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RESEARCH ARTICLE

FARMERS' FOOD: HOW PUSH-PULL TECHNOLOGY TRANSLATES THE HOUSEHOLD INCOME SOURCES TO FOOD PROVISION AND DIET ADEQUACY

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ABSTRACT

Farmers obtain their food in two most basic ways, that is, farm production and purchased foods. Purchased foods associate with certain incomes from which a farmer spends money. Income sources therefore provide a limelight to determining how household food provision is attained, especially by unveiling the extent to which they provide food and attribute to dietary diversity. Push-pull technology is the agricultural intervention put on light of this study. For over a decade, this technology that was once meant to eliminate insect infestation of cereal crops turned to be a successful food and dietary security measure by increasing production through its bumper harvests. This led to sources of income broadening from farm to non-farm income sources which have greatly enlarged the household food provision and dietary adequacy capacity. This study examined how Push-pull technology would translate the income sources into food provision and diet adequacy. It employed several methodologies to study the core of this science. The study found out that income sources majorly contributed to household food expenditures. Sale of farm products in PPT households (40, n=50) was however the greatest source of income contributing to food and diet adequacy. This income source contributed an average of Kshs. 100 to 500 per day for food by majority of PPT households (17, n=50). A chi-square test on sales of farm products provided a significance of 0.000 at P≤0.05 and proven by the symmetric measures that was tested by further chi-square statistical procedures. With all income sources connection to household dietary diversity consumption, PPT households derive its best statistics to indicate its accomplishment in dietary diversity. It is well pronounced in all food groups (A to L). Correlation computed gave a 2-tailed significance of 0.000 at P≤0.05 and a Pearson correlation significance of -0.489 when determining if PPT had a statistical comparison to HDDS. This study concluded that Push-pull technology have an aided income system which translates to food provision and dietary adequacy far much better than non push-pull strategy.

Key words: Push-pull technology (PPT), Non Push-pull technology (NPPT), Income sources, Food provision, Diet adequacy, Household dietary diversity score (HDDS), and Food group frequencies (FGF).

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INTRODUCTION

The main source of livelihood for farmers is crop and livestock production. Farmers rely on products they harvest to sustain their households. For instance, households that fully engage in farming activities for livelihood obtain their basic provisions from the farm. This means that household food majorly come from farm, and income can also be obtained from the sale of the farm products which can further be used to buy food items and sustain food security (Ogot *et al.,* 2017). Ultimately, food security should translate to an active healthy life for every individual. For this to take place, the nutritionally adequate diet should be biologically utilized so that adequate performance is maintained in growth, resistance or recovery from diseases, pregnancy, lactation and or physical work (Mwaniki, 2006).

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Hence adequate health and care must be provided in addition to adequate food. However, there are other sources of income from which household food contribution is attributed. Apart from selling the farm products, farmers may be receiving income from remittances, pension, salaries, rent, dividends, businesses or any other casual works which adds to household food provision and diet adequacy. Ogot *et al.* (2017) establishes that income sources is a considering factor to determining how best the households can access basic needs (specifically food). Income sources are the major strength of other food purchases and diet quality of the households. A household with a higher income has the ability to value diverse foods (Ogot *et al.,* 2017).Income forms a more ubiquitous asset to determine a universally germane of a wide array of important policy issues (Moore *et al.,* 1997). It is the sum of all the wages, salaries, profits, interests' payments, rents, and other forms of earnings received in a given period of time (Case, 2007). Rawal (2014) further defines income source as a source from which income gets generated or arises. It remains

a main drive to a social and economic life of populations. Defining income sources and their contribution to the household food provision is thus equally important as is in other sectors. DeWalt (1983) stated that although many studies as well as conventional wisdom suggested that increases in income resulted in improved diet and nutritional status in rural areas of developing countries, several studies have failed to demonstrate such relationship. He elaborates that increasing income is associated with consumption of purchased foods especially foods of animal origin, and is not associated with the consumption of staple foods produced within the household. While, a study by Babatunde (2009) concluded that off-farm income had a positive income on dietary quality and micro-nutrient supply. He stated that off-farm income has the same marginal effect as farm income which held the truth to dietary quality and micronutrient supply. So, both farm and off-farm income sources had shown a tendency to contribution of a better food security and nutrition.

To shed the picture on this study's perspectives, food provision basically implies an act of availing and utilizing food at household levels. Diet or nutritional adequacy is defined as the sufficient intake of essential nutrients, needed to fulfill nutritional requirements for optimal health (Castro-Quezada *et al.,* 2014). According to the criterion of adequacy defined, the requirement for a given nutrient may be at a lower or higher intake amount. The criteria that are generally used to define adequacy of intake are: the prevention of deficiency diseases, the prevention of chronic diseases or the reduction of risk for diet associated diseases, subclinical nutritional health conditions identified by specific biochemical or functional measures, or requirements to maintain physiological balance (Dhonukshe-Rutten *et al.,* 2013). This study looks at the external elements of these criteria, that is, determining the household dietary diversity. Different farmers have different unique ways of boosting their farm production and sales or income. Farmers have been main inventors of strategies which increase the subsistence production. The variability in these strategies links to pathways of household food provision and diet adequacy. Farmers have also adopted strategies invented and driven by researchers who have successfully identified the roads to boosted agricultural productions. Push-pull technology is one of the identified effective and efficient strategies that has been used by farmers to increase every element linking to efficiency of their livelihood along the Push-pull to food adequacy pathway. The synergies of Push-pull technology are crucial to determining how farmers lay food on the table and how they meet their diet adequacy through dietary diversity scale.

Past studies have validated food security measures by examining associations between the measure and proxies of household income, as well as markers of increased quality and quantity of the diet: total food expenditure and expenditure on food groups consisting of more expensive, nutrient-dense items (FAO, 1996; Melgar-Quinonez *et al.,* 2006; Hoddinott and Yohannes, 2002; Hatloy *et al.,* 2000). The present work builds on these analyses, identifying associations between a dietary diversity indicator and monthly per capita total expenditures, food expenditure, and expenditure on non-grain foods. This analysis adds to the literature supporting the use of dietary diversity measures as indicators that may be particularly useful in settings where more in-depth tools may not be easily applied. Push–pull technology is a novel cropping system developed by the International Centre of Insect Physiology and Ecology (ICIPE) in collaboration with Rothamsted Research (UK), Kenyan Agricultural Research Institute (KARI) and other national partners for integrated pest, weed and soil management in cereal–livestock-based farming systems (Zeyaur *et al.,* 2011). This technology basically eliminates pests by attracting stemborers with Napier grass (*Pennisetum purpureum*) that is planted on the border of the field as a trap plant, while it drives them away from the main crop using a repellent intercrop such as desmodium forage legumes (*Desmodium spp*.). Chemicals released by desmodium roots cause abortive germination of the parasitic striga weed and therefore providing effective control of this noxious weed (push-pull effect) (Zeyaur *et al.,* 2011). See Figure 1.

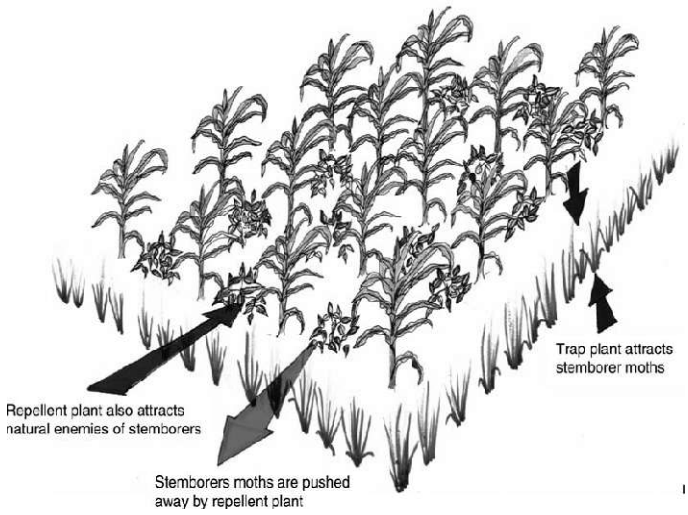


Figure 1. Push-pull plot (Source: Zeyaur *et al.*, 2011)

By effectively controlling stemborers and striga that infested the cereal crops, Push-pull technology has resulted in significant improvements in their yields (Khan *et al.* 2008a; Midega *et al.* 2010, 2014). More yields have caused farmers to work out more aims to spread and utilize their income. Distribution of household food budget has followed increase in the sales of farm products and income gains from other sources of income linked to Push-pull technology. This study is keen on determining the link between income sources and household food provision & diet adequacy; the what and how of Push-pull technology significance. In its brief, the objective of this study is to evaluate how Push-pull technology enable farmers to have adequate food, and what are the main sources of income arising by the technology that aid the households with their daily food (in adequacy and diversity)? It however hypothesized that vast income sources from the Push-pull households would translate into diet sufficiency and adequacy.

METHODS

Research Design

The study employed a cross-sectional survey design to explore the areas of Western Kenya where Push-pull technology was dominant. A common goal of survey research is to collect data representative of a population. The researcher uses information gathered from the survey to generalize findings from a drawn sample back to a population, within the limits of random error (Baartlett *et al.,* 2001). This study was based on regional analysis of farmers' sources of food (in terms of income and provision).

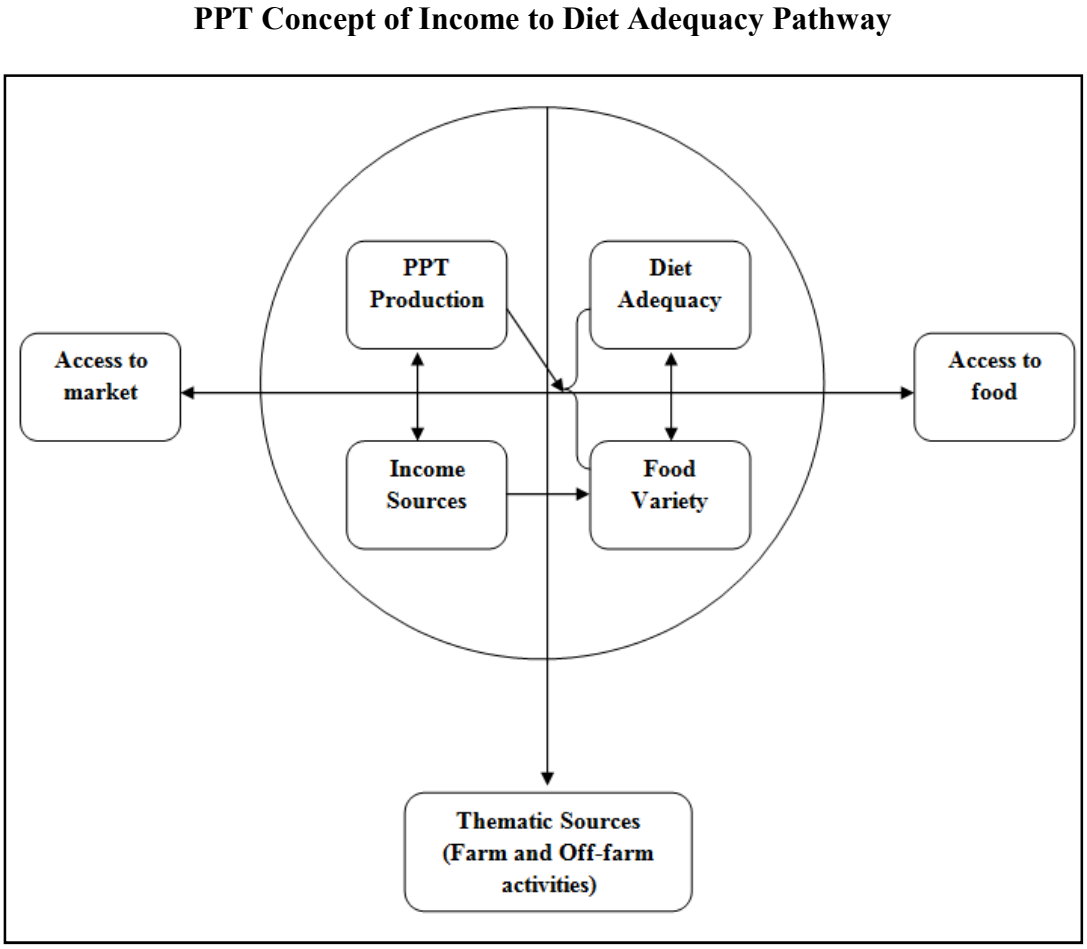


Figure 2. PPT Concept of Income to Diet Adequacy Pathway

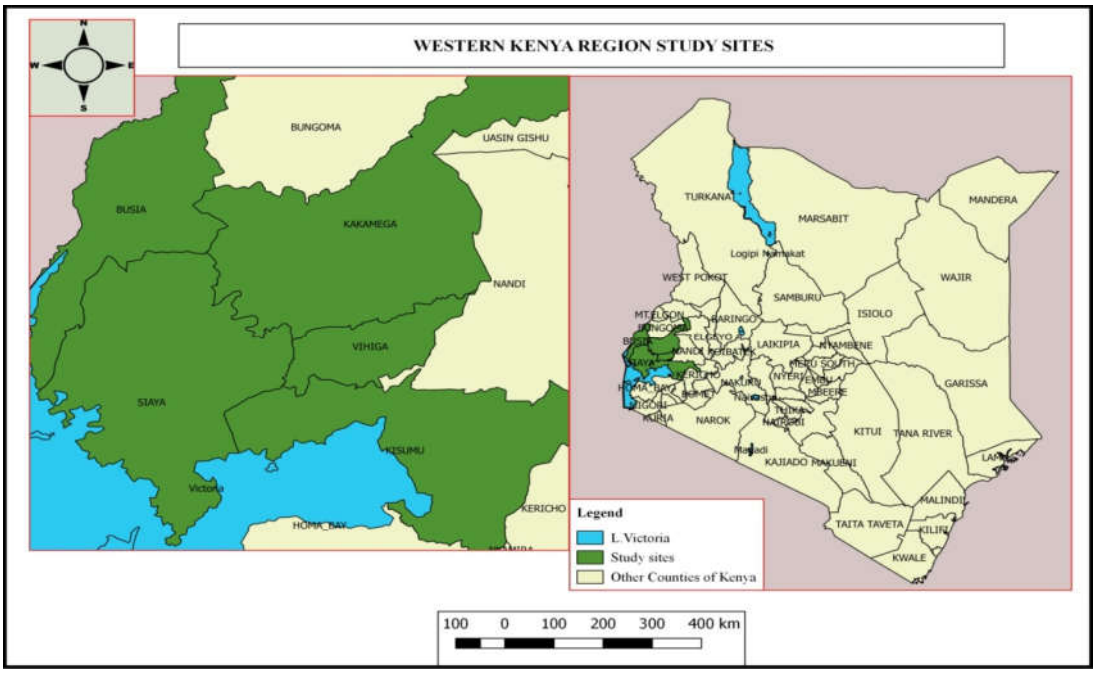


Figure 3. Map of Study Sites

Study Area

This study was conducted in areas of the Western Kenya Region namely: Busia (0°26'4.74"N, 34°14'31.78"E), Siaya (0°3'45.46"N, 34°17'16.11"E), Kakamega (0°13'11.34"N, 34°29'30.84"E), Vihiga (0°4' 53.72"N, 34°43'22.57"E) and Kisumu (0°5'18.15"S, 34°46'37.17"E).

These regions are dominant with Push-pull adopters for over a decade. Push-pull resources are also well distributed for easy studies. Mixed farming had also been an encouraging feature for the study sites to be selected. With a symbiotic relationship between ICIPE's Push-pull team, farmers and Agriculture Sectors of Kenya, these regions have had a lot of tolerance for

any research done within. Figure 3 below shows the map of the study sites.

Sampling Procedure and Data Collection

Sampling was quite comprehensive and predilection. A step by step approach was done by dictating processes as conducive to the researcher and institution. Being that the study area was defined by the number and acceptable factors of Push-pull adopters, the regional field staffs were consulted for validity and reliability of the study through description of the objectives. The specific conditions were explained and the farmers were identified through the requirement model. The model required that all farmers to be used in the study should be mixed farmers, and that for every Push-pull farmer identified, a non Push-pull farmer would be used for control study. And based on income sources, a Push-pull farmer was to at least practice sales of farm products as the major income source. Finally, all the farmers were to be identified from a proximity of the area selected for each region (that is, cluster sampling). The farmers meeting the inclusion criteria were listed by the regional field staffs and forwarded to the researcher. The list was refined to provide an optimal average for all the five regions. This had resulted as 10 Push-pull households per region (that gives a total of 20 farmers' households per region). Totally, this gave a sample of 100 households for the five regions, that is, 50 Push-pull and 50 non Push-pull households. Enumerators were recruited from the consecutive regions for the study function. They were vividly trained and charged for data collection process. They used questionnaires as the tool of data collection. The data collection tool was previously prepared by the researcher and a pilot test conducted to determine its effectivity in data collection before the next initiative was undertaken by the enumerators.

Analytic Framework

The study adapted a two-structure questionnaire model that encompassed the many-faceted food synergies. The pathways delineate a unit of food security and nutrition which proceeds right from sources of income and its interconnection to Push-pull technology all way to food provision and dietary adequacy (HDDS). This study used two models as below:

1) Income Sources and Food Expenditure Model

This questionnaire model encompassed a three dimension of assessment approach; 1) The yes/no response of the contributing income source, 2) The percentage contribution/extent, and 3) Amount that the income source contributes per day. Below is the model employed to obtain information;

A. ASSESSMENT ON FOOD EXPENDITURE

Where does the money/income used for food expenditure come from?

1. **Sales of farm products** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

2. **Remittances from the government/relatives/friends** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

3. **Pension** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

4. **Paid salaries/wages** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

5. **Rent** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

6. **Dividends** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

7. **Business** Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) >Kshs. 500

8. **Others** (Specify;_____) Yes [ ] No [ ]

a. If yes, to what extent?
i) <20% ii) 20% to 50% iii) >50%
b. What amount does it contribute per day?
i) < Kshs. 100 ii) Kshs. 100 to 500 iii) > Kshs. 500

2) Household Dietary Diversity Score and Food Groups Frequency Model

This questionnaire model is an inclusivity tool of 24 hour diet recall and food frequency. The only difference is that, as 24 hour diet recall contains a list of food items eaten within 24 hour time, this HDDS model designs it in food groups and their frequencies. This narrows down a multi-taskful functions of variables into a diminished but precise capacity of nutrition science. Below is the HDDS model used in this study;

HOUSEHOLD DIETARY DIVERSITY AND FOOD GROUPS FREQUENCY

Food group (Choose a food group consumed for the last 24 hours by indicating either 1 for yes or 0 for no)	**Yes=1, No=0**	**Frequency** 1.<Twice/week 2. Twice to Five times/week 3. Five to Ten times/week 4. > Ten times per week
A		
B		
C		
D		
E		
F		
G		
H		
I		
J		
K		
L		
Score		

Household Dietary Diversity Score Key
A. Any foods made from maize, sorghum, millet, rice, wheat
B. Any potatoes, yams, cassava etc
C. Any vegetables
D. Any fruits
E. Any meat or meat products
F. Any eggs
G. Any fish
H. Any foods made from beans, peas, lentils or nuts
I. Any milk or milk products
J. Any foods made with oil, fat
K. Any sugar or honey
L. Any beverages e.g. coffee, tea or cocoa

Statistical Analysis

Statistical Packages for Social Sciences software version 22 was used to analyze data collected. The data from the field was coded and entry made consecutively in a broad array of template with different statistical programmes. Frequencies, cross-tabulations, correlations and other statistical features were used to derive the analytical content of this study. Final presentations were drawn by use of tables, pie charts and bar graphs. Chi-square tests were done to determine the significance that the income sources have towards the contribution of household food (the extent of food expenditure by respective sources). Cross-tabulations were used for formation of statistical graphs and depictive statistical differences. Correlation computation was done to determine the significance of PPT adoption to fulfilment of household dietary diversity. The HDDS and food groups frequency model was presented comparatively between PPT and NPPT on clustered bar graphs to elaborate on number of households exploiting the nutrition/dietary diversity. Finally, pie-charts were prepared to distinct between the HDDS of PPT and NPPT households.

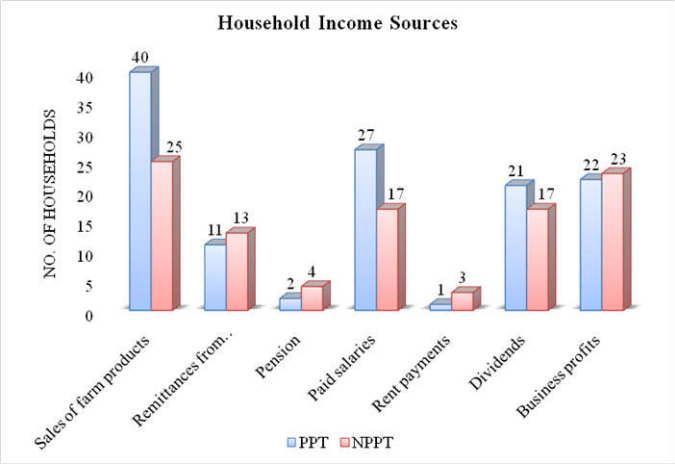
RESULTS

Demographic Information

The households surveyed had 69% of female-headed farmers and 31% male-headed farmers. These statistics were important owing to facts supported by many studies that females have a better role in ensuring food security and nutrition (FAO, 2011). Marital status is an agent of food provision determinant. For example, married couple households always have upper-hand in food provision and adequacy compared to widowed households. In statistics of this study, married couple households were 77%, households with single parents were 5%, widowed households 18% and none were divorced. Consequently, the average number of household members in PPT were 7.38 and in NPPT, 7.08. Number of household members is an acute determination of what quantity and quality of food farmers' households need (USDA, 2016).

The Income Sources and Gains of Farmers

More farmers were engaged in sales of farm products as their main income sources in both PPT and NPPT households. However, PPT households had more number of this income source compared to NPPT (PPT – 40, and NPPT – 25). Another income source that had reflected a relatively higher number was paid salaries and wages with PPT having 27 households and NPPT, 17 households. Other sources of income had also shown significant numbers as in Graph 1 below with the least being income from rent payments (PPT – 1, and NPPT – 3).



Graph 1. Graph of Income Sources by Households

Income gains used food expenditure by the households were analyzed and presented in Table 1 below. Evidently, sales of farm products as the main backbone to this study had farmers obtaining cash between Kshs. 100 and Kshs. 500 (specifically for food) majorly compared to other income categories. This had 17 households of PPT and 12 households of NPPT. Paid salaries had also emanated the same trend but with 18 household PPT and 10 households of NPPT (that is, between Kshs. 100 to Kshs. 500). Furthermore, business seemed to have had a greater number of households obtaining between Kshs. 100 to Kshs. 500 per day (PPT – 16 and NPPT – 18). Other incomes are also pictured significantly in Table 1.

Table 1. Income Sources and Categories

Income Source	Income Category for Food	PPT (n=50)	NNPPT (n=50)
Sales of farm products	Less than Kshs. 100	12	6
	Kshs. 100 to 500	17	12
	Above Kshs. 500	11	7
	None	10	25
Remittances from the government/relatives/friends	Less than Kshs. 100	3	0
	Kshs. 100 to 500	8	11
	Above Kshs. 500	0	2
	None	39	37
Pension payments	Less than Kshs. 100	0	0
	Kshs. 100 to 500	2	4
	Above Kshs. 500	0	0
	None	48	46
Paid salaries/wages	Less than Kshs. 100	2	3
	Kshs. 100 to 500	18	10
	Above Kshs. 500	7	4
	None	23	33
Rent payments	Less than Kshs. 100	0	0
	Kshs. 100 to 500	1	3
	Above Kshs. 500	0	0
	None	49	47
Dividends	Less than Kshs. 100	8	6
	Kshs. 100 to 500	12	8
	Above Kshs. 500	1	3
	None	29	33
Business profits	Less than Kshs. 100	3	1
	Kshs. 100 to 500	16	18
	Above Kshs. 500	3	4
	None	28	27

Chi-square Tests on Income Sources

At $p \leq 0.05$, chi-square tests have shown several significances on almost all income sources in both PPT and NPPT. Further, pension and rent payment sources of PPT depicts different significance values from the rest indicating a comparative lesser determination to contribution of the study objectives.

Table 2. Table of chi-square tests on income source

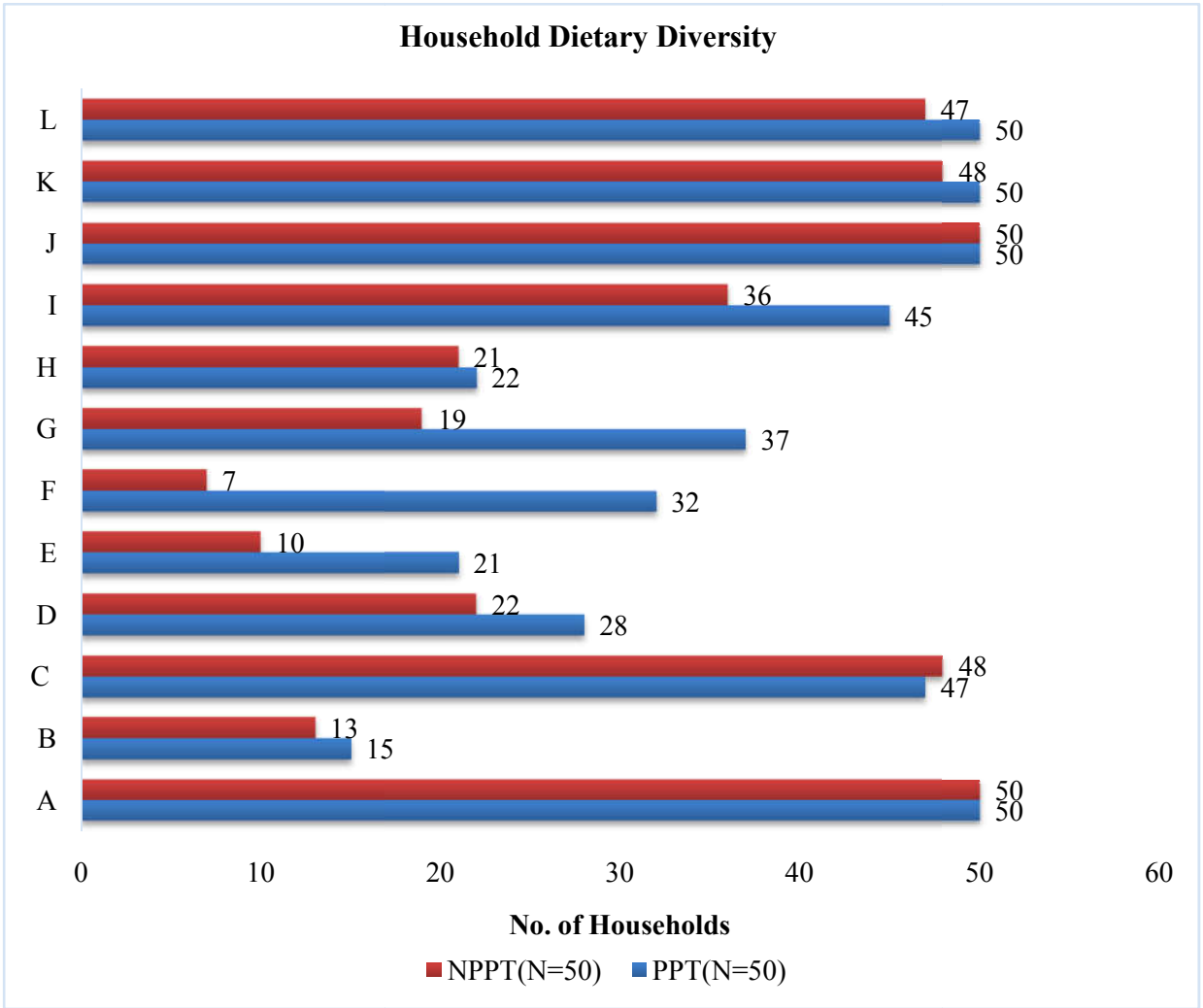
Income Sources	PPT			NPPT		
	Pearson Chi-square	Likelihood ratio test	Exact significances (2-sided)	Pearson Chi-square	Likelihood ratio test	Exact significances (2-sided)
Sales of farm products	50.000	50.040	0.000*	50.000	69.315	0.000*
Remittances from the government/relatives/friends	50.000	52.188	0.000*	50.000	57.306	0.000*
Pension payments	50.000	16.794	0.010*	50.000	27.877	0.010*
Paid salaries/wages	50.000	68.994	0.000*	50.000	64.104	0.000*
Rent payments	50.000	9.804	0.020*	50.000	22.697	0.000*
Dividends	50.000	68.029	0.000*	50.000	64.104	0.000*
Business	50.000	68.593	0.000*	50.000	68.994	0.059

*Significant at $P \leq 0.05$

Table 3. Symmetric measures (chi-square) for sales of farm products

PPT or NPPT farmer?			Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
PPT	Interval by Interval	Pearson's R	.817	.048	9.809	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.733	.073	7.465	.000[c]
	N of Valid Cases		50			
NPPT	Interval by Interval	Pearson's R	.878	.029	12.699	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.934	.025	18.185	.000[c]
	N of Valid Cases		50			
Total	Interval by Interval	Pearson's R	.863	.023	16.941	.000[c]
	Ordinal by Ordinal	Spearman Correlation	.862	.032	16.805	.000[c]
	N of Valid Cases		100			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error assuming the null hypothesis.
c. Based on normal approximation.



Graph 2. Graph of Household Dietary Diversity Consumption

However, NPPT's business income source seem not to present significance to the study elements. Table 2 reflects the chi-square tests. Symmetric measures for sales of farm products as an income source derived from the chi-square to compare between PPT and NPPT showed Pearson's R and Spearman Correlation significant in both groups. However, asymptotic standard errors and approximate T-value varied in all these statistical variables. Table 3 highlights the symmetric measures.

Statistics on Household Dietary Diversity

A distinction between PPT's and NPPT's household dietary diversity consumption showed an impressive trend to nest on. Graph 2 visually presents credible result that sees Food Groups A and J having maximum number of households for both PPT and NPPT. The key provided in the HDDS model above indicated Food Group A as carbohydrate cereals and J as foods with oil/fats. Among the food groups majorly consumed by the two groups of households, five food groups seemed to have hit an over 40 households threshold for both households (A, C, J, K and L). But even in that major food groups consumption, PPT shows a greater value in the remaining three food groups, that is, C, K and L. Generally, PPT households reflect more inevitable numbers of food groups consumption compared to NPPT households. Averagely, the household dietary diversity scores were 8.94/10 for PPT and 7.42/10 for NPPT. This depiction was overall for defining dietary consumption between the two groups of household. Figure 4 shows a pie chart of the HDDS scores between PPT and NPPT in their percentage segments.

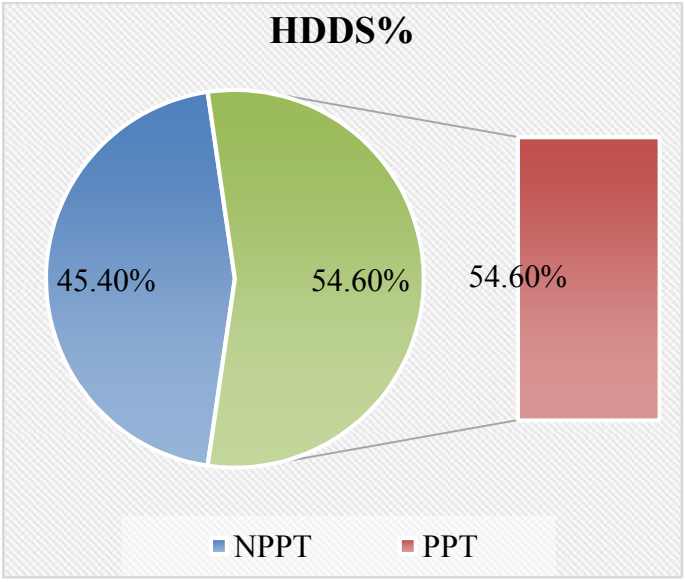


Figure 4. Pie chart of HDDS in %

The Household Food Group Frequencies

It was essential to find the food frequency through HDDS model which groups together all foods a household consumes. Frequencies of households were aligned in respect to food groups to present what food group was consumed on which frequency and by what number of households. Table 4 presents the FGF statitistics. Still, food groups A, C, K, L and J shows higher modes in both PPT and NPPT with frequencies ranges between twice to over ten times per week per individual food group.

Table 4. Table of Food Group Frequencies

Food Groups	Frequencies	PPT (n=50)	NPPT(n=50)
A	Less than twice/week	0	0
	Twice to five time/week	3	9
	Five to ten times/week	22	14
	Over Ten times/week	25	27
B	Less than twice/week	31	32
	Twice to five time/week	16	15
	Five to ten times/week	3	3
	Over Ten times/week	0	0
C	Less than twice/week	6	4
	Twice to five time/week	18	17
	Five to ten times/week	26	29
	Over Ten times/week	0	0
D	Less than twice/week	17	17
	Twice to five time/week	12	20
	Five to ten times/week	8	8
	Over Ten times/week	13	5
E	Less than twice/week	40	38
	Twice to five time/week	8	12
	Five to ten times/week	1	0
	Over Ten times/week	1	0
F	Less than twice/week	34	37
	Twice to five time/week	11	13
	Five to ten times/week	2	0
	Over Ten times/week	3	0
G	Less than twice/week	16	11
	Twice to five time/week	22	27
	Five to ten times/week	9	8
	Over Ten times/week	3	4
H	Less than twice/week	23	22
	Twice to five time/week	16	21
	Five to ten times/week	10	5
	Over Ten times/week	1	2
I	Less than twice/week	4	9
	Twice to five time/week	6	11
	Five to ten times/week	12	5
	Over Ten times/week	28	25
J	Less than twice/week	0	1
	Twice to five time/week	0	5
	Five to ten times/week	14	10
	Over Ten times/week	36	34
K	Less than twice/week	0	1
	Twice to five time/week	0	5
	Five to ten times/week	14	10
	Over Ten times/week	36	34
L	Less than twice/week	0	2
	Twice to five time/week	1	1
	Five to ten times/week	11	12
	Over Ten times/week	38	35

Correlations

Correlations computed to find out if Push-pull adoption had an impact on HDDS produced a significance at 0.01 level for 2-tailed. The Pearson correlation at -0.489** is a sure significance and an accurate depiction for this study.

Table 5. Correlations (HDDS v PPT)

		PPT or NPPT farmer?	Households Dietary Diversity Scores
PPT or NPPT farmer?	Pearson Correlation	1	-.489**
	Sig. (2-tailed)		.000
	N	100	100
Households Dietary Diversity Scores	Pearson Correlation	-.489**	1
	Sig. (2-tailed)	.000	
	N	100	100

**. Correlation is significant at the 0.01 level (2-tailed).

DISCUSSION

Farming households have unique ways to ensuring that food provision and diet adequacy is achieved. This process is

encircled around the determinant environmental factors that proceed to the latter. Such environmental factors may include the agricultural intervention that has been worked out for farmers' exploitation or even broad avenues through which income is obtained. Literature has confirmed the fact that participation in rural non-farm activities exerts a pronounced impact on rural agriculture (Reardon *et al.,* 1994; Barrett, 2001), household farm decisions (Reardon *et al.,* 1994; Ellis, 1998), rural development (FAO, 2013), income and welfare (Katera, 2013) and household food security Owusu *et al.,* 2011; Babatunde and Qaim, 2010). Farmers always aim for self-sufficiency, and this comes with definite practices and responsibilities for attainment. Among them is adopting a broader scale of income sources that may thrive the household for a year-all-round of food provision in the household. This study noted several characteristics of importance regarding income source and how it achieves the dietary adequacy; majorly for PPT. As clearly observed in Graph 1, sales of farm products remain a major source of income especially for PPT households. Other sources of income (e.g. paid salaries) supplement the provisions by sales of farm products. This feature conforms to a study by Ogot *et al.* (2017) which indicated sales of farm products as highest and greatest source of income for farmers. On its account, amount obtained from sales of farm products attributing to household food expenditure is majorly between Kshs. 100 to Kshs. 500 per day which reflects 17 households within the income category (Table 1). However, the distribution across these income categories do not differ largely since households spending over Kshs. 500 on food are moderate enough (11) just as it is with those spending less than Kshs. 100 per day (12).

Earlier work to analyze the impact of non-farm activities on household food security status in Ghana have been done by Owusu (2009) and Owusu *et al.* (2011) for the Brong Ahafo and Northern regions of Ghana, respectively. Both of these studies found that non-farm activities positively impacted on household income and food security status in selected regions in Ghana. Owusu (2009) evaluated how participating in both wage- and self-employment non-farm work impacts on farm household income in Brong-Ahafo Region of Ghana. The results from this study showed that non-farm employment has a significantly positive effect on farm household income and as well significantly reduces the likelihood of being poor (Daniel, 2016). Similarly, Owusu *et al.* (2011) examined the impact of non-farm work on household income and food security among farm households in the Northern Region of Ghana and found that participation in non-farm work exerts a positive and statistically significant effect on household income and food security status.

On chi-square tests, several significances are observed (almost in all income sources). The main attention is drawn on sales of farm products though, since it is the major link to determining food provision and diet adequacy as long as PPT intervention is concerned. The symmetric measures on chi-square tests by sale of farm products provide great significances (0.000^{*} at $p \leq 0.05$) on Interval by Interval Pearson's R and Ordinal by Ordinal Spearman Correlation (Table 3) which means sales of farm products as an income source exhibit features of contributing to the food expenditure (food provision) and further to dietary adequacy roles. This trail bridges up the gap between income source, income, food expenditure and dietary adequacy as in Graphs 1 & 2 and Tables 1, 2 & 3. Several studies (Reardon, 1992; Alderman, 1992; Dercon, 2002; Lay and Schuler, 2008; and Fox, 2015) have shown that farm households that combine their farming activities with non-farm income activities are better able to smooth income and consumption. In other words, having a diversified portfolio of income generating activities (and hence a diversified set of income sources) is a sure way to minimize income variability and to ensure an aided level of income (Alderman, 1992). Household dietary diversity consumption is a tendency or practice by which a household acquires and consumes variety of diets as per the standard nutritional requirements of the human body. Indicators of dietary diversity, derived from the recall of the number of foods or food groups consumed over a given time period, have gained increased attention in both the nutrition and food security communities in recent years (Ruel, 2002). It is fit to determine nutritional deficiencies using the statistics on dietary diversity consumption. Dietary diversity indicators prove popular in part because the data are fairly easy to collect and are associated with dietary quality, energy intake, and food security (Arimond and Ruel, 2004; Ruel, 2002). The use of dietary diversity indicators holds promise as a powerful tool for effective needs assessments and targeting, as well as efficient program monitoring and evaluation.

The more the number of households that achieves dietary diversity, the better the nutritional status of the households as noted by international organizations such as World Health Organization and Food and Agriculture Organization. Poor households often use additional income to purchase additional nonstaple foods, thus increasing household dietary diversity (Torlesse *et al.,* 2003; Behrman, 1989; Ruel et al, 2004). Indeed, a recent analysis found income was a significant determinant of household dietary diversity in Bangladesh (Rashid *et al.,* 2006). Finally, the household dietary diversity score (HDDS) gives a general situation of how households fulfill their nutritional requirements. In case of a suspected nutritional deficiency, HDDS is used to scale this up and work out for an objective to reverse the extreme deficiencies. In the study, PPT households have more of nutritional accomplishments, drawing from the trend in Graph 2. All food groups are higher in PPT compared to NPPT. Though, there are very lower achievements in food groups B and E which have less than a half of the PPT households consuming them (B represents any potatoes, yams, cassava etc and E represents any meat or meat products). A summary representative of dietary diversity, that is HDDS, provide a concluding framework comparing between PPT and NPPT. Push-pull technology households have a better score at 54.6% (8.94/10) as in Figure 4. Correlation computed on PPT's connection to the HDDS has given a positive significance to the validation of this study. This intercepts the essence of Push-pull technology attributing directly or indirectly (through income) to farmers' food; provision and adequate diet. As for food group frequencies, the four dimensional scale portrays that some of the major food groups consumed are majorly staple foods and directly-from-farm foods, for example, Food Group A (see Table 4). Both the FAO and the World Food Programme (WFP) use information on dietary diversity as one element to inform food security analysis; however, the organizations use different data collection methods and analytical strategies (FAO, 2004; WFP, 2007 & 2009). The FAO uses a 1 day household dietary diversity score (HDDS) based on guidelines produced by the Food and Nutrition Technical Assistance Project (Swindale & Bilinsky, 2006) and the WFP uses a food consumption score (FCS). Both the HDDS and the FCS have been validated in different countries as proxy measures of

household per capitaenergy intake (Hoddinott and Yohannes, 2002; IFPRI, 2006; Wiesmann *et al.,* 2009; and Rose *et al.,* 2008). With the uniqueness of incorporating both the measures, this study finds that most of food groups' consumption by the many PPT households ranges between five to over ten times per week. However, income determinant food groups are E, F, G, I, J, K and L (food groups that money are spent on). From these groups, income sources are placed in picture and in their order of income gains per day. This gives PPT recognition in the frequent provision of several food groups by income gains better than the NPPT as was seen in Table 1.

Conclusion

The roles that farmers undertake to lay food on table count a lot through numerous pathways. This study basically examined one pathway of concern to Push-pull technology as an agricultural intervention. This pathway is income (through thematic sources) to food provision and diet adequacy. They are all positively proven through the results and definite researches of this study. On a conceptual framework having income to diet adequacy pathways, it is clear that the links are relational and truly descriptive to the understanding of science of income and diet adequacy of farmers. Push-pull technology has greatly evolved from the management of pests all-the-way to household diet adequacy. It has been observed that PPT has added its value by stretching out its income sources (farm and non-farm) to household food provision for sustenance. In food provision, variety of food groups is consumed and dietary diversity is achieved. The same is not the case with the NPPT. Food group frequencies table has clearly shown the dietary diversity's extent of household provisions, and this has formed reliability to drawing a strong conclusion. Therefore, it is tested and proven that the avenues of food provision and diet adequacy of the Push-pull farmers (and their households) for this study are income sources from sales of farm products and non-farm activities which weave up together to provide for food. The extent of food provision in PPT is too much broader to be compared to the NPPT.

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