

How much a Drop Pay? Economic Water Productivity in Crop Production: Farm Level Evidence from Coastal District in Odisha, India

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Abstract

Water is one of the inevitable inputs for agriculture. The importance of water productivity has been recognized as it measures the benefits derived from agricultural systems relative to water use, of which economic water productivity (EWP) is particularly useful for comparing crops and guiding water resource allocation decisions. Our study explores EWP in Odisha, India, focusing on the coastal district of Balasore. Conducting a primary survey from 100 households through a multi-stage sampling procedure, the study employs a multi-method approach and statistical analyses to assess determinants of EWP in crop production. OLS regression results reveal age, agricultural income, and total input costs positively influence EWP, while crop diversification negatively impacts it. Soil testing emerges as a significant factor in enhancing EWP. Despite disparities in land size and crop choices, farmers exhibit potential for improving EWP. This can be achieved through easy access to finance, understanding value chain addition, market prices and demand, proper crop choices, and, most importantly, adopting collective decisions and sustainable management practices. Ultimately leading to livelihood enhancement within agricultural communities.

Keywords: *Crop diversification, Economic water productivity, Groundwater irrigation, Odisha, Paddy.*

1. Introduction

Land, labour, and water are essential resources for agricultural production. While the productivity of land and labor has been acknowledged for a long time, the concept of Water Productivity (WP) has gained attention relatively in recent times, especially in developing countries. The definition of WP can vary depending on the purpose, scale, and field of analysis (Molden et al., 2001; Bastiaanssen et al., 2003; Barker et al., 2003). From the perspective of plant physiologists and agronomists, WP refers to the ratio of dry matter or grain produced per unit of transpiration or evapotranspiration. For irrigation engineers, it is based on crop yields in relation to the water supplied through canals. Farmers assess water productivity by considering the total yield relative to the total irrigation water applied. Economists measure water productivity in economic terms, calculating the value of crop output per unit of water used (Singh, 2005). However, in all these definitions, WP signifies the ratio of the net benefits from agricultural systems to the amount of water utilized to achieve those benefits. WP can be broadly classified into three categories: Physical Water Productivity (PWP), Irrigation Water

Productivity (IWP), and Economic Water Productivity (EWP) (Descheemaeker et al., 2013). PWP is defined as the ratio of agricultural output to the amount of water consumed, including both green (rain) and blue (irrigation) water (expressed as kg/m^3) and IWP is the ratio of agricultural output to the amount of blue water consumed (also expressed in kg/m^3) (Kijne et al., 2003; Playán & Matoes, 2006; Chouchane et al., 2015). While PWP and IWP provide insights into water use efficiency, they do not capture the economic benefits of water utilization, therefore, it is useful to consider EWP as well (Cook et al., 2006; Pereira et al., 2012). EWP is defined as the value obtained per unit of water used (expressed in kg/m^3) (Igbadun et al., 2007; Teixeira et al., 2008; Garrido et al., 2010). These economic indicators offer valuable insight to compare different crops and assess the benefits derived from specific crops or agricultural practices (Chouchane et al., 2015). Furthermore, the economic perspective of WP offers policymakers with a well-informed basis for deciding how to allocate water resources between agricultural and non-agricultural uses (Kijne et al., 2003). In its broadest sense, WP aims to enhance food production, livelihoods, income generation, and ecological benefits while minimizing social and environmental costs per unit of water consumed (Sharma et al., 2018). Irrigation is one of the important factors of agriculture, contributing approximately 40% to global food production and utilizing roughly 20% of cropland areas worldwide (Borsato, 2020). Especially in arid and semi-arid regions, agricultural productivity heavily relies on irrigation (Ekinici & Acar, 2018). Groundwater serves as the primary water source for irrigation in these areas, but excessive extraction has led to unsustainable water practices that has increased energy consumption incessantly (Yavuz et al., 2016). According to the United Nations Report on Food and Agriculture, Indian farmers are putting undue strain on groundwater because of the decline of state-funded, large-scale surface irrigation. About half of the farmland is irrigated using contemporary technologies, and most of these regions are very water-stressed. In the heavily inhabited regions of the Middle Indus and Upper Ganges, unplanned, intensive, uncontrolled, and mismanaged pumping for irrigation, aggravated by free or subsidized energy, has caused a fast fall in water levels. Rapidly declining water levels have led to yield loss, unreliable water supply in rural and urban areas, pump failure, saltwater intrusion, drying of wetland habitats and land subsidence. These issues disproportionately affect the poor by raising the cost of drilling and pumping deeper (Hirji et al., 2017; Monney & Ocloo, 2017). The growing scarcity of land and water for food production underscores the importance of improving crop water productivity (CWP) both in terms of quantity and economic value. A study conducted by Sharma et al. (2018) assessed the water productivity of major Indian crops and revealed that water-intensive crops such as paddy, wheat, and sugarcane are predominantly cultivated in water-scarce regions of India. The EWP is also found to be least in these areas including eastern states like West Bengal and Odisha. A significant misalignment between cropping patterns and available water resources is observed when comparing the water productivity of these areas. Alauddin & Sharma (2013) attributed this low water productivity to insufficient technology dissemination and deficiencies in intelligent food trade practices. In addition to irrigation practices, various factors can influence water productivity (WP), including agronomic factors like crop selection and management, irrigation scheduling, and soil management (Li et al., 2016); hydrological factors such as water availability, and water distribution efficiency (Molden et al., 2010); technological factors such as irrigation methods and irrigation technology (Cetin et al., 2019); institutional factors such as water governance and access to financial resources and support (Eshete et al., 2020); and market conditions and prices (Raza et al., 2021). Our study focuses on Odisha, an eastern Indian state characterized by diverse agro-climatic and hydro-geological conditions. The coastal areas are the agriculturally productive benefiting from robust irrigation facilities, but are prone to salt-water intrusion. Conversely, the western zones grapple with droughts and inadequate irrigation infrastructure. Research by Pattanayak & Mallick (2018) highlights that

despite high irrigation levels in coastal districts, agricultural productivity remains low due to inappropriate crop choices, traditional farming methods, inefficient application of inputs such as fertilizers and seeds, and limited water conservation practices. Additionally, these districts are at risk of groundwater depletion and saltwater intrusion (Rejani et al., 2008). To address these issues, literature suggests replacing non-monsoon rice with more profitable and water-efficient crops like chili, green gram, and mustard, alongside implementing water-saving techniques (Panda & Kumar, 2011; Paria et al., 2021). The potential to enhance the economic returns per unit of water utilized in agricultural activities often exceeds the potential to improve PWP and IWP (Molden et al., 2010). In line with this understanding, our study attempts to explore the concept of EWP within the coastal communities situated in Odisha's Balasore district. Given that groundwater is the predominant source of irrigation in this region, our research aims to shed light on the economic aspect of water utilization, particularly groundwater irrigation. By quantifying the EWP of various crops cultivated by local farmers, our study seeks to provide a comprehensive analysis of the economic returns generated vis-à-vis the water resources employed. Moreover, makes an effort to identify and examine the determinants and factors that exert influence on EWP, thereby offering valuable insights into the economic dynamics of water use in agricultural practices in the study area.

2. Conceptual Framework

Figure 1 demonstrates the factors that can influence EWP. These factors are observed from the field experiences and validated through literature. Demographic factors of the farmers which can influence EWP include age and education. Improvements in agricultural water use efficiency depend not only on water-saving technologies but also on farmers' awareness of water conservation and market-driven mechanisms. Years of experience and knowledge will develop the technical know-how, soil-crop suitability, input use efficiency, market condition information, etc., which will affect their economic returns (Zhang et al., 2023). Secondly, the income and input cost factors will also affect the EWP. The income of a household on EWP can be bidirectional. As agriculture is the main source of income in rural areas, its share in total income will encourage farmers to invest in quality inputs specifically in water infrastructure, develop skills (training, precision farming, etc.), and easy access to credit, which will result in planting high valued, market oriented crops which will increase their income and subsequently EWP (Karlberg et al., 2015). The price, supply, and access of inputs such as irrigation, fertilizers, pesticides, seeds, and labour influence crop productivity. Many inputs may not be readily available in markets. Additionally, the availability of agricultural labor in rural areas is decreasing, as workers and young people are increasingly drawn to non-agricultural professions that offer higher incomes. An inadequate and inefficient amount of these inputs will result in higher input cost costs, lower production and thus low returns (Emran et al., 2021).

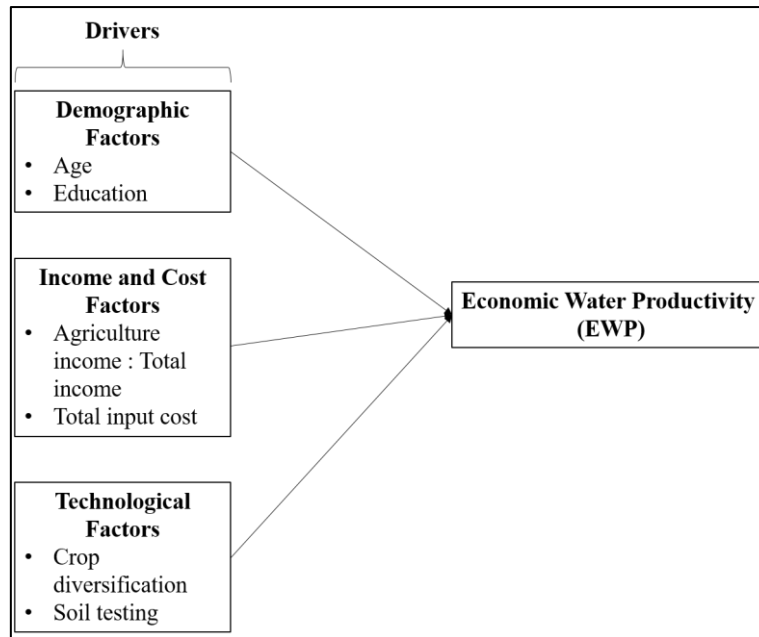


Figure 1: Conceptual framework of the factors influencing EWP in agriculture

Source- Authors’ compilation from field experience

Finally technological factors such as crop diversification and soil testing also influence EWP. Crop configuration and diversification increase grain production, enhance system resilience to abiotic and biotic stresses (especially in the stressed groundwater regions), decrease environmental damage, and increase net returns (Wang et al., 2023). The productivity and yield of crops are also influenced by the physical and chemical properties of the soil. So, soil testing will let farmers know the nutrient requirements of the soil and suitable crops to grow, which will increase the yield as well as income (Li et al., 2019).

3. Methodology

Figure 2 shows the methodological flow diagram adopted for the study, which is briefly explained in this section.

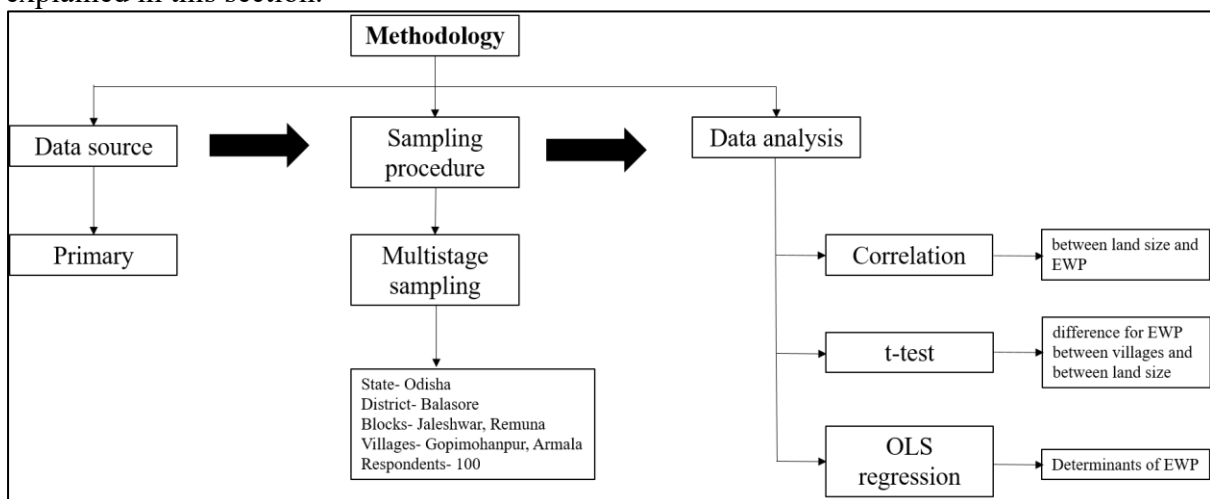


Figure 2: Methodological flow for the study

Source: Author’s own compilation

3.1 Sampling Design, Study Area Description and Data Collection

The study is based on primary survey conducted from March 2022 to September 2022 for the analysis by adopting a multi-stage sampling procedure. In the first stage, the Balasore district is selected purposively, which extracts the highest groundwater for irrigation (DGWR of Odisha, 2017). It is also one of the coastal districts of the state that faces salinity problems due to the over-extraction of groundwater. We have randomly selected two blocks in the second stage which are Jaleswar block and Remuna block. One village from each block is further chosen (third stage) at random for the purpose of the study. We have selected the village of Gopimohanpur from the Jaleswar block and Armala from the Remuna block. Finally, in the fourth stage, a total of 100 respondents, 50 respondents each from the two villages, are chosen by the simple random sampling method. With the help of well-structures interview schedules, the farmers were interviewed about their socio-economic conditions, input costs, output received, source and amount of irrigation applied, and other related information. The study area is presented in Figure 3.

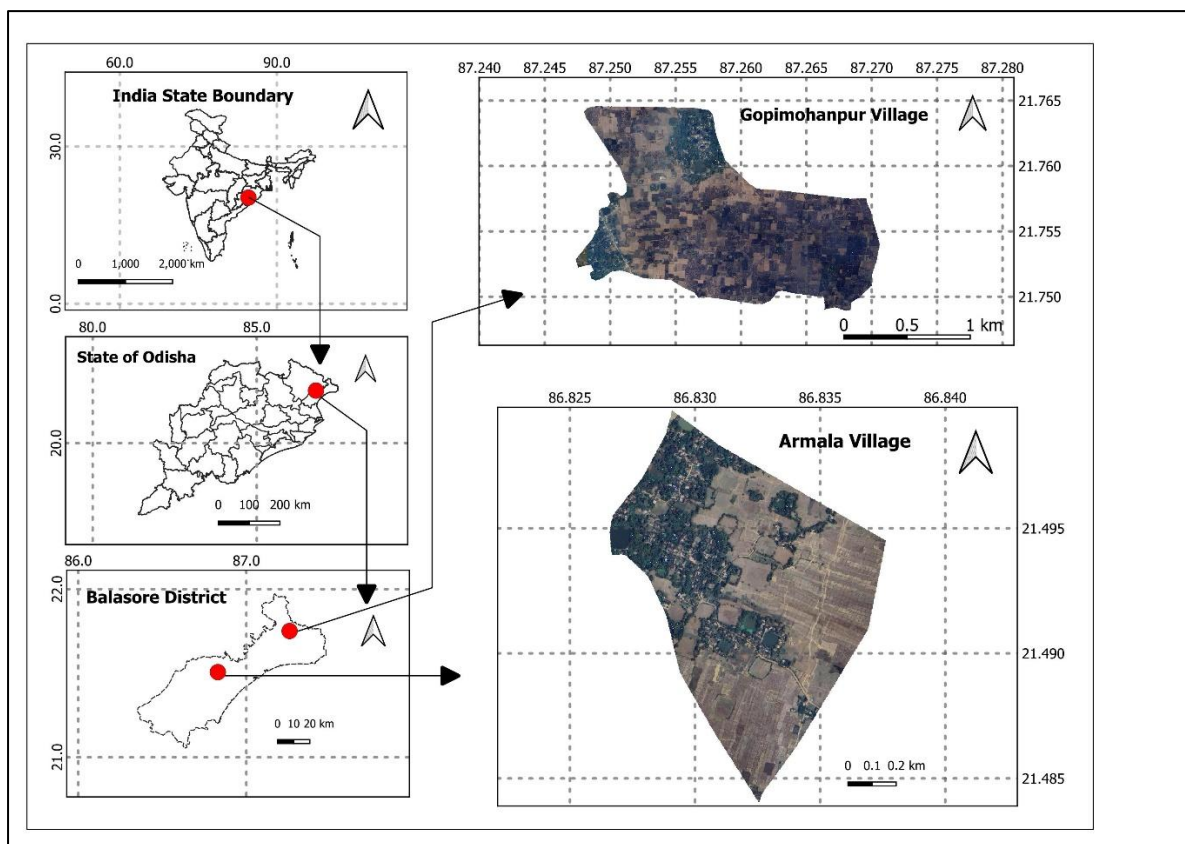


Figure 3: Study area presentation

Source: Author's own compilation

In the present study, groundwater is the only source of irrigation in the study villages, which is extracted from the tube wells. These tube wells are designed to draw 84960 liters per hour (lph) of water implemented by the department of OAIC (Orissa Agro Industries Corporation Limited). Using this water discharge rate, we estimated the total groundwater extracted by farmers in the study villages. This estimation was based on the concept that each crop has specific critical stages requiring irrigation during certain phases of its lifespan. The number of times irrigation is required indicates the critical stages of each crop. The time interval between water discharges varies for different crops based on their requirements. To calculate the total

water requirement for a single crop in its lifespan in the study villages, the following formula was used:

Total water requirement = Time of water discharged once (in hours) × Number of times irrigated (in hours) × Discharge of the tube well (lph) (DGWR of Odisha, 2017).

If a farmer practices multiple or mixed cropping, the amount of groundwater extracted for each individual crop is calculated using the same method and then added up to determine the total groundwater extracted by the farmer over a year. Upon receiving the amount of groundwater extracted, EWP for each sample is calculated by the following formula:

$$\text{EWP (Rs/m}^3\text{)} = \frac{\text{Selling price of crop output (Rs)}}{\text{Amount of groundwater extracted (m}^3\text{)}} \quad \dots (1)$$

The demographic details of the respondents can be found in Table 1. The table indicates that the majority of farmers in both villages are small and marginal. All households are involved in farming activities. However, due to insufficient income from agriculture alone, they are also engaged in other income-generating sources to sustain their livelihoods. When it comes to water conservation practices, the farmers predominantly practice System of Rice Intensification (SRI) method. They also mix a small amount of organic fertilizer and compost with chemical fertilizers as using only organic fertilizers does not result in the desired yield, leading to reduced profits. During the interviews, it was revealed that the farmers are willing to adopt water conservation practices. However, they face challenges such as lack of financing and limited access to information, preventing them from implementing these practices effectively.

Table 1: Socio-economic details of sample households

Aspects		Gopimohanpur	Armala
Population	Male	145(52.5%)	129(49.4%)
	Female	131(47.5%)	132(50.6%)
	Total	276(100%)	261(100%)
	Earner	127(46%)	125(47.8%)
	Dependent	149(54%)	136(52.2%)
	Total	276 (100%)	261(100%)
Occupation	Agriculture	50(100%)	50(100%)
	SHG	42(84%)	45(90%)
	Regular Employed	6(12%)	18(38%)
	Self Employed	27(54%)	50(100%)
	Casual Labours	12(24%)	16(32%)
	Total household	50(100%)	50(100%)
Land Holding Size	Marginal	33(66%)	9(18%)
	Small	15(30%)	26(52%)
	Semi-Medium	0(0%)	12(24%)
	Medium	2(4%)	3(6%)
	Total household	50(100%)	50(100%)
Water Conservation Methods Practiced	Compost	35(70%)	27(54%)
	SRI/SCI	36(72%)	38(76%)
	Mixed Organic and Fertilizer Farming	36(72%)	20(40%)
	Total	50(100%)	50(100%)

Source: Primary Data

3.2 Methodological approach

The study applies three methodologies as given below:

- To find correlations between variables- Pearson Correlation Coefficient
- To find if there exists any significant difference between the means of the group for EWP- t-test
- To find the factors affecting EWP for irrigation- OLS regression

3.2.1 Pearson Correlation Coefficient

The Pearson Correlation Coefficient (PCC), is used to evaluate the linear correlation between the variables (X, Y). It is expressed in the equation 2:

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$$\rho_{X,Y} = \frac{COV(X,Y)}{s_X s_Y} = \frac{E[(X-\mu_X)(Y-\mu_Y)]}{s_X s_Y} \quad \dots (2)$$

Where, $\rho_{X,Y}$ is the PCC between X and Y, $COV(X, Y)$ is the covariance of X and Y, s_X, s_Y are the standard deviations of X and Y, respectively. μ_X and μ_Y are the respective means of X and Y. $\rho_{X,Y}$ ranges from +1 to -1. A value of +1 implies that X is completely positively linearly correlated to Y. On the other hand, a value of 0 indicates that X is not linearly correlated to Y at all. Finally, a value of -1 implies that X is completely negatively linearly correlated to Y (Liu et. al., 2020). In the study, PCC is used to determine the correlation between land size and EWP.

3.2.2 t-test

Based on the equality of variances across the samples, an appropriate t-test will be applied. So, in order to test for the equality of the variances, Levene's test is applied to check for the equality of the variances. The following hypothesis is formulated for the test:

$$H_0 : s_1^2 = s_2^2 \text{ (equal variances)}, H_1 : s_1^2 \neq s_2^2 \text{ (unequal variances)} \quad \dots (3)$$

Where, H_0 and H_1 are the null and alternative hypothesis respectively, and s_1^2 and s_2^2 are the sample variance. If calculated Levene's significance value is found to be less than the level of significance (here we have taken a 5% level of significance), then we reject the null hypothesis and conclude that unequal variances exist (Carroll & Schneider, 1985).

Next, in order to determine the difference in the means, a t-test has been conducted using STATA. t-test is a parametric test that compares the means of two independent groups in order to determine whether there is statistical evidence that the associated population means are significantly different. In our study, our samples have different variances. So, for unequal variances, the equation of the test is presented in the following equation:

$$t = \frac{\mu_1 - \mu_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad \dots (4)$$

The hypothesis thus formed would be,

$$H_0 : \mu_1 = \mu_2 \text{ (equal means)}, H_1 : \mu_1 \neq \mu_2 \text{ (unequal means)} \quad \dots (5)$$

Where, μ_1 and μ_2 are the sample means of two groups, s_1^2 and s_2^2 are the sample variance, n_1 and n_2 are the sample observations, and H_0 and H_1 are the null and alternative hypothesis respectively (Ruxton, 2006). If the calculated value is found to be greater than the tabulated value, then we reject the null hypothesis and conclude there is a difference in the means of the

samples. For the analysis of the study, Levene's test and t-test is conducted to check the difference in variance and means of EWP between the sample villages and between the land holding size of the households.

3.2.3 OLS Regression

To find the factors that impact EWP, the OLS estimation technique has been applied. The various factors affecting the EWP are gathered based on reviewing past studies, pilot surveys, and expert opinions. The selected factors and the equation of the OLS used in the study are given below.

The regression equation is expressed in equation (6):

$$\ln EWP = \beta_0 + \beta_1 \ln Age + \beta_2 \ln Edu + \beta_3 AITI + \beta_4 \ln TIC + \beta_5 CD + \beta_6 ST + \epsilon \quad \dots (6)$$

Where the dependent variable *EWP* is the economic water productivity of the output sold (marketed output). The Independent variables are: *Age* is the age of the farmer, *Edu* is the education of the farmer, *AITI* is share of agricultural income to total income, *TIC* is the total input cost, *CD* is the crop diversification, and *ST* is the soil testing. β_1, \dots, β_6 are the respective slopes of the independent variables, β_0 is the intercept term. The error term ϵ , in the above regression equations follows all the properties of the OLS regression method (Gujarati & Sangeetha, 2007). A step-wise methodology is adopted using STATA software following the appropriate procedure. In addition, statistical tests like J-B test (Jarque–Bera test), VIF (Variance Inflation Factor), and Breusch-Pagan/Cook-Weisberg have been used to test the normality, multicollinearity, and heteroscedasticity in the model.

4 Results and Discussions

4.1 Gross Cropped Area, Crop Output Value, Groundwater Extraction, EWP among Farmers, and t-tests for EWP Comparisons

Table 2 illustrates the agricultural landscape of the study villages, detailing the gross cropped area, crop output value, groundwater extraction, and EWP achieved by farmers. Crops are categorized into paddy and non-paddy (including maize and vegetables). Farmers of Gopimohanpur village focus solely on cultivating paddy twice a year. Similarly, Armala village cultivates paddy twice a year but also includes maize and vegetable cultivation three times throughout the year. The table shows that for paddy cultivation, the farmers of Gopimohanpur village cultivate 256 acres of gross-cropped land, whereas the farmers of Armala village cultivate around 303 acres. They extract 905.8 million liters (905843.52 m³) and 794.6 million liters (794630.88 m³) of groundwater, respectively, over the year for paddy crop alone. Notably, Gopimohanpur despite having 15% less gross cropped area for paddy, extracts 12% more groundwater. When considering the overall water extraction per acre, it is observed that Gopimohanpur village farmers extract 3.5 million litres per acre of land whereas the second village farmers extract 3.3 million liters of water per acre. This implies that the former village extracts 5% more groundwater than the latter village. These disparities highlight the differing approaches to land and water management among farmers in these regions.

Table 2: Gross cropped area, value of crop output, amount of groundwater extracted, and EWP among the farmers

Village		Gopimohanpur	Armala	Total
Total observations		50	50	100
Gross cropped area (acres)	Paddy	256	303	559
	Non-Paddy	0	161	161
	Total	256	464	720
Value of crop output (Rs)	Paddy	10344733	12777665	23381523
	Non-Paddy	0	3125657	3125657
	Total	10344733	16406694	27014629
Groundwater extraction (m³)	Paddy	905844	794631	170047
	Non-Paddy	0	753170	753170
	Total	905844	1547801	2453645
EWP (Rs/m³)	Paddy	11.42	16.08	13.75
	Non-Paddy	0	4.15	4.15
	Total	11.42	10.6	11.01

Source: Author's own calculation from primary survey;

Note: Digits are rounded upto one digit

Turning to the economic aspect, crop revenue data highlights the financial returns generated by crop production. Each farmer in Gopimohanpur village earns an average annual income of approximately ₹ 2.06 lakhs (Value of paddy/total observations) from paddy cultivation, while a farmer from Armala generates ₹ 2.55 lakhs from paddy and an additional ₹ 620500 (Value of non-paddy/total observations) from maize and vegetable cultivation (non-paddy). These figures underscore the economic significance of crop diversification and the potential for additional income streams beyond traditional monoculture crops. Finally, the concept of EWP provides a valuable metric for assessing the economic returns derived from water usage in agriculture. The EWP for paddy in Gopimohanpur is calculated at 11.42 ₹/m³, indicating the revenue earned per unit of groundwater extracted. While Armala farmers achieve a higher earnings of EWP of 16.08 ₹/m³ per unit of groundwater for paddy. Additionally, the farmers of Armala village also achieve an EWP of 4.15 ₹/m³ for non-paddy (maize and vegetables) across all seasons in 160.5 acres of gross cropped area. However, despite growing diversified crops, the average EWP for all crops over the year is observed to be lower for Armala village (10.6 ₹/m³) compared to Gopimohanpur village (11.42 ₹/m³).

But whether the difference in this mean of EWP between the villages is statistically significant or not, a t-test is conducted in this regard. Table 3 shows if there exists any difference in the means of EWP of the crops that are sold by the farmers of the two villages.

Table 3: t-test for EWP between villages

Village	Obs	Mean	Standard Error	Standard Deviation	95% interval	confidence
Gopimohanpur	50	11.428	0.781	5.529	9.857	13.000
Armala	50	10.602	0.460	3.256	9.677	11.528
combined	100	11.015	0.453	4.533	10.116	11.915
Diff		0.826	0.907		-0.979	2.631
Levene Statistic	0.003			Pr(T > t)	0.365	
Unequal variance				Accept Ho There is no difference in means		

Source: Authors' calculation using primary data

The results in Table 3 reflect that there is no statistical difference between the EWP in between the villages as the p-value (0.365) is greater than the significant value (0.05). We also observe unequal variances within the group (Levene Statistic = 0.003, $p < 0.05$). Differences in land type (slope), input usage, and farmers' bargaining power in selling crop outputs have contributed to the unequal variances within the group. However, this variability does not translate into a significant difference in the average EWP values between the villages. The reason can be attributed to crop choice and its market value. Even though the farmers of Armala village carry out crop diversification, it provides lesser returns due to low market value and more groundwater extraction for irrigation. This compensates for the overall means of EWP; even though the EWP for paddy production is higher in Armala village than the Gopimohanpur village, resulting in no overall significant difference in EWP between the villages.

4.2 Examining the Relationship between Landholding Size and EWP through Correlation Coefficients and t-tests

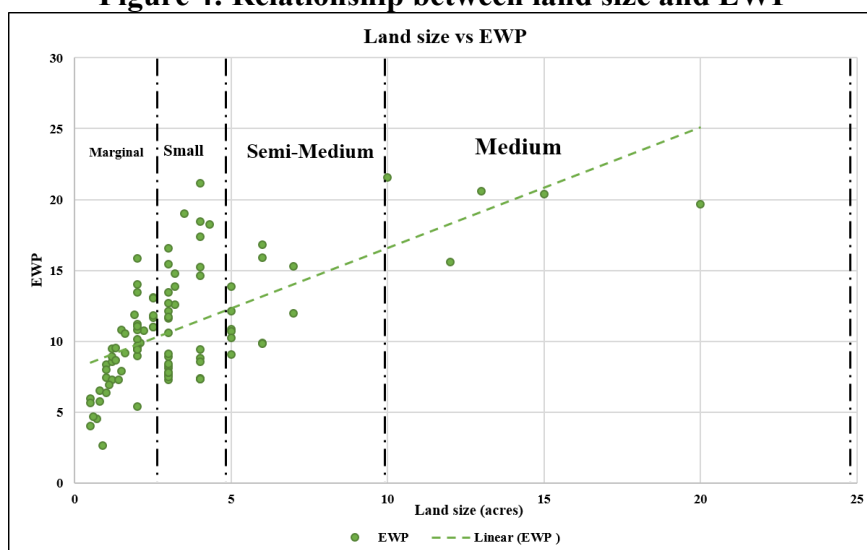
The farmers interviewed for the study belong to various categories such as marginal, small, semi-medium, and medium, (Table 1). Notably, none of the respondents are large farmers, highlighting the predominance of small-scale farming in the surveyed area. Table 4 and Figure 4 shows that there is a direct relationship between EWP and the land holding size. It is verified in the correlation matrix Table 5. The correlation matrix shows that land size is significantly positively related to EWP. The figure and the table explain that as the land size increases, EWP also increases.

Table 4: Land Holding Size and EWP of households

	Land holding size	No. of Obs	Average EWP
Marginal		42	8.7
Others	Small	41	11.66
	Semi-medium	12	12.2
	Medium	5	19.57
		58	12.45

Source: Primary data

Figure 4: Relationship between land size and EWP



Source: Authors' calculation using primary data

Table 5: Correlation between Land Size and EWP

	Land size	EWP
Land size	1	
EWP	0.734 (0.000)***	1

Source: Authors' calculation using primary data

Note: ***Significant at 1 percent level

To check the relationship shown in Table 4 and 5, we have conducted a t-test of EWP between different landholding sizes, which allows us to determine if there are statistically significant differences in EWP among various categories of landholders (Table 6). This analysis helps to assess whether land size has a significant impact on EWP and whether there are disparities in water productivity based on farm size. Since the number of marginal farmers is comparatively more than the rest of the land-holding groups, so we have differentiated the total respondent farmers into marginal and other groups (comprising small, semi-medium, and medium). Table 5 shows that there is a significant difference between the productivities between the different land holding groups as the p-value (0.000) EWP is less than the significant value (0.05). This explains that, as the farm size increases, the farmers get improved access to resources such as finance, technical expertise, and market information, enabling them to make informed decisions about crop selection and increasing bargaining power that increases returns per unit of water used. Additionally, land quality can significantly impact water productivity, with larger farms often having access to more fertile and well-drained soils that are conducive to higher crop yields with less water input. Soil properties such as water-holding capacity, drainage, and nutrient levels can influence crop water requirements and overall productivity, with larger farms often having the resources to invest in soil conservation and improvement measures that enhance water use efficiency, crop choice and diversification, and land quality.

Table 6: t-test of EWP between landholding sizes

Group	Obs	Mean	Standard Error	Standard Deviation	95% confidence interval	
Marginal	42	8.695	0.415	2.695	7.855	9.535
Others	58	12.696	0.638	4.861	11.417	13.974
combined	100	11.015	0.453	4.533	10.116	11.915
Diff		-4.0007	0.761		-5.513	-2.488
Levene Statistic	0.004			Pr(T > t)	0.000	
Unequal variance				Reject Ho There is difference in means		

Source: Authors' calculation using primary data

4.3 OLS Regression Analysis

To determine the variables that impact EWP, OLS regression analysis is carried out. Table 7 defines descriptive statistics of the variables used for the analysis. EWP, age, education, and total input costs are taken in logarithmic form. The share of agricultural income in total income is measured in ratio form. Crop diversification and soil testing conducted by the farmer are presented in categorical form. The table shows the definition, mean, standard deviation (SD),

minimum value (Min), maximum value (Max), partial correlation, and expected sign (Exp. Sign) of the regression coefficient of the independent value with EWP.

Table 7: Description of variables

Variables (type)	Definition/Measurement	Mean	SD	Min	Max	Partial Cor.	Exp. Sign
Dependent variable							
Economic water productivity (continuous)	Selling price of crop output sold/ Amount of groundwater extracted (Rs/m ³) (in logarithmic scale)	10.68	3.82	2.65	21.58	-	-
Independent variables							
Age (continuous)	Measures in years (in logarithmic scale)	53.16	7.3	35	65	0.24**	+ve
Education (continuous)	Measures in years of education (in logarithmic scale)	9.78	2.77	5	17	-0.01	+ve
Agriculture income : Total income (continuous)	Measured in Ratio (Total agricultural income(Rs)/Total family income (Rs))	0.54	0.23	0.11	1	0.40***	+ve
Total input cost (continuous)	Measures in Rupees (in logarithmic scale)	15546 4.1	1149 90.4	3688 5	75866 8	0.66***	+ve/-ve
Crop diversification (categorical)	Households cultivating diverse crops = 1; 0 otherwise	0.51	0.5	0	1	- 0.28***	+ve
Soil testing (categorical)	Households tested soil = 1; 0 otherwise	0.42	0.49	0	1	0.23**	+ve

Source: Authors' calculation using primary data

The average farmer's age is around 53 years, with 9.78 years of education, indicating that a significant portion of the farmers are relatively older, most of whom are under-matric. Agricultural income contributes substantially to the total income of the surveyed households, accounting for around 55% (0.54) on average. This indicates that agriculture remains a primary source of livelihood for many farmers in the study area. However, diversification of income sources is evident among the surveyed households, reflecting a strategy to minimize the risk of income loss by engaging in other sectors (Table 1). The average total input costs amount to Rs 155464.1. This figure reflects the overall expenses incurred by farmers for inputs such as seeds, fertilizers, labour and irrigation. The average crop diversification rate is 0.51, because half of the farming households in the study area are cultivating paddy while the other half (Armala village farmers) have diversified their crops. The persistence of paddy cultivation is attributed to various factors such as access to markets, price stability, and the availability of irrigation facilities. However, a significant factor contributing to the continued cultivation of paddy is the long-standing tradition and adaptation of the land and soil to rice farming practices. Farmers have cultivated paddy for generations, and the soil has been habituated to support rice cultivation effectively (Indoria et al., 2018). Despite this historical preference for paddy, farmers are also exploring other crop options as a risk mitigation strategy. Less than half of the surveyed farmers (42%) reported that they are testing their soil. The low ratio is mainly due to limited awareness and less access to soil testing services. This has led to inefficient use of

agricultural inputs, restricted crop choices, lower yields, and increased production costs (Mohanasundari et al., 2024). The extent to which these independent variables impact EWP is explained using the OLS estimation method.

Table 8 shows the regression results of the variables that impact EWP. The value of R square is 0.64 with overall model significance (Prob > F = 0.000). There is a lesser degree of multicollinearity as the VIF stands at 1.45. The coefficients are robust with homoscedasticity.

Table 8: Results of OLS regression for EWP

Dependent variable - Economic water productivity (sold)	Coefficient (Robust)	t-statistic
Age	0.429**	2.02
Education	-0.035	-0.45
Agriculture income : Total income	0.31***	2.84
Total input cost	0.451***	10.49
Crop diversification	-0.253***	-3.98
Soil testing	0.135**	2.23
Constant	-4.716***	-4.74
Number of observation		98
F (6, 91)		31.22***
Prob > F		0.0000
R-squared		0.6431
VIF		1.45

Source: Authors' calculation using primary data

Note: *Significant at 10 percent, ** Significant at 5 percent, ***Significant at 1 percent level

Age is positively and significantly related to EWP. With the increase in age, the farmers are aware of when and how much to irrigate, which results in managed groundwater extraction. Additionally, with more experience, farmers have established networks within the agricultural community, enabling them to negotiate favourable prices for their crops (Zhang et al., 2023). This management of groundwater utilization and market connection contributes to higher revenues and lesser water usage consequently positively impacting EWP. As agriculture has a major dependency, the increase in agricultural income enables farmers to access finance easily and invest in quality inputs and farming technology (Soth & Blank, 2019). This investment enhances production and yield, leading to higher EWP. That's why there's a positive and significant link between agriculture income and EWP. However, crop diversification has a negative and significant impact on EWP. Farmers are cultivating crops like maize, cabbage, cauliflower, which consume more water, but fetch lower market value for the producers. While diversification aims to reduce the risk of crop failure and boost income (Paria et al., 2021), in this case, farmers are not very educated, mostly have marginal and small land holdings, and the crop choices are based on perceptions and demonstrations from other farmers. Consequently, it negatively affects EWP. The total cost is positively and significantly related to EWP, which implies that crop production, in this case, is of increasing cost; that is, with an increase in cost, the revenue also increases. Firstly, high-quality seeds are essential for achieving higher yields, but they often come with a higher price tag (Ali & Talukder, 2008). The farmers purchase these seeds to ensure better crop performance. Secondly, the usage of fertilizers is more intensive in the study area due to the prevalent agricultural practices. Hybrid seeds, which are commonly used, require additional fertilizers for optimal growth, contributing to the overall cost of fertilizers. Moreover, labor costs are also a significant component of total

input costs. Skilled laborers from neighboring regions, such as West Bengal, are hired for cultivation, particularly for methods like the System of Rice Intensification (SRI). The skills of these laborers command a higher wage, elevating the overall cost of labor. Lastly, the study area faces challenges related to groundwater availability, leading to increased irrigation requirements. With lower groundwater levels, farmers need to irrigate their fields more frequently and for longer durations, resulting in higher irrigation costs. Additionally, the absence of water conservation practices further amplifies irrigation costs. Therefore, the total costs show a positive relationship with EWP. Similarly, soil testing also positively impacts economic water productivity. Soil testing facilitates the nutrient requirements of the soil (Chen et al., 2019). This guides farmers in applying the right amount of fertilizers, leading to improved crop yields and reduced reliance on groundwater for irrigation. Ultimately increasing EWP.

5. Conclusion and Policy Recommendations

Land and labour productivity has been known for a long, and the concept of water productivity has given importance to the value of water. Economic Water Productivity (EWP) measures the value of water in monetary terms. It captures the economic benefit of water utilization. Agriculture remains a major employment source in the Indian context, where groundwater is the major source of irrigation. But in recent decades, this common property resource has been facing over-extraction, resulting in its depletion. Specifically, the coastal areas are facing a threat of saltwater intrusion, low yields, higher irrigation costs, and pump failures due to lower groundwater levels. Agriculture is supposed to be productive in these areas because of easy access to irrigation and fertile lands. So, our study investigates the EWP of such a coastal district (Balasore) in the state of Odisha. A total of 100 farming respondents from two villages namely Gopimohanpur and Armala village, of the district were interviewed to know the determinants of EWP specific to groundwater irrigation. It is found that Gopimohanpur village extracts 5% more groundwater than the Armala village, where the EWP is 11.42 ₹/m³ and 10.6 ₹/m³, respectively. However, the t-test shows that there is no difference in the means of EWP because the crop diversification in Armala village is not so profitable and requires more water, resulting in no overall difference in EWP between the villages. The land holding size has a positive correlation with the EWP. This implies as the land size increases, prospects for resource access increase which will increase the EWP. Furthermore, the analysis identifies key determinants influencing EWP through OLS regression. Farmer's age, agricultural income, input costs, and soil testing positively impact EWP whereas crop diversification has a negative impact on EWP. Diversification toward water-intensive crops has compromised revenue as well as groundwater extraction.

The study provides a few policy implications based on the outcome of the study. As the study area consists of a majority of marginal and small farmers, access to finance becomes a shortcoming for investment in agriculture. Facilitating easier access to credit and financial support mechanisms can enable farmers to invest in technologies and practices that improve water productivity. Secondly, the farmers should be equipped with knowledge about market dynamics of demand and prices, which will improve their revenue. Thirdly, encouraging value addition with agricultural produce can increase their income per unit of water utilized, thereby improving EWP. Management of blue and green water through water conservation practices such as rainwater harvesting, farm ponds, bunds, etc enhance water availability but also reduce reliance on groundwater irrigation. Fourthly, there is a need to accurately identify the water productivity gap through thorough inspection and analysis of current water availability and utilization strategies. Understanding the dynamics of water availability and utilization will

provide insights into where improvements can be made. Lastly, conducting capacity-building programs and awareness campaigns on sustainable water management practices can empower farmers to adopt EWP-enhancing strategies. Training, workshops, demonstration farms, and farmer field schools can provide practical guidance and promote behavioural change towards water conservation.

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