm profit and an unappealing and unsustainable agricultural environment (Erenstein *et al.*, 2007 and Jat *et al.*, 2011).

Nonetheless, the implementation of a sustainable farming system is necessary in the area to maintain productivity and production while also lessening the impact of agricultural activities on the environmental.

Precision Conservation Agriculture is one of the important holistic choices for agriculture, which may help maintain production to guarantee food and nutritional security and lessen the environmental effect of agricultural activities. In many Indian Indo-Gangetic Plain (IGP) states, initiatives to promote precision conservation agricultural practices (PCAPs) and climate wise agriculture have been put into place in recent years to help the region's agricultural practices match sustainably.

Numerous national and international research institutions, as well as farmers' associations, have taken the lead on this. Even still, there has been some doubt about how sustainably farmers will adopt these tried-and-true technology, even with the positive outcomes that local scientists have reported from several field tests and farm trials. Also, a comprehensive approach is required to evaluate the perceived benefits and advantages of precision conservation agricultural practices in the area because of the gap between the views of scientists and farmers regarding PCA technology and practices.

MATERIALS AND METHODS

To choose the study's sample, a multi-stage purposive sampling approach was employed. The first step was choosing a district whereby the states that were chosen have developed programs to promote Precision Conservation Agricultural practices. The following step involved choosing six (6) villages at random from each district. Ten (10) farmers from each village who were taking part in the PCAP projects were chosen at random for the final stage. As a result, the sixty farmers who took part in the research made up the study's complete sample size. Based on the criterion of the PCAPs project implementation by Climate Change Agriculture and food security (CCAFS) by partnering institutions such as CYMMYT and Bourlag Institute of South Asia (BISA) in Haryana and Bihar, respectively, a district was purposefully chosen in each state of the IGP. Because the program's operations were more intense, the districts of Karnal in Haryana (Western IGP) and Samastripur in Bihar (Eastern IGP) were chosen. The villages of Badarpur, Kartarpur, Chand Samand, Taraori, Sagga, and Sambhli were chosen at random from the Karnal district in the state of Haryana.

Additionally, the villages of Repura, Kubauli Ram, Bishampur Digambara, Tajpur Shahpur Baghauni, Muzanna, and Chandauli Chakhari were chosen in the Samastripur district of Bihar state. Descriptive statistics tools, such as tables, percentages, and frequencies, were utilized to assess and characterize the data that had been gathered.

RESULTS AND DISCUSSION

Adoption of Precision Conservation Agriculture Practices: One of the best solutions for Climate Smart Agriculture in poor countries is Precision Conservation Agriculture (PCA), particularly for cereal-based systems like rice, wheat, maize, millet, sorghum, etc. Precision agriculture (PA) and conservation agriculture are the two ideas that form its foundation. Through the application of production inputs as needed, in the amounts needed, and where needed for the most economic production, Precision Agriculture (PA), a management strategy to increase productivity and economic returns with a reduced impact on the environment, is integrated into PCA (Searcy, 1997) and Conservation Agriculture (CA), a comprehensive strategy that aims to conserve the environment through minimum tillage, crop diversification, and permanent organic soil cover, is "a concept for resource-saving agricultural crop production that strives to achieve acceptable profits along with high and sustained production levels" (FAO, 2007). (Jat *et al.*, 2009; Jat *et al.*, 2011).

According to findings Table 1, all of the research region participants have utilized at least one precision conservation agriculture technique or technology. All the participants in the states of Bihar and Haryana were reported to have employed the recommended varieties. In the research region, this is a positive step toward the goal of climate smart agriculture. PCAPs are based on improved suggested varieties because farmers must employ certain inputs, like excellent varieties, in order to reap the benefits of implementing PCAPs. Within the state of Haryana, the vast majority of farmers who took part in the survey stated that they had employed Leaf Color Chart (91.7%), Green Seeker (66.7%), expert decision tools for nutrients (85%), and zero tillage (83.3%). This outcome indicates that farmers are making progress toward both resource conservation and sustainable nutrient management. Additionally, the majority of farmers who took part in the survey reported using crop diversity (96.7%) and direct seeded rice (63.3%). Farmers can minimize risk while optimizing their produce selling choices by engaging in crop diversification. Because farmers could choose different crops for the household's nutrition at different times, it could also assure nutrient security and balance diets at the household level.

The observation in Bihar state shows a nearly identical situation to that seen in Haryana state, with the notable exception that 100% of the participants adopted zero tillage. When you compare the circumstances in

Bihar and Haryana, this is rather astounding. Due to differences in how the subsidies associated with the adoption of zero tillage were handled in specific Haryana areas, the state used less zero tillage than Bihar. Farmers refused to accept the innovations because they were unhappy with the state of affairs. As in Haryana, the majority of participating farmers did, however, report using direct-seed rice (78.3%) and the leaf color chart (80.0%), green seeker (81.7%), and nutritional expert decision tools (93.3%). Due to the maximal support that the promoting agencies have received, many farmers are taking part in the promotion project in a participatory manner; the utilization of PCAPs may be significant, particularly among the participants. According to previous research conducted in the Indo-Gangetic Plain (Maheswari *et al., 2*008; Jat 2009; Jat *et al., 2*011; Aryal *et al.,* 2015; Kumar *et al., 2*017; Khatri-Chhetri *et al., 2*016), the outcome is consistent with their research.

Table 1: Distribution of respondents according to the PCAPs already used

S. No.	PCAPs	Haryana	Bihar
		Percentage	Percentage
1	Improved Recommended Varieties	100.0	100.0
2	Precision Laser leveling	36.7	11.70
3	Leaf Colour Chart	91.7	80.00
4	Green Seeker	66.7	81.70
5	Nutrient Expert Decision Tools	85.0	93.33
6	Precision Planters	53.3	20.00
7	Indigenous Precision Planters	25.0	15.00
8	Zero Tillage	83.3	100.0
9	Alternate Wet and drying	16.7	26.70
10	Mulching	35.0	5.00
11	Direct Seeded Rice	63.3	78.33
12	Crop diversification	96.7	100.00

Perceived benefits of PCAPs contribution towards CSA: Furthermore**,** the benefit of PCAPs as perceived by the farmers is a factor that could really influence adoption decision of farmers regarding the technologies and practices. The finding from the Table 2 shows that none of the participant farmers in Haryana reported negative benefits from using the PCAPs. This might be because, in contrast to findings from Bihar state, where farmers reported losses in employing alternating wet and drying as well as direct seeded rice owing to crop failure, none of the participating farmers in Haryana had any losses as a result of using PCAPs. On the other hand, 5.0 and 13.3% of the Haryana farmers who took part in the study reported no advantages from employing direct seeded rice and alternating wet and drying, respectively. Based on these findings, it can be concluded that while farmers did not suffer any bad effects from employing PCAPs, they also did not profit from the techniques. The farmers are able to break even in what might be considered a "no gain no loss" situation. This might be because direct-seeded rice and alternating wet and drying conditions have a significant crop failure risk. The majority of participating farmers (80.3%) also stated that employing crop diversity might have benefits of up to 10%. Given that the majority of respondents indicated they saw some advantages, this demonstrates the value of crop variety. Additionally, more than 25% of participating farmers reported feeling that there were advantages in using improved recommendation. This can be seen as evidence to maximum usage of improved recommended varieties by the farmers in the study area. In Bihar state, about half of the participant farmers reported 10-25% benefits in using Leaf Colour Chart and Green Seeker. This can be seen as a progress in the promotion of nutrient management practices in the study area.

Additionally, nearly 50% of the Bihar farmers who took part in the study stated that they saw benefits of adopting zero tillage and crop diversity of more than 25%, while the majority (68.3%) said they saw benefits of using enhanced recommended varieties of more than 25%. The results also show that employing alternate wet and drying and direct seeded rice had negative effects on 5.0 and 13.3% of the participating farmers in the state of Bihar, respectively. The farmers' crop failures during the alternate wet and drying and direct-seeded rice techniques in their fields were the cause of this unfavorable benefit impression. More than half of the farmers

questioned in Bihar stated they believed crop diversification, zero tillage, and better recommended varieties would help their operations by more than 25%. The outcome agrees with reports by D'antoni *et al., (*2012), Islam *et al., (*2014), and Kotsiri *et al.,* (2011). According to the findings of the weighted means score analysis, farmers in both Haryana and Bihar felt that employing upgraded recommended crop types will provide the most perceived advantages. This might be because suggested crop kinds have consistently performed satisfactorily over time. In addition, farmers in Bihar and Haryana felt that crop variety, leaf color chat, and zero tillage offered greater advantages than other methods. This might be because of the quick advantages of the techniques, which may have shaped their impression of the advantages of using them in their line of work.

Table 2: Distribution of respondents according to the perceived benefits of PCAPs adopted

S No	PCAPs	Negative Benefits (%)		Zero Benefit (%)		>10% Benefits (%)		10%-25% Benefits (%)		> 25% Benefits (%)		Weighted Mean Score	
		Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar
1	Improved recommended varieties	0.00	0.00	0.00	0.00	0.00	20.0	16.7	11.70	83.3	68.30	2.83	2.48
2	Precision Laser leveling	0.00	0.00	0.0	1.70	0	0.0	0.0	1.70	36.7	8.33	1.10	0.28
3	Leaf Colour Chart	0.00	0.00	0.0	1.70	16.70	16.70	50.0	53.30	25.0	8.33	1.92	1.48
4	Green Seeker	0.00	0.00	0.00	0.00	25.0	20.00	40.0	50.00	1.7	11.70	1.10	1.55
5	Nutrient Expert Decision Tools	0.00	0.00	0.00	5.00	20.0	26.70	50.00	50.00	15.0	11.70	1.65	1.61
6	Zero Tillage	0.00	0.00	0.00	1.70	0.00	20.00	66.7	28.30	16.70	50.00	1.83	2.26
7	Alternate Wet and drying	0.00	5.00	5.00	6.70	11.7	15.00	0.00	0.00	0.00	0.00	0.12	0.10
8	Residual Management Mulching	0.00	0.00	0.00	0.00	35.0	5.00	0.00	0.00	0.00	0.00	0.35	0.05
9	Direct Seeded Rice	0.00	13.30	13.3	5.00	50.0	16.70	0.00	35.00	0.00	8.30	0.50	0.98
10	Crop diversification	0.00	0.00	0.00	0.00	83.3	1.70	0.00	33.30	13.3	65.00	1.23	2.63

The perceived financial advantages of new and better technology and methods by farmers is another driving force that can help encourage the adoption of these innovations. According to a research conducted by Khatri-Chhetri *et al., (*2016), smallholder farmers in India's Indo-Gangetic Plains can gain economically from climate-smart agricultural methods by saving money on inputs, which increases their income and savings. The findings in Table 3 is agreement with this earlier report as it revealed that barely half of the respondents in Haryana perceived up to 10% benefits in their income level using PCAPs. The same scenario was reported in terms of savings. In terms of access to credits, as well as yield, cent per cent (100%) cent of the farmers in Haryana reported perceived zero benefits in using PCAPs. The reason for this may be that PCAPs has no influence on credit access as well as yield obtained from the field when PCAPs are used. In all, farmers interviewed reported that there are no significant changes in yield from their fields. This is contrary to the earlier report of Jat *et al.* (2009); Jat *et al.* (2014) and Aryal *et al.* (2015) as they reported increase in yield. The reason for this might be that scientist experienced increase yield at experimental field trial which was different from this experienced situation at the farmers' field. However, participant farmers reported some benefits in labour saving using PCAPs. The findings show that about half (53.3%) of the participants farmers in Haryana reported 10% to 25% perceived benefits in labour savings from using PCAPs. It is noteworthy that 61.7 percent of the participating farmers believed that employing PCAPs may result in government incentives of up to 10%. Because participating farmers may obtain government subsidies, this can be an excellent incentive for choosing to use PCAPs. However, research from Bihar indicates that just 8.3% of farmers report a decline in income as a result of utilizing PCAPs. This may have something to do with farmers that had crop failure when they tried direct-seeding rice together with alternate wet and drying methods. In the Haryana situation that was presented, all farmers who took part in the survey claimed that they saw no increase in yield from adopting PCAPs. On the contrary to the report from Haryana, 23.3 per cent reported up to 10% perceived benefits in access to credits as

result of using PCAPs in Bihar. This is different from the report findings from Haryana where cent per cent reported zero benefits in access to credit. In terms of labour savings, more than half (56.7%) reported 10% to 25% perceived benefits while using PCAPs on their field. Also, more than half (55.0%) reported up to 10% perceived benefits in government incentives when using PCAPs. This is almost same scenario reported in Haryana which shows that participating farmers have scope to enjoy government incentives attached to usage of PCAPs. Availability of Government incentives for farmers can be a good motivation when it comes adopting PCAPs. Also, contingency incentive plan can be developed for PCAPs such has alternate wet and drying where farmers reported crop failure. In general, farmers in Bihar and Haryana reported the greatest labor savings while utilizing PCAPs, compared to other perks.

In addition, three (3) criteria are used to determine if a technology or set of activities is climate smart. The social effect of these technologies is one of the metrics used. According to the study's findings, the majority of participating farmers in Haryana (80%) reported 10% to 25% in social advantages as a result of having access to scientists. It was also discovered that over half of the participants perceived 10% to 25% social benefits in terms of access to climate information services.

Table 3: Distribution of respondents according to their perceived benefits of PCAPs contribution towards CSA

Socio-Economic & Environmental Attributes	Negative Benefits %)		Zero Benefit (%)		>10% Benefits (%)		10%-25% Benefits (%)		> 25% Benefits (%)		Weighted Mean	
	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar	Haryana	Bihar
Income Levels	0.00	8.30	33.3	18.30	41.7	45.0	25.0	28.3	0.00	0.00	0.92	0.93
Savings	0.00	8.30	23.3	45.00	45.0	30.00	48.3	16.70	0.00	0.00	1.42	0.55
Access to credits	0.00	0.00	100.0	76.70	0.00	23.30	0.00	0.00	0.00	0.00	0.00	0.23
Access to Insurance	0.00	0.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Yield	0.00	0.00	100.00	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Labour	0.00	0.00	0.00	5.00	46.7	38.30	53.3	56.70	0.00	0.00	1.53	1.52
Government Incentives	0.00	0.00	38.3	6.70	61.7	55.00	0.00	28.3	0.00	10.00	0.61	1.42
Access to Scientists	0.00	0.00	0.00	3.33	20.0	5.00	80.0	23.30	0.00	68.30	1.80	2.56
Access to climate information service	0.00	0.00	16.7	5.00	25.0	21.70	58.3	73.30	0.00	0.00	1.46	1.68
Livelihood Diversity	0.00	0.00	73.3	100.00	26.6	0.00	0.00	0.00	0.00	0.00	0.27	0.00
Group Participation	0.00	0.00	33.3	6.70	66.7	55.00	0.00	28.30	0.00	10.00	0.67	1.42
Saved Irrigation Water	0.00	0.00	43.3	3.30	56.7	5.00	0.00	43.3	1.57	48.3	1.57	2.36
Improved Soil health	0.00	0.00	0.00	1.70	100.0	40.00	0.00	58.30	0.00	0.00	1.00	1.57
Reduce Air pollution	0.00	0.00	0.00	0.00	0.00	6.70	0.00	16.70	100.0	76.70	3.00	2.70
Reduce GHGs	0.00	0.00	0.00	40.00	60.00	60.00	40.0	0.00	0.00	0.00	1.40	0.60
Increase soil organic	0.00	0.00	16.7	11.7	58.3	58.3	25.00	20.00	0.00	10.00	1.08	1.28

Farmers may find this to be an excellent chance to learn more about the effects of climate change and improve their ability to adapt. Additionally, farmers' decisions to consistently use PCAPs in their fields may be made easier and more solidified by their awareness of the changing environment. Furthermore, the majority of Haryana respondents stated that they saw social advantages from group engagement of up to 10%. Due to the high degree of collective engagement in the community, farmers using PCAPs on their fields may find their decision to do so reinforced by strong social ties. According to the study's findings, all of the participating farmers in the state of Bihar (100%) reported receiving no social advantages from having access to market information. Also, the findings reveal that majority (68%) of participant farmers in Bihar perceived social

benefits of more than 25% with respect to access to scientists. The results also show that whereas half of the participating farmers in Bihar state reported 10% to 25% felt social advantages from group involvement, the majority of farmers reported 10% to 25% perceived social benefits from access to climate information services. Farmers in the states of Bihar and Haryana have reported perceived social benefits from using PCAPs, which has improved their social relationships and allowed them to continue using technology and practices in their fields. For example, group dynamics can have a positive impact on a farmer's ability to participate in society, which can lead to increased social benefits. This can then affect the farmer's decision to keep utilizing PCAPs on their land. Because both social advantages had the highest weighted mean score, the data further supported the idea that farmers in the states of Haryana and Bihar felt they had the greatest access to scientists and climate information services.

Perception of the respondents in Haryana and Bihar state regarding PCAPs technology attributes: Since the public became aware of climate change, many people have worked to find ways to slow down the effects of climate change. Encouraging the use of smart agriculture technology with a notably smaller environmental impact is one of the coordinated initiatives. The fact that agriculture contributes to greenhouse gas emissions is no longer news, thus farmers must work more to lessen the impact of their operations on the environment. One of the most beneficial ways to lessen the environmental impact of agricultural operations is to adopt PCAPs. Therefore, it is important to learn how farmers see the environmental advantages of PCAPs. According to the research's findings, 100% of the farmers in the state of Haryana who took part in the study claimed that their farms had improved soil health and optimal resource usage, which resulted in up to 10% environmental advantages. According to Berryl et al. (2003), Larkin, S.L. (2005), and Aryal et al. (2015), the outcome is consistent. This is a sensible comprehension on the part of the farmers, which can support the implementation of PCAPs on their property as the farmers themselves can acknowledge the benefits of PCAPs for soil health. Furthermore, a quarter of respondents felt that PCAPs lowering air pollution had an environmental impact of more than 25%. This is especially noticeable when zero tillage is used, which deters the burning of rice straw. The efficient use of water is a critical problem concerning the environment. According to the study's findings, 50% of the farmers in the state of Haryana who took part believed that PCAPs helped conserve irrigation water, with benefits being seen at 10% to 25%. Moreover, up to 10% of the participating farmers—more than half (60%)—perceived benefits in terms of a decrease in greenhouse gas emissions. Furthermore, only 50% of the participants said that they could sense environmental benefits of up to 10% more soil organic carbon.

According to the results from the state of Bihar, less than half of the farmers who took part in the study believed that there would be over 25% environmental advantages in terms of irrigation water savings, while more than half (58.3%) said there would be 10% to 25% environmental benefits in terms of better soil health. Furthermore, the majority of Bihar's participating farmers claimed that they saw advantages in lowering air pollution of over 25%, and over half saw benefits in reducing greenhouse gas emissions of up to 10%. Additionally, most of the participants in Bihar claimed that, in terms of optimal resource usage, 10% to 25% saw environmental advantages. The outcome is consistent with reports on the advantages of precision conservation agriculture methods for the environment published by Berryl *et al.*, (2003), Larkin, S.L. (2005), and Aryal *et al.*, (2015). Farmers in Haryana and Bihar saw the greatest environmental advantages from lowering air pollution when compared to other environmental benefits, according to the results of a weighted mean score study. Adoption of these technologies and practices may also be influenced by farmers' perceptions of the features of the technologies. According to Jamana's (2014) survey, the majority of farmers place themselves in the medium group when it comes to their assessments of the technical aspects used in soybean production. This is consistent with Table 4's findings from the current study, which indicate that while more than half (63.3%) of the farmers in Bihar state and roughly half (51.7%) of the participants in Haryana fall into the medium category of perceived technology attributes. Additionally, this outcome concurs with past research on how technological qualities are perceived (Adesina and Zinah, 1993).

Table 4: Perception of the respondents in Haryana and Bihar state regarding PCAPs technology attributes

Category	Haryana Percentage	Bihar Percentage
Low	15	16.7
Medium	51.7	63.3
High	33.3	20.0
	Mean=89.8 **SD**= 6.30 (Haryana)	**Mean**=89.8 **SD**= 6.30 (Bihar)

CONCLUSION

Farmers must adopt PCAPs in order to capitalize on their promise for sustainable food production with a reduced environmental effect. One of the main obstacles to the widespread adoption of precision conservation agriculture in farmer's fields has been the lack of knowledge on the psychological and socioeconomic factors impacting farmers' adoption behavior. Stakeholders can handle the combined issues of feeding the growing population and limiting the environmental effect of agricultural operations by utilizing precision conservation agricultural techniques. The study's conclusions suggest that farmers may efficiently adapt to and reduce the consequences of climate change by putting precise conservation agriculture strategies into practice. The assessments of farmers' perception on different component of climate smart agriculture reveals that farmer have some extent positive benefits perception towards PCAPs.

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