

Horticulture Crop and Farm Income of Agricultural Households in India: An Empirical Analysis(Maharashtra)

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Abstract

In a country like India, where agriculture is prone to risks such as unpredictable weather and fluctuating prices, farmers often face challenges in selecting the most profitable crops. The topic of “Horticulture crop adoption and farm income in rural India” is highly relevant in the context of Indian rural households, where agriculture is the primary source of livelihood for a majority of the population. The choice of crops grown by farmers significantly influences their income levels, food security, and overall economic well-being. The present study empirically tests the relationship between the choice of horticultural crops and farm income. The study area is the state of Maharashtra, and the units of the study are its households, which dominate the labour force. The propensity score matching technique is applied to the Situation Assessment of Agricultural Households Survey 2019 data for Maharashtra to examine the relationship between horticulture crop choice and farm income among agricultural households. There is a strong and positive impact of horticultural crop choice on farm income. Furthermore, important factors such as landholding size, irrigation, household size, age, information access, and gender positively affect the choice of horticultural crop at a household level. However, the recent decline in the extent of diversification in India is a concern. Horticultural crops are also known as high-value crops. Indian agriculture needs to promote high-value crops by providing institutional support, such as initial capital for the transition and measures to protect farmers from higher risk.

Keywords- Farm income, Agricultural households, Horticultural crops, Maharashtra, Propensity score matching.

1. Introduction:

Agriculture is the engine of the economy of India, providing a living for a significant part of the country's population. In agriculture, plant choice is of primary concern to farmers within the context of their profitability. Horticulture has become a promising industry in recent years, providing greater profit than conventional field crops. Maharashtra, a flagship agricultural state of India, has experienced explosive growth in horticultural farming with fruits, vegetables, spices, and flowers becoming increasingly popular. In this paper, the contribution of selecting horticulture crops to farm revenue in Maharashtra is analysed, and it shows a strong and positive impact on farm revenue.

In Maharashtra, farmers are confronted with a variety of challenges, including unpredictable monsoons, reduced soil fertility, and fluctuating market prices for conventional crops like cereals and pulses. On the flip side, agricultural products demand less area, require fewer hours to cultivate, and typically sell at a higher rate in the market. The growing demand for fresh food in the domestic and global markets makes horticulture a promising alternative to traditional farming. Farmers have been redirected to the horticultural path by government programs, such as the National Horticulture Mission and state-level schemes, which have provided subsidies, improved irrigation infrastructure, and market linkage. This is an optimistic outlook.

This study finds that farmers who switch to horticulture experience higher income levels due to several factors. To begin with, horticulture crops generally yield higher value per acre and thus achieve a higher quantity. Second, these crops open avenues for multiple harvests in a year, thereby securing a stable flow of income. Third, a large variety of horticulture crops, including mangoes, grapes, and pomegranates, have high export market potential, enabling farmers to realize high value prices. Further, horticulture farming promotes better water use management, e.g., drip irrigation, which helps to conserve water and improve use efficiency.

Nevertheless, it has some drawbacks to horticulture farming. On the other hand, initial investment in orchards, greenhouses, or cold storage facilities can be significant. In addition, marketing fresh produce is not easily attainable, particularly as efficient supply chains and infrastructure are not widely available to all growers. Pest and disease management are also important since horticultural crops tend to be more susceptible to infestation than staple crops. This challenge is met with a great need for policy support, improved rural infrastructure, and enhanced access to financial credit for small and marginal producers.

In summary, this paper highlights that the horticulture crop adoption significantly boosts farm income in Maharashtra. Results show that horticulture promotion can be a powerful instrument to enhance a farmer's economic condition and promote agricultural expansion. With proper planning, investment, and government support, horticulture has the potential to transform rural livelihoods, reduce income disparities, and also contribute to the overall growth of the agricultural sector. This study intensifies the growing research that supports shifting towards value-added crop production to boost farmers' income and build a stronger agricultural economy. This study paper is divided into five sections. First is the introduction, and the second section reviews background studies. The third section explains the data sources, key variables, descriptive statistics, and methodology. The fourth section presents the results from logistic

regression and propensity score matching (PSM), along with relevant figures and result tables. Finally, the fifth section summarizes the key findings and their significance in economic analysis.

2. Literature Review

Farm income is largely determined by the crop-based economy, with many developing countries like India favouring food crops and high-value cash flows such as those from agriculture. This is particularly true for horticultural crops. A multitude of studies have investigated the effects of crop cultivation and income on agriculture, encompassing factors such as landholding capacity, irrigation, market accessibility, education, institutional support, and climate. The present assessment reflects on significant discoveries from earlier studies and links them to this study's findings, which evaluate the influence of farm income upon horticultural crop selection using Propensity Score Matching (PSM) from the 77th Situation Assessment Survey (SAS) of Agricultural Household in 2019. The study area is Maharashtra.

Determinants of Crop Choice:

Multiple studies have analysed factors that influence crop selection in Indian agriculture. According to Sen and Bhatia (2004), a farmer's decision to cultivate valuable crops is heavily influenced by their landholding size. Their research indicates that larger landowners have greater opportunities to engage in horticulture due to their economies of scale and risk-taking abilities. According to BIRTHAL et al. (2007), small and marginal farmers are more likely to rely on staple food crops for sustenance due to limited land availability. They note however that the intensive use of labour and better market prices tends to result in higher profits for small cultivated workers.

Another significant factor in crop selection is the availability of irrigation. Access to irrigation is a significant factor in selecting high-value horticultural crops for farmers, as per Gulati and Kelley (1999), who emphasize the importance of reliable water supply. In areas with greater irrigation coverage, farmers growing fruits and vegetables are more prevalent, as per their findings. These findings are in line with the seminar paper, which found that "access to irrigation greatly increases the chances of horticulture being adopted".

Another important factor is market access. In the view of Pingali and Rosegrant (1995), farmers in proximity to urban markets tend to shift away from high-value crops as a result of better

demand, which is also due to greater price realization. Better transportation links and market connections favour horticulture among farmers. The argument put forth by Kumar et al. (2011) is that farmers in isolated regions are limited from switching to commercial crops due to the absence of input and output markets. According to this seminar paper, contract farming and the provision of information services have a significant impact on crop selection, as farmers with better market access are more likely to cultivate horticultural crops.

Effect of Crop Choice on Farm Income

Agricultural economics has extensively investigated the impact of crop selection on farm earnings. Research indicates that converting to horticultural crops from staple food crops can result in significant increases in farm income. Joshi et al. (2006) state that farmers who cultivate fruits and vegetables earn 40-60% more income than cereal growers in India due to the diversification of horticulture. Their findings indicate that valuable crops yield superior products and are highly productive due to their labour-intensive nature.

This view is backed up by research published in the seminar paper, which shows that farmers who switched to horticulture earned much higher wages than those who managed food crops. By utilizing PSM's (PSM) approach, this research attempts to overcome selection bias and demonstrate that income disparities are significantly associated with crop preference rather than other confounding variables. Rao et al. (2018) and their research indicate that the use of horticultural crops can result in household income increases of 25-30% in different Indian states, as evidenced by this finding consistent with other findings.

Income levels are also influenced by financial access. The Kisan Credit Card (KCC) and other credit-based options enable farmers to invest in valuable crops, as per Narayanan and Gulati's (2002) research. Similarly, the current investigation uncovers a similar pattern where having KCC increases the likelihood of starting horticulture, ultimately leading to higher income.

Farm income through crop production is largely determined by the extent to which education and skill development are involved. Behrman et al. (2012) state that farmers with higher educational levels are more likely to adopt modern agricultural practices and participate in commercial farming. This is supported by this research. Higher education levels among farmers are linked to higher incomes in horticulture, as per the seminar paper. The study concludes:

Challenges in Horticultural Crop Adoption.

The benefits of horticulture are clear, but certain hindrances hinder its adoption. Pingali (2012) states that the fluctuating prices in horticultural markets discourage risk-averse farmers from transitioning to these crops. In contrast, horticultural produce has a relatively short shelf life and is more easily affected by market prices. This uncertainty makes small farmers reluctant to make the transition. The seminar paper's conclusion is that horticulture adoption is heavily influenced by risk-reducing factors, including access to contract farming and institutional support.

The expensive production is also a problem. Mittal and Tripathi (2009) argue that horticultural crops demand more inputs (fiscal, seed and pesticide) than staple food crops do. In addition, horticulture demands intensive work that may not be affordable to all farmers. Farmers who possess more land and have effective financial support systems are more inclined to engage in horticulture, as per this study, which reinforces earlier research on the importance of resource availability in crop diversification.

Infrastructure and market support are also essential for horticultural prosperity. Reardon et al. (2003) suggest that farmers' decision to engage in horticulture is heavily influenced by cold storage facilities, transport networks, and food processing industries. The absence of proper storage and processing facilities results in post-harvest losses for farmers, which can negatively impact their profitability. This seminar paper confirms that horticultural crop selection is significantly influenced by access to agricultural information and infrastructure.

Policy Implications and Conclusion:

The literature review reveals that the adoption of horticultural crop cultivation can result in higher farm earnings, provided adequate support mechanisms. However, in line with current research, this seminar paper demonstrates how irrigation, market access and contract farming as well as education and financial support can all contribute to the adoption of horticulture and consequently its improvement in farm incomes. Still, despite price instability, high input costs, infrastructure constraints, widespread implementation remains problematic.

To encourage the growth of horticultural crops, policymakers should prioritize improving irrigation facilities and strengthening market links while also providing financial support and increasing access to information for farmers. Also, the purchase of cold storage and processing units can help to lower price risks and post-harvest losses. The implementation of stronger

contract farming mechanisms can provide farmers with more stable prices and reduce market volatility.

In summary, the literature provides strong evidence that horticultural crops (crop diversification) contribute significantly to farm income. The conclusions of this research paper are based on recent data from the 77th Situation Assessment Survey, 2019. The adoption of horticultural crops in India can result in improved rural livelihoods and agricultural growth, provided that targeted policy support overcomes key constraints.

3 Data and Methodology

Data description

3.1 Data and Variables

This research draws on cross-sectional data obtained from the 2019 cohort. A Situation Assessment Survey was conducted on agricultural households in Maharashtra, and it was provided by the National Sample Survey (NSS) office, Ministry of Statistics and Programme Implementation, Government of India (GoI). A survey on the title 'Land and Livestock Holdings of Households and Situation Assessment of Agricultural Households' was conducted by NSS 77th between January and December 2019. It's covering 2925 agricultural households. From July to December, here study is for the first visit to Kharif. The National Sample Survey (NSS) provides a definition for an agricultural household in India. Whether they have land or not, it refers to any household that participates in farming activities such as growing field crops and raising livestock. A household with a farm income must have earned no less than 4,000 in the previous year for their activities to be classified as such. Additionally, at least one family member must have been agriculturally self-employed for a minimum of 12 months before the survey is conducted. Horticulture households are those who cultivate horticultural crops, which includes the growing of various fruits, vegetables, flowers, medicinal and aromatic plants. These are also known as high-value crops.

Research Question

This study investigates:

How does the choice of horticulture crops influence farm income levels across different households in Maharashtra?

Hypotheses

H₀: Horticulture crop choice does not have a significant impact on farm income in Maharashtra.

H₁: Horticulture crop choice has a significant impact on farm income in Maharashtra.

3.2 Propensity score method (PSM)

This study uses Propensity score matching (PSM) to evaluate how choice of horticulture crop affects farm income. While Randomized Controlled Trials (RCTs) are commonly employed to assess the impact of interventions in the controlled environments, they are not suitable for this research since the data comes from a survey rather than an experimental setup. In this context, PSM provides a valuable alternative by simulating an RCT framework, enabling a fair comparison between households that have choose horticulture crops for production and those that have not. PSM operates by calculating a propensity score, which indicates the likelihood of household opting for a horticulture crop based on its characteristics. This approach ensures that both horticulture crops (treated) and non-horticulture crops(control) households share similar traits, thereby minimizing selection bias. In this analysis, the ‘Caliper’ matching technique is utilized, where a horticulture crops adopted household is paired with a non-horticulture crop adopted households whose propensity score is within a predetermined range (caliper 0.2). The technique enhances the quality of matches, avoiding poor pairing that could skew the findings. The PSM procedure involves two main steps. Initially, a logit regression model is applied to estimate the probability of choice of horticulture crop.

The Logit model specified as

$$P_i = P (Y_i = 1) = F(Z_i) = 1/1+e^{-z_i}$$

Here,

P_i= probability of Y_i= 1, where Y is status of horticulture crop adoption and ‘i’ represent household.

If Y_i=1, then i_{th} household adopt horticulture crop.

If Y_i=0, then i_{th} household adopt non-horticulture crop.

F(z_i) is the cumulative distribution function of the cumulative logistic function

$$Z_i = \alpha_0 + \beta_0(\text{Landholding size}) + \beta_1(\text{Irrigation}) + \beta_2(\text{Household size}) + \beta_3(\text{Age}) + \beta_4(\text{Literacy}) + \beta_5(\text{Agri training}) + \beta_6(\text{Social groups}) + \beta_7(\text{Contract Farming}) + \beta_8(\text{Institutional credit}) + \beta_9(\text{Drought}) + \beta_{10}(\text{Information access}) + \beta_{11}(\text{Gender})$$

In this study, calculate the marginal effects of the explanatory variables to understand how changes in these factors influence a household's choice to adopt horticultural crop. The marginal effect of a variable indicates how the probability of choice of horticulture crop (P_i) shifts with a one-unit increase in that variable (X_i). This analysis helps identify the key factors that significantly affect a household's decision to choose horticultural crop.

In the next step, I estimate the treatment effects to assess the actual impact of adoption of horticulture crop on farm income. This involves calculating the Average Treatment Effect on the Treated (ATT), which shows the difference in farm income between households that have adopted horticulture crop and the income they would have earned without adopting horticultural crop. Similarly, the Average Treatment Effect on the Untreated (ATU) estimates the potential income increase for non-horticulture households if they had chosen to diversify. Finally, the Average Treatment Effect (ATE) provides an overall view of the impact of horticulture crops on farm income across all households. These measures are essential for quantifying the economic benefits of diversification and offer insights into its role in enhancing farm incomes.

Let Y represent farm income, and let i denote the i_{th} agricultural household. The potential outcomes for the variable $Y_i(0)$ and $Y_i(1)$ correspond to the farm income of a controlled household (non-horticulture) and a treated household (horticulture), respectively.

However, introducing an indicator variable G to denote treatment status where $G=0$ for the controlled group and $G=1$ for the treated group implies that each household will exhibit only one observed outcome, given by:

$$Y_i [Y_i = G_i Y_i(1) + (1 - G_i) Y_i(0)]$$

Now for each household, effect of treatment is measured by $Y_i(1) - Y_i(0)$.

The ATE is $E[Y_i(1) - Y_i(0)]$. It measures the average of the difference in farm income between the two groups.

ATT, which is $E[Y_i(1) - Y_i(0) | G = 1]$, measures the difference between the farm income of diversified agricultural

households and the expected farm income they would have achieved if they had not gone for diversification.

ATU is defined as $E[Y_i(1) - Y_i(0) | G = 0]$

It measures the difference between the expected farm income that non-horticulture households would have achieved if they had horticulture and the actual farm income of the non-horticulture households.

Variable	Description	Mean	Std. Dev.	Min	Max
Horticulture	Horticulture crop (1,0)	0.100	0.300	0	1
Landholding size	Landholding size (ha)	1.441	1.412	0.008	14.2
Irrigation	Irrigation (yes=1, no=0)	0.416	0.493	0	1
Household Size	Household members	4.726	2.179	1	21
Age	Age (years)	52.552	13.433	18	100
Literacy	Education level (1-5)	1.477	0.883	1	5
Agri Training	Agri training (yes=1, no=0)	0.016	0.127	0	1
Social groups	SC/ST households (yes=1, no=0)	0.240	0.427	0	1
Contract Farming	Contract farming (yes=1, no=0)	0.010	0.101	0	1
KCC	KCC (yes=1, no=0)	0.095	0.292	0	1
Drought	Drought (yes=1, no=0)	0.342	0.474	0	1
Information Access	Information access (yes=1, no=0)	0.757	0.428	0	1
Gender	Gender (male=1, female=0)	0.922	0.267	0	1
Farm Income	GV of output per ha	77294.64	88629.95	661.69	916731.1

Table 1: Description of Variables and Summary Statistics (Maharashtra 2018-19)

4. Results and Discussion

4.1 Results from PSM

4.1.1 Covariates of Horticulture crops

The first step of the Propensity Score Matching (PSM) approach, through logistic regression results, provides insights into the factors influencing the choice of horticulture crops at the household level. Table 2 highlights the significance of various independent variables in determining whether a household engages in horticulture crop cultivation.

The results indicate that landholding size has a positive and statistically significant impact on horticulture crop choice. A larger landholding increases the probability of cultivating

horticultural crops, likely due to the higher capital investment and resource allocation required for horticulture. Access to irrigation is another crucial determinant, with a highly significant positive effect on horticulture crop choice. This suggests that households with better irrigation facilities are more likely to opt for horticultural crops, which often require consistent and reliable water supply.

Table2. Covariates of Horticulture crop at household level: Result of logit regression

Dependent variable: Horticulture crop = 1; non-horticulture crop =0

Table 1: Covariates of Horticulture Crop at Household Level: Result of Logit Regression					
Independent Variables	Coef.	Std Error	Z value	p-value	Marginal Effect
Landholding size	0.111***	0.036	3.08	0.002***	0.009***
Irrigation (Yes = 1, No = 0)	1.363***	0.144	9.48	0.000***	0.114***
Household Size	0.021	0.028	0.69	0.49	0.001
Age	0.006	0.005	1.26	0.209	0.0005
Literacy	-0.058	0.075	-0.78	0.438	-0.005
Agriculture Training	-0.014	0.502	-0.03	0.978	-0.001
SC ST (Yes = 1, No = 0)	-0.133	0.164	-0.81	0.418	-0.011
Contract Farming	-0.66	0.618	-1.07	0.286	-0.055
KCC	-0.17	0.218	-0.78	0.436	-0.014
Drought	-0.306**	0.15	-2.04	0.041**	-0.026**
Information Access	0.078	0.163	0.48	0.631	0.006
Gender	0.125	0.255	0.49	0.624	0.010
Constant	-3.52***	0.443	-7.94	0.000***	-
Number of observations			2925		
Log likelihood			-868.419		
LR Chi2(12)			149.471		
P value			0.000		

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

While household size and age have positive coefficients, their effects are not statistically significant, indicating that they do not strongly influence horticulture crop choice in this dataset. Literacy and agricultural training also show no significant impact, which suggests that formal education and specialized agricultural training alone may not be decisive factors in adopting horticulture. However, drought conditions negatively and significantly affect horticulture crop choice, indicating that households experiencing drought are less likely to cultivate horticultural crops due to their higher water dependency and associated risks.

The coefficient for Scheduled Caste (SC) and Scheduled Tribe (ST) households is negative, but not statistically significant, implying that social category does not play a strong role in determining horticulture crop adoption. Similarly, variables such as contract farming, access to Kisan Credit Card (KCC), access to information, and gender of the household head do not show statistically significant effects, suggesting that these factors may not directly influence horticulture crop choice at the household level.

The negative and significant coefficient for drought underscores the vulnerability of horticulture crops to climatic conditions. This highlights the need for climate-resilient strategies and better irrigation infrastructure to mitigate risks associated with weather variability. The constant term is negative and highly significant, reinforcing that several unobserved factors influence crop choice beyond the variables included in the model.

Overall, the findings suggest that landholding size and irrigation access are the most critical factors driving horticulture crop choice, while drought conditions significantly deter households from engaging in horticulture. These insights are essential for policymakers aiming to promote horticulture as a sustainable agricultural practice, particularly through investments in irrigation and climate adaptation measures.

Graph 4.1. Comparison of propensity score before and after matching

Propensity Score Matching (PSM) analysis - A graph showing the distribution of propensities before and after matching. The outcome provides insight into whether the matching process effectively balanced the control group against the treated group. A comparison of the distribution of propensity scores before and after matching can be seen on both sides (left panel). The distributions of propensity scores between the treated and control groups were markedly different before matching, as indicated by the solid blue line and the dashed red line. Neither group was shown in the chart. Lower propensity scores resulted in a significant peak in the control group, while the treated group was more dispersed. The difference in characteristics indicates that the two groups were not directly comparable at first. The treated and control groups are highly imbalanced before matching. Without matching, the comparison of incomes between these groups would not have yielded results that were biased towards horticultural crops as there was no difference in landholding, irrigation etc.

Comparison of Propensity Scores: Before and After Matching

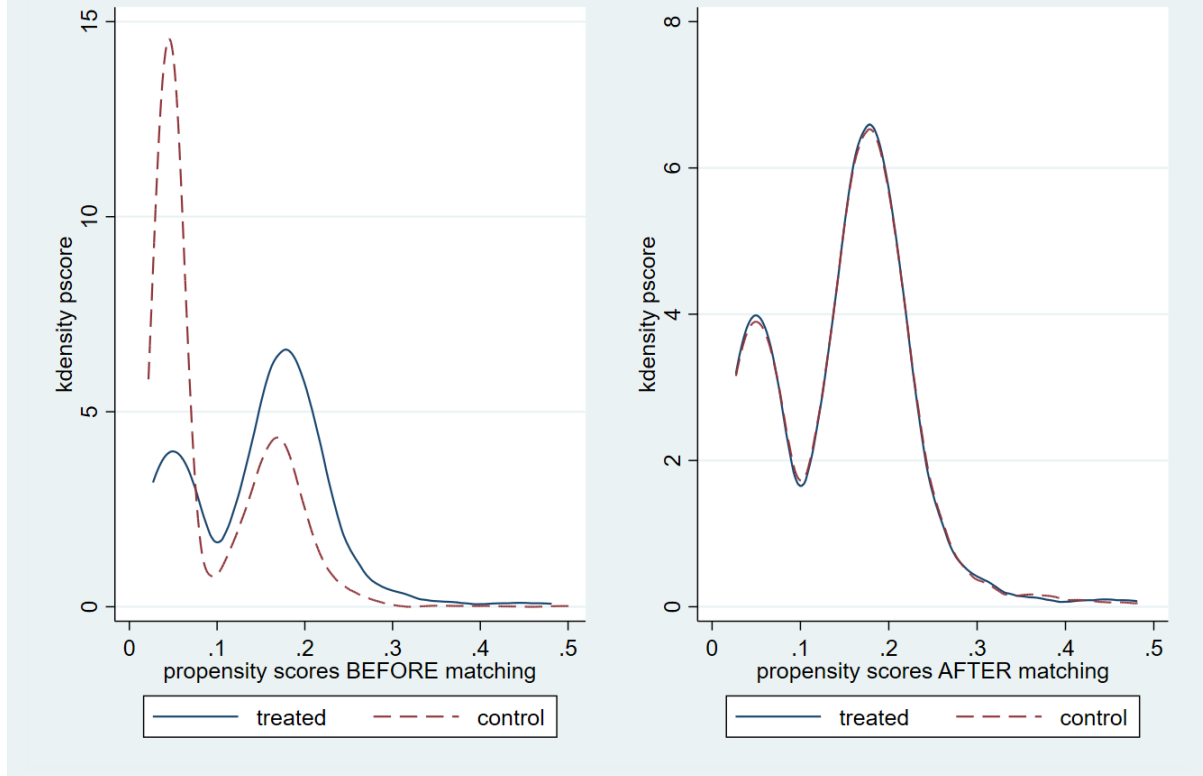


Figure 1. Comparison of propensity score before and after matching

The comparison group was successfully created through the matching process, as the distributions of both treated and control groups were found to be very similar. Both groups have comparable propensity scores, indicating similar observable traits. By reducing the impact of other confusing factors on farm income, we can now accurately estimate the effect of horticulture crop production. It is essential to ensure that we are comparing similar farmers, including those growing plants and those not in the same area, under similar conditions through matching. The reliability of our findings on the significant increase in farm income obtained from horticultural crops is enhanced. Poor balance would be indicated if the distributions did not remain the same after matching, and our treatments effects may not have been accurate.

In general, this graph provides strong evidence that the matching process was successful, which increases our confidence in PSM results. It supports the idea that horticulture crop use leads to higher farm income, not due to existing differences among farmers but because of the real benefits of growing a crop with these traits. The outcome can assist policymakers in crafting

more effective agricultural plans that encourage horticulture by addressing challenges such as access to irrigation, credit, and markets.

4.2.2 Horticulture crop and farm income

The Propensity Score Matching (PSM) approach is used to estimate the impact of horticulture crop choice on farm income. Table 3 presents the results, showing the Average Treatment Effect on the Treated (ATT), Average Treatment Effect on the Untreated (ATU), and Average Treatment Effect (ATE).

The ATT value is ₹78,842.35, which represents the difference in farm income between households that cultivate horticultural crops (treated group) and those that do not (control group). The average farm income for horticulture crop households is ₹154,955.31, while for non-horticulture crop households, it is ₹79,112.95. The T-statistic of 7.12 indicates that this difference is statistically significant. This means that choosing horticultural crops leads to a significant increase in farm income.

The ATU value is ₹66,769.91, which represents the expected income difference if households that did not cultivate horticultural crops had chosen to do so. The average farm income for non-horticulture households is ₹134,244.19, suggesting that these households could have earned more had they adopted horticulture. However, the standard error and T-statistic for ATU are not reported in this table.

Table3. Impact of Horticulture crop on Farm Income: Result from Propensity Score Matching approach.

<i>Variable Sample</i>	Treated	Controls	Difference	S.E.	T-stat
ATT	154955.307	79112.95	75842.35	10653	7.12
ATU	67474.2829	134244.19	66769.91	-	-
ATE	-	-	67666.30	-	-

The ATE, which represents the overall effect of horticulture crop choice on farm income across all households, is ₹67,666.30. This suggests that, on average, if all households switched to horticulture, farm income would increase by this amount.

These results highlight the positive impact of horticulture crop choice on farm income. The significant difference in income between horticulture and non-horticulture households suggests that horticultural crops offer higher returns compared to traditional field crops. This could be due to better market prices, higher productivity, or increased demand for fruits, vegetables, and other horticultural products.

From a policy perspective, these findings emphasize the need to encourage horticulture adoption, especially among farmers who currently grow non-horticultural crops. Providing better irrigation facilities, access to credit, training programs, and market linkages can help more farmers transition to horticulture and increase their incomes. Additionally, addressing constraints such as climate risks and perishable nature of horticultural produce through better storage and logistics can further improve the benefits of horticulture.

Overall, the PSM results clearly indicate that cultivating horticulture crops significantly boosts farm income, making it a viable strategy for improving farmers' livelihoods and promoting agricultural diversification.

Graph no 4.2 Balance Assessment of Covariates in Propensity Score Matching:

This figure shows a standard bias plot for balancing the covariates before and after Propensity Score Matching (PSM). To determine if the matching has reduced systematic differences between the treatment group (horticulture crop adopters) and control group(s), it is essential to have this graphic representation. Each standardized percentage bias for each covariate is shown by the x-axis, and every covary in this model is listed by its corresponding Y-axis. The purpose of this plot is to examine whether the covariates remain unbalanced after matching, which could impact the causal inference regarding how horticultural crop selection affects farm income.

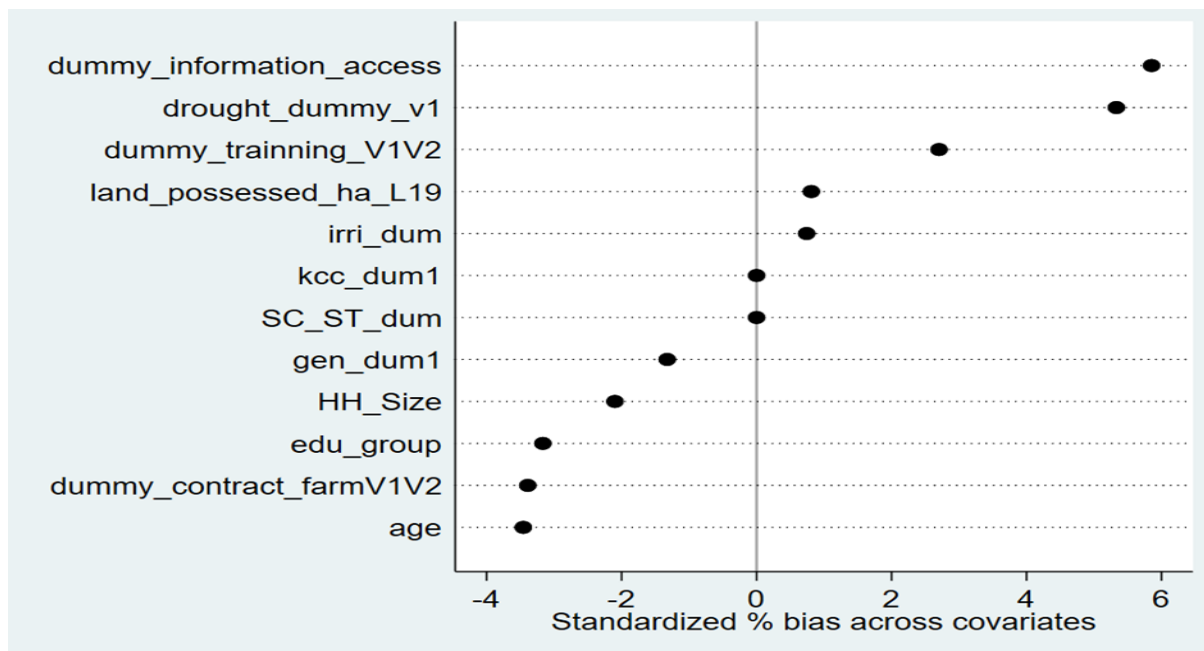


Figure 2. Standardized bias plot

Figure 2 indicates that all covariates have standardized biases within the acceptable range, and this proves that the PSM approach has effectively balanced both the treated and control groups. The graph displays the standardized bias for a specific covariate, with each dot representing merely one co-variant; since none of these are above about 10%, we must conclude that the sample in question is well balanced. The information access and drought variables were initially more imbalanced before being matched, but with the implementation of PSM, their biases have been reduced to an acceptable level. Due to the reduction of confounding effects in estimating the treatment effect, there is no significant difference between the two groups after adjusting for access to agricultural information and exposure to drought.

Landholding size and irrigation status have become equally important for farmers' crop selection after matching. The comparison between horticulture and non-horticulture farmers may have been biased due to differences in land ownership and access to irrigation. The reduction of bias after matching ensures that the estimated impact of horticultural crop selection on farm income is not affected by differences in structural farm characteristics. By taking into account the disparities in financial access and social background, the balance in Kisan Credit Card access and social category has been found to be even higher, resulting in greater similarity between treatment and control groups. The matching of demographic variables, including age, education

group, household size, and gender, has also achieved a satisfactory balance. The conclusion is that the comparison between treated and control groups has been fair, as it reduces differences in traits among farmers, which may affect both crop yield and farm profitability. The contract farming representation for contract farming involvement is well-balanced, suggesting that farmers in both groups have similar levels of exposure to contractual agreements, which prevents potential income estimation distortions.

Overall, the standardized bias plot shows that the matching process has effectively reduced bias across all covariates by providing a valid comparison between horticulture adopters and non-adopters. Due to the fact that all standardized biases are still below 10%, the results indicate that PSM has effectively reduced selection bias and improved the reliability of impact estimation. The balance contributes to the confirmation of the causal connection between horticultural crop preference and farm income, leading to more robust policy recommendations.

5. Conclusion

Based on the NSS 77th Situation Assessment of agricultural households in rural India (2019 survey), the result demonstrates that diversification into horticulture leads to significant increases in farm income, which supports earlier research by Basantaray et al. on the robust and advantageous effects of crop diversifiers on earnings. Agricultural professionals earn approximately ₹75,842 more than non-horticultural workers, emphasizing the financial advantages of crop cultivation.

This also confirms that other important factors in choosing horticultural crops include the size of land holding and irrigation, which are strongly associated with an increased likelihood of adopting a horticultural crop. Landholding size and landholding size are significant determinants of horticultural crop choice. Agricultural producers have greater flexibility to experiment with valuable crops, and irrigation provides water supply that is reliable while horticulture practices are more hazardous. A significant number of small and marginal farmers are unable to diversify due to inadequate market linkages, limited access to irrigation facilities, and lack of credit access. Enhancing rural infrastructure, expanding credit availability, and improving irrigation facilities can result in more farmers choosing valuable horticultural crops. In summary, choice of horticulture crop, along with adequate irrigation, can greatly augment farm income. To ensure

sustainable and profitable diversification of Indian agriculture, it is imperative to implement targeted policy interventions that prioritize infrastructure improvement and financial assistance.

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