NIGERIAN JOURNAL OF AGRICULTURAL ECONOMICS

VOLUME 12 NUMBER 1 OCTOBER 2022

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Published by the Nigerian Association of Agricultural Economists. ISSN: 0794-4748

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PROFITABILITY AND DETERMINANTS OF ADOPTION INTENSITY OF IMPROVED PLANTAIN PRODUCTION TECHNOLOGIES IN OGUN STATE, NIGERIA

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ABSTRACT

Nigeria must increase its current level of plantain production to meet the demands of its ever-growing population and exploit the crop's foreign exchange earning potential. Agricultural output growth can best be achieved through improved production technologies. However, the adoption and utilisation of these improved production technologies have not been encouraging in Nigeria. Therefore, this study examined the smallholder plantain farmers' awareness of improved production technologies, factors influencing their adoption intensity, and plantain production profitability in Ogun State, Nigeria. Primary data was collected with a well-structured questionnaire administered to two hundred and forty (240) plantain farmers randomly selected through a multistage sampling procedure. Data were analysed using descriptive statistics, Poisson regression model and Gross margin analysis. Findings showed a high level of awareness among farmers for some technologies, while awareness was very low for staking/propping, tissue culture, and de-budding. The Poisson regression model result revealed that the farmer's age, years of education, access to credit, farming experience, awareness index, and access to extension services ($p \leq 0.01$) positively influenced the adoption intensity of improved plantain production technologies in the study area. The cost and return analysis revealed that plantain production is profitable in the study area with an estimated gross margin/ha and a benefit-cost ratio of ₦545,510 and ₦ 2.26, respectively, indicating that the enterprise will yield ₦2.26 for every ₦1 invested. The study recommends encouraging farmers' adoption of these technologies by fostering their awareness levels through extension agents and other relevant stakeholders.

Keywords: Adoption Intensity, Improved Technology, Plantain, Profitability, Nigeria

INTRODUCTION

Agriculture plays a pivotal role in the economic growth of developing countries (Mahama, Awuni, Mabe, & Azumah, 2020) with no exception in Nigeria (Chiemela et al., 2021), employing a significant portion of the population and contributing substantially to the country's GDP (Nwogwugwu, Nwokoye, & Osai, 2023; Onwutuebe, 2019). Nigeria has recently faced challenges such as declining soil fertility, climate change impacts, and the need to enhance food security amidst a growing population (Abdulraheem et al., 2022; Dauda, 2023). Plantain (*Musa spp.*) production, a vital component of Nigeria's agricultural landscape, holds promise for addressing these challenges due to its nutritional value, economic importance, and potential for increased productivity through improved technologies (Okunola, Olapade-Ogunwole, & Adesiyan, 2022).

Plantain is considered an important staple food crop for many people in West and Central Africa (Lienou et al., 2022; Tenkouano et al., 2019), with no exception in Nigeria, one of the biggest producers and consumers of plantains in the world (Lescot, 2020; Salami, Osasona, Mark, Falola, & Subair, 2023). Plantain production is more profitable to farmers than other staple crops and contributes immensely to the nation's nutritional and food security (Udomkun et al., 2021). The consumption of plantain provides the body with essential minerals and vitamins (Oluseye, Sunday, & Damilola, 2019; Udomkun et al., 2021). Plantains can be consumed in ripened or unripe form, locally or industrially processed into various products such as chips and flour (Okunola et al., 2022). Among the various uses of plantain, plantain flour production is beginning to take a large share of its use in Nigeria. According to Okojie (2022), Nigeria's plantain production could not meet the plantain flour demand of 125000 Metric Tonnes; a plantain flour demand deficit of 99,800MT was reported in 2022. Also, despite its prominence as one of the largest plantain-producing nations globally, Nigeria is yet to feature among plantain-exporting countries as it produces mainly for domestic consumption rather than export (Olumba & Onunka, 2020). To continue to meet the plantain demand of her ever-growing population and exploit the crop's foreign exchange earning potential, the current level of plantain production in Nigeria must increase, which can be best achieved by adopting improved technologies.

Agricultural technologies have been found to include all forms of improved techniques and practices that contribute to the growth, efficiency and profitability of agricultural production, ranging from sophisticated techniques such as robots, temperature and moisture sensors, aerial images and global positioning system technologies in the developed world to less sophisticated ones including hybrid seeds and improved farm inputs, machinery, conservation agriculture, irrigation and improved agronomic practices standard in developing countries (Fadeyi, Ariyawardana, & Aziz, 2022). These technologies have the potential to increase yields, reduce production costs, and enhance the resilience of plantain farming against environmental stresses such as climate change, thereby improving the livelihoods of smallholder farmers and fostering economic growth in low-income and climate-sensitive countries like Nigeria. Research institutes in Nigeria, including the International Institute of Tropical Agriculture (IITA) and the National Horticulture Institute (NIHORT), have attempted and broke through in developing several improved techniques to boost the productivity of plantain farmers, amongst which are propping, hot water treatment, tissue culture, planting space, de-suckering, de-budding and improved hybrid varieties (Tenkouano et al., 2019). Despite the potential benefits of agricultural technological innovations, their adoption and utilisation have not been encouraging in sub-Saharan Africa, Nigeria inclusive, where agriculture is a mainstay of the economy (Ambali, Areal, & Georgantzis, 2021). Adopting improved production technologies is imperative to harness the vast arable land and resources available in Ogun state for plantain production and meet the growing demand. However, a farmer will only use what he is aware of; therefore, this study aims to access smallholder plantain farmers' awareness of various improved plantain technologies, the factors influencing their adoption intensity, and the profitability of plantain production in Ogun State, Nigeria.

METHODOLOGY

Study area: The study was conducted in Ogun State, Nigeria, between Longitude 6.9980^{0}N and Latitude 3.4737^{0}E in southwest Nigeria, with its state capital in Abeokuta. It is bounded in the North by Oyo and Osun States, east by Ondo State, south by Lagos State and west by the Republic of Benin. Ogun State covers a land mass of about 16,980.55 km^2 and has an estimated population of over 7 million (Ogun State, 2020). The more significant proportion of the state lies in the tropical rainforest zone, with a sizeable feature of guinea savannah in the far northern area of the state. The main occupation of the state is farming, which is primarily subsistence in scale. Ogun State is divided into four agricultural zones by the Ogun State

Agricultural Development Program (OGADEP): Ikenne, Ilaro, Abeokuta and Ijebu-Ode. Ijebu Ode zone was selected from these zones as the area of study primarily because it accommodates many plantain farmers.

Sampling Technique: Primary data were used for this study. A multistage random sampling procedure was employed to select the surveyed respondents. The first stage involved a purposive selection of the Ijebu-Ode ADP zone, a predominant plantain-producing zone. The second stage was a simple random selection of three blocks from the zones, while the third stage entailed a simple random sampling of two cells each from the selected blocks. In the fourth stage, four communities were randomly selected from each of the chosen cells, given the high concentration of plantain farmers in the communities. The last stage entailed a simple random selection of 10 respondents from each community based on the list of registered plantain farmers obtained from the OGADEP to make a sample size of 240 respondents. Of these, only 226 questionnaires were helpful for the study analysis.

Method of data analysis: The study data were analysed through:
Descriptive analysis: Descriptive statistics such as frequency, percentage and mean were used to analyse the plantain farmers' socioeconomic characteristics and the plantain production technologies employed.

Poisson regression model: The Poisson regression model was used to examine the factors influencing the adoption intensity of improved plantain production technologies among plantain farmers in the study area. Poisson regression is a nonlinear regression model that follows the Poisson distribution. It is suitable when the dependent variable is modelled as a count variable and the data does not fit the normal distribution. Following Wahyudi, Kuwornu, Gunawan, Datta, and Nguyen (2019), the Poisson regression model is presented as:

$$Prob(Y = y_i \,|\boldsymbol{x}_i) = \frac{e^{-\gamma_i}\gamma_i^{y_i}}{y_i!}\ , y = 1, 2, \dots 7 \qquad (1)$$

The most common formulation for γ_i is the log-linear model

$$\ln \gamma_i = \boldsymbol{x}_i'\boldsymbol{\beta} \qquad (2)$$

The expected number of events per period is given by

$$E[y_i|\boldsymbol{x}_i] = Var[y_i|\boldsymbol{x}_i] = \gamma_i = e^{x_i'\boldsymbol{\beta}} \qquad (3)$$

Thus:

$$\frac{\partial E[y_i|\boldsymbol{x}_i]}{\partial \boldsymbol{x}_i} \qquad (4)$$

The maximum likelihood estimation (MLE) techniques make estimating the parameters more straightforward. The log-likelihood function is specified as

$$\gamma_i = \exp\,(\beta_0 + \beta_i\,\boldsymbol{x}_i + \varepsilon) \qquad (5)$$

Where:
γ = Number of improved plantain production technologies adopted by a farmer
β_i is the vector of parameters to be estimated, and
X_i Represents the vector of the farmer's socioeconomic characteristics as defined below.
x_1 = Age
x_2 = Gender
x_3 = Year of schooling
x_4 = Household size
x_5 = Farm size
x_6 = access to credit
x_7 = Farming experience
x_8 = Awareness of improved technologies index
x_9 = access to agricultural extension services
ε = Error term

Profitability analysis: The profitability of plantain production in the study area was examined using Gross Margin (GM) and Benefit-Cost Ratio (BCR). Following Okunola et al. (2022), GM and BCR were calculated from the cost and return analysis as follows:

$$GM = TR - TVC \quad (6)$$

$$\text{Benefit} - \text{Cost Ratio (BCR)} = \frac{TR}{TC} \quad (7)$$

Where:
GM = Gross Margin (₦/ha)
TR = Total Revenue (₦/ha)
TVC = Total Variable Costs (₦/ha)
TFC = Total Fixed Costs (₦/ha)
TC = Total Cost of production (₦/ha) computed as TVC + TFC.

The fixed inputs, such as hoes, machete, spade, cutlass, etc., were depreciated using the straight-line method as they are not typically used in a production cycle. We assumed that the salvage value was zero and computed the depreciated fixed costs as follows:

$$DC = \frac{PV}{N} \quad (8)$$

Where:
DC = Depreciated cost (₦)
PV = Purchase value (₦)
N = Number of years of the asset's useful life

RESULTS AND DISCUSSION

Key demographic and farming characteristics of plantain farmers in the study area: Table 1 presents the summary statistics of the key demographic and farming characteristics of plantain farmers in the study area. On average, these farmers have adopted 3 out of the 7 identified improved plantain production technologies in the study area, suggesting a moderate level of technological adoption in the study area. The demographic variables show that the mean age of the sampled farmers is 41 years, indicating that they are predominantly in the economically active age range (Akerele, Akerele, Dada, & Akomolede, 2019). The gender variable shows a strong gender disparity in plantain farming, with 92% of the farmers being males, highlighting the patriarchal nature of plantain production in the study area. Each farming household comprises, on average, five members, reflecting a typical household size for agricultural families in the area (Ibrahim, Akerele, Oyawole, Uthman, & Aminu, 2019; Oyawole, Ojo, Aminu, & Oyawole, 2022). The farmers have an average of 11 years of schooling, suggesting a relatively high educational attainment, which could influence their farming practices and adoption of new technologies.

Furthermore, the average farm size dedicated to plantain cultivation is 1.6 hectares, which aligns with small to medium-scale farming operations expected in the study area. Approximately two-thirds of the farmers have access to credit facilities, which will support their ability to finance their farming activities and possibly adopt new technologies. On average, the farmers have 5.5 years of experience in plantain farming, indicating a mix of novice and moderately experienced farmers. A significant proportion, 89%, of the farmers have access to extension services, which is crucial for disseminating knowledge and improving farming practices.

Farmers' awareness of improved plantain production technologies: Table 2 provides insights into the farmers' awareness level regarding the various improved plantain production technologies. The table shows farmers' familiarity with each of the seven identified technologies. Explicitly, most (93.8%) of the farmers are aware of the use of improved suckers. This high awareness suggests that this technology is well-known among farmers, likely due to its direct impact on plantain productivity. The small percentage of farmers who are unaware suggests that awareness campaigns and information dissemination have been largely successful for this technology. Adequate spacing has the highest awareness level among farmers, with 97.3% aware of this practice. A significant proportion of farmers (82.3%) are aware of IPM techniques, including pest and disease control strategies. Awareness of staking is notably low, with only 14.2% of farmers familiar with this technology. Tissue culture technology has a low awareness level, with less than a quarter (21.2%) of farmers aware of it. This indicates that despite its potential benefits for producing disease-free and high-quality plants, tissue culture is not widely known among farmers. About two-thirds of the farmers (67.3%) are aware of de-suckering practices, which help manage plant density and improve yields. Awareness of de-budding is extremely low, with only 8.8% of farmers knowing about it. This suggests that de-budding is not commonly discussed or understood in the community.

Farmers' level of adoption of improved plantain technologies: Table 3 presents farmers' adoption rates of the various improved plantain production technologies. The table reveals significant differences in how widely these technologies are embraced, shedding light on both high and low areas of adoption. Specifically, the high adoption rate of improved suckers (92%) suggests that most farmers recognise the benefits of using high-quality planting material. Most farmers (87.6%) practice adequate spacing, critical for optimising plant growth and reducing resource competition. IPM practices are adopted by 46.9% of the farmers, reflecting a moderate level of engagement with pest and disease control strategies. Staking is one of the least adopted technologies, with only 5.3% of farmers practising it. This suggests that staking might be perceived as too labour-intensive, costly, or unnecessary in the local farming context. The extremely low adoption rate of tissue culture (3.5%) indicates that this technology is either not well-known or not easily accessible to most farmers. De-suckering is adopted by 47.8% of the farmers, indicating a reasonable level of engagement with this practice. Similar to tissue culture, de-budding is scarcely adopted, with only 3.5% of farmers practising it. Therefore, it is deduced that the use of improved suckers and adequate spacing is widely accepted, suggesting these practices are well-integrated into the farmers' routines and are seen as essential for productivity.

Factors influencing adoption of improved plantain production technologies: The parameter estimates of the Poisson regression used to model the determinants of the adoption intensity of improved plantain production technologies are presented in Table 4. The table shows that the likelihood ratio chi-square test statistic (LR Chi-square = 111.317) used to test the overall model fit was significant at the 1% level ($Prob > \chi^2 = 0.0000$), indicating that the model containing the complete set of predictors fits the data significantly better than the null (intercept only) model with no predictors. In other words, all the regression coefficients are significantly different from zero, and the chosen explanatory variables can be said to be relevant in explaining the model, and the model is a good fit. McFadden's pseudo-R-square, which describes the proportionate improvement in the model's fit with predictors relative to an intercept-only model, shows that our model has about 6% improvement relative to a null model. The estimated model shows that six (6) out of the eight (8) explanatory variables included in the model are significant determinants of the adoption intensity of improved plantain production technologies in the study area. These include the farmer's age, years of education, access to credit, farming experience, awareness index, and access to extension services, which all had a positive influence on the adoption intensity of improved plantain production technologies in the study area at a one per cent significance level ($p \leq 0.01$).

The results showed that farmer's age positively and significantly affected the adoption of improved plantain technologies in the study area. An increase in the age of a farmer by one year will lead to an increase in the log of expected counts of the number of technologies that will be adopted by the farmer while holding the other variables in the model constant. This implies that older farmers tend to be more open to the trial of new things to enhance their productivity. Older farmers are believed to be more knowledgeable, experienced and better able to evaluate technical information than younger farmers since they have amassed more knowledge over time. This finding is in tandem with that of Pivoto et al. (2019), Anang, Amesimeku, and Fearon (2021) as well as Mahama et al. (2020), who found a positive and significant relationship between age and intensity of adoption of sustainable soybean production technologies in Northern Ghana. Mahama et al.

(2020) opined that farmers become more accountable to themselves and their close family members as they get older and, thus, frequently have a great desire to implement various technologies that might increase yields and raise revenues to support their families. On the contrary, Lamptey, Sulemana, Donkoh, Zakaria, and Azumah (2022) obtained an inverse relationship between age and adoption of improved rice variety, noting that older farmers are more cautious when embracing new ideas. Also, Fadeyi et al. (2022), in a systematic review of factors influencing technology adoption among smallholder farmers in Africa, indicated a decreasing enthusiasm for adopting novel and emerging technologies as the farmer ages.

The years of education significantly and positively influence the adoption intensity of improved plantain production technologies in the study area. A one-year increase in the number of years a plantain farmer spent in school will lead to an increase in the log of expected counts of improved technologies that the farmers will adopt. Our findings conform with that of Mahama et al. (2020), who reported a positive impact of the number of years spent in formal schooling on the adoption intensity of soybean production technologies in Northern Ghana as well as that of Dinh and Dung (2021), who found that a positive and significant interaction between the farmers' education level and their decision on the new technology adoption in Vietnam. Education is one of the key factors influencing the adoption of technology as it eases the introduction of knowledge and increases the farmers' ability to access and process information (Fadeyi et al., 2022; Ishola & Arumugam, 2019).

The awareness index was a positive and significant predictor of the adoption intensity of improved plantain production technologies in the study area. This implies that farmers with a higher level of awareness of the technologies were predicted to adopt more improved plantain production technologies than farmers with a low awareness level. Awareness is essential to adopting improved technologies as they can only adopt a technology they are aware of or know about its uses (Ochieng et al. 2019). In a similar study, Addison, Anyomi, Acheampong, Wongnaa, and Amaning (2023) highlight the positive impact of awareness of technologies on their adoption intensity.

Extension visits also positively influenced the adoption intensity of improved technologies for plantain production in the study area. A unit increase in the number of extension officers' contacts a farmer gets will increase the log of expected counts for the number of technologies the plantain farmers will adopt. Farmers who have access to many visits by extension agents have a better opportunity to be aware of and understand the benefits of improved technologies and adopt them for increased productivity. Our result is consistent with the findings of Afodu et al. (2021) and Mahama et al. (2020), who reported that the provision of extension services during soybean production positively impacted the adoption intensity of technology in Northern Ghana. In conformity with similar studies in Vietnam (Dinh & Dung, 2021) and Ghana (Anang et al., 2021), farmers who have access to credit are predicted to adopt a higher number of technologies than those who do not. Finance has been a significant constraint to adopting improved technologies in Nigeria (Rilwanu, Sulaiman, & Bose, 2024). Adopting improved technologies, like improved hybrid varieties of fertiliser, amongst others, is capital intensive. Thus, access to credit will help smallholder farmers who are generally poor overcome budget constraints. Access to credit also supports risk management, scalability, and capacity building, ultimately contributing to increased productivity, profitability, and sustainability in farming practices.

Costs and returns to plantain production: Table 5 below reveals the analysis of cost and returns to plantain production per hectare of land per production season in the study area. The total variable cost (TVC), including labour, herbicides, pesticides, manure, suckers, and transportation costs, was ₦217,150, accounting for 86.3% of the total cost of production. Plantain production in the study area depends on family and hired labour, and the cost for family labour was computed using the prevailing wage rate. Labour cost accounts for 40.24% of the total variable cost, indicating that labour is the most used variable among the respondents. The average fixed cost was estimated at ₦24,435, which covers rent on land and depreciation on fixed assets such as hoes, spades, cutlass, etc. The gross margin and a benefit-cost ratio of ₦545,510 and ₦ 2.26, respectively, reveal that plantain production is profitable in the study area as for every ₦1 invested, the enterprise will yield ₦2.26.

CONCLUSION AND RECOMMENDATIONS

The study concluded that plantain production is profitable in the study area. The adoption level of improved plantain sucker and adequate spacing is higher compared to other available technologies. Tissue culture and de-budding had a very low adoption rate. This could be attributed to their very low awareness level among the farmers in the study area relative to the high awareness levels of improved plantain sucker, adequate spacing, IPM and de-suckering, among others. The farmer's age, years of education, access to credit, farming experience, awareness index, and access to extension services all positively influenced the adoption intensity of improved plantain production technologies in the study area.

Based on these findings, the following recommendations were made:

- There is a need for massive awareness and comprehensive information spread about the advantages and significance of each improved technology to enhance adoption.
- Extension agents should make efforts to increase their number of visits to farming communities because these encounters provide farmers with a forum to express their concerns and inquire about using these technologies while enhancing productivity in plantain farming.
- The farmers should be encouraged to acquire education as this will improve their understanding of these various technologies and raise their level of adoption.
- The government should create experimental programmes that reveal the benefits of adopting improved technologies to encourage laggard farmers.
- The government and other NGOs should help support the farmers financially by providing loans to enhance the adoption rate of the improved production technologies.

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Table 1: Key demographic and farming characteristics of plantain farmers in the study area (N=226)

Variable	**Description**	**Mean**	**Std. Dev.**
Count of improved technologies adopted	Number of improved plantain production technologies adopted	2.69	1.016
Age	Age of household head in years	41.301	9.147
Gender	Dummy for the gender of household head (male = 1)	0.929	0.257
Year of education	Number of years of schooling of household head (years)	11.08	8.078
Household size	Number of household members	5.473	1.841
Farm size	Area of land cultivated (Ha)	1.632	1.379
Access to credit	Dummy for access to credit by the household head (Have access =1)	0.712	0.454
Farming experience	Number of years of farming plantain	5.416	3.08
Access to extension services	Dummy for access to credit by the household head (Have access =1)	0.841	0.367

Source: Field Survey, 2019

Table 2: Distribution of farmers by awareness of improved plantain production technologies

S/N	**Improved Technology**	**Frequency**		**Percentage**	
		Yes	**No**	**Yes**	**No**
1	Use of improved sucker	212	14	93.8	6.2
2	Adequate spacing (3 by 2 or 2.5 by 2.5m)	220	6	97.3	2.7
3	IPM – pest and disease control	186	40	82.3	17.7
4	Staking (propping)	32	194	14.2	85.8
5	Tissues culture	48	178	21.2	78.8
6	Desuckering (2-3/stand)	152	74	67.3	32.7
7	Debudding	20	206	8.8	91.2

Mean Awareness index* = 0.552

*Awareness index is computed as the number of technologies the farmers are aware of divided by the total number of technologies

Source: Field Survey, 2019

Table 3: Distribution of farmers by adoption of improved plantain production technologies

S/N	Improved Technology	Frequency		Percentage	
		Yes	No	Yes	No
1	Use of improved sucker	208	18	92	8
2	Adequate spacing (3 by 2 or 2.5 by 2.5m)	198	28	87.6	12.4
3	IPM – pest and disease control	106	120	46.9	53.1
4	Staking (propping)	12	214	5.3	94.7
5	Tissues culture	8	218	3.5	96.5
6	Desuckering (2-3/stand)	108	118	47.8	52.2
7	Debudding	8	218	3.5	96.5

Source: Field Survey, 2019

Table 4: Poisson regression model coefficient estimates of the determinants of adoption intensity of improved plantain technologies

Variables	Coefficient	Standard Error	t-value	p-value
Age	0.011***	0.003	3.96	0.000
Gender	-0.009	0.107	-0.08	0.934
Year of education	0.01***	0.002	4.25	0.000
Household size	0.015	0.010	1.53	0.126
Farm size	0.013	0.009	1.51	0.132
Access to credit	0.25***	0.071	3.53	0.000
Farming experience	-0.002	0.006	-0.41	0.685
Awareness index	0.679***	0.203	3.35	0.001
Access to extension services	0.287***	0.082	3.48	0.000
Constant	-0.472**	0.199	-2.37	0.018
Pseudo r-squared	0.059	Number of observation	226	
LR Chi-square	111.317	Prob > chi2	0.000	
Akaike crit. (AIC)	714.371	Bayesian crit. (BIC)	748.576	

Note: *** *p<0.01*, ** *p<0.05*, * *p<0.1*

Source: Authors' computation

Table 5: Costs and returns to plantain production in the study area

Cost and return items	Unit	Average value ₦/ (ha)
Variable Costs		
Cost of chemicals (pesticides, herbicides)	Litres	8,930
Cost of fertiliser	Bags	17,850
Cost of sucker	Pieces	74,150
Cost of labour	Man-day	87,380
Cost of manure	Bags	20,725
Cost of transportation	-	8,115
Total Variable Costs (TVC)		**217,150**
Fixed Costs		
Land rent	ha	20000
Fixed asset depreciated (spade, cutlass, hoe, etc.)	Number	4435
Total Fixed Costs (TFC)		**24,435**
Total Cost (TC)		241,585
Revenue		
Plantain bunch	Bunches	685800
Plantain suckers	Pieces	76860
Total Revenue (TR)		**762660**
Gross Margin (GM) = TR - TVC		**545,510**
Benefit-cost ratio (TR/TC)		**2.26**

Source: Authors' computation