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Edited by:

Dr. Philip Daninga

Dr. Bertha Losioki

Dr. Luzabeth Kitali

Dr. Adili Zella

Dr. Gideon Bulengela

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Comparative Analysis of Objective and Subjective Measurement Methods of Horticulture Yields per Unit Area: Insights from Smallholdings of Kilolo District, Tanzania.

Adili Y. Zella[1], Luzabeth, Kitali[2] and Rose I Mbwete[3]
[1]Department of Economics, Faculty of Leadership and Management Sciences, The Mwalimu Nyerere Memorial Academy (MNMA), Dar es Salaam - Tanzania
[2]Department of Geography and History, Faculty of Arts and Social Sciences, MNMA, Dar es Salaam - Tanzania
[3]Department of Arts and Social Sciences, MNMA, Zanzibar – Tanzania

Corresponding author email: adil.zellah@mnma.ac.tz

Abstract

This research was undertaken to analytically compare the objective and subjective methods of measuring yields per unit area in the study area. The total number of 34 small scale horticulture farmers were involved in the study. Questionnaire and interview were used to collect information regarding to size of production fields and horticulture crop yields through recalling. GPS and crop cutting methods were used to determine the actual size and yields respectively. Quantitative method of data analysis was applied such that data were summarized using summary statistics (frequencies and percentages) with the aid of Microsoft excel software system and the Statistical Package for Social Sciences (SPSS) version 20. Also linear regression analysis was performed to test the relationship between field size and yields. The findings revealed that 78% of the surveyed farmers overestimated the size of their horticulture fields while 22% underestimated. The actual size of fields overestimated ranges from 20m^2 to 200m^2 and 50m^2 to 390m^2 for staggered and simultaneous harvest horticulture crops respectively. Underestimation of filed sizes ranges from 50m^2 to 500m^2 and 100m^2 to 125m^2 for staggered and simultaneous harvest horticulture crops respectively. On the other hand the findings reveal that 81% of farmers, overestimated yields and 19% underestimated. Overestimated of yields range from 22kgs to 881kgs and 52kgs to 297kgs for staggered and simultaneous harvest horticulture crops respectively while underestimation ranges from 24kgs to 273kgs and 184kgs to 526kgs for staggered and simultaneous harvest horticulture crops respectively. Additionally, the findings revealed that there is a weak positive relation between filed size and the yields of selected horticulture crops under subjective measurement methods. This has been evidenced by P-values of linear regression models which shows values greater than 0.05. This implies that field size and yields obtained from subjective methods were either overestimated or underestimated. The study concluded that measuring field size and yields of horticulture crops by using subjective methods results into significant distortions. Given this conclusion, it is thus recommended that scientific investigation should be directed towards investigating the mechanisms that can be used to improve the accuracy of subjective methods in measuring agriculture productivity.

Key words: Horticulture crops, objective methods, subjective methods, yields per unity area.

1. Introduction

Measuring productivity in agriculture has emerged a topic of concern in recent decades. This has been attributed by the increasing projects aiming at improving agricultural productivity (Fermont and Benson, 2011; Singh, 2015). This aspirations of measuring agricultural productivity has further gained momentum due to the increase of new variety of seeds and other agriculture inputs with the aim of increase productivity (Tchamou, 2018; Maruoda et al., 2013). This trend led to the emergence of various methods that are used to measure agricultural productivity in order to investigate the extent to which these new innovations in agriculture are effective (GSARS, 2018). Researchers in agriculture productivity employ those methods based in the purpose of research and the urgency of the need of conducting particular research (Ludena, 2010). Some of these methods have been applied long time ago while others have emerged in recent years (Odhiambo and Nyangito, 2003).

On the basis of accuracy, methods of measuring agriculture productivity in relation to field size has been categorized into two major groups (Abay et al., 2019; Desiere and Jollife 2018; Dillon et al., 2019). The first category includes objective measurement methods which mainly include crop cutting method for yield estimation and GPS for filed size determination (Fermont and Benson, 2011). Due to systematic procedures and accuracy of the tools used in objective methods of measuring agriculture productivity, these methods have been recommended by many scientists (Wollburg et al, 2021; Keita 2009). The second category of agriculture productivity measurement include subjective methods. Such methods are farmer recall and farmer inquiry (Beegle and Carletto, 2012). They involve farmers' estimations of the field size as well as the yield harvested over time by recalling information basing on their experience in agriculture over a certain period of time (Bevis and Barrett, 2019; Biemer et al., 2011).

Though many scientists recommend the use of objective methods in measuring agricultural productivity, subjective methods are also still applied in some circumstances (Carletto, 2011; FAO, 2018). For instance, when information on agricultural productivity is needed over extensive area covering a country or region it is difficulty to apply objective methods instead subject methods area applied. Therefore, despite the limitations of agriculture productivity measuring methods, both are useful in estimating productivity on the basis of the size of the area to be surveyed, the accuracy and the resources available including time and money ((FAO, 2018; Beegle and Carletto 2012).

Despite the application of both objective and subjective methods of estimating agriculture productivity, there is scant information related to agricultural productivity in developing countries, sub-Saharan Africa in particular (AfDB, 2011; AGRA, (2018). This implies that, measurement of agricultural productivity has not given great attention as it deserves (Carletto, 2013). This situation call upon the need for paying greater attention on this important aspect of agriculture in order to uplift further development of the sector (Kuteesa and Kyotalimye, 2019).

Like many other agricultural zones of Tanzania, information on measures of agriculture productivity in southern highlands of Tanzania is not adequately document (Cochrane and D'Souza, 2015). The situation is more serious on horticulture crops were measurement of productivity have been given less efforts compared to staple food crops such as cereals and tubers (Malongo, 2017). The little attention on horticulture crops productivity measurements is contributed by number of factors. First is the complex nature of horticulture crops such that they can be grown throughout the year. Second is short shelf life of most horticulture crops (URT, 2018). Third, some of horticulture crops can be harvested several times in one field and fourth is fragmentation of land under horticulture crop production (Carletto 2011). Due to these factors, it is somehow difficulty to estimation productivity of such crops. This intern results into inadequate information related to quantity produced and sold (MMA, 2017).

Although there are some difficulties in measuring the productivity of horticulture crops in many agro ecological zones of Tanzania including southern highlands, some efforts are in place. Some of researchers has shown interest on studying horticulture productivity in the area. They commonly employ subjective methods such as inquiry and recall. These subjective methods have been blamed to yield inaccurate data. It is from this grounds the present study was conducted to compare the validity of two methods were objective methods such as GPS for field size determination and crop cutting for yields estimation were used alongside subjective methods. Knowing the extent to which the two methods vary in the same data sets will provide the blue print for accurate estimations of horticulture productivity. This in turn will ensure equitable development of horticulture sub sector while meeting the growing nutritional needs of the community alongside increasing farmers' income through horticulture production.

2. Materials and Methods

2.1 Study Area and Justification.

The research was carried between April and August 2021in Kilolo district. The district which has an area of 7,874 km^2 is one of the four districts in Iringa region. The district lies between Latitude 7.0^0 and 8.3^0 south of the equator and between Longitude 34^0 and 37^0 east of the Greenwich. Kilolo district borders Mpwapwa and Kilosa districts to the north, Kilombero District to the east, Iringa District council to the west and Mufindi District to the south. Administratively, the district is divided into three divisions namely Kilolo, Mahenge and Mazombe, 24 wards, 106 villages and 555 hamlets with 46,002 households. According to 2012 census the district had a population of 218,130 out of whom 105,856 were males and 112,272 were females.

The district have three agro-ecological zones classified on the basis of the altitude. The first zone is highland zone which include the extension of the Udzungwa Mountains, with altitudes of 1,600 to 2,700m above sea level, annual precipitation of 1,000-1,600mm and the temperatures below 15^0C. The mild conditions and volcanic soils favour the cultivation of maize, peas, bananas, wheat, potatoes, horticulture crops and tea. The second agro-ecological zone is the midland zone which crosses the Mazombe Plains at 1,200-1,600m above sea level. Temperatures range from 15^0 to 20^0C with annual rainfall greater than 500mm but less than 1000mm. Soils are clay and sandy which allow the production of crops such as maize, sunflower, onions, sweet potatoes, tomatoes, cowpeas, beans and fruits. The third agro-ecological zone is the lowland zone which covers the Mahenge Plains at 900-1,200m above sea level. Temperatures range from 15^0 to 29^0C while rainfall is unreliable and averaged 500-600mm. Soils are red and sandy. Due to unreliable rainfall the zone is famous for drought tolerant crops such as sorghum, millet and cassava as well as irrigated paddy, leafy vegetables, tomatoes, onions and tropical fruits.

Kilolo District has been selected due to its potential for horticulture production due to conducive climate that permit the growth of multiple range of horticulture crops. The most horticulture crops grown in the study area are tomatoes, onions, cabbages, carrot, eggplant, okra and other types of fruits and leaf vegetables. Moreover, Kilolo is famous for the production of multiple range of fruits such as water melon, pears, guava and pawpaw. The horticulture farming system has been practiced in the study for a long time as one of the source of livelihoods. In recent years, horticulture farming system has been increasing due to commercialization of the horticulture crops. Therefore, horticulture farming system has become a main sources of livelihoods among households in the study area.

2.2 Sampling Techniques and Sample Size

Sampling process involved three main procedures. The first step was purposefully sampling which was used in selection of wards with accordance to agro-ecological zones. Three wards were selected namely Ilula, Ruaha Mbuyuni and Bomalang'ombe located in highland zone, midland zone and lowland zone respectively. The selection of wards on the basis of agro-ecological zone was done purposefully. The second step was selection of study villages where purposeful sampling was also applied. One village was selected from each ward due to the intensity and the level of commercialization of the horticulture farming system. Three villages were selected namely Ilula, Ruaha Mbuyuni and Bomalang'ombe.

After selection of study wards and villages, the next step was to identify the sample frame from which the sample was obtained. The sample frame was derived from the population size of three selected villages where horticulture farming systems is predominant. The list of farmers was obtained from villages authorities and their total sum was obtained and used to calculate the sampling frame. The total number of households from three selected villages was 1,453 with slight variation were Ilula had (564) households, Ruaha Mbuyuni (418) and Bomalang'ombe (418). Statistical analysis requirements approach was used where the formula for calculating sample frame as developed by Cohen (2014) was used as follows.

$$S = \frac{X^2 . NP(1-P)}{d^2(N-1)+X^2P\ (1-P)}$$ ………………………………………………………………… Equation 1

Where X = Z-score (1.96 for 95% confidence level)
P = population portion (50% for maximum sample)
d = degree of accuracy (0.05 for 95% confidence level)
N = population size

$$S = \frac{(1.96)^2\ (1{,}454)0.15\ (1-0.15)}{0.05^2(1.454-1)+(1.96)^2\ 0.15\ (1-0.15)} = 172$$ ………………………… Equation 2

Therefore, the sample frame was 172 households which is 12% of the total population under study. The next step was to compute the specific sample size of the study. This was obtained on the basis of the percentage of the sample frame were 20% of the sample frame which is equal to 34 individual farmers were used as a sample. After obtaining the sample size the next step was to compute the sample size for each village. This was done on the basis of the sample frame for each village as shown hereunder.

$n_h = \frac{N_h}{N} n$ ....

Equation 3

Whereby n_h = proportional sample of each village

N_h = the number of households of each village, and

N = the total number of households in all villages and n is the total sample size of the study population.

Therefore, the sample frame for each village was as follows.

Ilula = $\frac{564}{1,454} 172 = 67$ Households

Ruaha Mbuyuni = $\frac{472}{1,454} 172 = 56$ Households

Bomalang'ombe = $\frac{418}{1,454} 172 = 49$ Households

After obtaining the sample frame for each village which were 67, 56 and 46 households for Ilula, Ruaha Mbuyuni and Bomalang'ome respectively the next step was obtain the sample of specific farmers who will be visited in each village. This was done by finding the percentage of each village in relation to 34 farmers as follows.

Ilula = $\frac{67}{172} 100 = 38.9/100 * 34 = 13$ Households

Ruaha Mbuyuni = $\frac{56}{172} 100 = 32.6/100 * 34 = 11$ Households

Bomalang'ombe = $\frac{49}{172} 100 = 28.5/100 * 34 = 10$ Households

The next step was to group the farmers into two groups for each village on the basis of types of horticulture grown weather it is staggered or simultaneous gravest crop. Finally, the sample for each village was obtained as hereunder.

Table 1: The overall sample size

Sn	Village	Staggered Harvest Crop Farmers	Simultaneous Harvest Crop Farmers	Total
1	Ilula	7	6	13
2	Ruaha Mmbuyuni	5	6	11
3	Bomalang'ombe	5	6	10
	Total	**17**	**17**	**34**

Source: Field Survey (2021)

This study confined itself to investigate the relationship between field sizes and yields of major horticulture crops in the study area. Six crops were selected and grouped into two categories. The first category includes staggered horticulture crops which include tomato, eggplant and okra. These crops can be harvested several times before the plant complete its life cycle. The second category is simultaneous harvest horticulture crops which include cabbage, onion and carrot. These crops are harvested only once and the plant is cleared after harvest. Therefore, this study uses six horticulture crops to represent several other crops under these two categories. These six crops have been selected due to their potential in the study area and constitute large volume of horticulture crops in many parts of Southern Highlands of Tanzania including Kilolo.

2.3 Study design, techniques and tools

This is a quarsi-experimental study design in which quantitative and qualitative methods were applied. Also experiments were used to measure the harvested crops through crop cutting method and quantify by using standard measurements. The GPS was also used to depict the actual size of production fields. Questionnaire survey, in-depth interview, and field observation are techniques employed in this study. A self-administered structured close-ended questionnaire, observation checklist, and checklist for semi-structured in-depth interviews were tools that used to collect data by recall and farmer enquiry methods. All these tools were tested and revised accordingly before administered to the study population. The questionnaire was prepared in English and then translated into Kiswahili since the target population use Swahili as their main language. Similarly interview guides were administered in Kiswahili in order to insure that adequate information is collected. In-depth interviews were recorded with digital audio recording device under the permission of the respondents.

2.4 Data collection, analysis and presentation

Data collection process was carried though field survey. It involved surveying of household heads who were visited in their fields were farming activities are taking place in study villages. During survey, household heads were given questionnaires to fill in by responding to the questions. During households survey the researchers also observed the conditions of horticulture in the fields. Also data collection process involved visiting the horticulture production fields of selected farmers. In this process the actual area field used in production was measured by using GPS and data were converted in square meter and they were recorded. It was the January 2021. The second visit was conducted on May 2021 were the yields for selected horticulture crops were collected. The third visit was carried on September 2021 were information on yields were collected from though farm crop cut method. The fourth visit was carried out on December 2021 were information of farm/field size and yields were collected though farmer recall or estimations.

In order to ensure close follow-up of selected fields, the researcher requested mobile phone numbers for respective farmers. This ensured effective communication between the researcher and the farmers. The farmers were contacted frequently by the researcher in order to know the date for harvest. Knowing the date of harvest, the researcher visited the farmer and quantify the produce though crop cutting method and recorded the information. During the last visit the respective farmers were provided with questionnaire to fill in information related to size of the fields and yields obtained though recalling. Then the information obtained though farmer recall were compared with those collected by GPS and crop cutting methods.

Quantitative data from the survey was analysed quantitatively using SPSS version 20 software. Analysis was done with descriptive statistics model which computed frequencies, crosstabs, tables and graphs were shown. Also though SPSS inferential statistical analysis applied using linear regression model to test the relationship between yields of selected horticulture and size of farms/fields. Quantitative data has been presented in forms of tables while qualitative data has been presented in narration format.

3. Results and discussion

3.1 Characteristics of the Respondents

A sample of 34 smallholder farmers were involved in the study. All respondents were horticulture farmers, growing horticulture crops for both commercial purposes and for subsistence. 13% of surveyed farmers were aged 20 to 29 years old, 33% were aged 30 to 39 years old. While 46% were aged 40 to 49 years old and 18% of surveyed respondents were aged above 50 years old (Figure 1). 64% of the respondents were males while 36% of respondents were females. This shows unequal land ownership among sex such that men were found to have more access to land than females.

The education level of most farmers was generally low. Only 16% of had attained the secondary level formal education, 73% had completed primary education and 11% had never attended school. Understanding characteristics of respondents such as age, sex, education level is important in this study since such attributes have either direct or indirect in influence in horticulture production. For instance, age can influence agriculture though determining the nature of labour involved in production, sex can determine land ownership and land tenure and education level can determine farmers' behaviour in accepting new farming practices.

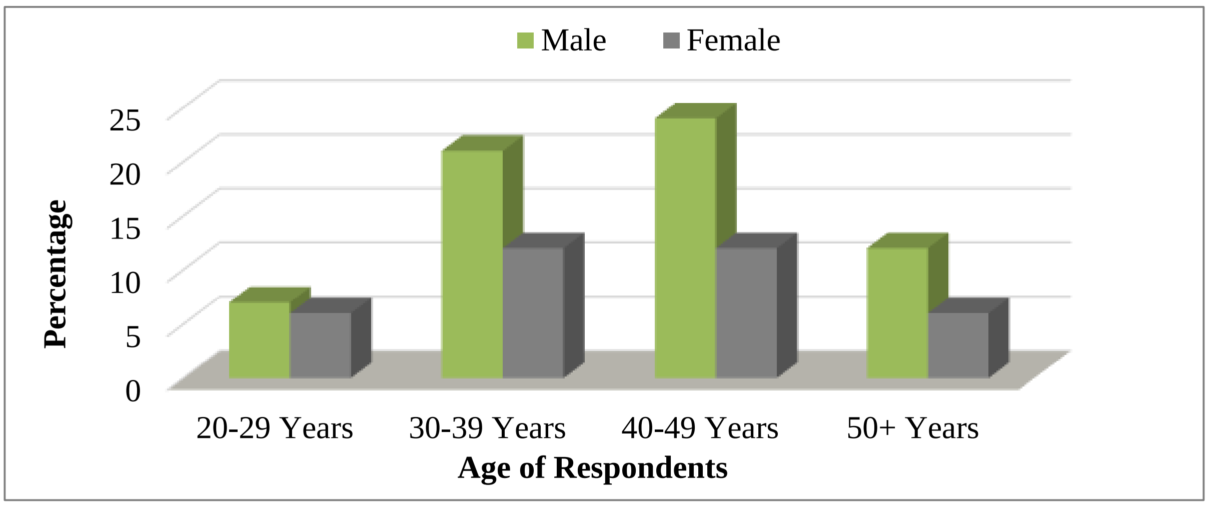

Figure 1: Age and Sex of the Respondents
Source: Field Survey (2021)

3.2 Overall Variation of Field Size and Yields for Staggered Horticulture Crops in the Study Area

The study noted that there is a variation between the sizes of the fields measured by GPS and those obtained through farmers' recall among farmers growing selected staggered harvest horticulture crops namely tomato, eggplant and okra. Either 70.6% of selected farmers under this category of horticulture crops overestimated the sizes of their production fields. The remaining 29.4% of farmers under this category of crops underestimated the size of their production fields. The study further revealed that there is a pattern of overestimation and underestimation were farmers owning small fields overestimate both area size and yields while those with relatively large fields tends to underestimate area and yields (Table 2-7).

The findings further revealed that overestimated field sizes of staggered harvest horticulture crops ranges from $20m^2$ to $200m^2$ while yields overestimation ranges from 16kgs to 881kgs. This implies that by average farmer who cultivate staggered horticulture crops overestimated the size of production field by the average of $98m^2$ and yields by 103kgs. On the other hand, the findings show that underestimation of production fields by farmers who cultivated staggered horticulture crops ranges from $50m^2$ to $500m^2$ while yields underestimation range from 24kgs to 273kgs. This implies that by average farmers who underestimated the production fields they underestimated by $76m^2$ and yields by 94kgs (Table 2-7). This wide range of overestimation and underestimation of production fields by staggered harvest horticulture crops in the study area is attributed by land fragmentation of production sites which are mostly located in the valley bottoms. This resulted to scattered ownership of production fields which makes difficulty for most of the farmers to correctly recall the sizes of their fields.

3.2.1 Variation of Tomato Yield per Unit Area in both Objective and Subjective Methods

The study revealed that there is a variation of both field sizes and yields of tomato across the data collected though GPS method as one of the objective method and those collected though farmers recall as example of subjective method. Similarly, the finding reviled the variation of yields of tomato across the data collected by crop cutting method and those collected by farmer recall method. The finding portrays that 76% of all surveyed farmers overestimated the size of their production fields though recalling while 24% underestimated the size of their fields. The analysis further reveals that 10% of surveyed famers overestimated their production fields by 3% to 6% of their actual sizes of their fields, 27% overestimated by 7% to 10% of the actual size of their fields. On the other hand, 31% of all surveyed farmers overestimated the size of their fields by 11% to 14% the actual size of their fields and 3% of surveyed farmers overestimated their production fields by 15% to 18% of the actual size of their fields (Table 2).

On the other hand, the findings revealed that 17% of all surveyed farmers underestimated the size of their fields of production by 5% to 8% of the actual size as compared to the GPS readings. Either, 5% of all surveyed farmers underestimated the size of their production fields by 9% to 12 % of the actual size of their fields. While 7% of the farmers underestimated their production fields by 13% to 15% of the actual size of their fields (Table 2). This variation of overestimation and underestimation of production fields is explained by differences in memorizing capacity. Some of the farmers reported sizes of fields which are closely to the actual size of their fields. These farmers revealed capacity high capacity of recalling information related to horticulture production.

With regard to tomato yields, the findings revealed that there is a significant variation of yields between crop cutting and farmer recall methods. The findings show that all surveyed farmers (100%) who cultivated tomato they overestimated yields. The overestimations ranges from 54kgs to 881kgs. The analysis further reveal that 24% overestimated tomato yields by 5% to 10% while 11% of surveyed farmers overestimated tomato yields by 11% to 16%. The remaining 41% and 24% of surveyed farmers overestimated yields by 17% to 22% and 23% and 28% respectively. This extent of overestimated is associated by the nature of this crop which allow consecutive harvest within production season up to six times before the plant complete its life cycle.

Table 2: The Variation of Tomato Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Tomato Yield per Unit Area in both Objective and Subjective Methods								
Surveyed Farmers by Series	**Field Size GPS (m^2)**	**Field Size by Recall (m^2)**	**Variation of Field size (m^2)**	**%Variation of Field size**	**Yield Crop Cutting (Kgs)**	**Yield by Recall (Kgs)**	**Variation of Yield (Kgs)**	**%Variation of Yield**
1	450	500	+50	11%	912	1100	+188	21%
2	500	550	+50	10%	986	1040	+54	5%
3	535	600	+65	12%	997	1200	+203	20%
4	550	650	+100	18%	1114	1300	+186	8%
5	600	670	+70	12%	1105	1400	+295	27%
6	620	590	+30	5%	1437	1600	+163	11%
7	650	700	+50	8%	1472	1600	+128	9%
8	700	720	+20	3%	1458	1800	+222	9%
9	750	850	+100	13%	1578	1800	+300	15%
10	800	900	+100	13%	1946	2300	+354	18%
11	900	990	+90	10%	1794	2200	+406	23%
12	1500	1700	+200	13%	2217	2800	+583	26%
13	1700	1800	+100	6%	2554	3150	+596	23%
14	2100	2000	-100	5%	3264	3800	+536	16%
15	2900	2500	-400	14%	3652	4250	+598	16%
16	3500	3000	-500	14%	4027	4700	+673	17%
17	4200	3600	-400	10%	4319	5200	+881	20%

Source: Field Survey (2021)

3.2.2 Variation of Eggplant Yield per Unit Area in both Objective and Subjective Methods

For the case of eggplant, the study also revealed that there is a variation of both field sizes and yields across the data collected though GPS and those collected though farmers recall. Similarly, the finding revealed the variation of yields of eggplant across the data collected by crop cutting method and those collected by farmer recall method. The finding portrays that 71% of all surveyed farmers overestimated the size of their production fields while 29% underestimated the size of their fields. The analysis further reveals that 24% of surveyed famers overestimated their production fields by 6% to 9% of their actual sizes of their fields, 41% overestimated by 10% to 13% of the actual size of their fields while, 6% of all surveyed farmers overestimated the size of their fields by 14% to 17% the actual size of their fields (Table 3). On the other hand, the findings revealed that 18% of all surveyed farmers underestimated the size of their fields of production by 5% to 10% of the actual size as compared to the GPS measurements. Either, 11% of all surveyed farmers underestimated the size of their production fields by 10% to 15 % of the actual size of their fields (Table 3).

With regard to eggplant yields, the findings revealed that there is also a significant variation of yields between crop cutting method and farmer recall method. The findings show that 64% of all surveyed farmers overestimated yields with the ranges from 22kgs to 156kgs while 36% of all surveyed farmers underestimated yields with the range from 122kgs to 273kgs. The analysis further reveals that 18% of surveyed framers overestimated yields by 7% to 12% while 47% of surveyed farmers overestimated by 13% to 18% (Table 3). On the other hand, the findings revealed that 24% of all surveyed farmers underestimated eggplant yields by 8% to 10% while 11% of surveyed farmers underestimated yield by 11 to 13% (Table 3). This pattern of overestimation and underestimation of eggplant yields is associated by the nature of this crop which allow consecutive harvest within production season up to five times before the plant complete its life cycle. This prolonged harvest made difficulty for the farmers to precisely estimate yields as most of them were not recording anywhere the harvested quantity.

Table 3: The Variation of Eggplant Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Eggplant Yields per Unit Area in Both Objective and Subjective Methods								
Surveyed Farmers by Series	**Field Size GPS (m^2)**	**Field Size by Recall (m^2)**	**Variation of Field size (m^2)**	**%Variation of Field size**	**Yields Crop Cutting (Kgs)**	**Yield by Recall (Kgs)**	**Variation of Yields (Kgs)**	**%Variation of Yields**
1	225	245	+20	9%	318	340	+22	7%
2	230	255	+25	11%	327	390	+63	19%
3	240	265	+25	10%	358	410	+52	15%
4	310	330	+20	6%	475	560	+85	18%
5	400	460	+60	15%	562	660	+98	17%
6	460	500	+40	9%	614	720	+106	17%
7	480	540	+60	13%	734	850	+116	16%
8	610	680	+70	11%	843	920	+77	9%
9	730	800	+70	10%	956	1100	+144	15%
10	805	890	+85	11%	994	1250	+156	16%
11	820	890	+70	10%	1123	1200	+77	7%
12	910	970	+60	7%	1387	1200	-187	13%
13	1100	1050	-50	5%	1469	1350	-119	8%
14	1350	1260	-90	5%	1512	1370	-122	8%
15	1660	1550	-110	7%	1924	1750	-174	8%
16	1720	1470	-250	15%	2157	1950	-207	10%
17	2010	1750	-260	13%	2373	2100	-273	12%

Source: Field Survey (2021)

3.2.3 Variation of Okra Yield per Unit Area in both Objective and Subjective Methods

Just like other selected staggered harvest horticulture crop, the results for okra revealed that there is a significant variation of field sizes of okra across the data collected though GPS method as objective method and those collected though farmers recall as subjective method. Similarly, the finding reviled the variation of yields of okra across the data collected by crop cutting method and those collected by farmer recall method. The finding indicates that 76% of all surveyed farmers overestimated the size of their production fields though recalling while 24% underestimated the size of their fields. The analysis further reveals that 41% of surveyed famers overestimated their production fields by 8% to 10% of their actual sizes of their fields, 29% overestimated by 11% to 13% of the actual size of their fields. On the other hand, the findings revealed that 18% of all surveyed farmers underestimated the size of their fields of production by 6% to 8% of the actual size as compared to the GPS readings. Either, 12% of all surveyed farmers underestimated the size of their production fields by 9% to 11 % of the actual size of their fields (Table 4).

Furthermore, findings revealed that there is also a significant variation of okra yields between crop cutting method and farmer recall method. The findings show that 71% of all surveyed farmers overestimated yields with the ranges from 16kgs to 71kgs while 29% of all surveyed farmers underestimated yields with the range from 24kgs to 57kgs. The analysis further reveals that 41% of surveyed framers overestimated yields of okra by 7% to 12% while 29% overestimated by 11% to 13% (Table 4). On the other hand, the findings revealed that 18% of all surveyed farmers underestimated eggplant yields by 6% to 8% while 12% underestimated yield by 9% to 11% (Table 4). This pattern of overestimation and underestimation of okra yields is associated by the fragmentation of most of okra field. During survey it was observed that most of okra plots were scattered a situation which made difficulty to the farmers to estimate okra yields accurately.

Table 4: The Variation of Okra Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Okra Yields per Unit Area in Both Objective and Subjective Methods								
Surveyed Farmers by Series	Field Size GPS (m^2)	Field Size by Recall (m^2)	Variation of Field size (m^2)	%Variation of Field size	Yields Crop Cutting (Kgs)	Yield by Recall (Kgs)	Variation of Yields (Kgs)	%Variation of Yields
1	260	290	+30	12%	226	210	+16	7%
2	310	350	+40	13%	238	220	+18	19%
3	355	390	+35	10%	261	240	+21	15%
4	370	400	+30	8%	285	260	+25	18%
5	410	450	+40	10%	319	290	+29	17%
6	425	470	+45	11%	278	310	+32	17%
7	480	530	+50	10%	289	330	+41	16%
8	500	550	+50	10%	294	350	+56	9%
9	545	600	+55	11%	306	370	+64	15%
10	590	650	+60	10%	319	390	+71	16%
11	615	680	+65	11%	358	420	+62	7%
12	650	700	+50	8%	411	450	+39	13%
13	810	760	-50	6%	484	460	-24	8%
14	870	800	-70	8%	507	470	-37	8%
15	990	870	-90	9%	549	490	-49	8%
16	1020	920	-100	10%	562	510	-52	10%
17	1090	980	-110	10%	587	530	-57	12%

Source: Field Survey (2021)

3.3 Overall Variation of Field Size and Yields for Simultaneous Horticulture Crops in the Study Area

The study shows that there is a variation between the sizes of production fields measured by GPS and those obtained through farmers' recall among farmers who grow three selected simultaneous harvest horticulture crops namely cabbage, onion and carrot. Similarly, among this category of farmers 70.6% overestimated sizes of their production fields while 29.4% underestimated their fields. Looking at the pattern of over and underestimation the results show that most owners of small fields have a tendency of overestimating the size of their farms while owners of relatively large fields tend to underestimate their fields (Table 5 & 7).

Moreover, the findings revealed that overestimated field sizes range from 50m^2 to 390m^2 with the average of 122m^2 while yields overestimate ranges from 68kgs to 297kgs with the average of 182kgs. This implies that by average farmer who cultivate staggered horticulture crops overestimated the size of production field by the average of $122m^2$ and yields by 182kgs. On the other hand, the results show that underestimation of production fields by farmers who cultivate simultaneous horticulture crops ranges from $100m^2$ to $125m^2$ with an average of $112m^2$ while underestimation of yields ranges from 197kgs to 526 with an average of 287kgs (Table 5 -7). This implies that by average farmers who underestimated the production fields they underestimated by $112m^2$ and yields by 287kgs. The findings show that large size of production fields and yields are distorted by subjective method. This distortion affects the quantification of agriculture productivity, horticulture in particular both in micro and macro levels.

3.3.1 Variation of Cabbage Yield per Unit Area in both Objective and Subjective Methods

The results for cabbage revealed that there is a significant variation of field sizes of Cabbage across the data collected though GPS method as objective method and those collected though farmers recall as subjective method. Similarly, the finding reviled the variation of yields of Cabbage across the data collected by crop cutting method and those collected by farmer recall method. The findings indicate that 82% of all surveyed farmers overestimated the size of their production fields though recalling while 18% underestimated the size of their fields. The analysis further reveals that 24% of surveyed famers overestimated their production fields by 5% to 7% of their actual sizes of their fields, 29% overestimated by 8% to 10% of the actual size of their fields and 24% overestimated by 11% to 13%. On the other hand, the findings revealed that 23% of all surveyed farmers underestimated the size of their fields of production by 11% to 8% of the actual size as compared to the GPS readings (Table 5).

Furthermore, findings revealed that there is also a significant variation of cabbage yields between crop cutting method and farmer recall method. The findings shows that 82% of all surveyed farmers overestimated yields with the ranges from 16kgs to 71kgs while 18% of all surveyed farmers underestimated yields with the range from 93kgs to 297kgs. The analysis further reveals that 29% surveyed farmers overestimated yields of cabbage by 7% to 10% while 29% overestimated by 11% to 14% and 18% overestimated by 15% to 18% (Table 5). On the other hand, the findings revealed that 24% of all surveyed farmers underestimated cabbage yields by 6% to 8% while 12% underestimated yield by 9% to 12% (Table 5). This pattern of overestimation and underestimation of cabbage yields is associated by the nature of the crop. Cabbage is one of the bulk vegetable which makes difficulty when it comes to measurements.

Table 5: The Variation of Cabbage Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Cabbage Yields per Unit Area in Both Objective and Subjective Methods								
Surveyed Farmers by Series	Field Size GPS (m^2)	Field Size by Recall (m^2)	Variation of Field size (m^2)	%Variation of Field size	Yield Crop Cutting (Kgs)	Yield by Recall (Kgs)	Variation of Yields (Kgs)	%Variation of Yields
1	670	600	+70	10%	892	1050	+158	18%
2	650	700	+50	8%	887	980	+93	10%
3	700	750	+50	7%	995	1100	+105	11%
4	750	850	+100	13%	1047	1200	+153	15%
5	800	900	+100	13%	1109	1300	+191	17%
6	850	850	+100	12%	1263	1400	+137	11%
7	900	960	+60	7%	1384	1500	+116	10%
8	950	1000	+50	5%	1461	1600	+139	10%
9	1000	1080	+80	8%	1502	1700	+198	13%
10	1100	1200	+100	9%	2148	2300	+152	7%
11	1200	1300	+100	8%	1949	2150	+201	10%
12	1300	1450	+150	13%	2322	2600	+278	12%
13	1400	1500	+100	7%	2603	2900	+297	11%
14	1500	1400	-100	7%	3478	3150	-328	9%
15	1600	1500	-100	6%	3732	3300	-432	12%
16	1700	1600	-100	6%	4212	3700	-512	12%
17	1800	1700	-100	6%	4426	3900	-526	12%

Source: Field Survey (2021)

3.3.2 Variation of Onion Yield per Unit Area in both Objective and Subjective Methods

The results for onion revealed that there is a variation of field sizes of across the data collected though GPS method as objective method and those collected though farmers recall as subjective method. Similarly, the finding reviled the variation of yields of onion across the data collected by crop cutting method and those collected by farmer recall method. The findings indicate that all (100%) of all surveyed farmers overestimated the size of their production fields. The analysis further reveals that 24% of surveyed famers overestimated their production fields by 5% to 6% of their actual sizes of their fields while 76% overestimated by 7% to 8% of the actual size of their fields (Table 6).

Furthermore, findings revealed that there is also a variation of onion yields between crop cutting method and farmer recall method. The findings show that all (100%) of all surveyed farmers overestimated yields with the ranges from 68kgs to 223kgs. The analysis further reveals that 29% surveyed farmers overestimated yields of onion by 4% to 6% while 71% overestimated by 7% to 9% (Table 6).

This pattern of overestimation and underestimation of onion yields is associated by the nature of the crop. Onion is one of the less bulk vegetable thus it can be easily measure by using standard measurement units such as kilograms or though sacks. Thus it was somehow easy for the farmers to estimate the yields.

Table 6: The Variation of Onion Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Onion Yields per Unit Area in Both Objective and Subjective Methods								
Surveyed Farmers by Series	**Field Size GPS (m^2)**	**Field Size by Recall (m^2)**	**Variation of Field size (m^2)**	**%Variation of Field size**	**Yields Crop Cutting (Kgs)**	**Yield by Recall (Kgs)**	**Variation of Yields (Kgs)**	**%Variation of Yields**
1	665	720	+95	8%	722	790	+68	9%
2	740	810	+70	9%	771	840	+69	9%
3	820	870	+50	6%	898	970	+72	8%
4	860	910	+50	7%	1047	1064	+86	8%
5	855	990	+60	6%	1211	1300	+89	7%
6	1230	1300	+70	6%	1309	1400	+91	7%
7	1620	1700	+80	5%	1352	1450	+98	7%
8	1775	1900	+125	7%	1488	1590	+102	7%
9	1920	2100	+180	9%	1490	1610	+100	7%
10	2105	2300	+195	9%	1697	1800	+103	6%
11	2200	2400	+200	8%	1923	2100	+177	9%
12	2535	2750	+215	9%	2272	2400	+128	6%
13	2650	2900	+250	9%	2493	2600	+107	4%
14	2920	3200	+275	9%	2699	2900	+201	7%
15	3200	3500	+300	9%	2897	3100	+203	7%
16	3840	4200	+360	9%	3383	3600	+217	6%
17	4310	4700	+390	9%	3677	3900	+223	6%

Source: Field Survey (2021)

3.3.3 Variation of Carrot Yield per Unit Area in both Objective and Subjective Methods

The results for cabbage revealed that there is a significant variation of field sizes of carrot across the data collected though GPS method as objective method and those collected though farmers recall as subjective method. Similarly, the finding reviled the variation of yields of carrot across the data collected by crop cutting method and those collected by farmer recall method. The findings indicate that 76% of all surveyed farmers overestimated the size of their production fields though recalling while 24% underestimated the size of their fields. The analysis further reveals that 53% of surveyed famers overestimated their production fields by 8% to 11% of their actual sizes of their fields, 18% overestimated by 12% to 15% of the actual size of their fields and 5% overestimated by 16% to 19%. On the other hand, the findings revealed that 24% of all surveyed farmers underestimated the size of their fields of production by 5% to 7% of the actual size as compared to the GPS readings (Table 7).

Furthermore, findings revealed that there is also a significant variation of cabbage yields between crop cutting method and farmer recall method. The findings show that 76% of all surveyed farmers overestimated yields with the ranges from 52kgs to 193kgs while 24% of all surveyed farmers underestimated yields with the range from 184kgs to 207kgs. The analysis further reveals that 18% surveyed farmers overestimated yields of carrot by 6% to 7% while 58% overestimated by 8% to 9% and 18% (Table 7). On the other hand, the findings revealed that 24% of all surveyed farmers underestimated cabbage yields by 6% to 8% (Table 7). This pattern of overestimation and underestimation of carrot yields is also associated by the nature of the crop. Carrot is one of the less bulk vegetable thus it can be easily measure by using standard measurement units such as kilograms or though sacks. Thus it was somehow easy for the farmers to estimate the yields.

Table 7: The Variation of Carrot Yield per Unit Area in both Objective and Subjective Methods in the Study Area

Carrot Yields per Unit Area in Both Objective and Subjective Methods								
Surveyed Farmers by Series	**Field Size GPS (m^2)**	**Field Size by Recall (m^2)**	**Variation of Field size (m^2)**	**%Variation of Field size**	**Yield Crop Cutting (Kgs)**	**Yield by Recall (Kgs)**	**Variation of Yields (Kgs)**	**%Variation of Yields**
1	530	610	+80	15%	868	920	+52	6%
2	545	640	+95	17%	886	950	+64	7%
3	600	690	+90	15%	917	990	+73	8%
4	680	750	+70	10%	946	1023	+77	8%
5	685	780	+95	14%	1161	1250	+89	8%
6	715	800	+85	12%	1276	1370	+94	7%
7	745	820	+75	10%	1347	1450	+103	8%
8	810	890	+80	10%	1385	1490	+105	8%
9	905	1000	+95	10%	1373	1500	+127	9%
10	995	1100	+105	11%	1561	1700	+139	9%
11	1040	1150	+110	11%	1786	1950	+164	9%
12	1175	1300	+125	11%	1919	2100	+181	9%
13	1285	1390	+105	8%	2207	2400	+193	9%
14	1560	1450	-110	7%	2453	2650	-197	8%
15	1610	1490	-120	7%	2573	2800	-207	8%
16	1785	1670	-115	6%	2699	2900	-201	7%
17	2325	2200	-125	5%	2916	3100	-184	6%

Source: Field Survey (2021)

3.4 Yield and Field Size Relation for Staggered and Simultaneous Harvest Horticulture Crops under Objective and Subjective Methods in the Study Area

3.4.1 Yield and Field Size Relation for Staggered Harvest Horticulture Crops under Objective Methods in the Study Area.

Linear regression analysis was used to test if field size measured through objective method (GPS) explain the yields of three selected staggered harvest horticulture crops measured through crop cutting method. The regression analysis reveals strong positive relation between field size and yields of three selected staggered harvest horticulture crops. For the case of tomato, the results indicated that the model explained 91.6% ($R^2 = 0.916$) of the variance and that the model was significant $F (1, 15) = 46.99$, $P = 0.042$. I similar vein, the results of linear regression for eggplant revealed that the model explained 89.7% ($R^2 = 0.897$) of the variance and that the model was significant $F (1, 15) = 31.95$, $P = 0.030$. On the other hand, the results for okra revealed that the model explained 88.8% ($R^2 = 0.880$ of the variance and that the model was statistically significant $F (1, 15) =28.93$, $P = 0.34$ (Table 8).

Table 8: Yield and Field Size Relation for Staggered Harvest Horticulture Crops under Objective Methods

Model	Coefficients	Multiple R	R Squared	P-value	F	Sign
Intercept	1047.4816	0.9575	0.9168	0.0244	46.9952	0.0426
Field Size (Tomato)	0.8666			0.0360		
Intercept	609.9916	0.9476	0.8979	0.0233	31.9534	0.0309
Field Size (Eggplant)	0.5824			0.0346		
Intercept	225.4973	0.9386	0.8809	0.0002	28.9398	0.0342
Field Size (Okra)	0.2734			2.5134		

a. Dependent variable: Horticulture Yields, b. Predictors: (Field Size) df: 1, 15; Confidence Level 95%, n=17.

Source: Field Survey (2021)

3.4.2 Yield and Field Size Relation for Staggered Harvest Horticulture Crops under Subjective Methods in the Study Area.

Liner regression analysis was used to test if the field size and yields of three selected staggered harvest horticulture crops measured through subjective method (recall) have statistical relations. The same fields which were previously measured through objective methods were revisited. The results for linear regression for tomato revealed that the model explained 49.05% ($R^2 = 0.495$) of the variance and that the model was statistically insignificant F (1, 15) = 19.28, P = 0.762. Either, the results of the linear regression for eggplant revealed that the model explained 47.98% (R^2 = 0.4798) of the variance and that the model was statistically insignificant F (1, 15) = 17.77, P = 0.637. While the results for okra revealed that the modal explained 45.64% (R^2 = 0.456) of the variance and that the model was statistically insignificant F (1, 15) = 15.90, P = 0.056. (Table 9).

Table 9: Yield and Field Size Relation for Staggered Harvest Horticulture Crops under Subjective Methods

Model	Coefficients	Multiple R	R Squared	P-value	F	Sign
Intercept	1130.1524	0.5109	0.4906	0.0582	19.2862	0.0762
Field Size (Tomato)	0.0886			0.0463		
Intercept	634.6600	0.6632	0.4799	0.0232	17.7795	0.06370
Field Size (Eggplant)	0.0775			0.0037		
Intercept	376.0723	0.4964	0.4565	0.0413	15.9047	0.05680
Field Size (Okra)	0.0366			0.0427		

a*. Dependent variable: Horticulture Yields, b. Predictors: (Field Size) df: 1, 15; Confidence Level 95%, n=17.*

Source: Field Survey (2021)

3.4.3 Yield and Field Size Relation for Simultaneous Harvest Horticulture Crops under Objective Methods in the Study Area.

Linear regression analysis was used to test if field size measured through objective method (GPS) explain the yields of three selected simultaneous harvest horticulture crops measured through crop cutting method. The regression analysis reveals strong positive relation between field size and yields of three selected simultaneous harvest horticulture crops. For instance, the results for cabbage indicated that the model explained 99.4% (R^2 = 0.994) of the variance and that the model was significant F (1, 15) = 59.27, P = 0.016. Meanwhile, the linear regression results for onion indicate that the model explained 98.7% (R^2 = 0.987) of the variance and that the model was statistically significant F (1, 15) = 47.49, P = 0.033. Furthermore, the results for carrot revealed that the model explained 97.4% (R^2 = 0.974 of the variance and that the model was statistically significant F (1, 15) =57.10, P = 0.024 (Table 10).

Table 10: Yield and Field Size Relation for Simultaneous Harvest Horticulture Crops under Objective Methods

Model	Coefficients	Multiple R	R Squared	P-value	F	Sign
Intercept	14.3942	0.9971	0.9943	0.0449	59.2752	0.01681
Field Size (Cabbage)	1.1238			0.0317		
Intercept	55.5149	0.9935	0.9871	0.0499	47.4996	0.03387
Field Size (Onion)	0.7899			0.3874		
Intercept	65.8821	0.9872	0.9746	0.0719	57.1095	0.02406
Field Size (Carrot)	0.6979			0.0224		

a. Dependent variable: Horticulture Yields, b. Predictors: (Field Size) df: 1, 15; Confidence Level 95%, n=17.

Source: Field Survey (2021)

3.4.4 Yield and Field Size Relation for Simultaneous Harvest Horticulture Crops under Subjective Methods in the Study Area.

Liner regression analysis was used to test if the field size and yields of three selected simultaneous harvest horticulture crops measured through subjective method (recall) have statistical relations. The same fields which were previously measured through objective methods were revisited. The results for linear regression for tomato revealed that the model explained 48.8% (R^2 = 0.488) of the variance and that the model was statistically insignificant F (1, 15) = 29.99, P = 0.086. In similar manner the results of the linear regression for onion revealed that the model explained 47.23% (R^2 = 0.472) of the variance and that the model was statistically insignificant F (1, 15) = 25.29, P = 0.057. Meanwhile the results for carrot revealed that the modal explained 46.9% (R^2 = 0.469) of the variance and that the model was statistically insignificant F (1, 15) = 23.93, P = 0.049 (Table 11).

Table 11: Yield and Field Size Relation for Simultaneous Harvest Horticulture Crops under Subjective Methods

Model	*Coefficients*	*Multiple R*	*R Squared*	*P-value*	*F*	*Sign*
Intercept	459.2810	0.4969	0.4886	0.4288	29.9982	0.08682
Field Size (Cabbage)	0.6382			0.4668		
Intercept	192.4713	0.4808	0.4724	0.4542	25.2990	0.05752
Field Size (Onion)	0.6519			0.0536		
Intercept	25.7661	0.4742	0.4691	0.5715	23.9382	0.04917
Field Size (Carrot)	0.6380			0.0412		

a. Dependent variable: Horticulture Yields, b. Predictors: (Field Size) df: 1, 15; Confidence Level 95%, n=17.

Source: Field Survey (2021)

Basing on the linear regression results it is concluded that there was strong positive relation between production field sizes and horticulture crop yields under objective measurement methods. This is revealed by the observation of the values of Coefficient of Correlation (Multiple R) which show positive values and they are greater than 0.5. Also the P-values of regression equations of horticulture crops under this category are less than 0.05 which implies that the field size is a significant determinant of horticulture yields. Meanwhile the linear regression results show weak positive relations between field size and horticulture yields for fields measured by subjective methods. This is unveiled by the observation of the values of Coefficient of Correlation that portray positive values which are less than 0.5 and others have slightly exceeding 0.5. Also the P-values of regression equation of horticulture crops under this category are greater than 0.05 which implies that field size is insignificant determinant of horticulture yields. This situation resulted from inaccurate estimations made by farmers either through overestimating field sizes and underestimating yields or the vice versa.

4. Conclusion and Recommendations

The study was conducted in Kilolo district, one of four districts of Iringa region. It attempted to analytically compare the objective and subjective methods of measuring yields per unit area in the study area. The total number of 34 small scale horticulture farmers were involved in the study. Questionnaire and interview were used to collect information regarding to size of production fields and horticulture crop yields through recalling. GPS and crop cutting methods were used to determine the actual size and yields respectively. Descriptive analysis of frequency and percentage was performed to reveal the variation of two methods in measuring field size and yield. Also linear regression analysis was used to test the statistical relationship between field size and yields of six selected horticulture crops.

The findings revealed that 78% of the surveyed farmers overestimated the size of their horticulture fields while 22% underestimated. Fields overestimation ranges from 20m^2 to 200m^2 and 50m^2 to 390m^2 for staggered and simultaneous harvest horticulture crops respectively. Underestimation of filed sizes ranges from 50m^2 to 500m^2 and 100m^2 to 125m^2 for staggered and simultaneous harvest horticulture crops respectively. On the other hand, the findings reveal that 81% of the surveyed farmers overestimated yields and 19% underestimated yields. Yield overestimation ranges from 22kgs to 881kgs and 52kgs to 297kgs for staggered and simultaneous harvest horticulture crops respectively while underestimation ranges from 24kgs to 273kgs and 184kgs to 526kgs for staggered and simultaneous harvest horticulture crops respectively. Additionally, the findings revealed that there is a weak positive relation between filed size and the yields of selected horticulture crops under subjective measurement methods. This has been evidenced by P-values of linear regression models which shows values greater than 0.05.

Therefore, for accurate estimation of field size and yields the use of objective methods is imperative. These methods will help to precisely approximate agricultural productivity and thus enable preparation of sound programme, projects and policies related to sustainable agriculture development, horticulture sub sector in particular. This in turn will help to ensure food security and nutrients requirements alongside with improving living standard of rural farmers though income generated from agriculture.

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