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Ecological Impact in Northern Tanzania Using Heckman AI Two-Step Selection Model

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ABSTRACT

This study explores the determinants of impact on ecology in Northern Tanzania. By examining key socio-economic, institutional, and structural factors influencing engagement the study provides insights in strengthening agribusiness networks and improving livelihoods. Data was collected from 215 farmers and 320 traders through a multistage sampling procedure. Heckman AI sample selection model was used in data analysis whereby the findings showed key factors influencing farmers' decisions on ecology were gender and years of formal education at $p < 0.1$, and access to finance and off-farm income at $p < 0.05$. The degree of farmers participation in social groups was influenced by age, household size, off-farm income and business network at $p < 0.05$, number of years in formal education and access to finance at $p < 0.01$, and distance to the market at $p < 0.1$. The decision of traders to impact on ecology was significantly influenced by age and trading experience at $p < 0.1$. Meanwhile, the degree of their involvement in social groups was strongly affected by gender, formal education, and trust at $p < 0.01$, as well as by access to finance and business networks at $p < 0.05$. The study concluded that natural ecology is influenced by socio economic and structural factors but trust among group members determine the degree of participation. The study recommends that strategies to improve agribusiness networks should understand underlying causes of impact on ecology and strengthen available social groups to improve performance of farmers and traders.

Keywords: Ecological Impact; Vegetable Farmers; Vegetable Traders; Heckman AI Model; Northern Tanzania

1. Introduction

There are several emerging causes of social impact on ecology and several factors that contribute to formation and participation in ecology by individuals including family, school, neighborhood, ethnic groups, relationships, social movements, social institutions and public organizations. The literature groups factors for social impact on ecology formation and participation into idiosyncratic factors such as cultural and behavioral traits, contextual factors such as political and racial diversity, and individuals' characteristics, such as education level, race, and gender[1–3]. The role of these factors is indispensable. They create a sense of effective social networking between individuals and organizations, which eventually results in an increase sustainable ecological situation. Generally, the aim of establishing impact on ecology is rooted in having relationships among people, invested to achieve shared common goals. Therefore, understanding impact on ecology can be achieved by understanding how individuals relate socially, as well as formation, transformation, and resilience of their social relations[4–9].

In agricultural settings, impact on ecology plays a crucial role in agricultural and rural development as it shapes the way people engage and collaborate with one another towards a common goal[10–14]. Tanzania faces a number of challenges in the agricultural sector, the major being inefficient and unproductive systems of agricultural practices, including limited access to financial and capital resources, poor agricultural information systems, coupled with weak linkages among agrifood actors. This restricts farmers and traders from accessing and using agricultural knowledge, ultimately hindering agricultural and rural development[15–18].

The study examines ecological impact through the lens of social capital theory, which posits that networks, trust, and shared norms among individuals and groups facilitate collective action and resource sharing, ultimately influencing ecological outcomes[16–20]. In agricultural contexts, social capital enhances access to information, credit, and markets, reducing transaction costs and promoting sustainable practices. This study operationalizes ecological impact as participation in ecological groups (farmer cooperatives, trader networks), which are manifestations of social capital[21–25]. The Heckman AI model is employed to address selection bias, as farmers/traders self-select into these groups based on unobservable factors (intrinsic motivation, trust)[26–31].

Farmers/traders who join ecological groups may dif-

fer systematically from those who do not (more educated, wealthier). The first step (probit model) estimates the likelihood of participation, while the second step (OLS regression) analyzes the degree of participation, adjusting for bias using the Inverse Mills Ratio [32–35].

2. Literature Review

There are challenges: Businesses may prioritize profits over sustainability, Valuing ecosystems in monetary terms is complex, Environmental issues and climate change require international cooperation [36–39].

Impact on ecology formation is crucial for sustainable development. It requires a mix of conservation efforts, policy reforms, technological innovation, and shifts in economic thinking to ensure that natural systems continue to support life and economic activity [40–43]. Despite the imperative role played by ecological impact on ecology in resource and information sharing, knowledge dissemination among vegetable supply chain actors, and collective action towards tackling vegetable sector challenges among farmers and traders, there remains the question of where impact on ecology comes from. There is lack of studies that provide evidence on the drivers of impact on ecology in Tanzania and the extent to which different socio-economic factors of vegetable farmers and traders influence the degree of participation to impact on ecology remains underexplored. Therefore, it is important to explore the different types of impact on ecology present among vegetable-farming households and traders, and to examine how both socioeconomic factors and impact on ecology impact their participation in ecological groups [44–49].

In Tanzania, vegetable farmers who actively participate in ecological groups benefit from collective bargaining and improved market linkages. It is thus interesting to measure how socioeconomic attributes influence the accumulation of impact on ecology and how they affect the degree of involvement in impact on ecology by individuals [50–54]. This study adopts exogenous factors for impact on ecology acquisition. It employs econometric analyses to establish factors that determine impact on ecology formation and the extent of engagement in ecological groups by vegetable farmers and traders in Tanzania [55–57].

One way to address agricultural challenges is through improved access to financial resources and lowering transaction costs in agricultural exchanges. High transaction costs in agricultural supply chains, such as transportation costs, trade barriers, tariffs, search costs, and costs of gathering information on produce, result in higher prices paid by the buyer and lower prices received by the sellers. Impact on ecology formation has been increasingly recognized in the literature as a development strategy to promote access to credit, resource sharing, and collective action, facilitating market linkages, and improving the performance of the agricultural sector at large. Information is shared effectively through social groups, thus minimizing transaction costs and improving market entry opportunities [58, 59].

The implications of impact on ecology in vegetable supply chains have been emphasized in the literature. A study about how impact on ecology influences the market participation of smallholder African Indigenous Vegetable Farmers in Kenya found that it is essential to train farmers on the value of building strong ecological networks to enhance their market participation. Another study analyzed aspects of ecological impact on ecology among farmers in ecological groups and concluded that active participation, trust, ecological norms, and dominant responsibility observed among group members build agricultural development. It shows that impact on ecology in vegetable farming, particularly through community-supported agriculture (CSA), fosters connections among farmers and traders, enhancing access to information and opportunities that are crucial for sustainable food systems and community engagement. Other studies also outlined the significant contribution of ecological impact on ecology to the performance of the horticulture sector [27–29].

This paper uses newest research and data. This is present study differentiates from existing research and makes a step towards better understanding the research problem.

3. Materials and Methods

The study was conducted in Arusha and Kilimanjaro regions in Northern Tanzania (**Figure 1**). Two districts from each region were selected for the study. Moshi Rural and Hai districts were selected for Kilimanjaro region while Arusha and Arumeru districts from Arusha region. The selected regions in Northern Tanzania grow a high volume of horticultural produce, but are also identified as one of the major sources of vegetables supplied to neighboring regions. Agri-

culture, in the form of crop farming and animal husbandry, is the main economic activity in the area. Additionally, the selected districts have a comparatively larger population with both, high and low-density zones with vegetable farming households who belong to various ecological groups and participate in a range of economic and ecological activities [60–65].

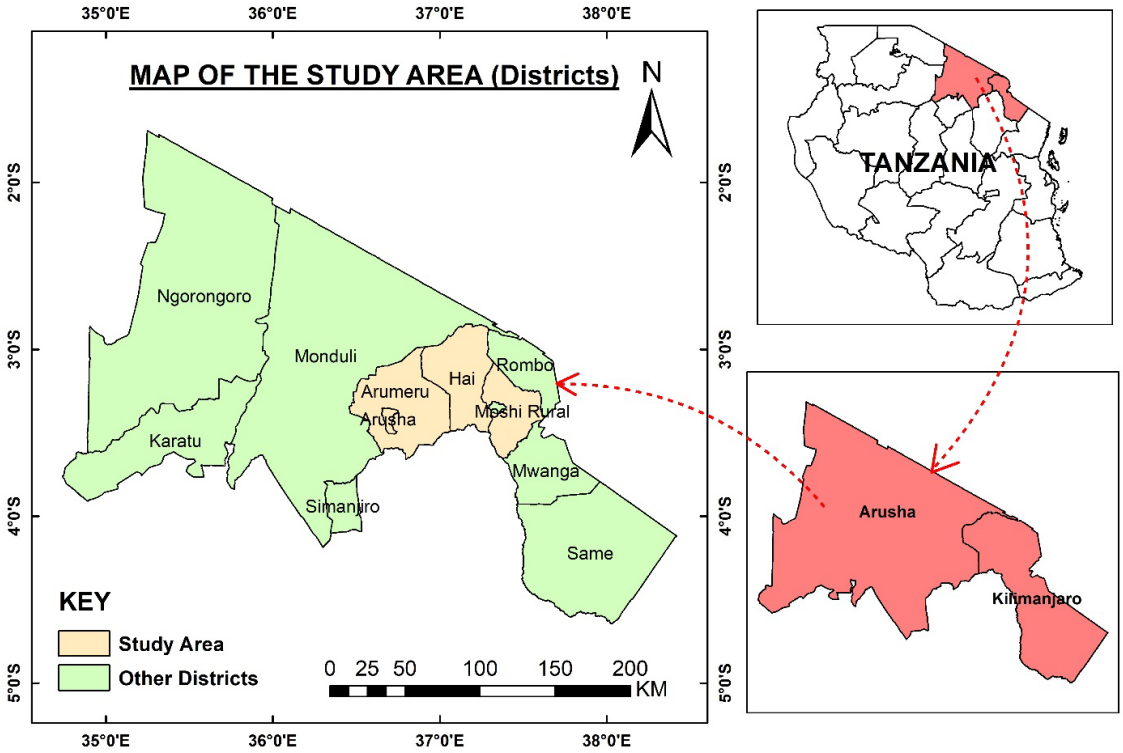

Figure 1. Map of Northern Tanzania showing the study areas.

The study employed a multistage sampling procedure in which two regions from Northern Tanzania (Kilimanjaro and Arusha) were purposively selected in the first stage, followed by a selection of two districts from each region. Moshi Rural and Hai districts in the Kilimanjaro region and Arusha and Meru districts in the Arusha region were selected for the study. These regions and districts were selected because of the predominance of tomato and sweet pepper production. The third stage was the random selection of villages and markets for inclusion in the study. Four (4) villages and four (4) markets in total were randomly selected for this study [66–69]. One village and one market were selected from each district. Finally simple random sampling was employed to obtain vegetable farmers and traders from the selected villages and markets in the final stage. A total of 215 farmers, 160 wholesalers, and 160 retailers were used for the study based on the availability of funds and time resources [70–72].

The socioeconomic characteristics of tomato and sweet pepper farmers and traders were analyzed using descriptive statistics and t-test was employed to measure statistically significant differences in variables mean between the regions. The Heckman AI selection model was employed for data analysis. In the first stage, the determinants of decision to participate in impact on ecology were identified, and in the second stage, the degree of participation in impact on ecology for traders and farmers was estimated [73–75].

The impact on ecology variables measured include ecological groups (agricultural groups and non- agricultural groups), group density (number of group members), trust among group members, and business network size of vegetable farmers and traders. Group membership density is the number of ecological groups belonging to a farmer or trader [76–79]. A business ecological network is the number of individuals the farmer or trader has mostly traded with. It entails both input and output trade partners for vegetable farmers and traders [80, 81].

When dealing with different researchers' views and discussions on impact on ecology, it is clear that the fac-

tors and effects of impact on ecology have no direct causal link. The fundamental concept of impact on ecology is that actors access production resources as members of networks without which they would not access. A Heckman AI two-step selection model is employed to assess both the measurement model for the factors influencing impact on ecology participation and the degree of participation in ecological groups.

The determinants measured in the model are gender of the household head or the trader, age, household size, trading experience, years of formal education, distance to the market, access to extension services, access to financial services, and off-farm income. The choice of determinants to be included in the model was based on a review of similar studies. Impact on ecology indices of cash contribution, meeting attendance and labor contribution were calculated following studies. Trust among group members was computed as a mean from a five-point like rt scale question where 5=very trust, 4=more trust, 3= general trust, 2= less trust and 0= no trust. The degree of participation in impact on ecology was estimated by the number of ecological groups belonging to an individual.

The Heckman AI's two stages are estimated separately to avoid selection bias. In stage one, the probit model is used to estimate the decision of vegetable farmers and traders to engage in ecological groups The model is specified as follows.

$$W_{ij}^{*} = \beta_{ij} X_{ij} + \mu_{ij}, \quad \mu_{ij} \sim N(0, \sigma^2), \quad i = 1 \ldots n \tag{1}$$

where W_{ij}^{*} is a dummy variable, with 1 denoting participation in ecological groups and 0 denoting otherwise. X_{ij} is the explanatory variable corresponding to the ith respondent of the jth category of respondents, β represents a vector of coefficients, while μ_{ij} denotes an independently normally distributed error term.

In stage two, the degree of participation was measured in an ordinary least squares (OLS) regression model using explanatory variables corresponding to the ith respondent of the jth category of respondents, combined with a set of impact on ecology dimensions of trust among group members, and network size. The model is expressed for the ith respondent with those participating in impact on ecology, that is, $Y^{*} = 1$ as shown in Equation 2.

$$Y_{ij}^{*} = \theta_{ij} z_{ij} + \mu_{ij} \tag{2}$$

where Y_{ij}^{*} is the degree ecological groups participation for the ith respondent in the jth category of the vegetable supply chain actors, θ_{ij} and z_{ij} are the socioeconomic and impact on ecology variables of the vegetable farmers and traders, respectively.

The Inverse Mills Ratio (IMR) was included in the second stage as a regressor in the OLS equation for all respondents participating in ecological groups. The IMR is added to correct for selection bias, as shown in Equation 3.

$$p\alpha_E \frac{\sigma(z_i\delta)}{\sigma(z_i\delta)} \tag{3}$$

Here σ represent the standard probability density function. A significant value of IMR suggests the existence of a selection bias. Consequently, the empirical form of the second-stage regression model can be written as:

$$Y_{ij}^{*} = \theta_{ij}\varphi_{ij} + \in_{ij} \tag{4}$$

where Y_{ij}^{*} is the degree of participation for farmers and traders belonging in ecological groups, θ_{ij} and φ_{ij} are respondents' socio-economic characteristics and impact on ecology variables, and $\in_{ij}$ is the IMR.

4. Results and Discussions

4.1. Descriptive Results

4.1.1. Demographic Characteristics of Vegetable Farmers

Descriptive statistics are presented in **Table 1**, which summarizes the demographic characteristics of the vegetable farmers. 53% of the sampled population in the study area grew tomatoes, while 47% grew sweet pepper. The average vegetable farming household size was 4.9 persons in both the Kilimanjaro and Arusha regions, implying that households are the main source of labor for agriculture, aligning with the results reported. The average age of the household head was 48 years in Kilimanjaro and 43 years in Arusha, which implies an adult population of a working age. This finding corroborates where most of tomato and sweet pepper farmers are in economically active working age. Overall, only 11% of vegetable farmers in the Arusha and Kilimanjaro

regions were female-headed, showing that the majority of households were male headed. Over 60% of the sampled respondents were male, implying that men were more active in tomato and sweet pepper production in the study areas than women because tomatoes and sweet pepper are regarded as high-value crops as they are sold at higher prices compared to traditional vegetables and are capable of generating higher income to farmers.

Across all regions, vegetable farming household heads had 8 years of education, implying that most had a primary level of education (**Table 1**). Households in Arusha were significantly more trained in horticulture ($p < 0.01$) than those in Kilimanjaro. Moreover, over 60% of households in Kilimanjaro accessed extension services in the last six months from the time of the survey, compared to 59% of the households in Arusha. This implies that the vast majority had access to agricultural-related services, which may be attributed to the presence of working agricultural groups in the study areas. Households in Kilimanjaro and Arusha owned an average of 0.4 hectares which confirms that the majority of vegetable farmers in the study area are smallholders. Similar results are reported where it is reported that most of tomato and sweet pepper farmers have farms between 0.2 to 0.4 hectares of land.

Table 1. Characteristics of sampled vegetable farmers in Arusha and Kilimanjaro regions.

	Pooled	**Arusha**	**Kilimanjaro**	**Regional**
	mean/sd	**mean/sd**	**mean/sd**	**Difference**
Age of the Household Head	45.98	43.82	48.42	-4.60**
	(13.29)	(13.20)	(13.03)	(1.79)
Sex of the respondent (1=Female, 0=Otherwise)	0.37	0.34	0.40	-0.05
	(0.48)	(0.48)	(0.49)	(0.07)
Sex of the household head (1=Female, 0=Otherwise)	0.11	0.05	0.18	-0.13***
	(0.32)	(0.22)	(0.38)	(0.04)
Total number of household members	4.90	4.90	4.89	0.01
	(1.92)	(1.76)	(2.10)	(0.26)
Household head level of education in years	8.04	8.18	7.88	0.30
	(2.45)	(2.75)	(2.07)	(0.34)
Total area under cultivation (Hectares)	0.39	0.39	0.40	-0.01
	(0.29)	(0.32)	(0.24)	(0.04)
Main crop cultivated (1=Tomato, 0=Sweet pepper)	0.53	0.55	0.50	0.06
	(0.50)	(0.50)	(0.50)	(0.07)
1 If farmer is a member of any agriculture group, 0 = No	0.46	0.50	0.42	0.08
	(0.50)	(0.50)	(0.50)	(0.07)
1 If farmer is a member of any ecological group, 0 = Otherwise	0.73	0.75	0.72	0.02
	(0.44)	(0.44)	(0.45)	(0.06)
Total number of ecological groups per farmer	2.92	2.72	3.72	-0.00
	(1.04)	(1.00)	(1.08)	(0.14)
1 If farmer received training in year 2023, 0 = No	0.55	0.63	0.46	0.18***
	(0.50)	(0.48)	(0.50)	(0.07)
1 If farmer accessed financial services in the last 6 months	0.61	0.61	0.61	-0.01
	(0.49)	(0.49)	(0.49)	(0.07)
1 If farmer had access to extension services, 0 = No	0.60	0.52	0.69	-0.18***
	(0.49)	(0.50)	(0.46)	(0.07)
Network size of most traded input and output partners	7.26	6.71	7.88	-1.17*
	(4.67)	(3.91)	(5.36)	(0.64)
Cash contribution	0.09	0.08	0.10	-0.02
	(0.11)	(0.08)	(0.14)	(0.02)
Labor contribution	0.42	0.43	0.40	0.03
	(0.14)	(0.14)	(0.13)	(0.02)
Meeting attendance	0.81	0.78	0.84	-0.06
	(0.43)	(0.40)	(0.46)	(0.06)
Observations	215	114	101	215

***, ** and * represent significance levels at 1%, 5% and 10%, respectively.
Source: Field Survey, 2024.

About 50% of the sampled households in Kilimanjaro and 42% in the Arusha region were in active agricultural groups where knowledge about horticultural production and marketing could be shared within the groups and other community members (**Table 1**). This further implies ecological interactions and collective action among vegetable-producing households. Overall, 73% of vegetable-farming households belonged to the ecological groups formed within their communities.

On average, each vegetable farmer belonged to three ecological groups (**Table 1**). The households join various associations to protect and promote their business interests. The meeting attendance index value was 0.81, implying that vegetable farmers attended most of the scheduled meetings in their ecological groups. This could be explained by the governance nature of most ecological groups where individuals are fined as a result of missing scheduled meetings. Meeting attendance is also an incentive for people within groups to support individuals during ecological events. On average, the cash contribution index is 0.69 in the study area. This high value implies that the ecological group, one of the main functions of the groups, is the cash contribution in the study area. On average, each vegetable-farming household had a trading network of seven people. This implies that vegetable farmers developed networks of trusted trading partners to protect their interests. On average, the mean number of labor days contributed by the groups annually was 42. The results conform to those of a study on ecological groups of non-paid labor days in Tanzania.

4.1.2. Demographic Characteristics of Vegetable Traders

Table 2 describes the demographic characteristics of tomato and sweet pepper traders in the study area. Overall, 48% of the sampled population in the study area traded tomatoes and 52% traded sweet peppers. Most of the tomato and sweet pepper traders (both wholesalers and retailers) were female, comprising 89% of sampled traders in the Kilimanjaro region and 81% in Arusha region ($p < 0.05$). On average, a trader had over a decade of experience trading vegetables in the study area. This implies that the sampled traders had vast experience and knowledge of the business. The average age of vegetable traders was 42 years in Kilimanjaro and Arusha, implying an adult population that is capable of making decisions to engage in ecological groups for improved vegetable business operations. Similar findings were obtained who reported that most traders were between the age of 30-50 years.

As it was for vegetable farming household heads, traders had an average of eight years of formal education, implying a primary level of education (**Table 2**). Overall, most traders (73%) belonged to ecological groups. The ecological groups comprised vegetable trading activity-related groups and non-trading activity groups. More traders in Kilimanjaro belong to groups formed for vegetable trading purposes than traders in the Arusha region ($p < 0.05$). On average, each trader belongs to at least two ecological groups. Traders share information on the prices and marketing of horticultural crops through trade-related groups. Trade groups also serve as platforms for capital contributions for traders, as shown in **Table 3**. In general, most traders in the study area had no access to horticultural training. Only 7% of traders in the Kilimanjaro and Arusha regions acknowledged that they had received training on vegetables in 2023 (**Table 2**). Moreover, over 60% of traders have access to finances, mostly through their ecological groups.

Overall, the meeting attendance index for traders is 0.83, implying that traders are mostly responsive to scheduled meetings. As for farmers, the trader's correspondence to scheduled meetings could be explained by the rules and regulations collectively agreed upon to govern their ecological groups, including fines for absentees. The cash contribution index for the Kilimanjaro and Arusha regions is 0.55 for traders which implies that cash contribution is one of the main attributes in the ecological groups, as it appears for vegetable farmers. On the contrary, the labor contribution for traders was only 0.20 per annum, implying that traders spent an average of 20 days in a year, providing labor for other traders in their ecological groups. This result is expected for vegetable traders because of the nature of their business settings in the market where many people flood markets, thereby rendering it difficult to work for others concurrently. The number of trading partners is statistically different between the two regions ($p < 0.05$), where an average trader in Kilimanjaro traded mostly with 13 people, whereas a trader in the Arusha region had an average of 17 people in their networks. This could be explained by the fact that the farmers' markets surveyed in Kilimanjaro were mostly auctions twice a week while those in the Arusha region were daily markets.

Table 2. Characteristics of sampled vegetable traders in Kilimanjaro and Arusha regions.

	Pooled	Arusha	Kilimanjaro	Regional
	mean/sd	mean/sd	mean/sd	Difference
Trader Category (1=Wholesaler, 0=Retailers)	0.50	0.50	0.50	0.00
	(0.50)	(0.50)	(0.50)	(0.06)
Age of respondents	41.99	42.19	41.80	0.39
	(9.10)	(8.48)	(9.69)	(1.02)
Sex of the respondent (1=Female, 0=Otherwise)	0.85	0.81	0.89	-0.08**
	(0.35)	(0.39)	(0.31)	(0.04)
Maximum number of years of schooling	8.18	8.20	8.16	0.04
	(2.10)	(2.22)	(1.97)	(0.23)
Number of years in trading	11.26	11.48	11.03	0.45
	(8.49)	(7.83)	(9.12)	(0.95)
Main vegetable traded (1=Tomato, 0=Sweet pepper)	0.48	0.45	0.51	-0.06
	(0.50)	(0.50)	(0.50)	(0.06)
1 If trader belongs to agricultural trade group, 0 = No	0.35	0.29	0.41	-0.13**
	(0.48)	(0.45)	(0.49)	(0.05)
Number of agricultural related trade groups engaged	1.29	1.17	1.36	-0.19
	(0.65)	(0.44)	(0.76)	(0.12)
1 If trader is a member in any ecological groups, 0 = No	0.73	0.69	0.76	-0.07
	(0.45)	(0.46)	(0.43)	(0.05)
Total number of ecological groups trader belongs to	1.92	1.91	1.94	-0.03
	(0.90)	(0.94)	(0.86)	(0.10)
Respondent's network of trading partners	15.17	17.21	13.13	4.08**
	(16.91)	(19.86)	(13.07)	(1.88)
1 If trader has access to financial services, 0 = No	0.60	0.67	0.53	0.14***
	(0.49)	(0.47)	(0.50)	(0.05)
1 If respondent attended agricultural related training	0.07	0.10	0.04	0.06**
	(0.25)	(0.30)	(0.19)	(0.03)
Cash contribution	0.55	0.56	0.55	0.01
	(0.15)	(0.13)	(0.17)	(0.02)
Labor contribution	0.20	0.18	0.21	-0.02
	(0.19)	(0.19)	(0.18)	(0.02)
Meeting attendance	0.83	0.81	0.84	-0.02
	(0.22)	(0.24)	(0.20)	(0.03)
Observations	320	160	160	320

***, ** and * represent significance levels at 1%, 5% and 10%, respectively.
Source: Field Survey, 2024.

Table 3. Functions of agricultural groups in the study areas.

Group Functions	Vegetable Farmers (%)			Vegetable Traders (%)		
	Pooled	Arusha	Kilimanjaro	Pooled	Arusha	Kilimanjaro
Ecological contributions	33	25	45	41	35	45
Collective Input Purchase	20	25	16	12	17	08
Collective Marketing	19	23	15	13	24	06
Agricultural Trainings	37	43	30	0	0	0
Capital Contribution	15	12	19	66	70	64

4.2. Functions of Agricultural Groups for Vegetable Farmers and Traders

4.2.1. Functions of Agricultural Groups

Table 3 presents the main functions of the agricultural groups for farmers and traders. Unlike traders, most farmers (37%) mentioned agricultural training, followed by ecological contributions for events (33%), as the main functions of their groups. Other functions include collective input, purchasing, and production marketing. Capital contribution was the most common among vegetable traders and the least among vegetable farmer groups. Unlike in the agricultural

groups, over 95% of respondents in the non-agricultural groups mentioned cash contributions for savings and loans as the main function of the ecological groups.

Most traders in the surveyed markets (66%) utilize their groups for capital contribution, famously known as the Kibati system, where each trader in the group contributes a certain amount to another trader. The cash contributed is then utilized as capital in their businesses. Other functions of the groups include contributions to ecological events, and only 13% and 12% of the vegetable traders reported collective marketing and sourcing of produce as functions of their groups, respectively.

4.2.2. Information Shared among Agricultural Groups in the Study Areas

The type of information shared among vegetable farmers in the groups was mostly agricultural practices (90%), where farmers could train each other on good agronomic practices. Over 80% of the farmers also exchanged information on the price of their produce and market information. Unlike farmers, price and market information were the most shared among vegetable traders. Ecological life information was also mostly shared among vegetable traders (67%), as shown in **Table 4**.

Table 4. Information shared among agricultural groups in study areas.

Information Shared	Vegetable Farmers (%)			Vegetable Traders (%)		
	Pooled	Arusha	Kilimanjaro	Pooled	Arusha	Kilimanjaro
Market Information	66	61	72	74	70	78
Price Information	88	85	92	74	81	68
Agricultural Practices	90	95	92	11	12	10
Ecological Life	23	19	30	67	58	75

4.3. Determinants of Vegetable Farmers' Participation in Impact on Ecology

Factors for participation in ecological groups for farmers include gender, years of formal education, access to finance and off-farm income (**Table 5**). Gender of vegetable farming household head significantly affects the decision to engage in impact on ecology groups ($p < 0.1$). A female household head was 14 percent more likely to decide to engage in ecological groups. A study found that women often participate more in ecological groups compared to men especially in rural areas. This can be explained by the fact that women are more likely to join ecological groups due to limited access to capital than men. In addition, women are predominant than men in the village community networks.

The education level of the household head significantly affected their decision to be a part of ecological groups ($p < 0.1$). A year increase in the household head's education level was associated with a two percent rise in the likelihood of joining ecological groups, indicating that education equips farmers with the necessary skills to access and interpret relevant information for making informed choices about engaging in impact on ecology. A higher education level is a strong predictor of participation in impact on ecology.

Access to finance significantly affected vegetable farming households' decisions to participate in impact on ecology ($p < 0.05$). An increase in the access to finance led to a fifteen percent rise in the likelihood of joining ecological groups. This may be because financial access facilitates joining cooperatives, which in turn promotes trust and stronger relationships among rural community members. Also socioeconomic factors, tied to financial resources and opportunities to collaborate, influence impact on ecology among smallholder farmers in Ghana.

Interestingly, off-farm income negatively affects vegetable farmers' decisions to participate in impact on ecology ($p < 0.05$). An increase in a percent of off-farm income reduced the likelihood of involvement in impact on ecology by one percent. This implies that, as farmers increase other sources of income, they become reluctant to participate in ecological groups.

4.4. Determinants of Degree of Participation in Impact on Ecology among Vegetable Farmers

The results in **Table 5** also show determinants of vegetable farmers' degree of participation in impact on ecology groups. These factors include age, household size, number of years in formal education, access to finance, distance to

the market, off-farm income, and trust. Each additional year in the age of the household head significantly ($p < 0.05$) enhances the level of participation in ecological groups by three percent implying that as individuals age, they become more involved in impact on ecology. This could be explained by the fact that younger farmers prefer not to join ecological groups because of trust issues and lack of adherence to rules and regulations imposed by groups. However. The results conflict with findings from other studies which argue that participation in community groups decreases with age. An increase of one household member increases the degree of participation in impact on ecology by 21 percent ($p < 0.05$). One possible explanation is that, as the household size increases, funds required to sustain household needs also increase; thus, households seek to join groups to increase access to credit.

Table 5. Determinants of vegetable farmers' participation and degree of participation in impact on ecology.

Variables		**Probability of Participation**		**Degree of Participation**	
		Coefficient	**t-Stat**	**Coefficient**	**t-Stat**
Sex of household head		0.146	1.82*	-0.179	-0.51
Age		-0.004	-1.10	0.026	2.01**
Household size		-0.021	-1.10	0.213	2.28**
Years of formal education		0.028	1.83*	0.246	3.18***
Farm size		-0.086	-0.68	-0.56	-1.13
Distance to market		-0.001	-0.19	0.043	1.69*
Access to extension services		-0.033	-0.46	-0.479	-1.50
Access to financial services		0.154	1.98**	1.27	4.02***
Off-farm income		-0.01	-2.07**	0.056	2.06**
Business network				0.065	1.57
Trust group members				0.325	1.32**
Constant		-5.425***			
Total observations		215			
Selected Observations		158			
Unselected Observations		57			
Wald Chi2 (10)		20.50			
Prob > Chi2		0.015			
Lambda	0.053				
Rho	0.125				
Sigma	0.425				

***, ** and * represent significance levels at 1%, 5% and 10%, respectively.
Source: Field Survey, 2024.

An increase household head's years of education significantly corresponded to a 24 percent increase in the degree of participating in ecological groups (**Table 5**). This is probably due to the fact that education equips farmers with the knowledge required to make informed decisions about participating in these groups. Educated farmers prefer to associate themselves with ecological groups that benefit them economically. Similarly showed that education level positively influences the degree of participation in impact on ecology by farmers. Access to finance significantly affects the degree of participation in impact on ecology. As the access to finance increases, the degree to participate in community groups increases by 13 percent ($p < 0.01$). Households headed by people with reliable sources of finance are most likely to accumulate more impact on ecology, perhaps owing to the loan repayment ability and the higher possibility of group cash contributions for ecological events.

As the distance to the nearest market increased, the degree of participation in impact on ecology increases by four percent. ($p < 0.1$). Geographically, households situated far from the market tend to face higher transaction costs and therefore seek for alternative options to reduce costs. Ecological groups minimize the effect of distance by providing farmers with relevant market information and the collective transportation of vegetable produce to markets. Similarly, it demonstrates that proximity to the market positively impacts ecological networking. Additionally, off-farm income plays a significant role in shaping the degree of involvement in impact on ecology (**Table 5**). A percent increase in off-farm income increased participation in impact on ecology by five

percent ($p < 0.05$). Financially stable farmers are more likely to engage in ecological groups that facilitate exchange of information, investment opportunities and knowledge transfer.

Trust between group members has a significant impact on participation in impact on ecology ($p < 0.05$). As trust among vegetable farmers strengthens, their involvement in ecological groups increase by 32 percent (**Table 5**). Trust plays a vital role in building and maintaining ecological relationships. One of the benefits of trust within farmers' ecological networks is that it affects their decisions to adopt sustainable agricultural practices. Generally, trust fosters greater participation in impact on ecology, which in turn positively impacts livelihood strategies and resilience to shocks.

4.5. Determinants of Vegetable Traders' Participation in Impact on Ecology

According to **Table 6**, age and trading experience significantly influence traders' likelihood of joining ecological groups at 10% significance level. Specifically, each additional year in a trader's age increases the likelihood of ecological group participation by four percent. This can be ascribed to ecological groups potentially favoring older traders who are assumed to be more mature in decision-making compared to younger traders. Older traders tend to demonstrate greater responsibility and a sense of security when participating in ecological groups. In addition, younger traders prefer not to join ecological groups because of trust issues and a lack of adherence to the rules and regulations imposed by groups. Similar results were obtained.

A longer trading history is associated with a four percent lower likelihood of involvement in ecological groups. Experienced traders may have an extensive and reliable network of input suppliers and vegetable customers, thus decreasing the probability of forming ecological groups for knowledge- and information-sharing and other collective initiatives. However, studies by contradict these findings.

4.6. Determinants of Degree of Participation in Impact on Ecology Groups among Vegetable Traders

Table 6 also highlights the factors that influence the extent of traders' involvement in ecological groups. Key determinants include the traders' gender, level of formal education, access to financial resources, business network and intensity of trust. Female traders had a 94 percent higher likelihood of participating in ecological groups ($p < 0.01$). A significant number of women in the surveyed markets were members of multiple ecological groups. This trend may stem from women's relatively limited access to credit and formal financial services, promoting greater reliance on informal ecological networks for financial support[20–23].

Table 6. Determinants of vegetable traders' participation and degree of participation in impact on ecology.

Variables		Probability of Participation		Degree of Participation	
		Coefficient	t-Stat	Coefficient	t-Stat
Sex of the trader		0.335	0.32	0.942	5.01***
Age		0.049	1.76*	0.005	0.37
Years of formal education		0.023	0.19	0.108	2.84***
Years in trading		-0.048	-1.70*	0.005	0.36
Access to finance		0.403	0.76	0.358	2.13**
Off-trade income		-0.001	-0.05	0.002	0.15
Business network				0.013	2.11**
Trust group members				0.623	4.03***
Constant	-1.55***				
Total Observations	320				
Selected Observations	233				
Unselected Observations	87				
Wald Chi2 (10)	5.69				
Prob > Chi2	0.459				
Lambda	0.623				
Rho	0.239				
Sigma	2.604				

***, ** and * represent significance levels at 1%, 5% and 10%, respectively.
Source: Field Survey, 2024.

An increase in the number of years of education led to an 11 percent increase in participation in ecological groups, a result that is statistically significant ($p < 0.01$). Education empowers traders with the knowledge to make better business decisions and effectively leverage their ecological networks for marketing their products, thereby enhancing their involvement in ecological groups. Other studies have also shown a similar relationship between the level of education and traders' decisions to join ecological groups.

Access to financial resources plays a crucial role in determining how actively traders engage in ecological groups (**Table 6**). A rise in financial access leads to a 36 percent increase in participation in ecological groups. This suggests that as traders gain more avenues for obtaining capital, their involvement in ecological group grows, largely because many rely on these groups as informal credit sources, informal credit sources, influenced by the interest rates applied[82–84].

Business networks had a notable influence on the degree of involvement in ecological groups ($p < 0.05$). As traders expand their networks, trust develops, which in turn boosts participation in ecological groups. Moreover, trust among traders had a highly significant effect ($p < 0.01$) on engagement in impact on ecology. **Table 6** also shows an increase in trust among trade members leads to a 62 percent increase in participation in impact on ecology groups. This highlights the crucial role that trust plays in business interactions. Similarly, studies affirm the significance of trust to improve ecological groups engagement among farmers and traders[85–89].

5. Conclusions and Recommendations

This study examines both, the determinants of participation and the degree of participation in impact on ecology among tomato and sweet pepper farmers and traders. Data analysis was conducted using Heckman AI sample selection model. The findings reveal that participation in impact on ecology is influenced by a range of factors, including human capital, socioeconomic conditions, and impact on ecology characteristics. Among these, access to financial resources and off-farm income have the strongest impact on farmers' involvement in ecological groups. Additional influential factors include the gender and educational background of the household head. The level of engagement within ecological groups is shaped further by age, household size, years of formal education, access to finance, proximity to markets, off-farm income, and the presence of business networks[90–94].

The paper fills the gap in ecological impact in Northern Tanzania. The future research direction is ecological impact in other African countries.

The probability of traders' engaging in impact on ecology is affected by their age and the duration of their trading experience. Likewise, the degree of traders' participation in ecological groups is influenced by gender of trader, years of formal education, access to finance, business networks, and trust. Ecological groups among vegetable farmers are formed mainly for exchange in agricultural information and cash contribution for capital and ecological events, while vegetable traders mainly utilize their groups for capital contributions within a famous system called "*kibati*".

The study concludes that impact on ecology is influenced by socioeconomic, institutional, and demographic factors but is driven by mutual trust within groups, which determines the degree of participation in ecological groups. The research findings recommend that future interventions made to improve vegetable supply chains should understand the underlying causes of impact on ecology in target areas to gear solutions that will enhance the utilization and strengthening of existing networks, but also build strong networks. Understanding the factors of impact on ecology enhances further understanding of the level of embeddedness within communities. Impact on ecology should be encouraged among vegetable farmers and traders, and interventions in the vegetable supply chain should be made in ecological groups. Through ecological groups, vegetable-producing households and traders will have improved access to markets, agricultural information, and other productive resources, resulting in financial leverage that will improve vegetable supply chain performance.

The importance of paper is in Ecological participation. Ecological participation is often endogenous (trust influences participation, but participation also builds trust). The Heckman model isolates exogenous drivers (education, access to finance) from endogenous feedback loops.

Financial access reduces liquidity constraints, enabling

group contributions. Off-farm income may reduce dependence on ecological groups (negative effect). Trust lowers transaction costs, fostering deeper engagement. Larger business networks amplify information sharing. Women often rely more on social capital due to limited formal access to resources[15–18]. Socioeconomic factors (education, finance) impact on Ecological participation and Improved ecological outcomes (sustainable practices, market access).

Author Contributions

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Confict of Interest

The authors declare that they have no conflict of interest.

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