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Economic analysis of integrated vegetable–poultry production systems in the Babati District of Tanzania

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Abstract

Background: Integrated vegetable–poultry production system has recently attracted attention both from the scientific and policy making communities for its potential contribution to food security as well as the opportunities it offers in improving the livelihoods of smallholder farmers in Tanzania. Despite the efforts made, its benefits and costs in heterogeneous and real-world settings are not fully understood. Despite the promising design of the vegetable–poultry production system, rather little is known of its profitability and its contribution to better living conditions of rural households in different real-world settings. The same applies regarding the knowledge on factors influencing the decision to adopt such an integrated system.

Methods: Using cross-sectional data collected from 250 households in Babati district of Tanzania, we employ a gross margin analysis and a logit model to evaluate the profitability and to investigate the factors influencing the decision to integrate vegetable and poultry production systems.

Results: We find that the integrated vegetable–poultry production system is more profitable than vegetable farming alone and the profitability increases as the poultry flock size increases. An integrating household should keep 18 birds to get significant higher profit than non-integrator. Furthermore, gender and education level of the household head, awareness of integration benefits, land owned, household size, off-farm income, and total income received by the household influence the decision to integrate vegetable and poultry.

Conclusion: The study strongly promotes the integration of vegetable–poultry production system and highlights the influence of gender and awareness of integration benefits on the decision to integrate vegetable and poultry. Hence, the policy implication is to empower women and provide capacity building through training and extension services such as provision of affordable and improved vegetable seeds and poultry breeds.

Keywords: Vegetable–poultry integration, Profitability, Gross margin, Logit model

Background

Attaining food and nutrition security remains a global challenge for both the developing and developed countries; however, the difference lies in the degree of severity and the share of the population affected [9, 36]. Despite the recent progress attained in nutrition and agricultural technology, close to 800 million people globally are still chronically undernourished and food insecure [13]. The 2016 Global Hunger Index report shows that one in four children under five years of age is stunted while wasting affects eight percent of these children worldwide [49].

Sub-Saharan Africa (SSA), by virtue of relying on rain-fed farming, is more vulnerable to recurrent drought, storms and flood events [23, 33]. Livestock and fishery are other important agricultural components which are

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also affected by climate change. This has a wide ramification that extend to famine, malnutrition and death in many developing nations. Tanzania has been affected by malnutrition as well as the rest of SSA. A quarter of world undernourished people amounting to 214 million live in SSA [13] which means that, 23.8% of total SSA population is undernourished [13]. Around 34.7% of children under five, and 5.5% of women aged between 15 and 49 years are considered to be underweight in Tanzania [46] while 58% and 45% suffer from iron deficiency and anemia, respectively [44].

Different international organizations such as World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), and Consultative Group on International Agricultural Research (CGIAR) have recognized the role that horticulture plays in poverty alleviation and decreasing the health disparity in Tanzania [27]. Vegetables in particular have received considerable attention and are generally produced by smallholder farmers who own less than two hectares of land [30, 50]. For instance, out of 8.8 million ha of land used in Tanzania, around 115,000 ha were allocated to vegetable production and a total of 635,000 tonnes of vegetables were produced in the year 2007/2008 [38].

Available evidence shows that, vegetable consumption contributes to households 'nutritional intake by providing additional nutrients such as vitamins, proteins and minerals [7, 24]. Moreover a daily intake of 400 g of vegetables combined with fruits could stop many chronic diseases, strokes and cancers [7, 14]. Ochieng et al. [39] find that increased consumption of traditional African vegetables has a positive and significant effect on dietary diversity of children under five years and women aged between 15 and 35 years in northern part of Tanzania. Furthermore, Uusiku et al. [47] and Weinberger & Lumpkin [51] argue that vegetables improve smallholder farmers' livelihoods, contribute a lot to their food security and enrich their nutritional status. Vegetable farming is also described as a valuable economic activity that provides income to farmers and offers employment opportunity mostly to women and young people in poor rural areas [12, 52]).

On the other hand, poultry production in rural areas is regarded as a cherished asset to local societies due to its share in poverty alleviation, provision of food, and its role in supporting gender equality [18]. For a long time, the marginalized and remote rural villages of Africa have been keeping poultry as a source of income and mainly involving women as they decide on most of household expenditures particularly food consumption [3, 18, 19]. Furthermore, Guèye [18] and Sonaiya [42] establish that over 80% of rural population in Africa keep poultry.

The demand for animal protein is expected to increase in Tanzania due to population growth that is expected to rise from the current 53.47 million to 137 million by the year 2050 [8]. This anticipated rise in demand for animal products will be met through improved poultry production and management interventions [10, 40]. The poultry sector contributes about 3 percent of the Gross Domestic Product (GDP) derived from agriculture in Tanzania, equivalent to 1% of the total national GDP [43]. However, despite the central role that the poultry plays, its potential is not yet fully explored [32, 35]. It is argued that if this sector is managed effectively and efficiently, its contribution to the national economy could be higher [32]. Further initiatives for improving agricultural practices seem necessary to render the sector more efficient and sustainable in order to respond to the foreseen food demand increases and to cushion the livelihood of the millions rural poor farmers.

The Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) is one of such initiatives implemented in Babati District, Manyara Region, Northeast Tanzania. In 2010, Babati District was reported along with other 27 Districts to have a high level of poverty and poor nutritional status in Tanzania [21]. This raised a number of programs in Babati that promoted production and consumption of nutritious food. Africa RISINGis a program funded by United States Agency for International Development (USAID) and seeks to provide options that contribute to rural poverty alleviation and improve the nutrition standards and the general wellbeing of rural farmers by increasing vegetable and rural poultry production. One of the initiatives within the program is to promote integration of vegetable and poultry production systems. Vegetable–poultry integration is viewed as an alternative to the conventional farming system aiming to increase their productivity and household consumption of micro-nutrient rich foods.

Vegetable–poultry integration is proposed and supported by different scholars as one of the promising ways to significantly improve the overall food security and the nutritional status of the agricultural-dependent households. For example, more benefits could be derived when vegetable farming is associated with poultry in an integrated farming approach. This is a position strongly supported by Akteruzzaman et al. [5], arguing that there are more returns for investment when poultry is integrated with vegetable farming. The integration provides an opportunity for vegetable residues to provide feed to poultry while poultry supplies the needed minerals[1] to vegetables [2, 20]. The manure derived from poultry is an

[1] The mineral from poultry manure are mainly nitrogen (N = 2.94%), phosphoric acid (P2O5 = 3.22%) and potassium oxide (K2O = 2.03%) which represent a significant percentage of common commercial fertilizers [28].

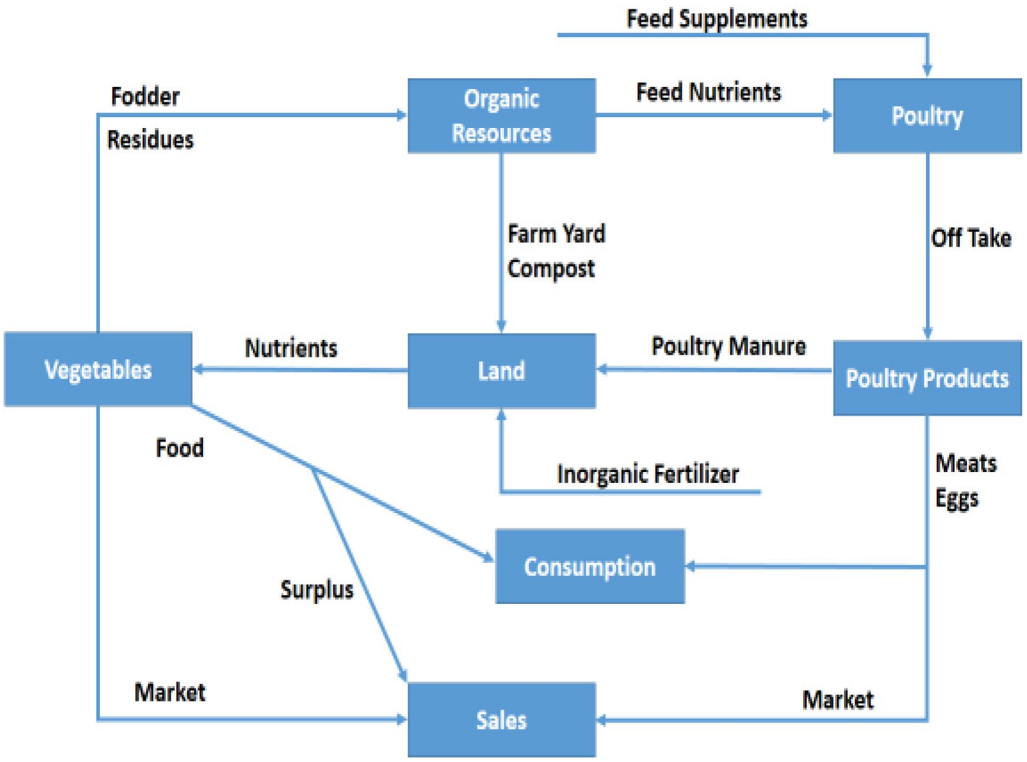

Fig. 1 Schematic representation of the elements of vegetable–poultry integration system (source: own illustration adapted from Thorne [45] p. 2)

important organic fertilizer for vegetable and relatively cheaper compared to chemical fertilizers. Hochmuth et al. [20] assert that the waste from poultry speeds up the mineralization process, improves the soil structure and moisture holding capacity, therefore improving soil fertility and subsequently increasing farm profitability.

Figure 1 demonstrates the elements of vegetable–poultry integration and their interactions within this farming system.

From Fig. 1, there are three key interfaces in vegetable–poultry integration system that make the integration successful. These include vegetable–poultry, poultry-land and land-vegetables interactions. The vegetables produced are consumed at the household level and surpluses are taken to market hence generating income to the household. Vegetable residues are fed to poultry together with non-vegetable feed supplements. The feed from vegetables are rich in nutrients contributing to poultry productivity. The organic resources not used as feed are decomposed and used in land as compost or farmyard manure. In turn, poultry generates a range of products such as meat and eggs that are either consumed or sold in the market for cash. Furthermore, poultry produces the manure that improve the soil quality for vegetable growth, and this increases yield. As a result, the integrated system recycles the resources and promises food security and additional income to the household.

Despite the promising design of the vegetable–poultry production system, rather little is known of its profitability and its contribution to better living conditions of rural households in different real-world settings. The same applies regarding the knowledge on factors influencing the decision to adopt such an integrated system. This study intends to partially close these gaps particularly focusing on the role of gender and awareness of benefits from vegetable and poultry (V–P) integration. This paper also informs on different ways of integration in order to achieve significant benefits. Analyzing profitability and adoption factors of a production system continues to be pertinent for policy as it gives clear acumens into farming system and its capacity to efficiently use farm resources. The analysis of such integrated production system is carried out to allow for policy recommendations regarding its adoption and scaling to other regions in SSA to address poverty, food and nutrition challenges for people living in rural areas.

The remaining parts of the paper are arranged as follows: the Analytical framework is in the second section. Section three presents the data and descriptive analysis while the results of the study and their discussions are in

the fourth section. We conclude with main findings and policy implications in section five.

Methods and materials

Analytical framework

The utility maximization theory within the agricultural household model originally presented by Strauss (1986) is applied to assess the economic benefits of vegetable–poultry integration to the rural households. A utility maximizing farmer i chooses to integrate vegetable–poultry only if the random utility of integrating is greater than that of not integrating; that is, $U_I^*(\pi) > U_N^*(\pi)$ or $U_I^*(\pi) - U_N^*(\pi) > 0$. Since the utilities are not observable, their difference is represented by a latent variable U_i^* depending on a group of socio-economic and institutional factors determining the profit of either integration or no-integration (X_i). Following the adoption studies by Asfaw et al. [6] and Feleke and Zegeye [15], the random utility function becomes:

$$U_i^* = X_i^{'}\beta + u_i \cdots i = 1, 2, \ldots, N \tag{1}$$

where $X_i^{'}$ is a vector of explanatory variables explaining integration decision, β is a vector of parameters to be estimated and u_i is a random error term, assumed to be independent and distributed as $u_i \sim$ NID (0, 1).

When the choice of the farmer is known, the observable part of vegetable–poultry integration can be presented by a binary variable (y_i) related to U_i^* as:

$$y_i = \begin{cases} 1 \text{ if } U_I^*(\pi) > U_N^*(\pi) \\ 0 \text{ otherwise} \end{cases}. \tag{2}$$

Specifically, a logit model is employed to examine the determinants of vegetable–poultry integration among smallholder farmers. We represent the logit model to estimate the probability of farmers' decision to integrate vegetable and poultry production systems as:

$$P\left(y_i = 1 \middle| X_i^{'}, \beta\right) = F(X_i^{'}\beta) = \frac{e^{X_i^{'}\beta}}{1 + e^{X_i^{'}\beta}}, \tag{3}$$

$$P\left(y_i = 0 \middle| X_i^{'}, \beta\right) = 1 - F(X_i^{'}\beta) = 1 - \frac{e^{X_i^{'}\beta}}{1 + e^{X_i^{'}\beta}} = \frac{1}{1 + e^{X_i^{'}\beta}}, \tag{4}$$

where y_i is the response for the *ith* household. This means that $y_i = 1$ for a vegetable–poultry integrating household and $y_i = 0$ for non-integrating household. $X_i^{'}$ is a vector of explanatory variables determining the probability to integrate, F is the standard normal cumulative distribution function and β is a vector of parameter estimates. Following the model setup above, the independent variables are those that affect the profits of either the integrated or non-integrated system and are selected based on the theory and previous literature. They comprise household and farm characteristics [15, 17, 31], resource ownership [6, 37], institutional and access related [6, 37], and the agro-climatic zone [15, 17]. Specific motivation and expected effect on the probability to integrate is explained below.

It is important to note that the direct interpretation of coefficients of the estimates from the logit model above is not possible except their signs only. Therefore, the marginal effects are calculated to estimate the change in probability of integrating vegetable and poultry as a result of a unit change in a specific explanatory variable.

In addition, gross margin (GM) analysis is employed to calculate the profitability of the integrated vegetable–poultry production systems. GM analysis is often used to determine the profitability of a proposed farming technology or approach [4, 26]. It is represented by the formula:

$$\text{GM} = \text{TR} - \text{TVC}, \tag{5}$$

where GM is the gross margin; the difference between the total revenue and total variable cost; TR is the Total Revenue; the product of output price and quantity of output produced; TVC is the Total variable cost; the difference between the total cost and total fixed cost.

To compute the cost of vegetable–poultry inputs, we consider the prevailing market price for purchased inputs and for household self-supplied inputs. Furthermore, the profitability of the integrated system is calculated by summing up the GM of vegetable production and the GM of poultry production.

Study area and data collection

This paper is based on the household survey conducted in June 2017 in Babati District of Manyara region in Tanzania. Babati District covers a surface area of 5609 km^2 out of it, 4969 km^2 is the total land area while the remaining 640 km^2 is covered by water [29]. The data in this study originates from five villages where Africa RISING is operational namely,Bermi, Galapo, Matufa, Seloto, and Shaurimoyo. The data was collected as part of the partneship arrangement between the Advisory Service on Agricultural Research for Development/German Agency for International Cooperation (BEAF/GIZ[2]) and World Vegetable Center(WorldVeg), Eastern and Sourthen Africa region[3] under the framework of the Africa RISING program in Tanzania. Tablets were used for real-time data

[2] BEAF/GIZ funded the author to stay at WorldVeg for a period of 6 months.

[3] WorldVeg funded the entire data collection costs under Africa RISING program.

Table 1 Data definitions and descriptive statistics

Variables	Data description	Non-integrators (1) ($N=110$)		Integrators (2) ($N=140$)		*t*-test (1–2)
		Mean	SD	Mean	SD	
Gender of head	1 if household head (HH) is male	0.845	0.363	0.836	0.372	0.208
Marital status of head	1 if HH is married	0.691	0.464	0.836	0.372	−2.739***
Household size	Number of household members	4.745	2.304	5.571	1.855	−3.139***
Education	Number of years of formal education of the household head	6.654	2.758	7.329	2.551	−2.001**
Age of head	Age of the HH in years	46.373	14.691	48.186	11.362	−1.101
Land owned (ha)	Total land owned in hectares	0 .916	0 .866	1.420	1.334	−3.436***
Off-farm income	1 if household have access to off-farm income sources	0 .464	0 .501	0 .386	0 .489	1.238
Total income	Total household income in USD	125.003	111.658	177.983	178.064	−2.727**
Credit	1 if household access credit	0.191	0 .395	0 .221	0.417	−0.588
Extension	1 if household access extension service	0 .6	0 .492	0 .736	0.442	−2.290**
Attending V–P training	1 if any household member ever attend training about V–P integration	0 .391	0 .491	0 .550	0 .499	−2.521**
Awareness of V–P benefits	1 if the household is aware of the benefits of V–P	0.854	0.354	0 .964	0 .186	−3.154***
Bermi	1 if farmer is from Bermi	0.155	0.363	0.236	0.426	−1.594
Galapo	1 if farmer is from Galapo	0.264	0.443	0.157	0.365	2.084**
Matufa	1 if farmer is from Matufa	0.255	0.438	0.157	0.365	1.918*
Seloto	1 if farmer is from Seloto	0.164	0.372	0.221	0.417	−1.141
Shaurimoyo	1 if farmer is from Shaurimoyo	0.164	0.372	0.229	0.421	−1.273

***, **, * Denote the level of significance of difference in means at 1%, 5%, 10%, respectively

collection through surveyCTO (Survey platform for electronic data collection) and the semi-structured questionnaires were filled by both integrators and non-integrators of vegetable–poultry production systems. The data was analyzed using STATA14.

We used a multi-stage sampling procedure where the first stage involves choosing Babati District in Manyara due to the pre-determined sites based on the Africa RISING Eastern and Southern Africa projects sites. The second stage is the selection of five villages out of total villages in Babati District. The five listed villages are the only villages in Babati that work with World Vegetable Center, Eastern and Sourthen Africa region. The third stage was a random sampling of households (both integrators and non-integrators).

The questionnaire captured valuable information on various aspects including household characteristics, land ownership, land allocated to vegetables, source of income and ownership of poultry and access to credit and extension service. Furthermore, data on inputs used such as labor, manures, chemical fertilizers and other variables such as productions, consumptions, sales and prices were collected.

In this paper, integrators are regarded as farmers who are producing vegetables, feeding vegetables to poultry, applying poultry manure to fertilize the vegetables and own at least five adult birds. On the other hand, non-integrators are described as vegetable producers that may own less than five adult birds or none. The treshold number of birds was selected based on the quantity of manure that can be produced. Poultry One Guide to Raising Backyard Chickens (POGRBC) establish that, the manure produced by five to ten chickens is enough to fertlize the vegetable garden as one chicken can produce around 45 lb of manure annually [41]. Furthermore, on average, households in Tanzania own five to twenty birds per household [43]; hence we chose the minimum number of five birds to define integrators.

Descriptive analysis and expected effects

The definitions and sample statistics for the variables used in the logit estimations are presented in Table 1. The farmer, farm and institutional variables theoretically expected to influence the household's decision to adopt vegetable–poultry integration have been included in the empirical logit model. Marital status has been included because married head with larger household size has higher labor availability [17]. Likewise, a more educated head of household has better skills and access to information and therefore, is in a better position to evaluate the relevance of vegetable–poultry integration. The exact relationship of age of household head on integration decision is unclear since younger farmers are generally innovative and risk takers, but they may lack the

farming experience [6]. Similarly, the effect of gender of the household head is ambiguous because male headed households often have superior farming capacity and better access to land, while women in developing countries are more involved in vegetables and poultry sectors than men, implying that they can influence this decision. Therefore, the ultimate effect of gender and age on decision to integrate vegetable with poultry is still an empirical question [6].

Results indicate that 56% of farm households are integrators while 44% are non-integrators of vegetable–poultry production systems. The two groups are significantly distinguishable in terms of farmer, farm and institutional characteristics. For instance, on average, integrators are married and have larger household size compared to non-integrators ($p < 0.01$). Similarly, integrators' group is headed by a relatively educated household heads with 7.3 years of formal schooling compared to 6.6 years of non-integrators ($p < 0.05$). This may imply that households headed by educated farmer may have higher skills and better ability to access information that can positively influence vegetable–poultry integration.

Due to input/output market failures, the farm-households' production is affected by its level of wealth or poverty. This study uses land size owned, off-farm income and total income received by household as proxy for assets and resource ownership. Mariano et al. [31] find that farm size influences the adoption of integrated crop management practices while Namwata et al. [37] find a positive influence of household income on adoption of improved agricultural technology. Land area is decreasing in Tanzania due to population growth and the density is projected to increase further by the year 2050 [8]. It is expected that the size of land owned by the household will positively influence the integration whereby households with lager land holding may allocate a portion of their land to vegetables and poultry. On average, land owned by integrators is 1.42 hectares bigger than 0.912 hectares of non-integrators. Off-farm income and total income is likely to influence vegetable–poultry integration in a positive way by providing the needed funds for the initial vegetable–poultry investment. Moreover, integrators earn on average a total income of United States, Dollar (USD) 177.98 which is higher than that of non-integrators (USD 125).

All institutional and access related variables are expected to have a positive relationship with vegetable–poultry integration. This is because farmers who have access to extension services and information on new agricultural technologies are more likely to adopt these technologies [6, 17]. Therefore, we expect that farmers who have access to extension services and have attended vegetable–poultry integration trainings are more likely to integrate. This is the same case for farmers who have access to credit as lack of starting capital seriously challenges the adoption of new technologies [37]. On average, 74% of the integrators have access to extension services compared to 60% of non-integrators. Further results show that 55% of integrators and 39% of non-integrators had attended at least one vegetable–poultry related training in the past one year presiding the survey. Information access is likely to influence household's decision to adopt vegetable–poultry integration. Thus, households who have knowledge and are aware of benefits from vegetable–poultry integration are expected to integrate. Most of the households seem to be aware of benefits from vegetable–poultry integration as 96.4% of integrators and 85.4% of non-integrators are aware of these benefits.

Table 2 Logit model—factors influencing the probability of V–P integration in Babati district

Variables	dy/dx	Std. Err	Z
Gender of household head	−0.277**	0.120	−2.32
Marital status of household head	0.230**	0.106	2.16
Household size	0.024	0.015	1.63
Education level of household head	0.019*	0.011	1.67
Age of household head	−0.0005	0.003	−0.19
Land owned	0.089***	0.032	2.76
Off-farm income	−0.161***	0.060	−2.67
Total income	0.0006**	0.0003	2.37
Credit	−0.015	0.0709	−0.21
Attending V–P training	0.074	0.063	1.18
Extension	0.030	0.065	0.46
Awareness of V–P benefits	0.236**	0.110	2.15
Bermi	0.046	0.095	0.48
Galapo	−0.184**	0.089	−2.08
Matufa	−0.082	0.088	−0.93
Shaurimoyo	0.067	0.094	0.71

***, **, * denote the level of significance of difference in means at 1%, 5% and 10%, respectively

Empirical results and discussions

Factors influencing the probability to integrate vegetable–poultry production systems

The maximum likelihood estimates of the logit model of integrating vegetable–poultry production systems in Babati district are presented in Table 2. The Chi-squared test statistic of the model is significant at 1% level implying the combined significance of vegetable–poultry integration variables. The quantitative impact of each factor that influence vegetable–poultry integration is determined by calculating the marginal effect of each explanatory variable on the probability of integrating vegetable–poultry. By using the margin command and

delta method approach in STATA, the coefficients of average marginal effects as well as the standard errors are estimated.

The household characteristics that significantly influence the decision to adopt vegetable–poultry integration are gender, marital status, and education level of the household head and the household size. The gender of the head is negatively related to the probability of integrating poultry into vegetable farming. The probability of integration decreases by 27.7 percentage points if the household is headed by a male ($p < 0.05$). This could be because more women are involved in poultry activities than men. Family poultry production in developing countries is regarded as a sector for women and more than 70% of producers are women [3, 11].

The marital status of the head of the household influences vegetable–poultry integration as anticipated. The likelihood of integrating poultry into vegetables increases by 23 percentage points if the head of the household is married ($p < 0.05$). The married farmers are more likely to integrate because of required quantity of food that is increased as a result of marriage. These results are consistent to those of Namwata et al. [37] and Voh et al. [48] reporting a positive relationship of marriage and adoption of improved agricultural technologies in Tanzania and Nigeria. Expectedly, more educated farmers are more likely to integrate vegetables with poultry than less educated ones all other things equal. This reflects that education improves an individuals' capacity to process information and to adopt appropriate technologies to cope with farming constraints. The finding is consistent with earlier literature that consider education as a substitute for access to information and place the more educated farmers in a position to evaluate the importance of new technologies faster [17, 25]. The marginal effects of this variable indicate that an increase in formal education level by one year increases the probability of integrating vegetable–poultry by 1.9 percentage points ($p < 0.1$).

Farm assets and resource ownership variables influence adoption of integrated vegetable–poultry production systems. Farmers who own a bigger land size are more likely to integrate vegetable–poultry than those with smaller land. One hectare increase in land owned by the household increases the probability of integrating vegetable–poultry by 8.9 percentage points ($p < 0.01$). This is probably due to increasing demand for land for vegetable–poultry integration. Most rural farmers dedicate a large portion of their land to the production of staple food crops such as maize and rice. Therefore, farmers with large areas of land can diversify their production by allocating an additional portion of the land to the integration of both farming systems, a choice that is not available to farmers who possess a small area of land [25, 31, 34]. This presents a serious challenge to vegetable–poultry integration promoters in Babati District since most farm households are small scale farmers who hold an average of about 1.2 hectares of land.

We find that having an off-farm income source negatively influences the decision to integrate vegetable with poultry ($p < 0.01$). The probability of integrating vegetable with poultry decreases by 16.1 percentage points if the farmer has an off-farm income source. The availability of off-farm income may reduce the consideration (or value) that households give to vegetable–poultry integration as they rely on the other sources of income. The common sources of off-farm income include small businesses such as shops run by households' members in village market centers and salaries from regular jobs (mostly primary teachers and nurses). However, the total income that a given household gets is positively related to the vegetable–poultry integration ($p < 0.05$). This result is similar to previous findings by Namwata et al. [37] and Fernandez-Cornejo et al. [16] who find that households with high income are more likely to adopt new farming practices.

Awareness of the benefits of vegetable–poultry integration influences the decision to adopt this integrated system ($p < 0.05$). The likelihood of integrating poultry into vegetable increases by 23.6 percentage points if the farmer is aware of the benefits derived from an integrated production system. This finding is supported by Abara and Singh [1] who prove that, small scale farmers are more likely to adopt new farming practices if returns from conventional and the alternative farming practices are significantly different.

Lastly, the fixed effects location variables are important in explaining vegetable–poultry integration. Households in Galapo village are less likely to integrate vegetable with poultry production than those in Seloto village. The probability of integrating vegetable–poultry decreases by 18.4 percentage points if the household resides in Galapo village ($p < 0.5$) due to the differences in weather conditions as other villages have less rainfall and are dry compared to Galapo.

Profitability of vegetable–poultry integration

We compute vegetable GM for both integrators and non-integrators followed by poultry GM for integrators who are keeping poultry. The total variable cost (TVC) of vegetables is composed of a various cost components namely seed and transplanting, nursery management, compost, poultry manure, fertilizer, pesticide, and labor costs (Table 3). Highest are mostly labor, compost and pesticides costs while the poultry manure cost is the lowest incurred by non-integrators. Integrators are using the self-produced poultry manure in vegetable production, which saves them the cost as they do not need to buy

Table 3 Average vegetable and poultry input costs and production quantity (*N* = 250). Source: own calculation based on the data collected

Variables	Non-integrators (1) (*N* = 110)		Integrators (2) (*N* = 140)		*t*-test (1–2)
	Mean	SD	Mean	SD	
Seed cost (USD)	2.838	3.891	3.129	4.189	− 0.562
Nursery management cost (USD)	3.154	5.017	3.936	9.073	− 0.813
Compost cost (USD)	7.967	22.489	6.416	19.532	0.583
Fertilizer cost (USD)	3.555	6.960	3.927	7.586	− 0.399
Pesticide cost (USD)	4.812	5.204	4.631	5.635	0.260
Labor cost (USD)	35.124	38.483	45.092	50.593	− 1.713*
Poultry manure cost (USD)	2.427	3.348	0	0	1.453
Parent stock cost (USD)			5.524	9.405	
Total feeds cost (USD)			19.641	25.835	
Disease control cost (USD)			4.151	3.941	
Poultry labor cost (USD)			3.091	3.640	− 0.413
Vegetable production quantity (kg)	827.738	1231.736	896.235	1354.147	
Yield (kg/ha)	7903.232	7517.613	10,575.940	13,295.090	− 1.885*

* Denotes the level of significance of difference in means at 10%

it. However, they would have sold their poultry manure and get revenue from it. Therefore, integrators' opportunity cost of using poultry manure in vegetable production cancels out the lost revenue from selling the poultry manure.

The total revenue (TR) from vegetable production is computed as the product of vegetable price per kilogram and quantity of vegetable produced in kilograms. We calculate the vegetable GM per household[4] and per hectare of vegetable farming for a season of 6 months.

Vegetable TVC per household is 67.1 USD for integrators and 57.5 USD for non-integrators while the seasonal TVC per hectare is USD 599.6 and USD 688.1 for non-integrators and integrators, respectively (Table 4). The average seasonal TR per household is USD 203.7 and USD 213.5 for non-integrators and integrators, respectively. Based on GM per hectare for one season, vegetable production is beneficial for both groups, however, integrators get around 18% (USD 170.9) more than the benefits received by non-integrators.

On the other hand, the poultry TVC comprise costs of parent stock (initial chicks or chickens), total feed cost (feeds and feed preparation), disease control cost (medication and vaccinations), as well as labor costs. Feeding is the highest cost of poultry production constituting about 60.6% of TVC followed by the parent stock cost (17%), disease control (13%) and labor costs (9.4%) (Table 3). This result reaffirms previous findings showing that feed costs constitute the biggest proportion of the total cost of poultry production [22, 53]. Poultry total revenue is computed by summing up all the revenue from poultry and egg sales and the estimated value of poultry self-produced manure. All calculations are based on a 6 month production period.

On average, an integrating household owns about 16 birds and TVC is USD 32.4 indicating an average TVC per bird of USD 2.6 (Table 5). The average poultry TR is USD 83.9 which means that an integrating household gets an average TR of USD 6.8 per bird. As a result, the poultry GM per household is USD 51.5 and one bird can generate a GM of USD 4.2 in the 6-month production period implying that poultry farming is profitable.

Based on our findings in both Tables 4 and 5, we compute the profitability of vegetable–poultry integration system by summing up the GM from vegetable and poultry production. We consider four different

Table 4 Average costs, revenues and gross margins per hectare from vegetable production (*N* = 250)

Variables (in USD)	Non-integrators (mean)	Integrators (mean)
Vegetable area (in hectares)	0.108	0.106
Total variable cost (TVC)	57.539	67.132
TVC per hectare	599.589	688.086
Total revenue (TR)	203.729	213.483
TR per hectare	1566.116	1825.610
Gross margin (GM) per household	146.190	146.351
GM per hectare	966.527	1137.524

[4] GM per household was calculated based on land each household allocated to vegetables.

Table 5 Average costs, revenues and gross margins from poultry production (*N* = 140)

Variables (in USD)	Integrators (Mean)
Flock size (number)	15.75
Total variable cost (TVC)	32.407
TVC per bird	2.575
Total revenue (TR)	83.946
TR per bird	6.802
Gross margin (GM) per household	51.538
GM per bird	4.227

scenarios to calculate the profits of vegetable–poultry production system in this paper. The first scenario is the vegetable–poultry GM per household which is computed as a sum of seasonal vegetable GM per household and poultry GM per household. In the second scenario, we compute the vegetable–poultry GM by summing up the vegetable GM per household and poultry GM from a flock size of 16 birds, which is the mean size of poultry owned by integrators. Scenario three is the sum of vegetable and poultry GM per household from flock size of 20 birds. This number is chosen based on TALIRI report that on average, households in Tanzania own between 5 and 20 flock size per household [43]. The last scenario presents the sum of vegetable GM per hectare and poultry GM from a flock size of 200 birds, which is the maximum number of birds owned in the sample. We perform the *t*-test to test the significance in means of GMs' differences between integrators and non-integrators (Table 6).

In all the four scenarios, integrators have higher GM than non-integrators since integrators get extra revenue from the poultry that is not earned by non-integrators. However, it is important to note that, the GM differences between the two groups are significant in two of the four scenarios. Scenario 1 and 2 do not significantly distinguish the profits earned by households from both groups while scenario 3 and 4 show that, the integrating households get higher GM and they are significantly different at 10% and 1% significance levels, respectively.

Based on our findings, it is important to know the minimum number of birds per household and per hectare that an integrating household should keep to earn significant profits than a non-integrator. We perform different simulations and find that an integrating household should keep at least 18 birds to get significant higher profits than non-integrator. This implies that an integrating household with poultry flock size of 18 birds or more will significantly get higher profits since the profitability is proportional to the poultry flock size. Furthermore, we find that the flock size of 102 birds integrated into one hectare of vegetable farming will produce profits to integrators that are significantly higher than that of non-integrators.

Conclusion and policy implications

Vegetable–poultry integration is seen as one of the promising ways to improve the overall food security and nutritional status of the agricultural-dependent households. This is partly because integration can reduce malnutrition by providing additional vitamins, minerals, and proteins that are often in short supply for poor households. In addition to its nutritional benefits, the production system can play a potential role in poverty alleviation through provision of income and women empowerment in rural areas if it can be designed profitably. Consequently, the profitability was an essential issue in many policy discussions in SSA countries. Therefore, we identify the factors influencing the farmers' decision to integrate and analyze profitability of the vegetable–poultry integration system among rural households in Tanzania.

We employ the logit model to examine the factors influencing the decision to integrate vegetable–poultry production systems and use the gross margin analysis (GM) to calculate the profitability of integrated vegetable–poultry production systems. The results reveal that, the more educated household heads, female headed, households that are aware of benefits from integration, and households with larger land holdings are more likely to adopt vegetable–poultry integration

Table 6 Profitability of V–P integration (*N* = 250)

Variables (in USD)	Non-integrators (1) *N* = 110	Integrators (2) *N* = 140	*t*-test (1–2)
V–P GM per household (scenario 1)	146.190	197.890	− 1.135
V–P GM per household/16 birds (scenario 2)	146.190	213.987	− 1.476
V–P GM per household/20 birds (scenario 3)	146.190	230.987	− 1.825*
V–P GM per hectare/200 birds (scenario 4)	966.527	1982.978	− 2.687***
V–P GM per household/18 birds	146.190	222.442	− 1.652*
V–P GM per hectare/102 birds	966.527	1568.706	− 1.652*

***, * Denote the level of significance of difference in means at 1% and 10%, respectively

system. Therefore, we recommend the promotion of farmers' education and capacity building through village community-based organizations (CBOs), farmer field schools and cooperatives to improve their knowledge on new technologies that increase their profits.

Moreover, we suggest the policy measures that empower women to scale up the integrated production capacity since they dominate the poultry production sub-sector. Besides, we recommend the promotion initiatives that increase farm productivity by providing affordable improved vegetable seeds and poultry breeds to integrating households. These scaling initiatives should be combined with sensitization of the communities about the benefits of vegetable–poultry integration through trainings and provision of better extension services. Furthermore, we recommend stakeholders to scale good agricultural practices to increase vegetable production and intensify the poultry production as the flock size determines the magnitude of profits.

Abbreviations

Africa RISING: Africa Research in Sustainable Intensification for the Next Generation; BEAF: Advisory Service on Agricultural Research for Development; CBO: Community-based organizations; CGIAR: Consultative Group on International Agricultural Research; FAO: Food and Agriculture Organization of the United Nations; GDP: Gross Domestic Product; GIZ: German Agency for International Cooperation; GM: Gross margin; HH: Household head; IFAD: International Fund for Agricultural Development; IFSNAR: Integrated Food Security and Nutrition Assessment Report; IPCC: Intergovernmental Panel on Climate Change; NSCA: National Sample Census of Agriculture; POGRBC: Poultry One Guide to Raising Backyard Chickens; SSA: Sub-Saharan Africa; TALIRI: Tanzania Livestock Research Institute; TDHS-MIS: Tanzania Demographic and Health Survey and Malaria Indicator Survey; TNNS: Tanzania National Nutrition Survey; TR: Total revenue; TVC: Total variable cost; USAID: United States Agency for International Development; USD: United States, Dollar; V–P integration: Vegetable and poultry integration; WFP: World Food Program; WHO: World Health Organization.

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Authors' contributions

I confirm that, all authors have greatly contributed in generation of this manuscript. HN contributed to the conception, design, tool preparation, collection of data, analysis and interpretation of data, and drafting of the manuscript. OJ contributed to the conception, design, interpretation of data, drafing and revision of the manuscript. HT contributed to the design, interpretation of data, drafing and substansive revision of the manuscript.

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Availability of data and materials

The data that support the findings of this study are available from World Vegetable Center but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of World Vegetable Center.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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