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Positive Yield Impact of Predacious Mites in Tea Production Areas of Kenya

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Abstract

Tea agro ecosystems are least disturbed in comparison to other crop systems due to the plant canopy type. A survey on predacious mites' abundance and impact on leaf yield in different tea production areas was carried out in 2014-2015 in Kenya. Major pest species were the red spider mite *Oligonychus coffeae* and the yellow thrip, *Scirtothrips dorsalis*. The red crevice mite, *Brevipalpus phoenicis* was found in few areas and in low numbers. Predacious mites of Phytoseiidae Family were highest at 5.8 and 6.8 mites per sample during dry and wet seasons, respectively. Phytoseiid abundance during the dry and wet seasons did not differ much within most sample sites. Presence of phytoseiid mites in combination with NPK-fertilizer-high altitude led to the strongest correlation to leaf yield than any other combination variable. High phytoseiid density- high altitude was third with positive impact to yield increase after high altitude combined with NPK-fertilizer. The findings here show contributory positive impact of phytoseiids in tea leaf yield in an agro eco-system.

Keywords: ecosystem, yield, impact, NPK-fertilizer, altitude

1. Introduction

Tea, *Camellia sinensis* (L) O. Kuntze, is one of the most inexpensive popular beverages in the world. Tea beverage is prepared from the tender leaves and buds of *C. sinensis*, which is a woody perennial plantation crop cultivated as a monoculture on large and small holdings. World main tea producers are India, Sri Lanka and China, with Indonesia, Japan, Kenya, Malawi, Uganda, Georgia, Turkey, Iran and Argentina (FAOSTAT 2016). Other minor producers are Vietnam, Mozambique, Tanzania and Democratic Republic of Congo. The tea plant has unique characteristics which influence its pest ecology in a very special way (Roy et al. 2014). Tea plantations are usually evergreen, comprising of either one cultivar of the world six varieties or genetically diverse clone cultivars (FAO 2015; Majumder et al. 2010). In some cases, some cultivars yield higher leaf than others in specific conditions of temperature and altitude (Jayakrishnan & Ramani 2015). The varied ecological requirement of the crop range from 0-2000m above sea level in the Asia continent while in Africa tea is only produced in the high altitude areas of the tropical climate (Majumder et al. 2010). Tea crop near the equator produces almost the same yield in relation to cultivar potential (FAO 2015). In Kenya the crop occupies the most arable land and is the number one foreign earner in economic terms with world volume supply of 8% of 432,400 metric tons (FAOSTAT 2016; Maity & Ghosh 2015). Worldwide tea crop suffers from attack by a number of pests and pathogens, causing significant yield losses (Jepson et al. 1975; Muraleeedharan et al. 2015). However, detailed information on pest abundance and production practices in Kenya have not been closely analyzed to reflect the actual biotic production constraints. Whether the Kenya tea agro-ecosystems are stable or need some modification in the prevailing environmental conditions could be assessed before decision on management option of the target pest.

Worldwide, the major pests of tea plant include the mite species, *Oligonychus coffeae* Nietner (Acari: Tetranychidae) that lowers leaf quality and yield in plantations (Roy et al. 2014a). Coupled with other pests like plant bugs and thrips the leaf quality and continuous rejuvenation goes down (Roy et al. 2014). Other small-sized

mites are *Acaphylla theae* Watt (Eriophyidae) and *Calcarus carinatus* Green (Eriophyidae), being common in Asia and Africa (Childers & Achor 1999; Childers & Rodriques 2011).

The present work focused on determining production practices by the small holder farmers and assessing what pest constraints are in Kenya's tea production systems. Rather, a diagnostic approach on what prevailed in the different production systems, with emphasis on beneficial biological agents like predacious mites and their impact on the pests and final leaf yield was what was assessed in the study survey.

2. Materials and Methods

2.1 Survey Sites

A survey was carried out to determine pest status and beneficial organism of the predacious mites in tea production areas in Kenya in 2014-2015. The areas covered included the North Rift Valley and eastern-central highlands of the country where tea plantations were established. Tea crop plots established some 20 years ago were targeted for the study which provided the highest biotic factors, as a stable agro-ecosystem. The type of production system, either monoculture or intercrop was scored as such during the sample data collection. The selected sample plots were the different production practices of the small-scale farmers who did not use chemicals pesticides.

2.2 Pest Status

Throughout the two-year survey, presence of major pests was analyzed for their abundance on the impact on leaf yield in the production systems at specific sites. Farmers provided data of their annual crop management operations. Care was taken to determine site pest abundance during wet and dry production seasons. Specific site environmental factors were analyzed in relation to pest status on tea crop. Information on leaf yield status were corroborated from farmer records at each site at specific conditions in the production areas. To sample for invertebrate herbivore pests, a blue plastic disc of 60cm-diameter was placed under plant canopy and three quick shakings carried out on three plants. With the aid of a hair camel brush, all pest specimens were collected from the plastic disc and preserved in 70% alcohol glass vials of 50ml. Later in the laboratory, spider mite specimens were separated from other specimens and identified by the second author (using identification key by El-Banhawy & Knapp 2011).

2.3 Analysis of Input Levels

Tea production inputs included nitrogen-phosphorous-potassium (NPK) fertilizer which is basic for high leaf yield in the presence of rainfall showers. Farming practices like quantity of fertilizer application per year and resulting leaf yield volume at each farm were recorded. Weeding by hand implements ensured least damage of the secondary root system of plants, applied by 100% of the farmers. Regular pruning of the plant tops enabled a flat plucking table and thickened canopy providing a living shelter for beneficial organisms. An open approach of enquiring from the producers the type of pesticide use; either fungicides, herbicides or insecticide was adopted.

2.4 Diagnosis for Beneficial Organisms

The presence and abundance of beneficial organisms was scored. Later, the specific organisms were identified and their abundance in relation to the yield of tea leaf in the prevailing conditions scored. This enabled further analysis of the impact of the major beneficial organisms in the production sites. All observable beneficial organisms were considered for their abundance and leaf yield impact at the specific sites.

2.5 Interactive Environment-biological Factors

Once the biological and environmental factor data were assembled, an analysis approach was carried out to reflect site region abundance of beneficial organisms' vis-a-vis environmental conditions and regressed with yield volume for positive or negative effect. Sample units were three tea bushes per farm and at least three fields per region. Comparable altitude and farm acreage was also scored at each site. Both the major pests and abundance of predacious mites was also counted.

2.6 Data Collection and Analyses

Data analyses by analysis of variance (ANOVA) was carried out and Student Newman Keuls Test for means separation for significant difference on altitude, leaf yield, and production acreage in addition to fertilizer quantity as well as phytoseiid density per sample. Correlation levels of various parameters like combination of phytoseiid-altitude, fertilizer-phytoseiid-altitude among others were analyzed to determine effect to leaf yield. General Linear Model Procedure (GLM-PROC) was used to get the factual relationship of ideal conditions for healthy tea leaf production.

3. Results

3.1 Site Pest Status

The common pests across the ten sample regions were the red spider mite, *Oligonychus coffeae* (Nietner), the yellow thrip, *Scirtothrips dorsalis* (Hood) and the crevice mite, *Brevipalpus phoenicis* Gijskes (Table 1). The red mite, *O. coffeae* had highest significant ($p < 0.05$) density than the other two pests in Imenti South. Narrowing down to specific regions, highest density of *O. coffeae* was at 6.8 mites per sample in Kericho, followed by Nandi Hills region at 6.3 mites /sample.

Similarly, the thrip *S. dorsalis* had highest density at 11.3 individuals per sample in Murang'a, followed by Kericho at 4.0. The least abundant pest, the red crevice mite *B. phoenicis* was scored at a peak of 5.0 mites per sample in Kiambu and at 4.7 mites/ sample in Nandi Hills region. The thrip, *S. dorsalis* was absent in Nyeri, Imenti South and Imenti North, while *B. phoenicis* was absent in Imenti South. Leaf brown scotching by *O. coffeae* was evident in Murang'a and Imenti South especially during the dry spell months of July to September. The thrip damage was rarely clear besides low wilting appearance of leaves during the dry spell. The low abundance of the crevice mite, *B. phoenicis* did not result to any observable plant stress from the cell-sacking herbivore.

Table 1. Major pest species on tea crop in different production regions of Kenya in 2014-2015

Region	Major pest	Density/ sample	*F*-value	*P*-value
Imenti North	*O. coffeae*	2.0^{A}	1.8	0.2844
	S. dorsalis	0.0^{A}		
	B. phoenicis	1.3^{A}		
Imenti South	*O. coffeae*	6.0^{A}	18.8	0.0093
	S. dorsalis	0.0^{B}		
	B. phoenicis	0.0^{B}		
Murang'a	*O. coffeae*	4.7^{A}	3.0	0.1623
	S. dorsalis	11.3^{A}		
	B. phoenicis	4.3^{A}		
Nakuru	*O. coffeae*	3.7^{A}	4.9	0.0840
	S. dorsalis	2.7^{B}		
	B. phoenicis	0.8^{C}		
Mt. Elgon	*O. coffeae*	1.3^{A}	3.0	0.1600
	S. dorsalis	2.3^{A}		
	B. phoenicis	1.3^{A}		
Nandi Hills	*O. coffeae*	6.3^{A}	3.4	0.1352
	S. dorsalis	2.0^{A}		
	B. phoenicis	4.7^{A}		
Kakamega	*O. coffeae*	4.3^{A}	6.3	0.0588
	S. dorsalis	2.8^{B}		
	B. phoenicis	2.8^{B}		
Nyeri	*O. coffeae*	2.3^{A}	4.0	0.1111
	S. dorsalis	0.0^{A}		
	B. phoenicis	0.3^{A}		
Kericho	*O. coffeae*	6.8^{A}	2.5	0.2013
	S. dorsalis	4.0^{A}		
	B. phoenicis	2.3^{A}		
Kiambu	*O. coffeae*	5.3^{A}	2.2	0.2275
	S. dorsalis	2.0^{A}		
	B. phoenicis	5.0^{A}		

Similar superscript letters within each region pest species denote no significance ($p > 0.05$) difference of abundance (Fishers LSD, $F_{2, 8}$).

3.2 Site Leaf Production Levels

Tea crop production plots were largest in Kiambu (54.2 ha) on corporate farms owned by the small holder farms, while smallest production plots were reported in Imenti North and Kakamega at 0.4 ha (Table 2). Leaf yield was

highest in Kiambu at 9,167kg followed by Nandi Hills 5,420 kg per year. Lowest leaf yield was scored in Mt. Elgon region followed by Nyeri at 925 and 1,089 kg, respectively. Much of the tea crop was produced in pure crop system besides some areas of Imenti North and Imenti South which included intercropping with bananas, maize, potato and khat production in the same plots.

Table 2. Tea production acreage range (ha), altitude (m), fertilizer input (kg) and subsequent yield (kg) per year at specific site regions in Kenya 2014-2015

Site region*	Altitude (m)	Acreage (ha)	NPK (kg)	Fertilizer kg/ha	Yield (kg/ha)	Cropping system
Imenti North	1,894 ± 17	0.4 ± 0.5	317 ± 85	793 ± 25	5,367 ± 578	Bananas, maize
Imenti South	1,789 ± 24	4.2 ± 2.0	466 ± 176	110 ± 12	7,733 ± 604	Potato, Khat
Murang'a	2,046 ± 17	0.9 ± 0.8	320 ± 168	355 ± 15	4,100 ± 872	Pure
Nakuru	1,849 ± 23	1.1 ± 0.3	200 ± 100	181 ± 9	4,000 ± 515	Pure
Mt. Elgon	2,016 ± 58	0.3 ± 0.2	125 ± 35	416 ± 13	925 ± 106	Pure
Nandi Hills	1,680 ± 13	3.3 ± 1.2	355 ± 29	108 ± 16	5,420 ± 512	Pure
Kakamega	1,628 ± 41	2.4 ± 0.1	366 ± 115	153 ± 8	7,067 ± 290	Pure
Nyeri	2,089 ± 38	1.1 ± 1.0	283 ± 124	257 ± 11	1,089 ± 221	Pure
Kericho	1,925 ± 10	2.3 ± 2.1	367 ± 184	160 ± 17	1,400 ± 430	Pure
Kiambu	2,371 ± 65	54.2 ± 50.9	1,366 ± 98	25 ± 4	9,167 ± 365	Pure

*Mean parameter (± standard deviation) indicative of value range at the different site regions.

Highest NPK-fertilizer input was reported in Imenti North and Mt. Elgon regions at 793 and 416 kg/ha, respectively. Lowest fertilizer rate was scored in Kiambu at 25 kg/ha. Small production plots in eastern and central regions of Imenti North, Imenti South and Murang'a showed the highest fertilizer application, leading to high leaf yield at 5367, 7733 and 4100 kg /ha, respectively. Similarly, high yield levels were scored from Kakamega, Nandi Hills and Kiambu regions.

3.3 Identity of Beneficial Organisms

Sites recording significantly ($P< 0.0001$, $F_{11, 43} = 8.7$ and $P< 0.0001$, $F_{11, 45} = 7.3$) highest predacious mites (Phytoseiidae Family) were Nyeri and Imenti North at 13.3 and 9.5 individuals per sample during dry season, while for the wet season Nyeri and Imenti North had 14.0 and 12.3, respectively (Table 3). Phytoseiid abundance during the same dry and wet seasons did not significantly differ within most sites. Sites with significant ($P< 0.05$) higher density of phytoseiids during wet season were Mt. Elgon and Kakamega at 6.0 and 3.3 mites per sample. Kericho had significantly ($P < 0.05$) higher density (6.8) of phytoseiids during dry season than the wet period (1.5).

Table 3. Comparable predacious mite density in tea production areas of Kenya during dry and wet seasons in 2014-2015

Year /Period			**Dry season**	**Wet season**	***cv%***	***F***	***P***
	Site areas	Altitude	No. phytoseiids	No. Phytoseiids			
2014/2015	Imenti South	1,789.5bcd	3.0c^{A}	5.3bc^{A}	35.8	0.3	0.8361
2014/2015	Murang'a	2,046.0ab	6.0bc^{A}	11.5ab^{A}	35.2	2.8	0.2150
2014/2015	Imenti North	1,894.8bc	9.5ab^{A}	12.3ab^{A}	15.1	2.5	0.2126
2015/2015	Mt.Elgon	2,016.0ab	1.8c^{B}	6.0bc^{A}	21.6	14.1	0.0276
2014/2015	Nandi Hills	1,680.5cd	3.5c^{A}	2.3c^{A}	50.7	1.0	0.5211
2015/2015	Kakamega	1,628.0d	1.3c^{B}	3.3c^{A}	25.7	9.4	0.0482
2014/2015	Kericho	2,016.8ab	6.8bc^{A}	1.5c^{B}	21.6	18.5	0.0188
2014/2015	Sotik	2,061.0ab	3.8c^{A}	2.8c^{A}	48.8	2.4	0.2448
2015/2015	Nyeri	1,833.0bcd	13.3a^{A}	14.0a^{A}	42.5	0.7	0.6283
2015/2015	Thika	2,202.3a	7.5bc^{A}	7.0bc^{A}	23.2	2.4	0.2508
2015/2015	Limuru	2,017.0ab	6.8bc^{A}	8.5abc^{A}	22.4	2.2	0.2716
------/2015	Nakuru	1,849.3bcd	-	6.7bc	-	-	-
	Mean	1,919.5	5.8	6.8			
	F	7.5	8.7	7.3			
	P	< 0.0001	< 0.0001	< 0.0001			

Different lower case letters within column denote significant ($P < 0.0001$) difference of altitude and predacious mite density among sites (Fishers Least Significant Difference; GLM PROC). Similarly, different upper case letters across the two seasons mite density indicate significant ($P < 0.05$) difference at same 5% level (*df* =1, 11).

A total of 34 phytoseiid species was identified from all the sites. The most abundant species were *Ueckermannseius macrosetosus* (130), *Amblyseius herbicolus* (115), *Typhlodromips culmulus* (100) and *Euseius rhusi* (100) in cumulative collections over the period (Fig.1). Thus, *U. macrosetosus* and *A. herbicolus* were 23 and 20 % present in the sample fields.

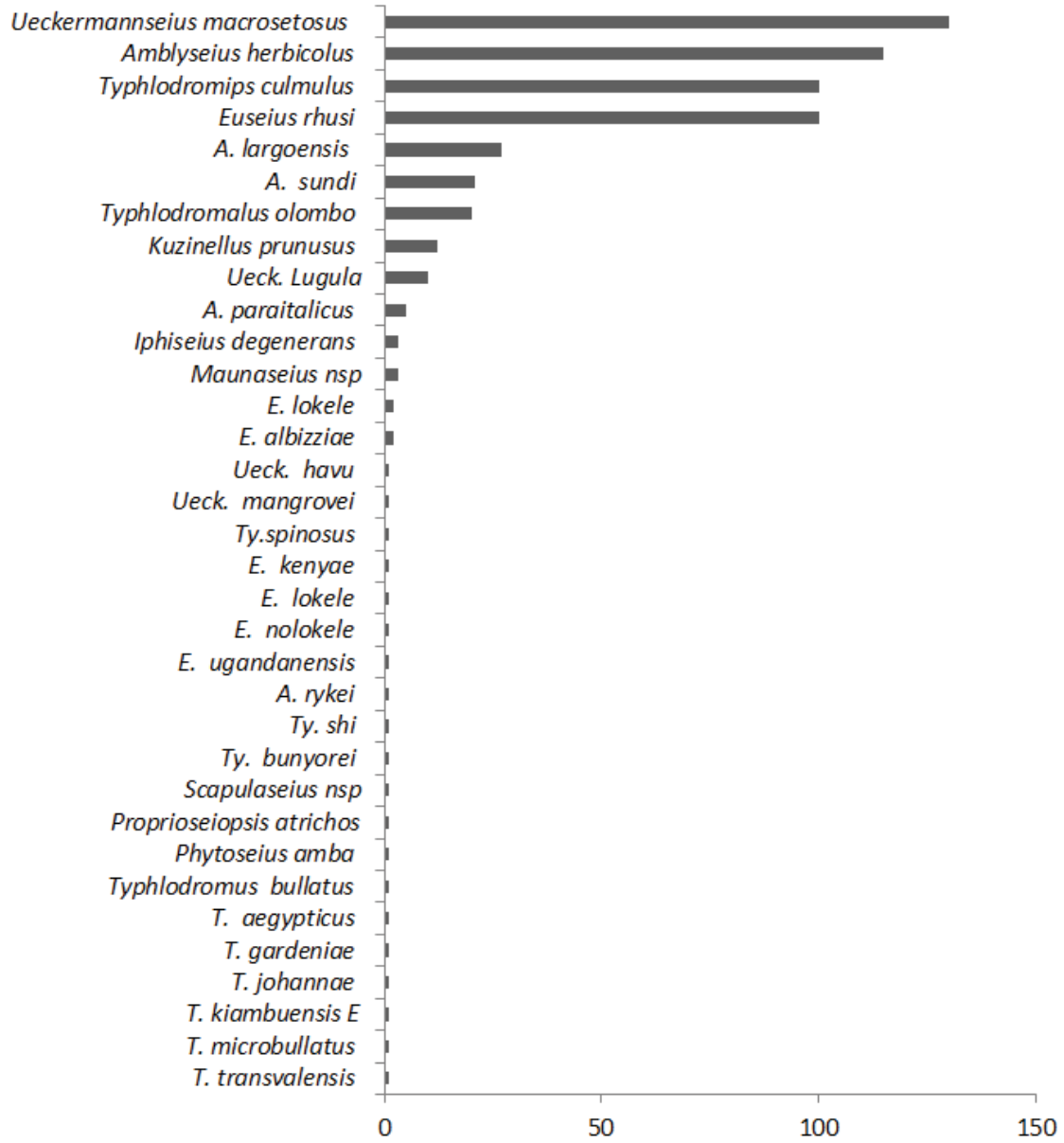
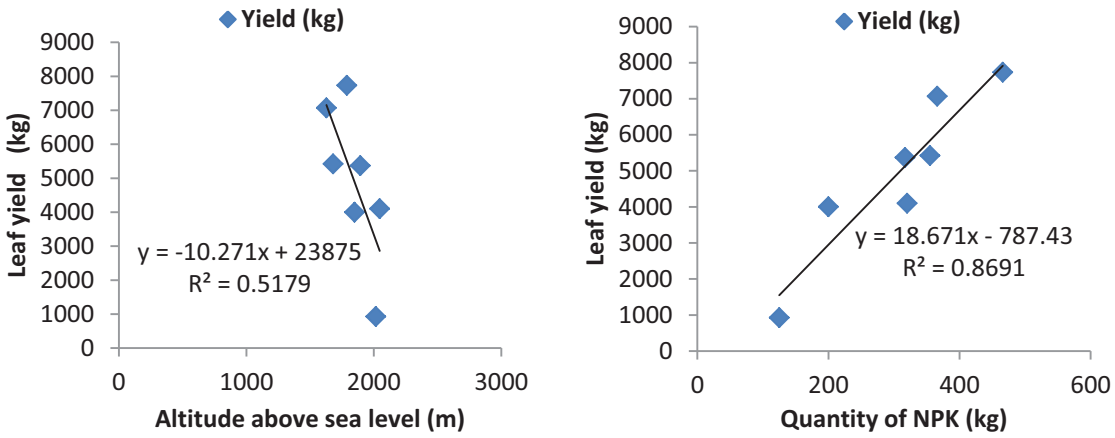


Figure 1. List and abundance of the phytoseiid predatory mites associated with tea plantation in Kenya (No. Sample= 110; No. individuals =569).

3.4 Environment-biological Impact

Highest leaf yield was observed within the range of 2000m above sea level (Fig.2A). Quantity of fertilizer input per year correlated ($R^2 = 0.8691$) with leaf yield at the production sites, as indicated in Figure 2B.



A B

Figure 2. Relationship between tea leaf yield and altitude (Fig.2A), and fertilizer (NPK kg) at production sites of Kenya (Fig.2B).

3.5 Predacious Mites' Positive Impact

Presence of phytoseiid mites in combination with NPK and high altitude led to strongest significant ($P< 0.05$; $R^2= 0.9699$, $F_{2,8} = 32.2$) correlation to yield than other variable sets (Table 4). Higher phytoseiid density ($P< 0.05$; $R^2= 0.6411$, $F_{2,8} = 3.57$) combined with altitude was third in positive impact to yield after altitude combined with NPK fertilizer ($P< 0.05$; R2= 0.8453, $F_{2,8} = 10.93$).

Table 4. Effects of various variables to tea yield in Kenya production areas in 2014-2015 periods

Variable	R^2	*t*	*F*	*P*
Altitude (m) above sea level	0.5179	2.9	5.41	0.0682
Fertilizer (NPK)	0.8613	5.6	31.04	0.0026
Phytoseiid density	0.0245	0.35	0.13	0.7373
NPK x Phytoseiid density	0.2119	2.2	0.54	0.6210
Altitude x Phytoseiid density	0.6411	3.20	3.57	0.1288
Altitude x NPK	0.8453	4.92	10.93	0.0239
Altitude x NPK x Phytoseiid density	0.9699	10.1	32.2	0.0088

GLM PROC (SAS) correlation at 5% level.

4. Discussion

The type of tea production system in Kenya remains monoculture in most places probably due to the high value of the crop as major foreign earner of the country. It was only in isolated fields in eastern Kenya highlands of Imenti North and South that inclusion of food crops like bananas, maize, potato and khat were included within tea plant plots or in small production portions. A faunistic survey in Hungary on grape agro ecosystem diversity has shown that phytoseiids presence lead to reduced number of phytophagous mites in vineyards, as it has also been reported on coffee production systems in Kenya (El Banhawy et al. 2009; Szabo et al. 2010).

Results from the present study have shown that the highest leaf yield was within the range of 2000m above sea level in Kiambu where highest yield was reported and correlated to NPK fertilizer applied per year. Yield increase is usually a positive response to fertilizer input in most production farms (Jayasinghe & Toyoda, 2004). Kenya's tea production regions receive high amount of rainfall which could lead to high nutrient leaching and retardant growth of plants, hence need for fertilizer input to sustain leaf yield throughout the year. The results showed that increased NPK-fertilizer input lead to higher leaf yield in small plot holdings in eastern and central Kenya.

Predacious mite abundance was highest in Nyeri at 14.0 and 13.3 mites per sample during the wet season and dry season respectively. Imenti North followed closely at 12.3 and 9.5 mites per sample in the wet season and dry season, respectively. These sites had low red mite density, *O. coffeae* and the yellow thrip *S. dorsalis*, while red crevice mite *B. phoenicis* was found in few areas and in low numbers. Incidentally, Nyeri is in the central Kenya within the Mt. Kenya region while Imenti North is located in the eastern Kenya hilly areas. Nyeri altitude is

comparatively higher (> 2000m) while Imenti North is < 1900m above sea level. The results showed that most predacious mites were within the 2000m range. Conversely, other factors contributed to phytoseiid abundance, most probably being rainfall amount and probably compact plant canopy leading to high humidity regimes to the mite niche ecology (Waage, 2001; Walzer et al., 2007). In the same evaluation Mt. Elgon is within the 2000m altitude range but could only yield 1.8 and 6.0 mites per year during the dry and wet seasons, respectively. Likewise, phytoseiid species distribution and their prey availability and preference was another factor (Waage, 2001). More so, these populations could also be affected by chemical sprays leading to reduced biodiversity of these beneficial agents for pest suppression (Duso et al., 2009). Predacious mite species diversity was 23 from 546 specimens analyzed. The most abundant species were *Ueckermannseius macrosetosus* (van der Merwe), *Amblyseius herbicolus* (Chant), *Typhlodromips culmulus* (van der Merwe) and *Euseius rhusi* (van der Merwe) presenting over 80% of the total phytoseiid fauna collected from the farms. The tea canopy was found more compact than that of cassava which was recently found to host 29 species of Phytoseiidae Family where *Typhlodromalus aripo* (De Leon) and *Euseius fustis* (Pritchard & Baker) led by 71% of the field sample frequency (Molo et al. 2016; Mutisya et al., 2017).

The tea leaf yield status in relation to predacious mites' abundance showed a positive correlation in most of the places sampled. The highest combination of phytoseiid density to yield was observed where altitude-NPK-phytoseiid were highest as inputs followed by altitude-NPK combination. Higher altitude-phytoseiid input provided the third best results to leaf yield level. A pioneer work of ten-year study on agroforestry advantage to increased phytoseiid diversity has been reported in vineyards where tree biodiversity led to higher diversity of phytoseiid within the defined production system (Tixier et al., 2015). Considering the fact that no chemical application is allowed in Kenya's tea production farms other control options are needed. Babu et al. (2008) reported efficacious results of managing *O. coffeae* by application of botanical products like neem. If the option does not work especially within the large commercial farms another option of irrigating the affected farm area would lead to low pest numbers with increased plant vigor and enhanced predacious mite mites due to increased humidity in the agroecosystem (Walzer et al., 2007). Where thrips damage tea, the use of biocides can supplement the predacious mites and preserve the ecosystem with enriched biological diversity where pests are suppressed below economic injury of tea leaf as in other crops (Roy et la. 2014b; Mutisya et al. 2015).

The study results showed that enhanced predacious mite density led to reduced pest status like red spider mites and thrip populations. Further, tea production system of the smallholder farms in Kenya offers high phytoseiid density combined even in high altitude leading to positive impact on leaf yield. In addition, the thick tea canopy and high leaf drop lead to increased soil amendment and high turnover of carbon quantities. These findings translate into an agro ecosystem which is fairly stable and rich in biological diversity of phytoseiid species even at high altitude of > 1900m above sea level.

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The Importance of Prison Farms: Evidence from Malawi's Prisons

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Abstract

While Malawi's per capita cereal production may be higher than her per capita cereal consumption, Malawi is a net cereal importer and thus food insecure. The food situation is much worse in Malawi's prisons because inmates generally eat one meal per day.

The general objective of this study was to determine the importance of farms in Malawi's prisons by comparing food insecurity in prisons with farms to that in prisons without farms. Using structured questionnaires in face to face interviews, the study collected data from 1000 prisoners and 30 officers-in-charge from all prisons in the country. The data was analysed using Stata 12 and employed the probit and the Foster-Greer-Thorbecke (FGT) models as an analytical tools.

Results from the analysis showed that practically all prisoners in Malawi's prisons were food insecure. There was a higher perception of food insecurity in prisons without farms than there was in prisons with farms. Conditions of severe food insecurity were experienced more in non-farmed prisons than in farmed prisons, and more prisoners in non-farmed prisons depended on food brought to them from their homes. Food insecurity was more prevalent in prisons without farms than in prisons with farms.

Keywords: Malawi's prisons, occurrence of food insecurity, severity of food insecurity

1. Introduction

Politically, Malawi is divided into four regions, these being the Northern, the Central, the Eastern and the Southern regions. There are six prisons with a prisoner population of 1,717 in the Northern region. In the Central region, there are eight prisons with a prisoner population of 3,784. The Eastern region has eight prisons with 4,072 prisoners, while the Southern region has 3,025 prisoners in eight prisons. There were 12,598 prisoners in Malawi's 30 prisons in 2016 when this study was conducted.

Statement of the Problem: Although Malawi is generally food insecure, it is common in Malawi that most people consume three meals per day. What differs is mainly the quality, quantity and variety of the food that they eat. Inmates in Malawi's prisons, however, generally eat one meal per day (African Commission on Human and Peoples' Rights, 2002; Penal Reform International, 2005). These reports mention food issues as observations made in relation to health and human rights. None of these reports showed evidence of any studies having been conducted to analyse prisoners' access to food in prisons with farms compared to that in prisons without farms. This study identified this as a problem. The study, therefore, intended to make this comparison and fill this knowledge gap.

Justification of the Study: The overall objective of Malawi's Food and Nutrition Security Policy is to significantly improve the food and nutrition security of the Malawi population (Malawi Government, 2005). The specific objective of the Food Security Policy is to guarantee that all men, women and youth in Malawi have, at all times, physical and economic access to sufficient nutritious food required to lead a healthy and active life (Malawi Government, 2006). Since prisons accommodate about 0.08 percent of the Malawi population, it is important that prisons are food secure and that every prisoner has access to not less than the minimum meal requirement. Given the Malawi Government's commitment to ensuring food security, it was important that this study be carried out so that issues of prisoners' access to food are analysed and comparisons made between prisons with farms and prisons without farms. It was important to study and understand these parameters in order

to lay the foundation upon which efforts to improve and re-engineer the food situation in Malawi's prisons could be based. This would enable policy makers and prison management to take appropriate policy and budgetary measures regarding prison subvention, strategic resource allocation, food production or procurement, and food demand and consumption levels to accurately address the problem and ensure prison food preparedness and improve prison food security. Also, since no study had been conducted in this area, it was important to conduct this study so that the existing knowledge gap could be filled.

Objectives of the Study: The general objective of this study was to demonstrate the importance of prison farms by analysing prisoners' access to food in prisons with farms compared to that in prisons without farms. The specific objectives of the study were:

i. To analyse the perception of food sufficiency in prisoners from prisons with farms compared to that in prisons without farms;
ii. To determine the number of meals per week that prisoners received from home in prisons with farms compared to that in prisons without farms, and
iii. To determine food security occurrences and frequencies in prisons with farms compared to that in prisons without farms.

Limitations of the Study: There were two major limitations to the study. The first was that all interviewees were male. This was because, for security reasons, the research team was only allowed to access prisoners that committed less serious offenses. Such prisoners were allowed to go out for farming activities because they were considered a lower security risk. The research team was advised to interview the sampled ones as they carried out their farming chores. The second limitation was that no female prisoners were in this category, not necessarily because they committed serious crimes, but because female prisoners were not allowed to go out for farming duties and the research team was not allowed to enter into the female side of the prison. As a result of these two limitations only 1000 male prisoners, instead of the required 1418 prisoners were interviewed.

The food situation in Malawi: The Millennium Development Goals (MDGs) through the medium term development strategy, the Malawi Growth and Development Strategy (MGDS), identified nine key priority development goals (Malawi Government, 2010). The first of these development goals was to eradicate extreme poverty and hunger. To achieve this, the Government's target was to halve, between 1990 and 2015, the proportion of people who suffered from hunger. One of the indicators for monitoring hunger was the proportion of the population living below the minimum level of dietary energy consumption of 2,100 kilocalories per person per day (Ecker & Qaim, 2008; Malawi Government, 1999).

Malawi is an aggregate net exporter of food. The bulk of the food exports, however, are non-cereals such as tea and sugar and so although the country is a net food exporter, it remains a net importer of cereals and thus food insecure. Maize is the staple food in Malawi (De Graaff, 1985; Kidane, et al., 2006; World Bank, 2008; Food and Agriculture Organisation [FAO], 2010; International Food Policy Research Institute [IFPRI], 2012; FAO, 2015).

The food situation in Malawi's prisons: It is a requirement of the United Nations that every prisoner should be provided, by the administration at the usual hours, with food of nutritional value adequate for health and strength, of wholesome quality and well prepared and served (Medecins Sans Frontieres, 2009). The Malawi Prison Act Cap. 9:02, (1983) provides a dietary schedule for prisoners belonging to various categories of prisons. Despite these legally binding dietary guidelines, the practice on the ground is different. The African Commission on Human and Peoples' Rights (2002) observed that Malawian prisoners received only one meal per day and that meals were not balanced as prisoners ate the same food every day. The report also observed that the meals comprised of maize (*nsima*) and boiled beans and sometimes pigeon peas or vegetables. Neither meat nor fish was provided but salt was available in all prisons. This is a typical case of food insecurity.

2. Materials and Methods

Data Collection Techniques: Both primary and secondary data were collected using questionnaires, one administered to prisoners, and the other to prison officers-in-charge. A total of 1,000 male prisoners from all the 30 prisons were randomly selected and interviewed using questionnaires administered in face to face interviews. Secondary data were collected from official records obtained from the Malawi Prison Service Headquarters and the various prisons that were visited.

Data Analysis: Data were entered in Excel and analysed using Stata 12. The output from the analysis was reported using descriptive statistics such as means, proportions and percentages.

Sampling Methods: All prisons in Malawi formed the field of study and every inmate, except those that had been in prison for less than four weeks, was an eligible interviewee. The four-week requirement is a normal

procedure followed by the USAID-funded Food and Nutrition Technical Assistance (FANTA) project which developed a questionnaire (Maxwel & Frankenberger, 1992; Swindale & Bilinsky, 2006) upon which the questionnaires used in this study were based. In order to select respondents from the population of inmates, the stratified random sampling and simple random sampling methods were used. The stratified random sampling method was applied to select *n* units out of *N* sub-populations called strata. In this case, each prison was a strata and from each strata *n* number of inmates were selected using simple random sampling in order to give each prisoner an equal chance of being selected (Bryars, 1983; Agresti, 1996; Zikmund, 1997; McGill, McLennan & Migliorini, 2000). In order to select participating inmates, tables of random numbers (Magnani, 1997) were used. In selecting prison officers for the interview, the purposive sampling method was used.

Sample Size: For more precision on sample size calculation, when population size and population proportions are known, the formula given below is used (Kothari, 2004).

$$n = \frac{z^2}{e^2} \frac{p.q.N}{(N-1)+ z^2.p.q} \quad (1)$$

where n = sample size, z = 1.96 = z-value yielding 95% confidence level, p = proportion of the population of interest, $q = 1 - p$, N = 12,598 = the population of interest, e = 5% = absolute error in estimating p.

The population proportion for each prison was calculated as in Equation **(2).**

$$\text{Prison proportion, } p = \frac{\text{Number of prisoners at a given prison}}{\text{Total prisoner population in Malawi}} \quad (2)$$

In 2016, the total number of, both convicted and un-convicted, inmates in Malawi's prisons was 12,598 (Malawi Government, 2016), while the population of Malawi as given by the United Nations Development Program (UNDP) in its 2011 Human Development Report was 15,380,900 (UNDP, 2011). Following the reasoning articulated above and applying Equation **(1)**, the value of *n,* the sample size, was found to be 1418. However, only 1,000 inmates were interviewed because of the study limitations.

Data were collected by three trained interviewers using a questionnaire that had been reviewed by a group of key informants, refined by eight prisoners that were representative of the survey population but who were not part of the survey sample, and pretested on fifteen prisoners through a preliminary survey. Data collected were subjected to regression and correlation analysis and results summarized.

3. Model Specification

Data from the prisoner questionnaire were entered in SPSS and then imported into STATA 11 for analysis using the probit model in order to analyse prisoners' perceptions of food sufficiency and determine the number of meals received from home. The Foster Greer Thorbeck model was used to determine prisoners' food security occurrences and frequencies.

The Probit Model

Data from the questionnaire that was administered on inmates were analysed using the probit model in order to establish relationships between and among variables. The probit model was considered appropriate because the questionnaire resulted in dichotomous variables which could easily be analysed using this model. The prisons were categorized in terms of whether a prison had a farm or not. A prison was considered to have a farm if it owned more than six hactares of farm land and otherwise, if it had less than that.

Following the arguments presented by (Maddala, 1992; Wooldridge, 2002; Verbeck, 2004; Gujarati D. , 2004; Greene, 2003), a regression model shown in Equation (3) was assumed.

$$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_j X_{ij} + U_i \quad (3)$$

where y_i^* is not observed, in which case it is a "latent" variable, then what is observed is a dummy variable y, defined by Equation (4).

$$y_i = 1 \text{ if } y^* > 0 \quad (4)$$

$y_i = 0$ otherwise

This was the basis of both the probit model. In equation (3) it is assumed that a latent variable exists for which a dichotomous realization is observed. For example, if the observed dummy variable is whether or not the prisoner

is food secure, y_i^* would be defined as "prisoner's perception of being food secure".

From equation (4), multiplying y_i^* by any positive constant doe not change y_i. So, if y_i was observed, the β's in (3) could be estimated only up to a positive multiple. As a result, it is customary to assume var(U_i) = 1. This fixes the scale of y_i^*. From equations (3) and (4), Equation (5) was obtained.

$$P_i = \text{Prob}(y_i = 1) = \text{Prob}[U_i > -(\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij})] = 1 - \text{F}[-(\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij})] \quad (5)$$

where F is the cumulative distribution function of *U*. Since the distribution of *U* is symmetric, given that 1 – F(-Z) = F(Z), then

$$P_i = \text{F}(\beta_0 + \sum_{j=1}^{k} \beta_j X_{ij}) \quad (6)$$

Because the observed y_i were realizations of a binomial process with probabilities given by (5), the likelihood function became

$$\text{L} = \prod_{vi=1} P_i \prod_{vi=0} (1 - P_i) \quad (7)$$

In (6), the functional form for F depended on the assumption made for the error term *U*. If the cumulative distribution of U_i was logistic, a logit model would be obtained. If the errors in U_i in (3) followed normal distribution, a probit model would be gotten. In that case Equation (8) would be gotten.

$$\text{F}(Z_t) = \int_{-\infty}^{\frac{Z_t}{\sigma}} \frac{1}{\sqrt{2\pi}} \exp(-\frac{t^2}{2}) dt \quad (8)$$

The cumulative normal and logistic distributions are generally very close to each other, except at the tails, in that the logistic tail is slightly fatter than the probit tail as the normal curve approaches the axes more quickly than the logistic curve.

After estimating the parameters, β_i, it was important to predict the effects of changes in any of the independent variables on the probabilities of any observation of the dependent variable. These effects were called marginal effects, given by $\frac{dy}{dx}$, in the probit analyses given in this study. Marginal effects were calculated at different levels of the independent variables to get an idea of the range of variation of the resulting changes in probabilities (Maddala, 1992; Gujarati, 2004).

The probit model has been used widely in analysing data in various research endeavours. For example, the probit model was used to analyse factors impacting adoption of genetically modified cotton (Banerjee & Martin, 2009). The model was also used to analyse the effects of some socio-demographic factors on the decision of the consumer to purchase packed or unpacked fluid milk in Sivas, Turkey. In that study, four estimators (household size, income, milk preferences reason, and milk price) were found statistically significant (Uzunoz & Akcay, 2012). The probit models were also been used in management research as analytical tools to the extent that they appeared in 15% of all articles published in the *Strategic Management Journal* in 2005 (Hoetker, 2007).

Each of the food security conditions of "anxiety", "insufficient quality", "un-preferred food", "limited variety", "unwanted food", "smaller meal", "fewer meals", "no-food-at-all", "sleeping hungry", "whole day and night", "augmenting", and "shameful means" was regressed against the independent variables of "age", "education", "how far", "meals per week", and "status". Table 1 carries descriptions of the variables.

Table 1. Description of variables for the probit models

Dependent Variable	Variable Description
Anxiety	Anxiety And Worry That There Would Not Be Enough Food In Prison
Insufficientquality	Insufficient Food Quality
Unpreferredfood	Not Eating The Kinds Of Food That One Preferred Because Of Lack Of Food
Limitedvariety	Eating A Limited Variety Of Foods Due To Lack Of Food
Unwantedfood	Eating Unwanted Food Because There Was No Other Food To Eat
Smallermeal	Eating A Smaller Meal Than One Needed
Fewermeals	Eating Fewer Meals In A Day
Nofoodatall	Having No Food At All To Eat Because Food Was Not Available
Sleepinghungry	Going To Sleep At Night Hungry Because Food Was Not Available
Wholeday&night	Going A Whole Day And Night Without Eating
Augmenting	Augmenting Food Intake Through Outside Supply
Shamefulmeans	Acquiring Food Through Borrowing, Begging Or Stealing
Independent Variables	Variable Description
Age	Age Of Prisoner In Years
Education	Education Level Of Prisoner In Years
Howfar	How far the prisoner's home or relatives are from prison
Meals/week	Number Of Times Per Week Prisoner Received Meals From Home
Status	Social Status Of Prisoner, Eg, Rich/Important/Influential Or Poor
Prison	Prison Where Prisoner Is Incarcerated

The Foster-Greer-Thorbecke (FGT) model

The Foster-Greer-Thorbecke model was used to determine food security occurrences and frequencies in prisons with farms compared to those in prisons without farms. The FGT model is expressed as in Equation (8) (Gujarati, 2004).

$$F(\alpha) = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{(m - y_i)}{m}\right]^{\alpha} \quad (9)$$

where *n* is the number of sample prisoners; y_i is the food caloric intake per adult equivalent of the i^{th} prisoner; m is the cut-off between food security and insecurity (expressed in caloric requirements); q is the number of food-insecure prisoners; and α is the weight attached to the severity of food insecurity.

It must be noted, however, that $m - y_i = 0$ if $y_i > m$. As for the weight α, giving no weight to the severity of food insecurity is equivalent to assuming that $\alpha = 0$. If that were done, the formula would collapse to $F(0) = \frac{q}{n}$, which is called the head count ratio. The head count ratio or the incidence of food insecurity would be the share of the prison population whose food intake was below the food security threshold of 2,100 kilocalories. It was also possible for one using several food insecurity thresholds, say one for food insecure and another for extreme food insecure, to estimate the incidence of both food insecurity and extreme food insecurity. A weakness of the headcount ratio, however, is that it ignores the depth of food insecurity in that should the hungry become hungrier, the head count ratio would not change (United Nations, 2015).

Giving equal weight to the severity of food insecurity among all food insecure prisoners was equivalent to assuming that $\alpha = 1$. If the sum of the numerator were taken, one would get the food insecurity gap, which when divided by m would give the food insecurity gap index (Gujarati, 2004). The food insecurity gap index would provide a better indication of the depth of food insecurity. It would also allow food insecurity comparisons and would provide an overall assessment of Malawi prisons' progress in curbing food insecurity. The food insecurity gap index would also help in the evaluation of Malawi's prison policies related to food and other initiatives. By multiplying the prisons' food insecurity gap index by both the food security threshold and the total number of prisoners in the country one would get the total amount of food needed to bring the food insecure prisoners out of food insecurity and up to the food security threshold (Gujarati, 2004). This means that the food insecurity gap index is an important measure beyond the head count ratio. If there were two prisons having similar headcount ratios, but different food insecurity gap indexes, it would mean that the prison with a higher food insecurity gap index had more severe food insecurity. The food insecurity gap index is additive, meaning that the index can be used as an aggregate food insecurity measure, as well as decomposed for various

sub-groups of the prisoners (Sen, 1976).

The index F(1) provided the possibility to estimate resources required to eliminate food insecurity. Giving weight to the severity of food insecurity among the most food insecure prisoners was equivalent to assuming that $\alpha > 1$. Therefore, allowing $\alpha = 2$, gave rise to Equation (10).

$$F(2) = \frac{1}{n}\sum_{i=1}^{q}\left[\frac{(m - y_i)}{m}\right]^2 \quad (10)$$

This yielded the severity of food insecurity. The severity of food insecurity took into account not only the distance separating the food insecure from the food security threshold but also the inequality among the food insecure. That is, a higher weight was placed on those who were further away from the food security threshold (Foster, Greer, & Thorbecke, 1984).

So, F(0) was the percentage of food insecure prisoners, F(1) the food insecurity gap and F(2) the severity of food insecurity.

4. Results and Discussion

The specific objectives of this study were to analyse the perception of food sufficiency, to determine the number of meals per week that prisoners received from home, and to determine food security occurrences and frequencies in prisons with farms compared to those in prisons without farms. The results have, therefore, been presented and discussed following this same sequence.

Prisoners' perception of food sufficiency. The general perception of prisoners in all prisons in Malawi was that there was insufficient food in prison. However, 59 per cent of the prisoners in prisons with farms perceived themselves as being food sufficient compared to 49 per cent in prisons without farms. Conversely, 41 per cent of prisoners in farmed prisons indicated food insufficiency compared to 51 per cent in prisons without farms. This result suggested that one was better off food-wise when incarcerated in a prison with a farm and worse off in a prison without a farm. Table 2 shows the prisoners' perception of food sufficiency in prisons with farms compared to those in prisons without farms.

Table 2. Prisoners' perceptions on whether food received was sufficient

	Prison with farm	Prison without farm
Sufficient	59.3	48.7
Insufficient	40.97	51.3
total	100	100

Table 3 contains results of the marginal effects from the robust regression of the probit models that were run to determine factors that affected the perception of conditions of food insufficiency in prisons with farms compared to those in prisons without farms.

Table 3. Factors affecting the perception of conditions of food insufficiency in prisons with and without farms.

Dependent Variable	**Independent Variables**									
	Prison with Farm, i.e. >= 6 Ha					Prison without Farm, i.e. < 6Ha				
	Ageprisoner	*Educationprisoner*	*Howfar*	*Meals*	*Status*	*Ageprisoner*	*Educationprisoner*	*Howfar*	*Meals*	*Status*
Anxiety	0.000106	0.001118	-0.024224	-0.085660***	0.095198**	0.008184***	0.001402	0.111606**	-0.021878	-0.095180**
Unpreferredfood	0.000268	0.006517	-0.023282	-0.042319***	-0.037752	0.002962	0.000672	-0.029234	-0.035903*	-0.042823
Limitedvariety	0.000136	0.008528	0.011761	-0.050089***	-0.070930**	0.006562***	0.016408***	0.002299	-0.012399	-0.092090**
Unwantedfood	0.002921	0.008387	-0.063043	-0.026828	-0.079061*	0.003977	0.002663	-0.043016	0.013332	-0.032477
Smallmeal	0.000162	0.009116	-0.021597	-0.069223***	-0.019060	0.004389*	-0.000190	0.031080	-0.044540*	-0.056314
Fewermeals	0.003100	0.006151	-0.054762	-0.024346	-0.045153	0.000915	0.001589	-0.020961	-0.024805	-0.146802***
Nofood	-0.000909	0.000798	-0.025666	-0.021713	-0.030859	0.000374	-0.008514**	-0.026790	0.010779	-0.054495*
Sleephungry	-0.000067	-0.012858**	-0.060623	-0.023975	-0.022482	0.004374**	-0.006483	0.000906	0.006296	-0.047823
Day&night	0.000753	-0.008900**	-0.021120	-0.057568*	-0.016844	0.002331	-0.006928*	-0.094432**	0.008649	-0.003885
Augment	-0.001065	0.012451*	0.026967	0.058373**	0.030610	0.001968	-0.007854	0.087379	0.095732***	0.168364***
Shamefulmeans	-0.001244	0.003567	0.087475**	-0.039198*	0.084230*	0.000410	-0.006891	0.228903***	0.028702	0.015008

Note: Marginal effects reported

*** significant at 1%, i.e. $p < 0.01$

** significant at 5%, i.e. $p < 0.05$

* significant at 10%, i.e. $p < 0.10$

Anxiety over food. In prisons with farms, the prisoner's age was an insignificant factor in determining the level of anxiety and worry over food, where as in prisons without farms, the prisoner's age significantly caused an increase in anxiety over food. This suggested that food was scarcer in prisons without farms and older prisoners had more difficulties to access it. The further away from prison that the prisoner's home was, caused an insignificant two per cent in the prisoner's anxiety over food at a farmed prisons, but caused a significant increase of 11 per cent if the prisoner was at a prison without a farm. Frequent receipt of home meals significantly reduced anxiety over food by about nine per cent at farmed prisons, while insignificantly reducing anxiety at non-farmed prisons. Being of higher status significantly increased the prisoner's anxiety over prison food by 10 per cent in farmed prisons and significantly reduced this perception by 10 per cent in non-farmed prisons. This was possibly because being of higher status meant that the prisoner was used to good life and having abundant good food and would thus find the prison food situation worrying. On the other hand, a prisoner of higher status would easily have access to alternative means of acquiring food and hence be less worried over prison food when everyone else was worried. Also prisoners of high status had the means to be able to bribe cooks and get bigger portions of food than other prisoners. This would also make them less anxious about food. It was, however, clear from the results that prisoners that were incarcerated at prisons with farms worried less about food than those at prisons without farms.

Eating un-preferred food. The number of meals per week that the prisoner received from home was the only significant factor that caused one to eat or not eat un-preferred food in prisons both with and without farms. An increase in the frequency of home-meal receipts, on the whole, caused a negative four per cent on prisoner's perception of eating un-preferred food, irrespective of whether their prison had or did not have a farm. Notes written down during interviews indicated that prisoners who often received meals from home did not rely on prison food. Those who received home meals every day did not eat much prison food. Because of this comfort, these prisoners ate more of the food that they preferred and perceived prison food as un-preferred.

Eating a limited variety. Both *meals* and *status* were of negative significance in affecting eating a limited variety of foods in prisons with farms. Frequently receiving meals from home caused a negative five per cent, while *status* caused a negative seven per cent in the prisoners' perception of eating a limited variety of foods. These results were not surprising because as the frequency of home meals and the level of status increased, one became better nourished, and better supplied even in variety of food and therefore found prison food less adequate in its variety.

In prisons without farms, *prisoner age*, *education* and *status* were significant factors in influencing one's perception of prison food being of limited variety. *Prisoner age* and *education* each had a positive influence of about one and two per cent respectively. *Status* caused a negative influence of about nine per cent. *Prisoner age* had a positive effect possibly because the older prisoners more readily understood food varieties and indeed found prison food to be of limited variety. *Prisoner education* also exerted a positive effect. This was also because education helped one to understand the six food groups and thus allowing him to find prison food to be of limited variety. But both *prisoner age* and *education* were insignificant factors in causing this perception in farmed prison. This is a possible indicator that access to food was comparably better in farmed prisons. Higher status, on the other hand, enabled the prisoner to negatively judge prison food variety, possibly because he had exposure to more and better food variety.

Eating unwanted food. Prisoner status significantly influenced the prisoners' perception of eating unwanted food in prisons with farms. Higher prisoner status caused a negative eight per cent in the prisoner's perception of prison food being unwanted. Again, the higher status would have exposed the prisoner to more appetising food from home thereby making him see prison food as unwanted. In prisons without farms, no variable was found to significantly influence prisoners' perception of eating unwanted food. This finding may mean that prisoners in prisons without farms were so desperate for food that they could not judge any food, not even prison food, as unwanted.

Eating a smaller meal. The number of meals per week received from home caused the prisoner to significantly perceive the prison ration as being small in prisons with farms. Receiving more meals from home caused a negative seven per cent in the prisoner's perception of the size of the prison ration being small. This could be attributed to the fact that home portions could be more generous thereby having the effect of making the prisoner see the prison ration as being smaller by comparison.

The age of the prisoner was of positive significance while the number of meals received from home was of negative significance in prisons without farms. The rationale given in earlier sections about the effect of *home meals* was applicable here also. However, the fact that older prisoners were more aware of the smallness of the

meal size in non-farmed prisons was cause for concern. This could be an indication that food was scarce in non-farmed prisons and older prisoners became easy victims, possibly due to lack of physical strength to compete with the younger ones.

Eating fewer meals. No variable significantly influenced the perception of eating fewer meals in prisons with farms. This meant that prisoners in prisons with farms did not really feel that they ate fewer meals. This could be a pointer to the fact that farmed prisons were better endowed with food. Prisoner status, however, significantly caused a negative 15 per cent on the perception of eating fewer meals in prisons without farms. The negativity would arise from the fact that higher status would mean access to more meals from outside prison, thus, by comparison, making the prisoner aware that the prison provisions were fewer.

No food at all. In prisons with farms, no variable significantly caused the perception that there was no food at all to eat at the prison. This meant that in farmed prisons, they always had something to eat, possibly confirming the proposition that farmed prisons were better supplied with food. However, in prisons without farms, prisoner education and status negatively but significantly caused in the prisoner the perception that there was no food to eat at the prison. Prisoner education influenced this perception by nearly one per cent while status influenced it by five per cent. As was seen before, this was not surprising as an increase in both education and status would have exposed the prisoner to better opportunities which would enable him to spot shortfalls in prison rations. In spite of the aforesaid, this increased perception of there being no food at all to eat could be an indication that prisons without farms were finding it difficult to feed their prisoners.

Sleeping hungry. Prisoner education was a significant factor in causing the perception that the prisoner was sleeping hungry in prisons with farms. An increase in education caused a negative one per cent in this perception. Again, this was expected for reasons articulated earlier in this paper. In prisons without farms, prisoner age caused a small but positively significant influence in the perception that the prisoner was sleeping hungry. It was possible that the older prisoner slept hungry because in times when food was extremely scarce, the older prisoner lacked the physical strength to compete with the younger prisoners for food and so the older one slept hungry. On the other hand, this finding confirmed the earlier finding that prisons without farms had difficulties in feeding their inmates; the older prisoners simply being easier victims.

Day and night. Prisoner education and meals received from home were negative but significant factors in causing the perception of staying the whole day and night without eating. Being more educated caused a negative one per cent while receipt of more home-meals caused a negative six per cent in this perception in prisoners at prisons with farms. This was because higher education possibly allowed the prisoner to have alternative means of accessing food and receipt of more home-meals helped the prisoner not to stay a whole day and night without food.

In prisons without farms, education and how far from home the prisoner was, caused a negative but significant effect of about one per cent and nine per cent, respectively, on the prisoners' perception of staying a whole day and night without eating. It was expected that education would lower the perception of staying a whole day and night without food because of the capacity of the educated prisoner to find alternative sources of food. The anomaly was when prisoners who came from distant places showed a reduced perception of staying a whole day and night without food, and at a farm-less prison for that matter. The only plausible explanation for this scenario could be that these prisoners had completely lost hope or any sense of self-worth that they had resorted to simply accept life and situations as they unfolded. Possibly these prisoners had stayed a whole day and night without eating many times before so much so that it did not matter anymore now and they had accepted this as normal practice, hence their reduced perception of staying a whole day and night without eating. This finding was a possible indicator of severe food scarcity in prisons without farms.

Augmenting food intake. Prisoner education and receipt of home-meals were positively significant in augmenting food intake in farmed prisons. In non-farmed prisons, significant factors were *meals* and *status*. Receipt of more home meals caused a ten per cent increase in augmentation whereas higher status caused a 17 per cent increase. These results were expected as education, receipt of home meals, and status were factors that have been found to enable prisoners gain easy access to outside resources, including food. The fact that there was more augmentation with outside food in prisons without farms also meant that in these prisons food was scarcer.

Shameful Means. In farmed prisons, how far the prisoner's home was from prison, meals received from home, and the prisoner's status were significant factors in influencing the perception of obtaining food through shameful means such as borrowing, begging or stealing from other inmates or people. An increase in the distance between prison and the prisoner's home increased this perception by about nine per cent. This meant that increased distance to the prisoner's home, probably out of desperation, made the prisoner resort to these

shameful means more and more. On the other hand, increased receipt of home-meals caused a four per cent reduction in this perception. This was expected as receipt of home meals would make a prisoner better fed and, therefore, have no need to beg, borrow or steal food from other people.

An increase in the prisoner's status, however, increased this perception by about eight per cent. This is another anomaly because, so far, it has been seen that prisoners of higher status lacked no food and, therefore, should have no reason to borrow, beg or steal food from anyone. The question that was asked to the inmates was "In the past four weeks, did you **or any inmate** at your prison resort to other means of acquiring food such as borrowing, begging or stealing from other inmates or people because there was not enough food?" If attention is focussed on **"or any inmate"**, it may be seen that the prisoner could give a "yes" response not with respect to himself, but other inmates. If that respondent was one of higher status, chances were that he was the one from whom food was borrowed, begged or stolen, considering that he was the one in possession of more food than anyone else. Given the foregoing, the prisoner of higher status would likely know some inmates at his prison who resorted to shameful means of obtaining food, such as borrowing, begging or stealing. His "yes" must, therefore, be understood in the sense that an increase in the prisoner's status increased his perception of suffering from these shameful means.

In farm-less prisons, how far away the prisoner's home was from prison, significantly increased the prisoner's perception of engaging in shameful means of obtaining food. An increase in distance between prison and home increased this perception by about 23 per cent, meaning that prisoners from far away were more likely going to engage in this behaviour, possibly out of desperation. By comparison, increased distance caused a nine per cent increase in the perception of using shameful means in farmed prisons but caused an increase of 23 per cent in non-farmed prisons. This big percentage difference was a serious indicator of food scarcity in non-farmed prisons.

Meals per week received from home. Most prisoners did not receive meals from outside prison, and less than one percent received such meals every day of the week, irrespective of whether or not the prison had a farm. This was not surprising as most prisoners came from far from prison, making it difficult for relatives to visit often. Comparing farmed and non-farmed prisons, it transpired that 86 per cent of the prisoners from farmed prisons received no meals at all from home while 77 per cent of the prisoners from non-farmed prisons did not receive home meals. This meant that only 14 per cent of prisoners from farmed prisons received food from home when 23 per cent of prisoners from no-farmed prisons received food from home. This result gives evidence to the fact that prisoners in Malawi were better fed when imprisoned at a farmed prison than when at a non-farmed prison. Also, less than half a per cent of prisoners from prisons with farms received home meals every day of the week, when one per cent of those from prisons without farms received home meals every day. This is an indication of how desperate the food situation was in prisons without farms. Table 4 shows the number of meals per week that a prisoner received from home.

Table 4. Meals per Week Received from Home

Meals per week (%) (n = 1000)								
No. of meals/week	0	1	2	3	4	5	7	Total
Without farm	76.72	13.41	5.59	2.98	0.37	0	0.93	100
With farm	85.53	7.78	4.32	1.08	0.43	0.43	0.43	100
Pearson Chi-square	17.99	***						

Prisoner food security occurrences and frequencies. Out of the eleven conditions of food insecurity which were studied, six were indications of less serious food insecurity while the other five were indications of severe food insecurity. The six indicators of less serious food insecurity were: anxiety, un-preferred food, limited variety, unwanted food, small meals and fewer meals. The five indicators of severe food insecurity were: no food at all, sleeping hungry, not eating whole day and night, augmenting and using shameful means. The results in Table 4 show that fewer prisoners in farmed prisons experienced the conditions of severe food insecurity compared to those in non-farmed prisons. For example, only eight per cent of the prisoners in farmed prisons experienced staying with no food at all versus 11 per cent in non-farmed prisons. In farmed prisons, 17 per cent slept hungry compared to 24 per cent in non-farmed prisons. Only ten per cent in farmed prisons stayed a whole day and night without eating versus 14 per cent in non-farmed prisons. In farmed prisons, 39 per cent augmented prison food with outside food compared to 45 per cent in non-farmed prisons. About 58 per cent in farmed prisons used shameful means of obtaining food compared to 65 per cent in non-farmed prisons. These results, therefore, showed that a prisoner was better off, food-wise, if incarcerated in a farmed prison than in a non-farmed prison.

Table 5 presents prisoner food security occurrences and frequencies.

Table 5. Prisoner food security occurrences and frequencies

condition of food insecurity	Without farm	With farm
Anxious	60.52	62.2
Unpreferred food	80.82	83.8
Limited variety	82.12	79.48
Unwanted food	52.14	55.94
Small meal	76.54	75.59
Fewer meals	77.09	78.62
No food	11.36	7.78
Sleep hungry	24.39	17.06
Whole day & night	13.59	9.5
Augmenting	45.44	38.88
Shameful means	64.8	58.32

Food security prevalence. Prisoners in Malawi's prisons were found to be severely food insecure. The worst case scenario was prisoners in non-farmed prisons, where 95 per cent of the prisoners were severely food insecure compared to 79 per cent in farmed prisons. On the other hand, the most food secure prisoners (11 per cent) were those incarcerated in prisons with farms because only one per cent of those in non-farmed prisons considered themselves food secure. Table 6 shows prisoner food security prevalence in percentage terms.

Table 6. Food security prevalence

food security Status	**With farm**	**Without farm**
Food secure	11.3	1.3
Mildly food insecure	2.1	0.5
Moderately food insecure	7.3	3.4
Severely food insecure	79.3	94.8

Note: Some columns do not add up to 100 % due to rounding off errors.

5. Conclusion

About 41 per cent of the prisoners in prisons with farms indicated food insufficiency compared to 51 per cent in prisons without farms. The prisoner's age significantly caused an increase in anxiety over food and also caused a small but positively significant influence in the perception that the prisoner was sleeping hungry in prisons without farms. The prisoner's age and education were also significant factors in influencing one's perception of prison food being of limited variety but both were insignificant in prisons with farms. The prisoner's education and status negatively but significantly caused the perception that there was no food to eat at the prison. Older prisoners were more aware of the smallness of the meal size in non-farmed prisons. These findings were possible indications that food was scarce in non-farmed prisons.

The further away from prison that the prisoner's home was, caused an insignificant two per cent in the prisoner's anxiety over food in farmed prisons, but caused a significant increase of 11 per cent if the prisoner was at a prison without a farm. By comparison, increased distance caused a nine per cent increase in the perception of using shameful means in farmed prisons but caused an increase of 23 per cent in non-farmed prisons. Prisoners who came from distant places also showed a reduced perception of staying a whole day and night without food at a farm-less prisons, possibly indicating that these prisoners had completely lost hope or any sense of self-worth that they had resorted to simply accept life and situations as they unfolded. Prisoners incarcerated in prisons without farms whose homes were far away from prison were also so desperate for food that they could not judge any food, not even prison food, as being unwanted.

In prisons with farms, no variable significantly caused the perception that there was no food at all to eat at the prison. This meant that in farmed prisons, they always had something to eat, possibly confirming the proposition that farmed prisons were better supplied with food.

The fact that there was more augmentation with outside food in prisons without farms also meant that in these prisons food was scarcer. About 14 per cent of prisoners from farmed prisons received food from home

compared to 23 per cent in non-farmed prisons. Fewer prisoners in farmed prisons experienced the conditions of severe food insecurity compared to those in non-farmed prisons. In non-farmed prisons, 95 per cent of the prisoners were severely food insecure compared to 79 per cent in farmed prisons. On the other hand, the most food secure prisoners (11 per cent) were those incarcerated in prisons with farms as only one per cent of those in non-farmed prisons considered themselves food secure. The findings in this paper gave evidence to the fact that prisoners in Malawi were more food secure and better fed when imprisoned at a prison with a farm than at a prison without a farm.

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Non-traditional Economic Estimation of Dairy Cow Income in Grazing Systems

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Abstract

The objective was to evaluate the economic efficiency of two groups of cows in a grazing system using a non-traditional estimation strategy. Retrospective data were used corresponding to the lactations of 216 primiparous and multiparous cows of Holstein breed American-Canadian biotype with records of all their productive life, from their incorporation to the system until their sale or death, collected between the years 1992-2012. It was concluded that the economic efficiency of the two groups of cows analyzed is not only determined by milk production, but by a set of additional variables such as longevity and reproduction.

Keywords: milk production, reproduction, longevity, efficiency

1. Introduction

Considering the rentability of the business seems something logical for any enterprise regardless its final product, since that allows knowing how efficient it is in all its aspects and, besides, to make the right decisions on time. However, in the milking business this is not so and producers give privilege to short-term profit related to a higher milk production rather than to the stability and sustainability of the business associated to aspects such as the sale of surplus heifers, the sale of males, the lower percentage of discard, the less use of technology in supplies, and others.

The milking industry in Argentina has shown a productive stagnation close to 11,000,000 liters per year since 2011. These liters are produced in farms whose number has remained rather stable varying from 11,282 in the year 2011 (Sánchez *et al.*, 2012) to 11,500 productive units estimated in the year 2016 (Bargo, 2016). The poor growth in the Argentinian industry between 2011 and 2015 happened within a context of relative good prices both of milk and of a key supply such as maize. In this scenario, there would seem that the problems related to the growth of the national milking industry are related mainly to the performance of the farms, which are facing trouble increasing their production levels, even under auspicious economic conditions (Pace Guerrero and Gastaldi, 2016). Even though it might not be the only way to take, Galli *et al*., (2017), working in a group of farms in the south of the province of Santa Fe, have shown that there are concrete possibilities of improving their systems of production through the application of technology of processes based on planning and managing the available resources.

In most dairy establishments, producers ignore their productive rate, their production costs and the economic result of their cattle business and of other branches of the business. For that reason, they can hardly make the proper decisions to improve their results (Ferrada Neira, 2004). Facing the urgent need to increase the technical and economic efficiency of the milking production systems, the determination of other indicators represent a highly important tool, since they are essential to determine the productivity of the herd. At the same time, it is necessary and decisive to make an analysis of the higher production costs that the market demands, in order to

evaluate the rentability of the herd and to secure their future maintenance. This reflection is rooted in Camargo's (2012) statement, that there is an imposition of increasing cow productivity as the only way out, which necessarily derives in an increase in production costs, including hand labor and those deriving from land as a productive resource. In coincidence with reports from Horn et al., (2012), a reduction in the yield of milk production does not necessarily lead to lower profits, if it is accompanied by an increase in cow longevity. According to Stott (1994), the economic advantage of longevity lies primarily in retaining productive cows for as long as possible, while ensuring that less productive cows are replaced as soon as it is economic to do so. In this context, the aim of this work was to evaluate the economic efficiency of the two groups of Holstein cows in a grazing system using a non-traditional estimation strategy

2. Materials and Methods

Retrospective data were used corresponding to the lactations of 216 primiparous and multiparous cows of Holstein breed of American-Canadian biotype with records of all their productive life -from their incorporation to the system until their sale or death- collected between the years 1992-2012, in the farm belonging to the agro-technical school Gral. San Martín, belonging to the National University of Rosario. The farm is located in the city of Casilda, province of Santa Fe, Argentina (33º 02´ 39´´ south latitude, 61º 10´ 05´´ west longitude). It has milk control of the Rural Society of Totoras, Oficial Entity N° 13, and exhibits the following characteristics: (1) only Holstein cows are used; (2) food is basically pastures (alfalfa) with supplementation (maize grain, maize silos and rolls) supplied in different proportions according to the seasonal availability of the alfalfa meadows; (3) regular gynecological controls are carried out; (4) there is an official milking control; (5) it is free from tuberculosis, campylobacteriosis and trichomoniasis, in control of leptospirosis, bovine infectious rhinotracheitis and bovine viral diarrhea; (7) cows are artificially inseminated with semen from American or Canadian origin and (8) available data are reliable. These characteristics guarantee minimum standards of health and food managing and technical support, which places this farm above the average in the area, in these aspects.

In the period when the data were collected, cows were handled in the same milking facilities. Animals were divided into two categories: pure cows (PC) (n=88) and cows with breed records (CBR) (n= 128). The difference between both is based on the fact that the formers are inseminated with semen from tested bulls while such a practice is not kept constantly in the case of the laters. In order to achieve the condition of pure cow, seven generations of tested progenitors are needed, which implies that the members of the group of cows with breed records are in different stages of that way to attain it. During the evaluated period, cows consumed forages under direct gazing (consociated pastures, and annual winter and summer pastures) or conserved (maize and sorghum silos, pasture hay) and concentrated (maize and sorghum grains). The weather was not uniform during the study, both as regards rainfalls as well as combinations of temperature and relative humidity.

Each cow belonging to each of the two above mentioned groups was characterized according to the values of two reproductive indicators: age at first delivery in days (EPP) and first delivery-delivery interval in days (IPP) and two productive indicators: milk production adjusted to 305-day lactation yield in liters (PL) and butyrose fat produced in kilograms (GB). Even though the quantity of butyrose fat and the quantity of milk are closely related, both indicators were included because the first one does not refer to real values but to values adjusted to a time of lactation common to every individual (305 days), while the quantity of fat shows the kilograms of butyrose fat effectively produced throughout the whole productive life of the animal.

The whole behavior of the four indicators mentioned was evaluated with the multivariate technique of principal components. For the purpose of analysis, the principal components generated with such technique corresponding to each animal were treated as new random variables. Individual values corresponding to the first (PC1) and the second (PC2) principal component, were graphed in a system of orthogonal Cartesian axes. Four quadrants were defined through two perpendicular lines which intersect each of the axes in the medium values of such components. Quadrants were numbered correlatively from I to IV, anti-clockwise, starting from the top right quadrant. Next, the animals in each quadrant were identified, yielding four groups of cows (Quadrant I: high values for both components; Quadrant II: low values for PC1 and high values for PC2; Quadrant III: low values for both components and Quadrant IV: high values for PC1 and low values for PC2). At the same time, within each quadrant, cows were discriminated into pure or with breed records. The association between both categories (type of cow and quadrant of origin) was evaluated by means of Chi-square test. The quadrant effect on each of the productive and reproductive traits involved in the principal component analysis jointly with three indicators of cows' longevity (NP: numbers of deliveries registered throughout their reproductive life, IL: milk index, defined as milk production per day of life and calculated as the ratio between the total milk production in liters of a cow throughout its life and the number of days required for producing them, and IG: index of fat, defined as the production of butyrose fat per day of life and calculated as the ratio between the total production of butyrose

fat in a cow's life in kilograms and the number of days required for producing them); was assessed by means of a one way analysis of variance followed by the Bonferroni test of multiple comparisons.

For the analysis of the economical balance, the following indicators were considered:

1. Pl total (litres): pl 305 * 100
2. Births: estimation of births adjusted in a year according to Magnasco (1998).
3. Born female: births / 2 (rounding out to females)
4. % loss: estimated in agreement with González Besteiro (2010)
5. Real females: born females - 8% of loss
6. Apt females: Females really apt for replenishing, estimating 24 months as the optimum (Bargo, 2016) expected value 100, as the values went further, it was calculated (value of epp of each group in months *100 / 24 months as the optimum value (Marini, 2016).
7. replacement: 100 cows / (np*100)
8. lack or surplus of cows: replacement – apt females
9. Milk: pl total * Price per liter paid to the producer. Price per liter paid to the producer $5.10 (Liniers Market, 2017. https://www.mercadodeliniers.com.ar).
10. Discard cow: (weight of the discard cow* replacement) * Price of the kilogram of discard cow. Weight of the discard cow: 550 kg. Price of the kilogram of discard cow $18 (Liniers Market, 2017. https://www.mercadodeliniers.com.ar).
11. Calf: weight of the calf * price of the kilogram of calf. Weight of the calf: 80 kg when weaning. Price of the kilogram $35 (Liniers Market, 2017. https://www.mercadodeliniers.com.ar).
12. Heifers: number of heifers * Price of the heifer $18000 (Liniers Market, 2017 https://www.mercadodeliniers.com.ar).
13. Outflow: need to purchase in any category
14. Balance: Income (milk + discard + cow + calf + heifer) – Outflow (heifer)
15. **$1= € 24,72** (https://www.lanacion.com.ar/economia/divisas)

Finally, three situations were modelled with the solely variation of milk production (5000, 6500 and 8500 liters), remaining the values of the other traits identical for the three cases. For each of the three models the economic balance using only CI and CIV data were calculated. These two quadrants were chosen because CI represents cows typical of intensive systems while CIV represents cows from extensive grazing systems.

3. Results

The first principal component (PC1) explained the 35.12% of the phenotypic variance and was correlated in a positive and significant way (P<0.0001) with milk production (r = 0.804) and fat production (r = 0.544), in a negative way (P = 0.004) with age at first delivery (r = -0.194) and positively (P<0.0001) with interval between deliveries. Therefore, it was named PRODUCTION.

The second principal component (PC2) explained 25.04% of the total variance and was correlated positively and significantly (P<0.0001) with age at first delivery (r = 0.865) and with the interval delivery-delivery (r = 0.317; P < 0.0001), in a negative way (P < 0,0001) with fat production (r = -0.313) and positively with milk production (r = 0.193; P = 0.005). Therefore, it was called PRECOCITY.

The distribution of pure cows and cows with breed records was not homogeneous (X^2 = 17.8; P = 0.0005) in the four quadrants. In the first quadrant, it is observed a little higher proportion of pure cows (27.5%) than cows with breed records (20.2%), same as in the fourth quadrant, where nevertheless the difference is bigger with 37.5% of total pure cows facing a 16.9% of cows with breed records. In the other two quadrants, there is a majority of cows with breed records particularly in the second quadrant with 41.1% versus 21.3% of pure cows. In the third quadrant the values are 24.2% versus 13.8% for cows with breed records and pure respectively.

Figure 1 resumes the values of productive indicators corresponding to both categories of cows, according to the quadrant they belong. It is observed that, within each quadrant, there are only significant differences between the categories of the cows (p≤0.05) as regards IL, IPG and IG in Quadrant I and as pl305 in Quadrant IV.

Table 2 presents the values derived from the proposed model of economic balance applied to cows of both categories belonging to Quadrants I and IV, both with high values of PC1 (PRODUCTION) and different value

of PC2 (PRECOCITY). In it there can be observed that cows of Quadrant IV, independently from their category, pure or with breed records, generate bigger economic income than those from Quadrant I due to the fact that – although cows from Quadrant IV generate lower incomes from milk production, they present higher incomes from the sales of heifers and calves.

Table 1. Productive-reproductive characterization of the two types of milking cows throughout their useful lives, discriminated according to the Quadrant they belong to, defined by the values of the first and second components, generated from a multivariate principal component analysis

Quadrant II				**Quadrant I**			
	Pure Cows	**Cows with breed records**			**Pure Cows**	**Cows with breed records**	
	15	35			30	23	
epp	1134±44	1178±33	ns	**epp**	1035±23	1058±40	ns
np	3 (2-6)	3 (1-7)	ns	**np**	3 (1-8)	2 (1-8)	ns
pl 305	5516±208	5281±124	ns	**pl 305**	6858±141	6729±121	ns
GB	651±60	520±52	ns	**GB**	858±74	682±87	ns
il	7,8±0,4	6,5±0,4	ns	**il**	9,6±0,3	8,2±0,5	*
ipp	458±18	452±11	ns	**ipp**	533±17	610±28	*
ig	0.261±0.01	0.227±0.01	ns	**ig**	0.319±0.01	0.280±0.01	*
pl total	19704±1923	17930±1814	ns	**pl total**	25640±2127	20426±2846	ns
Quadrant III				**Quadrant IV**			
	Pure Cows	**Cows with breed records**			**Pure Cows**	**Cows with breed records**	
	13	47			30	24	
epp	850±36	853±14	ns	**epp**	853±22	866±19	ns
np	3 (1-6)	4 (1-7)	ns	**np**	4 (2-9)	5 (2-10)	ns
pl 305	5059±173	5247±102	ns	**pl 305**	6686±121	6265±175	*
GB	517±72	628±42	ns	**GB**	1177±71	1233±84	ns
il	7.4±0.4	7.8±0.3	ns	**il**	11.5±0.4	11.2±0.3	ns
ipp	452±29	430±7	ns	**ipp**	494±12	479±13	ns
ig	0.272±0.01	0.264±0.01	ns	**ig**	0.398±0.01	0.368±0.01	ns
pl total	14992±2132	18804±1290	ns	**pl total**	34160±2231	37476±2527	ns

Table 2. Productive and reproductive traits of pure cows and cows with breed records located in Quadrants I and IV

	Trait	**Quadrant I (> CP1 y > CP2)**		**Quadrant IV (< CP1 y > CP2)**	
Type of cow		VP	VRC	VP	VRC
Real data	PL 305 (liters)	6858	6729	6686	6265
	NP	3	2	4	5
	IPP (days)	533	610	494	479
	EPP (months)	33	33	28	28
Model to 100 cows	PL total (liters)[1]	685800	672900	668600	626500
	Births[2]	71	59	75	75
	Born Females[3]	36	30	38	38
Constant	% loss[4]	8	8	8	8
	Real females[5]	33	27	35	35
	Apt females[6]	21	17	29	29
	Replacement[7]	33	50	25	20
	Replacement heifers[8]	-12	-33	+4	+9
Income	Milk[9]	2948940	2893470	2874980	2693950
	Spent cows[10]	326700	495000	247500	198000
	Calf[11]	98000	81200	103600	103600
	Heifer[12]	0	0	100000	225000
Outflow[13]	Heifer	300000	825000	0	0
Balance[14]		3073640	2644670	3326080	3220550

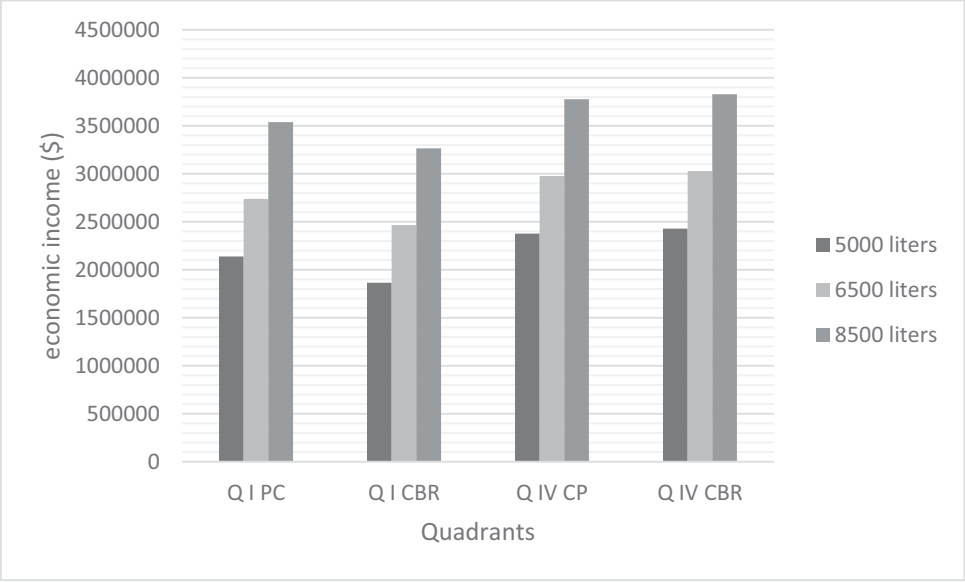

Figure 2. Relationship between milk production and economic income

Figure 2 describes the economic income corresponding to pure cows and those with breed records, located in Quadrants I and IV as regards three values of milk production: 5000, 6000 and 8500 liters. Logically, it is observed that as milk production increases, there is higher income both in QI as in QIV. However, independently from milk production, the combination of the higher efficiency in the rest of the variables involved (number of deliveries, delivery - delivery interval and age at first delivery), determines higher incomes from cows in QIV.

4. Discussion

Even though animal health and welfare together with sustainability and the minimum use of supplies are nowadays founding factors for milk production; for the last decades, the main objectives pursued when breeding milking cows have been maximizing the efficiency of milk per cow and the early maturity in heifers (Horn *et al.,* 2012). It can be seen in Figure 1 that cows belonging to Quadrant I present a high milk production as well as kilograms of GB, higher rates of milk and GB, but also lower life expectancy, higher age at delivery, and a longer delivery-delivery interval. Cows in Quadrants II and III show quite similar results, except for age at first delivery, which is higher in cows of Quadrant II. As for the rest of the indicators, they are cows with low life-expectancy, low IL and IG, with lower milk production per lactation, but a shorter delivery-delivery interval. Cows in Quadrant IV are those with the longest life-expectancy, the higher IL and IG, with a production level similar to those in Quadrant I but with a shorter delivery-delivery interval than these. There are no big differences as regards the predominance of pure cows or cows with breed records between Quadrants I and IV. The difference observed in terms of income lies in that cows of one or the other category belonging to Quadrant IV show a longer life expectancy combined with milk production (6000-6500 liters) according to the nutritional and environmental conditions of the grazing system. These conditions allows animals to produce without affecting their reproductive efficiency; which lets them reach higher rates of milk and fat, showing their adaptation to this particular productive system.

Cows in Quadrant I would represent those from intensive systems (higher milk production) while cows in Quadrant IV would be examples of those adapted to grazing systems (higher lifetime). The key factor for these cows, independently from their group (pure or with breed records), is their lifetime expectancy. In the last 25 years, the average number of deliveries in specialized breed has fallen from 3.5 to about 3.0 (Knaus, 2009). In evolutionary terms, life expectancy is correlated with a higher opportunity of reproduction and therefore a higher biological effectiveness, that is to say a higher biological efficiency. Cows in Quadrant IV are an example in this sense since, in comparative terms, they present longer life expectancy, get pregnant sooner (lower age at first delivery), expressed higher values of IL and IG and, even though they are not those with the highest adjusted production, they produce the higher quantity of GB with delivery-delivery intervals not so far from the optimun from Quadrant I. They are cows “for extensive grazing systems” which show reproductive imbalance due mainly to the handling and nutritional conditions. The model presented in Chart 1 considers all the cow’s productive life

and shows that the higher incomes come from those located in Quadrant IV despite the fact that they are –in comparison- those with the lowest production; but this is so due to their long life span (higher number of deliveries), better reproductive efficiency (shorter delivery-delivery interval) and younger age at first delivery. Part of this revenue advantage in longevity lies in retaining productive cows for a longer period of time, ensuring that less productive cows are replaced as soon as economically possible. Therefore, in this context, the potential productive life rather than the average productive life of dairy cows become important. The proportion of forced (involuntary) slaughter governs the potential productive life and, therefore, the economic advantage of longevity (Stott, 1994). This reveals the role of those traits, which were not taken into account in pre-established economic calculations (where income is only shown by means of milk sale). The higher percentage of income comes through milk sale, but there is still a 15% of the total income that may come from selling the surplus heifers, male calves and spent cows, which –despite not having a big influence in the total income- are worth to be considered. These results are in agreement with previous reports (Marini and Oyarzabal, 2002b), showing that higher milk production would not be enough in order to guarantee higher incomes (Chart 1 and Figure 2), but the economic balance in the different groups under analysis indicate that the global productive efficiency is related not only to milk production but also to the behavior of other traits related to the reproductive and lifetime circle, that is to say, with the adaptation to the particular conditions of the grazing system (allowing the use of lower quantities of concentrated and conserved forages, while keeping the production). In addition, these results agree with those found by Horn *et al.,* (2012) where a reduction in the performance of milk production does not necessarily mean lower incomes, if it coincides with a longer lifetime span. The economic advantage of a longer lifetime lies mainly in the fact of keeping productive cows as long as possible, while making sure the less productive cows are replaced as soon as it is economical to carry out. By reducing involuntary sacrifice, the costs of replacement are reduced and production increases due to a lower frequency of cows with low performance and a longer lifetime of cows with high performance (Rogers *et al*., 1988).

5. Conclusion

It is concluded that the economic efficiency of the two groups of Holstein cows under analysis is not only determined by milk production, but also for other traits such as lifetime and reproduction.

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Impacts of Cooperative Thrift and Credit Facilities on Members' Business Output in Ogun State, Nigeria

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Abstract

Cooperatives play an important role in facilitating access to credit, procurement and storage distribution of input and marketing of products. They create employment opportunities particularly in the rural areas and allow disadvantaged groups to be organized for social and economic benefit. This study was conducted in Abeokuta North and Abeokuta South Local Government Areas of Ogun State, Nigeria. Both primary data and secondary data were used for the study. Multi–stage random sample was used to sample 108 cooperative members. Data collected were analysed using descriptive tools, budgetary analysis, logit and multiple regression model. The findings shows that majority (50.9 percent) of the cooperators are male, 77.8 percent were married, 59.3 percent were Christians while 98.1 percent were educated. Majority (87.9 percent) had experience ranging from 1 – 10 which is good in business. The total variables cost from business was estimated at ₦70,983.47, total fixed cost was ₦276,271 and this accounted for only 79.56 percent of the total cost. Returns on Investment (RRI), Profitability Index (PI), Return on Variable Cost (RRVC) and Operation Ratio (OR) were 181.62%, 0.63, 173.42% and 0.21 respectively. Also some (48.1 percent) of the respondents enjoyed loan benefit, while 40.7 percent enjoyed business improvement benefit. The results showed that start up capital, labour and credit obtained were significant to cooperative members'access to credit. The result revealed that majority (72.2 percent) of the respondents suffered from non-remittance of deduction by the government as their own challenges. The study concluded that cooperative credit societies is very productive and effective in helping members achieving their goals and also improve their standard of living. Cooperatives societies should encourage members in quick accessibility to loan.

Keywords: business, cooperative, logit, multiple regression and credit

1. Introduction

International Co-operative Alliance (ICA) (1895) defined Cooperative Society as an autonomous association of persons united voluntarily to meet their common economic, social and cultural needs and aspirations through a jointly owned and democratically controlled enterprise. Also, Ebonyi and Jimo (2002) described cooperative societies as associations of persons who have voluntarily come together to achieve common objectives through the formation of democratically controlled organization; making equitable contributions to the capital required and accepting a fair share of the risk and benefits of the undertakings. UWCC, (2002) summarily described Cooperative Society as a business or group enterprise that is voluntarily owned and controlled by its members, patron and operated for them on a non-profit or cost basis.

The essence of cooperatives as observed by Dogarawa (2005) is an effective way for people to exert control over their livelihoods; provide a unique tool for achieving one or more economic goals in an increasingly competitive global economy; own what might be difficult for individuals to own or pursue by their efforts; strengthen the communities in which they operate through job provision. Generally, cooperative provides an economic boost to the community. This cooperation to Audu *et. al.,* (2007) enables people to achieve through joint efforts, what they are unable to achieve while working as individual.

Unavailability of funds to rural dwellers has been consistently reported in extant literatures and researches to be

a hindrance to rural productive ventures (Ekong 2007; Aremu, 2004; Ndifon, 2012). Cooperative societies therefore have the enormous potentials to address these issues. Afolabi (2008) elucidated that group efforts are necessary to bring people together so that they can use pooled resources to produce. Cooperative societies are therefore veritable instruments to use in achieving this goal. The ILO report in 2001 and Mukarugwiza (2010), characterized cooperative societies as having the potentials for economic, social and political development of their members. According to the ILO (2001), the economic role of cooperative involves provision of opportunities for improved incomes to members as well as tool to help alleviate poverty. Cooperatives play an important role in facilitating access to credit, procurement and storage distribution of input and marketing of products, these create employment opportunities particularly in the rural areas and allow disadvantaged groups to be organized for social and economic benefit.

According to Brawerman *et al*., (1991); Gertler, (2001); Dogarawa, (2005); Gibson, (2005); Berko, (2001) craft and artisans cooperatives have the ability to develop rural economy and improve the socio-economic conditions of its members. Because of this, there has been considerable expectation from these cooperatives to achieve social and economic goals and also spur development and alleviate poverty. It is against this background that various Micro and Small Scale Enterprises (MSEs) have grouped themselves for greater efficiency and effectiveness through mutual cooperation.

Thrift and Credit Societies are member-based organizations that help members to address economic problems. They are not banking institutions because of their goal. The ultimate goal is to encourage thrift among the members and to meet credit needs of people who might otherwise fall prey to loan sharks and other predatory lenders (Babatunde *et. al.,* 2007).

Cooperative societies are widely spread organization in developing countries, they are known for strong commitment of, as well as participation in the decision making of their members (Haan *et al*., 2003).

These societies mobilize local savings and administer credit to members, thereby encouraging thrift and entrepreneurial activity. When first started, credit cooperative use relatively unsophisticated administrative practices, so that the costs are very small and most interest income from loans may either be distributed to the members or reinvested in the credit cooperative within a capitalization programme. Consequently, they can be set up in poor communities, where access to means of secure savings and to credit at non-exploitative terms is of greatest importance (UNDESA, 1999).

The vision of the cooperative development policy of the government, as expressed by the Federal Ministry of Agriculture and Rural Development is to promote members' entrepreneurial capacities so that they can generate adequate surpluses for themselves and create opportunities for economic progress for the public. Asaolu (2004) described cooperative societies as popular organizations which are voluntary associations set up by citizens in order to promote their common welfare. This is because; according to Lawal (2006) Cooperative Society is a kind of business for the benefit of its members. It is a general view that solution to economic problems lies in the human factor; and that more can be accomplished when people coordinate their efforts with each other and take concerns and talents of other into considerations. Reeves (2003) opined that creating wealth requires that we cooperate with each other to make the most valuable use of our limited time, effort and resources, and that human progress can continue to be made through, communication, coordination and cooperation.

The micro-finance power of cooperative societies cannot be overemphasized. Small scale enterprises (SSEs) have been promoted greatly by Micro-finance Institutions (MFI's), the major and most geographically spread of which are cooperative societies. Apart from ready access to micro-credits, Small Scale Enterprises (SSEs) obtain loans with soft and convenient term. Adelaja (2006) noted that the current banking consolidation programme though desirable, is likely to be more of threat than opportunity for MSMEs. Therefore there is the need to embrace the cooperative options. Most members of cooperative societies engage in one economic activity or the other and thus contribute in no small measure to economic outputs of the nation. Economic development is better achieved through cooperation to solve the problem of scarcity.

There have been many misconceptions and opinions from individuals, small and medium business enterprises and corporate business entities that microfinance institutions have outlived their relevance in the twenty first century with the proliferation of larger commercial banks that provide a wide range of financial services due to their sophisticated infrastructure, technology and innovations (Philip, 1993).

However, there are other schools of thought that agitate that micro-finance institutions such as Credit Cooperative are still relevant in the twenty first century. Though large commercial banks provide wider coverage and larger volumes of financial services to their clientele but such services are mainly confined to larger commercial and industrial sectors. Thus, their services are not defused in the hinterland (Darko, 2005).

Again in as much as traditional banks are perceived to provide needed financial services to individuals, small and medium scale enterprises (SME's) access to credit facilities remains a formidable constraint to most small scale business. Not only accessibility to credit but where they are made available, their inadequacies, high cost of borrowing pose a great challenge to many small scale businesses in due to predominant agrarian economic activities that most people engage in. It is against this background that this study investigated the effect of Cooperative Thrift and Credit Facilities on members' business performance.

2. Objectives of the Study

The major objective of this study is to examine the Impacts of Cooperative Thrift and Credit Facilities on Members' Business Output in Ogun State. The specific objectives are to:

(i) examine the cost-return structure of the business of the respondents.

(ii) identify the factors that determine the profit of the members' business.

(iii) examine the factors affecting members access to credit facilities.

3. Research Methodology

3.1 Study Area

The study was conducted in Abeokuta North and Abeokuta South Local Government Areas of Ogun State. The State comprises Four Divisions which are Egba, Ijebu, Remo and Yewa. The State has 20 Local Government Areas. Abeokuta South Local Government Area of Ogun State created through a Local Government Edict. No 9 of 1976, with its headquarters in Ake. The Local Government Area lies in the rain forest zone of Nigeria. Its lies within latitude 6^0 55^1 7^0 N and longitude 3^0 46^1-4^0 15^0 E, and has human population of about 2,236,689. Abeokuta South Local Government Area is one of the twenty Local Government Areas in Ogun State which lies in the western part of Nigeria. (NPC Report, 2006).

3.2 Sources and Methods of Data Collection

Both primary data and secondary data were used for the study. Personally administered questionnaire were used to collect data from a random sample of 108 cooperative members spread across 18 randomly selected cooperative societies covered by the study. Supplementary data were also obtained from secondary sources, including research journals, CBN Statistical Bulletins, FAOSTAT, and the Internet.

3.3 Sampling Techniques

Multistage random sampling technique was used in sampling the respondents. In the first stage two (02) Local Government Areas (i.e Abeokuta South and Abeokuta North) was purposively selected. The second stage involves random selection of nine (09) cooperative societies from each of the Local Government Areas to make eighteen (18) cooperative societies and the final stage includes random selection of six (06) cooperators from each of the eighteen (18) societies chosen in the second stage, thus making the total respondents of one hundred and eight (108) respondents used for the research work.

3.4 Methods of Data Analysis

In analyzing the data obtained for the study, a number of analytical methods was employed and these include; descriptive statistics, budgetary analysis, regression and the Logit regression model.

3.5 Analytical Techniques

3.5.1 Socio-Economic Characteristics of Small-Scale Business Owners in the Study Area

Descriptive Statistics: This includes the use of means, frequency and percentage tables. This was used to present information on respondents' socio-economic variables such as age, sex, household size and business experience

3.5.2 Cost and Return Structure of Small Scale Business Owners in the Study Area

Budgetary Analysis

The gross margin of an enterprise is the difference between the total value of production and the variable cost.

Gross Margin can be expressed mathematically as;

Gross Margin Analysis: The budgetary technique was used to determine the gross margin at various scales of operation as earlier used by Asaolu (2004)

*Model used in estimating the **Gross Margin** is:*

$$GMI = \Sigma TR - \Sigma TVC \quad (i)$$

$$TR = Py \ .Yi \quad (ii)$$

$$TVC = Px. \ X \quad (iii)$$

$$TC = TVC + TFC \quad (iv)$$

$$NFI = GM - TFC \quad (v)$$

Where:

GMI = Gross Margin Income (₦)

TR = Total Revenue (₦)

TVC = Total Variable Cost (₦)

TC = Total Cost (₦)

NFI = Net Income (₦)

Py = Unit Price of Output Produced (₦)

Y = Quantity of Output (Kg)

Pxi = Unit Price of Variable Inputs Used (₦)

Xi = Quantity of Variable Inputs (Kg)

Rate of return on Investment (RRI) = NI/TC X 100

Rate of Return on Variable Cost (RRVC) = (TR-TFC)/TVC X100

Operating Ratio (OR) = TVC/TR

3.5.3 Benefits of Credit Cooperative to Members

Descriptive Statistics: was used to describe the benefits of credit cooperative to members business. This included the use of means, frequency and percentage tables.

Examine the determinants of business profit of the cooperative members

Production functions were fitted into the data to examine the **d**eterminants of profitability of the investment among cooperative members. The implicit form of the linear regression model used is:

$$\text{Implicit form: } Y = \beta_0 + \beta_1 X_1 + U \quad (vi)$$

$$\text{Explicit form: } Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + U \quad (vii)$$

Where:

Y= Dependent variable

β_0 = Constant

Xi = Co-efficient of Independent Variables

U = Error term

Y = Total profit (₦)

X_1 = Gender (1 = male, 0 = female)

X_2 = Educational level (years of formal schooling)

X_3 = Start- up Capital (₦)

X_4 = Labor (mandays)

X_5 = Age of SMEs owner (years)

X_6 = Business experience (years)

X_7= Family size (number)

X_8 = Amount of credit obtained (₦)

X_9 = Membership of cooperative society

U = Error term

3.5.4 Factors Affecting Members Access to Credit Facilities in the Study Area

The Logit Regression Model

This was used to determine the socio-economic factors affecting cooperative members' access to credit. This is mathematically stated thus:

$$L1 = In\ [p1/1-p] = \beta_o + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_5X_5 + \beta_6X_6 \quad \text{(viii)}$$

Where Pi = 1 if respondent had access to credit

Pi = 0 if respondent had no access to credit

X_1 = Age of respondents in years

X_2 = Education in years spent in schools

X_3 = Membership of cooperative society

X_4 = Occupation (1 if employed, 0 if otherwise)

X_5 = Gender (1 for male, 0 if otherwise)

X_6 = Ownership of tangible Asset (house, large areas of land, motorcycle, vehicle e.t.c)

X_7 = Household size (Number of person)

4. Results and Discussion

Table 1. Distribution of Sampled Cooperative Members' Household by Socio-Economic Characteristics, N =108

Group	Frequency	Percentage	Mean
Age Group			
Below 30 years	30	25.9	
31 - 40 years	43	39.8	
41 - 50 years	27	25.0	35 years
51 - 60 years	7	6.5	
Above 60 years	3	2.8	
Sex			
Male	55	50.9	
Female	53	49.1	
Marital Status			
Single	20	18.5	
Married	84	77.7	
Divorced	2	1.9	
Widow/widower	2	1.9	
Religion			
Christianity	64	59.2	
Islam	40	37.0	
Traditionalist	2	1.9	
None	2	1.9	
Household size			
1 – 3	34	31.5	
4 – 6	58	53.7	
7 – 9	14	13.05	
Above 10	1	0.9	
Educational Level			
Primary	34	31.5	
Secondary	33	30.5	
Tertiary	39	36.1	
None	2	1.9	
Business Experience			
1 – 5 years	73	67.6	
6 – 10 years	22	20.3	6years
11 – 15 years	3	2.7	
Above 15 years	10	9.4	
Cooperative Membership Years of Experience			
1 – 6	68	63.0	
7 – 12	27	25.0	7years
13 – 18	12	11.1	
Above 18	1	0.9	
Total	**108**	**100**	

Source: Field Survey, 2015

4.1 Description of Socio – Economic Characteristics of Cooperative Members'

In Nigeria, Socio–economic characteristics are important in securing and using credit. The variables discussed include age, gender, marital status, religion, household size, education, business experience, labour used, occupation, cooperative membership experience, credit requested, credit granted and credit obtained among others, as these variables are set to have direct or indirect influence on the performance and decision making activities of the members.

The distribution of age, sex, marital status and religion of respondents is presented in Table 1. Cooperative requires the involvement of agile, productive and able – bodied people in most business activities. Younger people are expected to be able to do more work than older ones. From the survey the age of the respondents

wasrevealed mean of 35 years. A total of 90.7% of the respondents were with the age range of 18 to 50 years, this result shows that Cooperative credit enhance their performance. Also, they are expected to be very active and desirous for performance –oriented opportunities (Olarinde *et al* 2004).

From the findings, the distribution of the sampled household heads of respondents by sex showed that majority (50.9 percent) are male and others (49.1 percent) are female. This implies that both female and male cooperators are well represented and give room for gender equality for effective running and performance. The distribution of respondents according to marital status shows that 77.8 percent of the respondents were married. It also suggests that they would be desirous of opportunities that could be applied towards increasing their income earning capacity and improving their standard of living. The religion distribution of the household head showed that 59.3per cent are Christian while 37.0per cent are Muslims, this implies that most of the respondents are religious and this could aid their credit repayment as at when due.

Data in Table 1 also presents the household size of the respondents; this comprises their wives, children and their dependants. In African setting, women and children labour constitute significant source to labour for small–scale business. The findings revealed that the mean household size 5 persons. It also shows that majority (99.1 percent) of their household members range from 1 to 9. This implies that the larger the number of household size, the higher the source of labour through family and cooperative credit beneficiaries better in performance. This suggests that as the household size increased the more tendencies for cooperative members to diversify against risk and make way for increased performance by involving family members.

Education is an indispensable tool needed to enhance technical advancement in using cooperative facilities; it plays prominent roles in eradication of ignorance. The findings revealed that large proportion (98.1 percent) of the cooperative members had one form of education and the other. This implies that majority of them would be quick adopter of innovation and equally improve their standard of living.

Business experience plays a dominant role in managing risks associated with the business. The experience gained by respondents as measured by the numbers of years the cooperative members has been into business has bearing on their resources used and overall management of their business activities. The findings revealed that majority (87.9 percent) had experience ranging from 1 – 10 years which is good in business.

The findings also revealed that majority of the cooperative members have long stayed in cooperative, this thereby assist in their various operation in cooperative activities. The result shows that 63.0 percent had experience between 1 – 6 years which could be good in cooperative activities and management.

4.2 Description of Cost and Return to Cooperative Members

Budgetary Analysis result from business of the cooperative credit members is presented in Table 2. The total variables cost from business was estimated at ₦70,983.47. The total fixed cost was estimated at ₦276,271.00 and accounted for 10.26 percent of the total revenue. This showed that fixed cost constituted the larger proportion of cost of business for the respondents. In addition, Total Revenue (TR), Gross Margin (GM) and Net Farm Income (NFI) of the business were estimated at ₦973,533.33, ₦702,549.87 and ₦426,278.87 respectively. The result shows that Rate of Returns on Investment (RRI), Profitability Index (PI), Rate of Return on Variable Cost (RRVC) and Operation Ratio (OR) were 181.62%, 0.63, 173.42% and 0.21 respectively. The implication of this is that cooperative credit beneficiaries made profit in their businesses and which invariably increased their performance and involvement in cooperative activities.

Table 3. Estimate of Cost and Returns of Cooperators' staple foods and related items

Inputs	Mean cost (₦)	% Total cost
Packaging materials cost	4,263.33	1.23
Transportation cost	2,390.00	0.69
Levy	3,788.89	1.09
Labour cost	14,150.36	4.07
Electricity cost	4,791.11	1.38
Total Variable Cost	70,983.47	20.44
Rent cost	116,021.11	33.41
Scale cost	2,518.89	0.73
Generator cost	31,505.56	9.07
Furniture cost	5,331.11	1.54
Total Fixed Cost	276,271.00	79.56
Total Cost	347,254.47	
Total Revenue	973,533.33	
Gross Margin	702,549.87	
Net Income	426,278.87	
Profitability Indices:		
Rate of Returns on Investment (%)	181.62%	
Profitability Index or Return on Sale	0.63	
Rate of Return on Variable Cost (%)	173.42%	
Operating Ratio	0.21	

Source: Field Survey, 2015

4.3 Description of Benefits of Credit Cooperative to Members of the Societies by Respondents

Cooperative as an autonomous association of person who come together on the basis of equality for the purpose of economic growth and betterment of members and self-help are active in the area of advancing credit to members (Adegeye and Dittoh, 1995).

The purpose for which loan is obtained however determine the benefit members enjoy from the socieities.Table 3 presents the various benefit cooperatives members enjoyed. The result revealed that majority (48.1 percent) of the respondents enjoyed loan benefit, while 40.7 percent enjoyed business improvement benefit, 9.3 percent enjoyed savings and dividend benefits and 1.9 percent enjoyed purchase of household commodities benefit. The members are therefore enjoined to use the loan for the purpose for which it is collected and avoid diversion so as to increase quick repayment.

Table 3. Description of Benefits of Credit Cooperative to Members' of the Societies by Respondents

Variables	Cooperative Credit Beneficiaries	
Members' Benefit	**Frequency**	**Percentage**
Improve Business	44	**40.7**
Loan Benefits	52	48.1
Dividends	10	9.3
Purchase of Household Commodities	2	1.9
Total	**108**	**100**

Source: Field Survey, 2015

4.4 Description of Estimates of Business Performance of Cooperative Members

Based on the R^2, F-value, t-statistic and theoretical expectation of the variables, the linear function was chosen as lead equation. Table 4 shows the regression estimates for the determinants of factors affecting effect of credit on cooperative members' business in the study area. The findings revealed that 86.5% and 61.3% of the variation of credit beneficiaries and non-beneficiaries members respectively were explained by the independent variables included in the model. The F-statistics (61.316) confirmed the suitability of the overall regression equation. The results revealed that three (start up capital, labour and credit obtained.) of the nine variables included in the model were significant at 1% and 5% respectively. The results obtained indicated that they are more resourcefully efficient than the non-credit beneficiaries. This is expected and pointed to the positive impact of

cooperative credit on members' business performance. The variables used had direct relationship with members' business performance. The negative sign of the business experience variable may be due to the fact that the higher the level of experience may lead to familiarity and they may not likely cater for their business.

Table 4. Regressions Estimate of Factors of Business Performance

Variable Code	Variable Name	Regression Coefficient	T-Value
βo	Constant	75509	0.213
X_1	Gender	0.2433	0.136
X_2	Educational Level	892.8	1.182
X_3	Start-up Capital	1.090	10.855***
X_4	Labour	0.34779	1.716*
X_5	Age	0.17836	0.136
X_6	Business Experience	0.4469	-0.795
X_7	Family Size	0.4917	1.616
X_8	Amount of Credit Obtained	0.069	13.528***
X_9	Membership of Cooperative	11596	0.370
Variance Parameters			
Multiple R^2	=	0.865	
Adjusted R^2	=	0.851	
F – Value	=	61.316***	

Source: Field Survey, 2015

***Significant at 1%; **Significant at 5%; *Significant at 10% respectively.

4.5 Description of the Logit Model Explaining the Factors Affecting Credit Access

The Logit regression model was used to examine factors that determine cooperative members' access to loan. It measured the parameters of the conditional probability of having access to the required level of funds and marginal changes in explanatory variables on the performance measures. The regression parameters and diagnostic statistics were estimated using Maximum Likelihood Estimation (MLE) technique. Table 5, presents the determinants of cooperative credit acquisition. The findings showed that one of the seven included regressors has significant influence on the cooperative members'access to credit. The chi-square (σ^2) value was 27.185, with a p–value of less than 0.01 and log likelihood function–52.571. Hence, sigma square was statistically significant, thus indicating that the model displays a good fit. The models also met the parallelism assumption that requires that parameters in the subsequent equations are the same. The link test also revealed that the model was correctly specified.

The variable that had significant co-efficient is occupation (X_4). It should be noted that a positive sign on a parameter indicated that higher values of the variables tend to increase the likelihood of credit accessibility and impact on business performance. Similarly, a negative value of a co-efficient implied that higher values of the variables would reduce the probability of credit accessibility and impact on the business performance. Specifically five of seven variables were positive while the rest are negative.

Hence, occupation should attract topmost importance on the priority list of cooperative members.

Table 5. Logit Model Explaining the Determinants of Credit Acquisition of Cooperative Members

Variables	**Maximum Probability Coefficients**	**Standard Error**	**Marginal Effects**
Constant	1.217 (2.148)	0.437	-0.915
Age (X_1)	0.4283 (0.979)	0.437	0.8805
Years in Education (X_2)	0.4290 (0.552)	0.7774	-0.6250
Membership of Cooperative (X_3)	0.1202 (1.485)	0.8096	-0.1248
Occupation (X_4)	0.4293 (4.288)***	0.1001	-0.1514
Gender (X_5)	-0.1100 (-0.116)	0.9463	0.3432
Asset(X_6)	0.2310 (1.604)	0.1440	0.7618
Household Size (X_7)	0.8519 (-0.703)	0.1212	0.9291
Chi – square value ($\sigma^{2)}$ = 14.467***; P < 0.01 (significant at 1%); Log likelihood Value = -59.571			

Source: Field Survey, 2015

*** Significant at 1%; **Significant at 5%; * Significant at 1%; T–value are in parenthesis

4.6 Description of Challenges Faced by Members of the Societies by Respondents

Challenges faced by the cooperative societies' members are numerous but from the study the following were deduced. From the findings, Table 6 presents the various challenges of cooperatives members' of the societies. The result revealed that majority (72.2 percent) of the respondents suffered from non-remittance of deduction by the government as their own challenges; while 14.8 percent had challenges of delay in loan approval; 11.1 percent had insufficient funds as their peculiar challenges and 1.9 percent had overdue loans as their peculiar challenges. It implies that individual societies have various challenges they encountered before loan can be approved and granted to their members.

Table 6. Description of Challenges faced by Members of the Societies by Respondents

Variables	**Members' challenges**	
Members' Challenges	**Frequency**	**Percentage**
Non remittance of deduction by the government	78	**72.2**
Delay in loan approval	16	14.8
Insufficient funds	12	11.1
Overdue loans	2	1.9
Total	**108**	**100**

Source: Field Survey, 2015

5. Conclusion and Recommendations

In conclusion, Abeokuta metropolis of Ogun State was purposively selected owing to their cooperative involvement. The respondents were selected through cooperative societies but data from one hundred and eight respondents were used for the purpose of analysis. Descriptive statistics, frequency table, percentage, mean, linear regression and logit models were used for the analysis of the data collected.

This showed that fixed cost constituted the larger proportion of cost of business for the respondents. In addition, Total Revenue (TR), Gross Margin (GM) and Net Farm Income (NFI) of the business were estimated at ₦973,533.33, ,₦702,549.87 and ₦426,278.87 respectively. The result shows that returns on investment (RRI), profitability index (PI), Rate of Return on Variable Cost (RRVC) and Operation Ratio (OR) were 181.62%, 0.63, 173.42% and 0.21 respectively. The implication of this is that cooperative credit beneficiaries are business are profitable. The purpose for which loan is obtained however, determines the benefit members enjoy from the societies. The study revealed that cooperative credit societies is very productive and effective in helping members achieving their goals and also improve their standard of living. Looking at the results it was deduced that joining cooperative societies will enhance the welfare of members and likely boost their business profitably.

From the study, the following policy options are recommended

(i) Government should be ready to remit cooperative deductions to their necessary accounts.

(ii) Cooperative societies should encourage members to have quick accessibility to loan.

(iii) Cooperative members should be faithful to repay their overdue loans.

(iv) Government should provide viable means of assisting cooperative societies to improve their management activities.

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Climate Change Adaptation Strategies in Agriculture: Cases from Southeast Asia

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Abstract

Climate change has become apparent and been threatening more and more in Southeast Asia. Its impacts on agriculture and adaptation strategies at household level in farming systems areas are explored. The study focused on better understanding of climate change impacts and adaptation practices in four villages of Myanmar and Cambodia. Household questionnaire survey, focus group discussions and key informant interviews were used for data collection at household and community level supplemented with secondary data. Dry Zone farmers of Myanmar reported increase in crop diversity while in the Kampong Speu province in Cambodia, the number of rice growing farmers increased together with cultivation of other crops, such as cassava, palm fruit, sugarcane, mangoes, watermelons and vegetables. Farmers changed their cultivation practices as adaptation strategies in various ways: change in cropping calendar, crop varieties, machinery for cultivation practice, and change in area for cultivation. The shift in cropping calendar has occurred from two weeks to one month. Diverse strategies were reported in adapting to water scarcity in agriculture, such as system of rice intensification and water pumping. Farmers also adopted strategies for coping with declining soil productivity. These include animal manure application, compost making and application, crop rotation and crop residues retention. In particular, Dry Zone farmers prefer to apply animal manure rather than other practices because of its vast benefits, such as buffering capacity, effectiveness for plant growth and cheaper price. Cooperative actions are becoming increasingly needed when an individual could not afford adaptation strategies. However, barriers to adaptation strategies are to be reduced to promote climate adaptive practices in agriculture.

Keywords: Myanmar, Cambodia, crop calendar, water stress, adaptation strategies

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) assessment report revealed that adverse impacts of climate change are expected to affect agricultural sector in Southeast Asia mainly due to increase in occurrence of droughts, increase in the occurrence of intense rains, and rise in temperature. The occurrence of droughts will result in crop failure in areas with rain-fed cultivation, while occurrence of intense rains will result in decline in crop yield from crop damages (MoNREC, 2016).

Agriculture sector is the backbone of economy for both Myanmar (FAO, 2018) and Cambodia (Jalilian et al., 2010). In Myanmar, agriculture sector contributes 34% (2008-2009) of GDP, employs 61% of the labor force and 70% of the population reside in rural areas and are mainly engaged in agriculture, livestock and fishery for their livelihood (DAP, 2010). Likewise, as confirmed by MEF (2010), agriculture continues to have a central place in rural livelihood, accounting at least a third of GDP of Cambodia. Agriculture in Cambodia is strongly correlated with rain-fed system; therefore any variation in climate will have impact on agricultural productivity and eventually economics of the country as a whole. Moreover, climate change has become apparent and been threatening more and more in the region (UNDP & MoE, 2001).

In Myanmar, a general warming trend of mean annual temperature and with decreasing trend of precipitation within the range of 2 to 339 mm have been reported across the country (NCEA, 2010a). The abnormal synoptic

situations of climate in recent years, has changed rainfall pattern of Myanmar from bimodal distribution to unimodal distribution. In that case, duration of rainy season was significantly reduced to 105 days from 145 days of normal distribution, with later onset of monsoon, lack of dry spell period in July and earlier withdrawal of monsoon. This may lead to implications for agricultural sector as 48% rice cultivation is in the favorable rain-fed lowland (Swe et al., 2014). In terms of climatic stressors, and adverse impacts, the Central Dry Zone is one of the most impacted regions in Myanmar (MoNREC, 2016) because disappearance of dry spell period in July delays crop harvesting or causes the crops yield to decline (NCEA, 2010b; Lwin, 2010). Similarly, Cambodia experienced a prolonged dry season, followed by a month of heavy rains resulting in flash floods that destroyed crops. It is predicted that the temperature increase would be high (0.036°C per year) in low-altitude areas such as central Cambodia and the northeast; and lower (0.013°C per year) in high-altitude areas such as the south-west (UNDP, 2011). Drought and soil fertility depletion are among the most important factors limiting crop production in Cambodia (Touch et al., 2016b).

Adaptation to climate change is considered key in combating climate change in addition to mitigation measures throughout the world. Adaptation, a complex, multidimensional, and multi–scale process, has been defined as adjustments to behavior or economic structures that reduce vulnerability of society in the face of scarcity or threatening environmental change (Adger et al., 2003; Bryan & Behrman, 2013). The adaptation responses have been classified according to the scale at which they occur; intent; timing with respect to the climate stress; duration; form/type; and effect (Bryant et al., 2000; Smit & Skinner 2002; Agrawal & Perrin 2008; Heltberg et al., 2009). The Intergovernmental Panel on Climate Change (IPCC, 2007, 2012) distinguishes between planned adaptation, which results from deliberate interventions; and autonomous adaptation, which is spontaneous, acts of reducing risks. However, study also argued on the autonomous adaptation as it might not occur spontaneously, rather it depends on how changes impact the livelihood of people (Ayers, 2011). As adaptation to climate change impacts is the major development agenda in many developing countries, it is very crucial to have really applicable practices in the field. The recently formulated Climate Smart Agriculture Strategy (MoNREC, 2016) in Myanmar emphasizes on adaptive measures, such as crop varieties, farming practices, disaster-risk management, and crop loss risk management. Likewise, several agricultural technologies and practices based on water and land management (such as system of rice intensification, climate resilient farming etc.) that fit with principles of climate resilient agricultural development are being tested, developed and promoted in Cambodia (UNDP, 2011). Traditional knowledge can provide efficient, appropriate and time-tested ways of advising and enabling adaptation to climate change in communities, locally adapted practices have to be regarded as the starting point in developing new strategies for adaptation to have really applicable practices in the field (UNFCCC, 2007).

Adapting agricultural systems to climate change is urgent because its impact on agriculture is already evident and the trends will continue even if emissions of GHGs are stabilized at current levels whereas adaptation can substantially reduce the adverse economic impact (Bank, 2006). Despite a lot of adaptation options currently being applied, more adaptation options than that of current level are required to reduce upcoming impacts (UNFCCC, 2007). The impacts of climate change on smallholder farms will be locally specific and difficult to quantify due to variations and complexity of farming systems and farmers´ livelihood. The issue of understanding climate change impacts at farm level can be enhanced by documenting local knowledge, attitudes and practices (Tiyo et al., 2015; Debela et al., 2015). It is not well documented at local level what and how adaptation is practiced. Therefore, this paper aims to 1) study farmers´ perception on trends, causes and impacts of climate change; 2) assess adaptation strategies in cultivation practices to climate change impacts in Dry zone and rain-fed areas; and 3) analyze factors influencing household adaptation decisions.

2. Research Methodology

2.1 Study Area

The study was conducted in Shwe Twin village of Nyaung Oo township and Takama village of Kyaukpadaung township of Central Dry Zone region in Myanmar; and Kork and Tropang Andong villages of Kampong Speu province, which is one of the 24 provinces of Cambodia (Figure 1). There were a total of 124, 100, 115 and 105 households in Shwe Twin, Takama (in Central Dry Zone area), Tropang Andong and Kork (in Kampong Speu province) villages respectively. The selected study areas in both countries have similarities in terms of frequent and prolonged drought and poor and delayed rainfall. Further, agriculture is the major livelihood activity of both study areas.

Dry Zone covers approximately 35% of Myanmar's cultivable land. The annual rainfall is about 600 mm to 1400 mm. The crops that are grown in the study area are sesame, groundnut, sunflower, rice, millet, cotton and

tobacco (DMO & FD, 2009). Kork village is located in Sangke Satop Commune of Aoral Disctrict and Tropang Andong is located in Nitean Commune of Basedth District in Cambodia. Rice is the dominant crop in the study sites together with the production of other crops such as cassava, palm fruit, sugarcane, mangoes, watermelons and a number of vegetable crops (USAID, 2008).

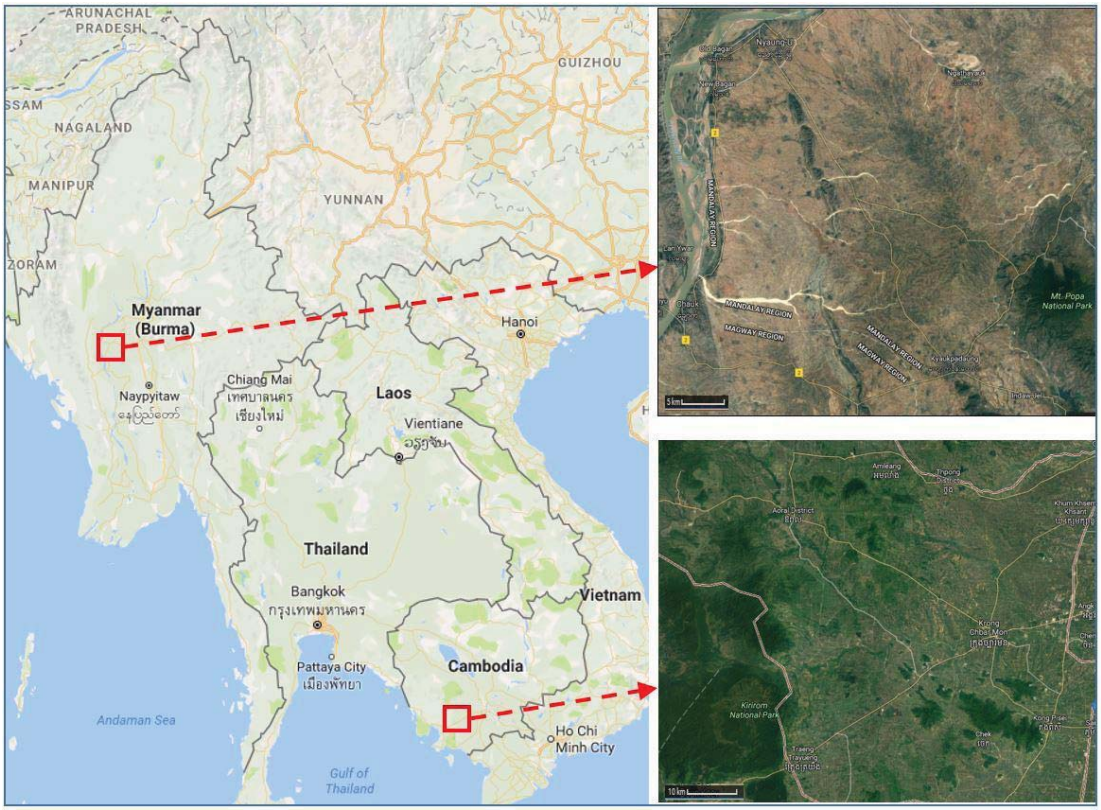


Figure 1. Location of the study area

2.2 Data Collection

Both qualitative and quantitative approaches were applied in this study. Different data collection methods were used to collect primary and secondary data in this study.

2.2.1 Secondary Data Collection

Climatic parameter, such as rainfall data and monthly maximum and minimum temperature data were collected from village head, provincial department for DRR and government ministries, such as DMH (Department of Meteorology and Hydrology), MAS (Myanmar Agricultural Services) and the Ministry of Water Resource and Meteorology. In addition, secondary data of historical climate change events, such as drought, excessive rainfall, heat and cold waves, and its impacts on rural livelihoods, agriculture related land use maps of study areas, soil fertility status, crop yields, irrigation systems, and government policies on climate change were reviewed from the reports of various organizations, namely MOECF (Ministry of Environmental Conservation and Forestry) and MOAI (Ministry of Agriculture and Irrigation); EcoDev (Ecosystem Development Group) NCEA (National Commission for Environmental Affairs), provincial department for DRR (Disaster Risk Reduction) and provincial department of environment besides other sources of published literature.

2.2.2 Primary Data Collection

Household questionnaire survey, focus group discussion and key informants interview were used as primary data collecting methods. A structured questionnaire comprising both close and open ended questions were used at household level. Random sampling was used for household survey and a minimum of 30% households was selected to represent the total population in each area. However, based on availability of respondents and their willingness to participate in survey, number of surveyed households increased. Thus, a total of 39 (31%), 67 (67%), 35 (30%) and 34 (32%) households were selected from Shwe Twin, Takama (in Central Dry Zone area, Myanmar), Tropang Andong and Kork (in Kampong Speu province, Cambodia) villages respectively. Heads of

the sample households were interviewed using the questionnaire. The data collection was mainly focused on perception of farmers to climatic trends, causes and impacts of climate change and their adaptations to climate change.

Focus group discussions were held in order to reaffirm individual perceptions collected from household questionnaire survey and to do in-depth survey especially for qualitative outputs concerned with farmers' perception to climate change and their behaviors responding to climate change events by asking the questions from a checklist. One focus group discussion in each village was conducted. The group consisted of 10 to 15 participants of both male and female with age above 60 years. The reason behind selecting elderly people was to get the age experienced perceptions regarding changes in climate and cropping pattern.

In addition, key informants i.e. key farmers, NGO staff, irrigation officers, people involved in DRR and agricultural extension workers were interviewed in order to carry out an in-depth survey about history and current climate change events, farmers' responses and government and NGOs activities in responding to climate change in the study areas by using checklist.

2.3 Data Analysis

The data were analyzed using SPSS (version 19.0). Mann-Kendall's test was used in order to perform trend analysis for rainfall and temperature data which could subsequently compare the farmers' individual perception about rainfall as well as temperature trend. In this case, 30 years monthly rainfall data and monthly rainy days from all study sites were used for rainfall trend analysis.

Qualitative analysis of information from household survey, focus group discussions and key informant interviews was used throughout the study. Descriptive statistics were used to analyze the quantitative data and were presented in percentages in figures and tables. One-Way ANOVA (Analysis of variance) was used in order to identify the differences between three different series groups i.e. current, past 5 years and past 10 years regarding agronomic practices and inputs used in agricultural production.

A weighted average index (WAI) was also applied, as shown in the following equation, in order to analyze farmers' perception to causes and impacts of climate change and respondents' satisfactory level of current coping strategies, respondents' perception for the responsibility and their willingness to take part in climate change adaptation activities. Previous studies have also applied the weighted average index (WAI) to assess farmers' perceived important adaptation strategies to climate change (Ndamani & Watanabe, 2015; Devkota et al., 2014)

$$\text{WAI} = \frac{\text{F1 (1)} + \text{F2 (0.8)} + \text{F3 (0.6)} + \text{F4 (0.4)} + \text{F5 (0.2)}}{\text{N}}$$

Where, WAI = Weighted Average Index, F1 = Frequency responding for the 1st rank, F2 = Frequency responding for the 2nd rank, F3 = Frequency responding for the 3rd rank, F4 = Frequency responding for the 4th rank, F5 = Frequency responding for the 5th rank, N = Total number of responses

3. Results and Discussion

3.1 Perception of Farmers on Determinant Climatic Factors

Farmers, who were interviewed, reported that rainfall and temperature might have determinant effect on agriculture. In Kork and Tropang Andong villages in Cambodia, majority of the farmers (62%) responded that they received less amount of rain compared to last thirty years. However, the Mann-Kendall's test showed no significant trend in the rainfall pattern since last thirty years (Figure 2). Nevertheless, in the year 2000, the province received the highest rainfall in the whole country. There was significant flood for three consecutive years during 2000 to 2002 (UNDP, 2011). Majority of the respondents (68%) mentioned that the average temperature for both dry and rainy season was increasing. However, there was no statistically significant increase in temperature. In Shwe Twin, Takama villages in Central Dry Zone area, majority of the respondents (91%) perceived unusual trend of rainfall (table 1) and 80% of the farmer perceived unusual length of dry spell period. Half of the respondent farmers perceived early onset of the rainy season, while 31% had seen it as a usual trend. However, the annual rainfall data did not show significant trend (Figure 3). While it shows significant trend for annual raining days in both study areas. This means the regular amount of rainfall was distributed in more than usual number of days in last 30 years. In this case, farmers' perception on unusual length of dry spell period could not be well validated by recorded rainfall data. Both farmers' perception and climatic data revealed the same trend of increasing temperature in Central Dry Zone although statistically not significant. The graphs resulted from the climatic data highlight that the maximum temperature in Dry Zone area is under increasing trend while minimum temperature is unchanged in last 30 years.

Farmers perceived increasing temperature and decreasing rainfall trends, which is also explained by the recorded data although not statistically significant. The results are in consistent with other studies in Southeast Asia by McSweeney et al., 2012; Touch et al., 2015; and Touch et al., 2016a. Farmers are often able to perceive the climate change reasonably correctly (Le Dang et al., 2014; Touch et al., 2016a).

Table 1. Farmers´ perception on rainfall trend

Trend	Percentage of Respondents	
	Cambodia	Myanmar
Increasing	23	40
Decreasing	62	51
Usual	15	9

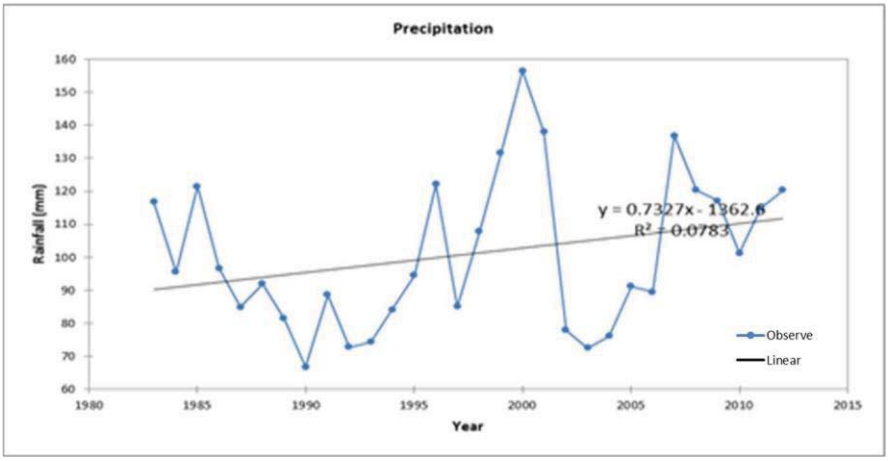
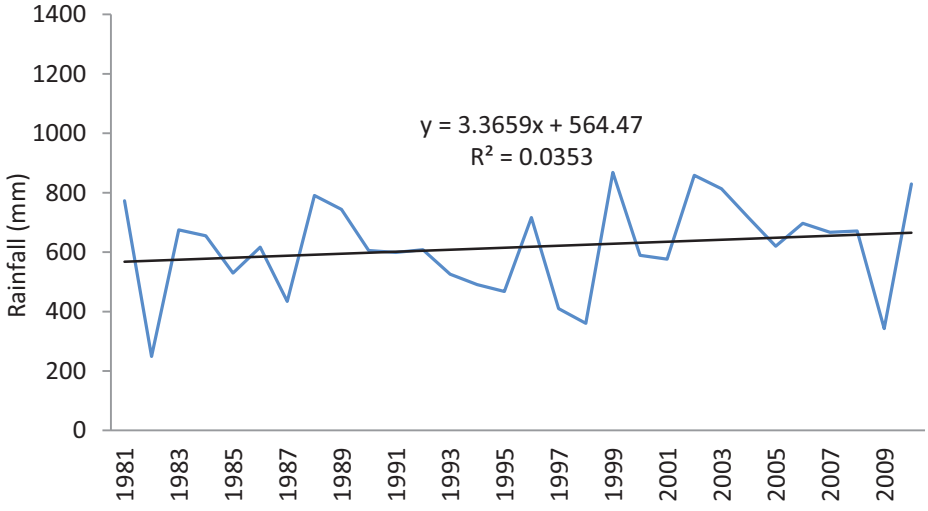


Figure 2. Annual Rainfall of Kampong Speu Province of Cambodia in last 30 years (1983-2012)



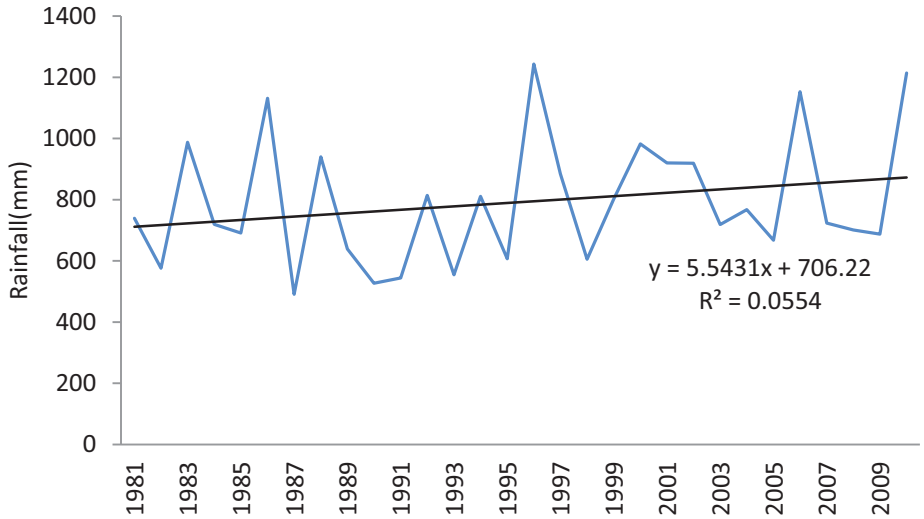


Figure 3. Annual Rainfall of Kyaukpadaung Township & Nyaung Oo Township in Myanmar in last 30 years (1981-2010)

3.2 Farmers´ Adaptation in Cultivation Practices to Climate Change Impacts

3.2.1 Change in Crops Grown

Rice is the dominant crop for the Kampong Speu province. Majority farmers (70% respondents) were growing rice in their land. Farmers also have grown some other crop such as cassava, palm fruit, sugarcane, mangoes, watermelons and variety of vegetables. The increase in the number of rice growing farmers compared to last thirty years was because they have either shifted from other crops to rice or they started rice cultivation in fallow land in order to increase their income.

Dry Zone farmers are adopting diverse crops compared to 10 years ago. More than 40% of respondents perceived that crop diversity is increasing. In fact, all crops except rice were grown since more than a decade, whereas rice cultivation was started after 2006 (Figure 4). Likewise, sesame-growing area was considerably shrunk as its cultivation was significantly decreased over the period of 10 years especially due to decreasing early monsoon rainfall, as sesame is an early monsoon crop. The sesame cultivation area was also occupied by pigeon pea and groundnut as the farmers found multiple benefits in terms of animal feed and firewood without having much labor investment whereas high profit is the major motivation for growing groundnut.

The crop types in Cambodia and Myanmar are different as the crops depend on local climate. Rice is the dominant crop together with cassava, fruit trees and vegetables with less crop diversity in Kampong Speu province. This finding was in line with other study in Cambodia, which also reported decline in crop diversity with cassava had become predominant crop with fruit trees (Touch et al., 2016a). In contrast to Cambodia, crop diversity was higher in Dry Zone region. In both countries, farmers reduced the cultivation of some crops because profitability had declined over few years due to yield decline and occasional crop failures. The similar trend of profit making by adopting new crops and vegetables was also observed by Raut et al. (2011) and Dahal et al. (2009) in hills of Nepal. This contradicts the decision to intensify crop production was motivated by the wish to maximize food for own consumption, rather than the profit factor (Ellis, 1989). However, more active adaptation is driven by farm characteristics and socio-economic condition, such as farm income, farm size (Habiba et al., 2012; Alauddin & Sarker, 2014).

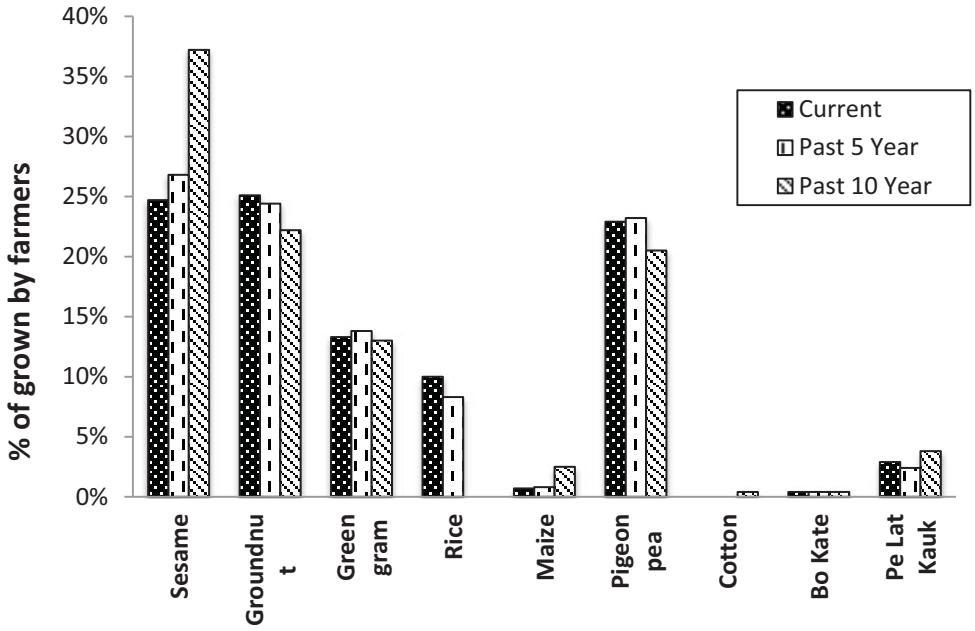


Figure 4. Crop diversity trend in Dry Zone in Myanmar in last 10 years

3.2.2 Shift in Cropping Calendar

Majority of respondents (72%) of Kampong Speu province explained their adaptation in agriculture. Farmers have changed their cultivation practices in various ways: change in cropping calendar; crop varieties; machinery for cultivation practice and change in area for cultivation as indicated in figure 5. Majority of farmers have shifted their cropping calendar. In the past, farmers used to start rice seeding in May, while at present rice seeding is done late in June (Figure 6). Farmers (37% of respondents) started growing new crop varieties that are suitable with present climate. Few (3%) farmers have changed the cultivation and agronomic practices, such as increased or decreased amount of fertilizer and pesticide, mixed cropping and minimum tillage. Cropping calendar in Dry Zone area usually covers eight months with the onset of early monsoon rain during third or fourth week of April. However, from the survey and discussions with the farmers, it was recorded that the crop calendar has shifted further by two weeks starting from early May instead and harvesting in late December for sesame and pigeon pea cultivation in Shwe Twin village due to late onset of monsoon rain (Figure 6). No shift in cultivation was reported for Takama village.

Different adaptation strategies have recently been initiated to combat the adverse impacts of climate change at national as well as the local levels. In this study, the shift in crop calendar has occurred by two weeks to one month in both study countries. In other Southeast Asian countries also, adjustment on cropping calendar has been observed particularly on planting and harvesting time based on the start of rainy season (Arunrat et al., 2017). In some areas, communities are responding autonomously to climate change stresses (Tiwari et al., 2014). As a coping mechanism in agricultural production, farmers are shifting their agricultural calendars. They have changed the timing of sowing seeds and timing of plantation, as well as adopted early ripening and drought tolerant varieties in their farmlands (Paudel et al., 2014; Tiwari et al., 2014). Study showed that the timing of plantation, number of planting and harvesting in a year however, substantially depends on both economic and climate conditions (Kotera et al., 2014), although weather induced limitation on workability is a key factor. The delay of some farm operations could lead to crop failure (Sawano et al., 2008). Nonetheless, studies showed adaptation practices were location specific and affected the socioeconomic condition (Hinkel, 2011; Vincent, 2007).

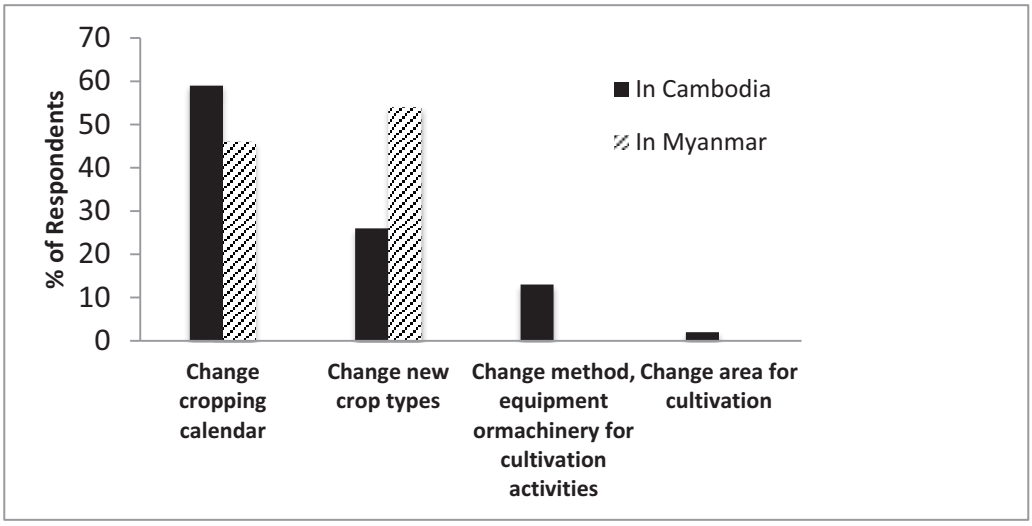


Figure 5. Percentage of Respondents who have changed their cultivation practice due to change in climate

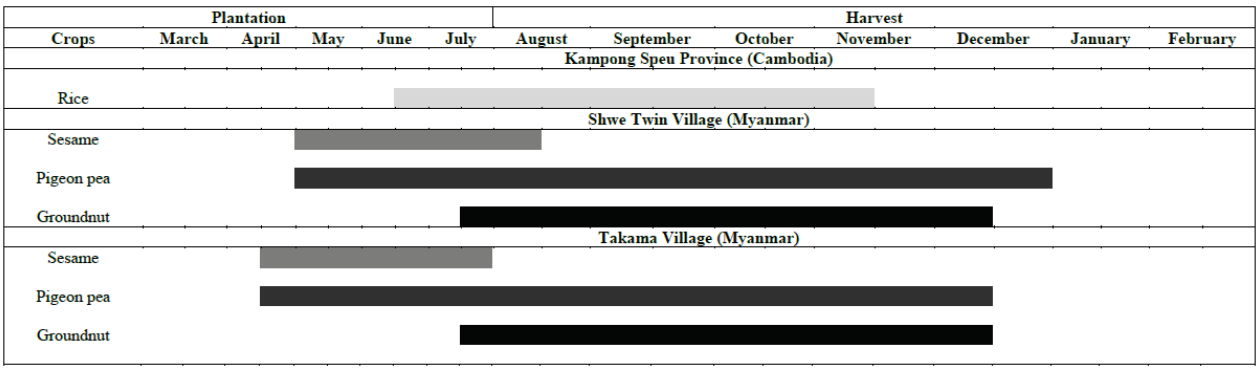


Figure 6. Current cropping calendar in study sites

3.2.3 Adaptive Measures to Cope with Water Stress

Diverse strategies were reported in solving water scarcity in agriculture as individual adaptation. Farmers during interview and group discussion mentioned about the changing growing period of crops was one of the most practiced measures. Few farmers practiced drought resistant crop varieties and were strongly satisfied with it. Farmers were aware of System of Rice Intensification (SRI) and mentioned that it is highly effective under water stress condition although only few farmers were practicing SRI. Farmers during the group discussions suggested some options such as water pumping, agricultural water harvesting techniques that could be applied as an adaptation strategy to water scarcity in agriculture. However, majority of farmers are less aware of the adaptation practices among farmers. Lower rainfall is likely to have devastating effects in drier areas with rain-fed agriculture (MoNREC, 2016). Even water pumping and ground water availability will face challenges. Motivating farmers for adopting short-duration and drought-tolerant varieties would help to minimize the risk of crop failure from water stress (Arunrat at al., 2017).

Farmers were asked about their level of satisfaction on adaptation measures to cope with changing climate in agricultural yield, water stress/drought and soil degradation as shown in table 2. Increasing the amount of fertilizer is the first priority for the farmers as a coping strategy followed by change in growing period. However, farmers have realized that increased chemical fertilizer application is not the best option. They were doing this due to barriers in adopting other adaptive measures.

Table 2. Farmers´ satisfaction with adaptation measures with regard to agricultural yield, water stress/drought and soil and land degradation

Measures/Satisfaction	1st	2nd	3rd	4th	5th	Total	WAI	Priority
Kampong Speu Province in Combodia								
Increase amount of fertilizer	3	9		3	2	17	0.166	1
Change in growing period				16			0.09	2
SRI	3	3					0.076	3
Water Pumping		3	3	2			0.07	4
Change in crop varieties	3	1					0.054	5
Pond, dike and dam construction	1						0.014	6
Vegetable plantation	1						0.014	6
Kyaukpadaung township of Central Dry Zone region in Myanmar								
Chemical fertilizer application	0	26	9	0		35	0.238	1
Foliar fertilizer application	0	3	23	2		28	0.155	2
Well land preparation	1	11	4	1		17	0.115	3
Animal manure application	1	6	1	0		8	0.058	4
Changing to high yield variety	0	8	0	0		8	0.058	4
Growing pure variety	0	4	0	0		4	0.029	5
Pursuing good crop management practices	0	3	0	0		3	0.022	6
Increased fertilizer application	0	0	2	0		2	0.011	7
Pursuing Crop rotation	0	1	0	0		1	0.007	8

3.2.4 Adaptation to Declining Soil Productivity

According to farmers, they have adopted strategies for improving soil productivity. Those strategies include animal manure application; compost making and application; crop rotation and returning crop residues back to land for improving soil productivity. In particular, Dry Zone farmers prefer to apply animal manure rather than other practices because of its vast benefits, such as buffering capacity, effectiveness for plant growth and cheaper price. While farmers also reported of using chemical fertilizers for quicker benefits in terms of plant growth and yield regardless of its high cost. Similar trend of soil fertility management by farmers were reported in other study conducted in Cambodia that the farmers were well aware of soil fertility management (Touch et al., 2016a). The crop residue retention in their farmlands increased yield as well as this could reduce probability of crop failure during the period of higher temperature and rainfall variability (Montgomery et al., 2015). Recent research in Cambodian rain-fed lowland (Poulton et al., 2015) and upland (Touch et al., 2015) cropping systems has shown significant climate risk reduction by adjusting planting dates according to availability of soil moisture and better management of crop residues.

3.3 Cooperative Adaptation to Climate Change Impact

Cooperative actions are needed when an individual could not afford adaptation strategies. The best example of cooperative adaptation was for weeding. By forming groups, hand weeding was cooperatively carried out in agricultural fields of group members on the rotational basis. In fact, hand weeding by group of farmers was very beneficial for Dry Zone farmers not only to weed control but also to save money for wage labor for weeding. Farmer from Trapang Andong village also increased such cooperative actions. Several farmers already started practicing SRI in-group that has been introduced and some other farmers are also willing to adopt the same to cope with current climate. However, farmers emphasized on the barriers to adaptation strategies either adopted individually or through cooperative as described in table 3.

Table 3. Adaptation strategies and limitation

Problem	Strategy	Barriers
Water stress	Growing drought resistant plant variety	Lack of locally adapted variety
	SRI	Lack of proper knowledge on SRI
	Water pumping	Limited financial resource
Soil productivity declination	Compost making and application	High labour demand
	Fallow the cultivated land for 2 or 3 years	Lack of compensation for alternative livelihood strategy
Weed problem	Herbicide application	High cost
		Lack of proper knowledge
Pest problem	Fumigation by burning crop residues	Laborious and less effective
	Digging small canal around the field to control rodents	Laborious and less effective

3.4 Interactions among Institution, Technology and Farmers' Decision Making for Climate Change Adaptation

In order to support climate adaptation and improve food security, we need to improve our understanding of the interactions among institution, technology and farmer decision making for climate change adaptation. Intervention from government becomes important when individual adaptation is not effective enough to cope with the impacts of climate change. National Commission for Environmental Affair (NCEA) of Myanmar is currently working to strengthen community resilience under climate change including activities, such as adaptive capacity building, awareness campaigns, training and climate change workshops throughout the country. In addition, establishment of NAPA (National action plan for adaptation) is ongoing under the enforcement. In addition, the government has implemented many mini and mega dam projects across the country in order to extend agricultural production. Currently, there are 140 dams constructed in the Dry Zone with watershed areas of 4.5 million hectares. Moreover, pumping water from the river is another attempt of government to cope with water scarcity in agriculture. However there is no proper policy for land as well as water use rights and government enforced to use water only for irrigation for rice cultivation. In Kampong Speu province, during the survey, 38% of farmers reported that the government and NGOs have disseminated adaptation technologies to reduce climate change impact on agriculture. Focus group discussions and key informants interview provided other technological intervention from government as well as NGOs, such as new rice varieties, providing water pumping machine during drought, road construction, SRI training and demonstrations, promoting vegetable seeds, fertilizers, rice storage techniques, and underground water pumping machine. Department of Agriculture in cooperation with Food and Agriculture Organization and with Live with Dignity organization were working on the climate change adaptation in agriculture in the two villages in Kampong Speu Province.

There is poor dissemination of research outcomes for the benefit of farmers due to poor linkages among government organizations, farmers, academic institutions and poor agricultural extension strategies according to the key informants. In Myanmar, there is no weather forecasting channel particularly for agriculture till date. Some farmers during the group discussions reported the need of such weather forecasting and communication system for early preparedness. Few local NGOs, Tun Lwin Foundation and Eco Dev, are trying to establish the networks to disseminate agriculture concerned weather forecasting. Studies showed that lack of information about the impacts of climate change and limited knowledge about adaptation measures being given as main reasons for not using any adaptation strategies (Arunrat et al., 2017). The study by Raut et al. (2012) indicated the success of agricultural extension through radio and television as a way of reaching farmers in which most of the farmers listened to or watch agricultural programs related to pest and diseases, use of organic and chemical fertilizers that were delivered via radio and television.

The agro-chemical companies are extending to sell out their products like pesticides and chemical fertilizers by pursuing different marketing strategies. However, their main mission is only to make profits without paying much attention on capacity building of rural farmers. Farmers were relying on those companies who provided extension staffs with agro-chemicals to be distributed to the farmers and farmers acknowledged the contribution of such extension services. In other study by Raut et al. (2011, 2012) in the region reported the efficient services on agro-inputs, agricultural exposure and trainings, provided by the NGOs compared to services provided by Government Organizations (GOs).

The agriculture adaptation to climate change therefore, should be addressed with a three-tier approach: 1) Institutional involvement and its extension must be strengthened and effective, 2) Region specific appropriate adaptation technology must be ensured, 3) Encouraging farmers for making decisions on adoption of adaptive

strategies to climate change in agriculture through incentives. Agricultural extension services provide a mechanism for informing farmers about new technological developments. Based on the reflections by farmers who have already adapted and the successful stories in and around the similar geographical areas, the most appropriate adaptation technology should be ensured. The incentives to change ongoing cultivation practices with climate adaptive could be the driver of agricultural adaptation to climate change. This implies that for successful implementation of adaptation measures, the involvement of institutions and their extension should be strengthened and effective for region specific appropriate adaptation technology implementation.

4. Conclusion

Farmers in Cambodia and Myanmar use diverse adaptation strategies at household level to minimize the risk of climate change impacts on farming systems. They have changed cultivation practices with adaptive measures mainly for crop varieties, agricultural yield, water stress due to drought, and soil and land degradation. The adaptation strategies in both the countries include changes in crops grown, cropping calendar, machinery for cultivation practice, change in area for cultivation, system of rice intensification (SRI), water pumping, animal manure application, compost making and application, crop rotation and crop residues retention. Cooperative adaptation strategy was becoming successful among the farming communities when an individual could not afford adaptive measures. However, barriers to adaptation strategies are to be removed to promote climate adaptive practices in agriculture.

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Changing Trends in Cultivation Practices and Adoption of Climate Adaptive Farming in Eastern Nepal

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Abstract

Climate change impacts are likely to affect the agricultural production leading to further food insecurity. In this context, the trend of cereal production with climate variables was studied in order to understand the linkages between climate change and crop productivity. The study was conducted in three districts of Sagarmatha zone, namely Solukhumbu (mountain region), Okhaldhunga (hill region) and Saptari (Terai region) representing three ecological zones in Nepal. A household survey (295 households), focus group discussions and key informant interviews were used to collect data on the history of the cultivation systems, varieties of crop grown, trends on crop yield, and adaptation to climate change. Results showed farmers' introduction of high yielding varieties of crops and vegetables due to economic benefit, while traditional varieties are no longer cultivated. The infestation of pest attack is increasingly seen since two decades, while few pests were reported to be disappeared. Although majority of farmers in Saptari and Okhaldhunga districts used pesticides as per the prescribed doses, pesticide use is still random in Solukhumbu district. The multiple comparisons of means showed that there is a significant difference in the average production of rice and maize since 30 years until recently ($p<0.05$) in these three districts**.** The average production of rice, maize and wheat increased with decreasing average annual temperature and rainfall in Saptari district since 30 years. In contrast, in Okhaldhunga and Solukhumbu districts, the average production of three cereal crops increased with increasing average annual temperature and rainfall. With the late arrival of the monsoon, farmers have adopted coping strategies particularly for rice cultivation through occasional shift in crop planting dates and selection of shorter duration crop varieties that can be harvested early.

Keywords: agriculture, climate change, terai, hill, mountain, crop productivity, and adaptation

1. Introduction

South Asian countries have a number of common features such as high human-to-land area ratio, a high share of agriculture making up gross domestic product (GDP), weak infrastructure and a high proportion of population below the poverty line. The per capita arable land area in the region is declining with increasing population. The average per capita cropland (ha/person) for the region was 0.38 in 1960, and is projected to be about 0.10 in 2025, and 0.093 by 2050 (Lal, 2011). The necessity of increasing food production due to rapid population growth, especially during the 20th century, was achieved through the 'Green Revolution' by growing input-responsive and improved varieties with increased application of fertilizers and irrigation (Lal, 2011). This led to a remarkable increase in yield in Asia in the late 1960s, and global food production increased three-fold between 1961 and 2006 (FAO, 2008).

However, increased agricultural production is an ever-growing requirement to fulfil the food demand and poverty reduction in Nepal (Pyakuryal et al., 2005), as the traditional farming practices are unable to fulfil the increasing food demand with most of the districts in a food deficit situation (CBS, 2003). Although agricultural land expansion is an option for increasing food production, there is little scope left for expansion of arable land (Pingali & Rosegrant, 2001). Hence intensification of the already cultivated lands is the only viable option (Dahal et al., 2009). The areas with access to road, market, inputs and institutional development located close to the semi- and peri-urban areas are the most potential sites for agricultural intensification (Dahal et al., 2008).

Natural frequent occurrences of loss of fertile soil, nutrients, natural disasters such as Glacier Lake Outburst Flood (GLOF) in mountain regions; landslides in the Hills and floods in Terai are accelerated by changing weather patterns (Regmi & Adhikari, 2007). As a result of variations in weather patterns, the type, frequency and intensity of extreme events such as droughts, heavy precipitation and flood events are also expected to rise with relatively small average temperature increases. Changes in rainfall pattern are likely to lead to severe water shortages and/or flooding. Under such circumstances, Nepal, being one of the poorest countries, adaptation to climate change entails taking adequate measures to reduce the negative effects of climate change by making the appropriate adjustments and changes (MOE, 2010). Accordingly, the Government of Nepal has recently initiated different adaptation strategies to combat the adverse impacts of climate change at the national as well as local levels.

Although, the government has just initiated a planned climate change adaptation pilot programme, communities in this region have been responding autonomously to climate change stresses (Tiwari et al., 2014). These involve changes in cropping practices and technologies, diversification of livelihood systems, accessing financial resources, such as, micro-insurance and micro-credit, migration, off farm activities, and water conservation practices. As a coping mechanism for agricultural production in a changing environment, farmers are shifting their agricultural calendars (Paudel et al., 2014).

The Agriculture Prospective Plan (APP) of 1995 has set per capita targets for food production of 245 kg, 380 kg and 482 kg for the mountain, hill and Terai regions, respectively, which were to be met by 2014/15 (APP, 1995). The APP strategy is to accelerate the agricultural growth rate by transforming the subsistence-based agriculture into a commercial one through diversification and production of high-value commodities in agriculture. Despite this, the performance of the agricultural sector has fallen short of the targets. Production of the country's major cereal crops has remained stagnant for the past few decades (Bajracharya & Sherchan, 2009). This is partly because of the deficiency in availability of inputs such as improved and good quality seeds, affordable chemical fertilizers, and incentives for farmers to plant high value commodities. Moreover, climate change effects are likely to adversely impact the agricultural production leading to further food insecurity (Jat et al., 2016). Therefore, there is a need to assess the trend of cereal production over the past few decades with regard to climatic variables in order to develop adaptive strategies for cereal production linked with climate change. Thus we aimed to assess the production trend over a period of three decades in three districts of Nepal representing each ecological region; and to understand the linkages between climate variables and crop productivity. We also aimed to assess how the local communities are coping with changing climate in crop production process.

2. Materials and Methods

2.1 Study Area

The study was conducted in the three districts of Sagarmatha zone, namely Solukhumbu (mountain region), Okhaldhunga (hill region) and Saptari (terai region) representing three ecological zones (Figure 1). Sagarmatha zone was selected based on the zone's climate change vulnerability due to the presence of glacial lakes, snow-fed rivers, landslides, flash floods, flood and drought. All the selected districts of the zone have incurred higher economic losses by natural disasters during 1993 to 1994 and 2000-2005 (DWIDP, 2014). The Solukhumbu district experiences water scarcity during winter and significant reduction in irrigation water due to the variability of the summer monsoon (Bartlett et al., 2010). The news related to climate change in the study areas has also been highlighted in national newspapers. Some examples include news that people in the mountains are unaware of the changing climate (Published in Republica, 29 August 2014). Hilly district like Okhaldhunga has experienced growing numbers of landslides and flash flooding cases where as Terai districts including Saptari are in higher risk of being flooded due to increased water level due to glacial lake outbursts in mountains (The Himalayan Times, 2011). One VDC in each district, Tingla (Solukhumbu district), Prapcha (Okhaldhunga district) and Hanumannagar (Saptari district) was selected for the study. The VDCs were selected based on intensity of agriculture, climate change vulnerability, and accessibility.

2.2 Survey Methods

Both primary and secondary data were collected through field visits and rigorous literature survey. Household survey, focus group discussions and key informant interviews were used to collect primary information on history of cultivation systems, varieties of crop grown, agro-inputs use, trends on crop yield, linkage between agricultural productivity with climate change, and perception and adaptation of communities to climate change. The survey was done between April and September 2015.

Purposive random sampling was done to select the households for survey in order to include all nine wards of each VDC. Out of the total households in the VDCs (CBS, 2011), at least 10 % of the households from each VDC were selected for the questionnaire survey. A total of 295 households (95 from Hanumannagar and 100 each from Prapcha and Tingla VDCs) were included in the survey. A structured questionnaire that comprised both close and open-ended questions was developed and pretested with respondents of similar biophysical and socioeconomic conditions to confirm rightness of the questions. Two local enumerators were involved in the survey. The local enumerators were well trained before the start-up of the survey. The interview was conducted with the head of the households who are usually a male member and usually a decision maker in the family.

Focus group discussions consisting of 20-25 participants was carried out in all the study sites. The participants of group discussions were selected representing each ward including women and marginalized people such as ethnic minorities. The participants were mainly farmers and permanent residents of the VDCs. Each discussion lasted for 3 to 4 hours. The discussions mainly focused on the different aspects such as agricultural activities, trend of agro-cultivation, agro-inputs, crop productivity and climatic effects on agro-products. Similarly, the perception on change in crop production and climate change were also documented.

Key informant interviews were also carried out in each VDC. A total of ten key informants, three to four key informants from each studied VDCs, were identified during the focus group discussions and interviewed separately. Key informant interviews were mainly focused on in-depth data on the cultivation dates irrigation, use of fertilizers, crop production, weather variables, etc. Climate change adaptation measures adopted by farmers were also documented during the field visits.

The meteorological data for three decades were obtained from the Department of Hydrology and Meteorology to relate the trend of agricultural activities with climate change.

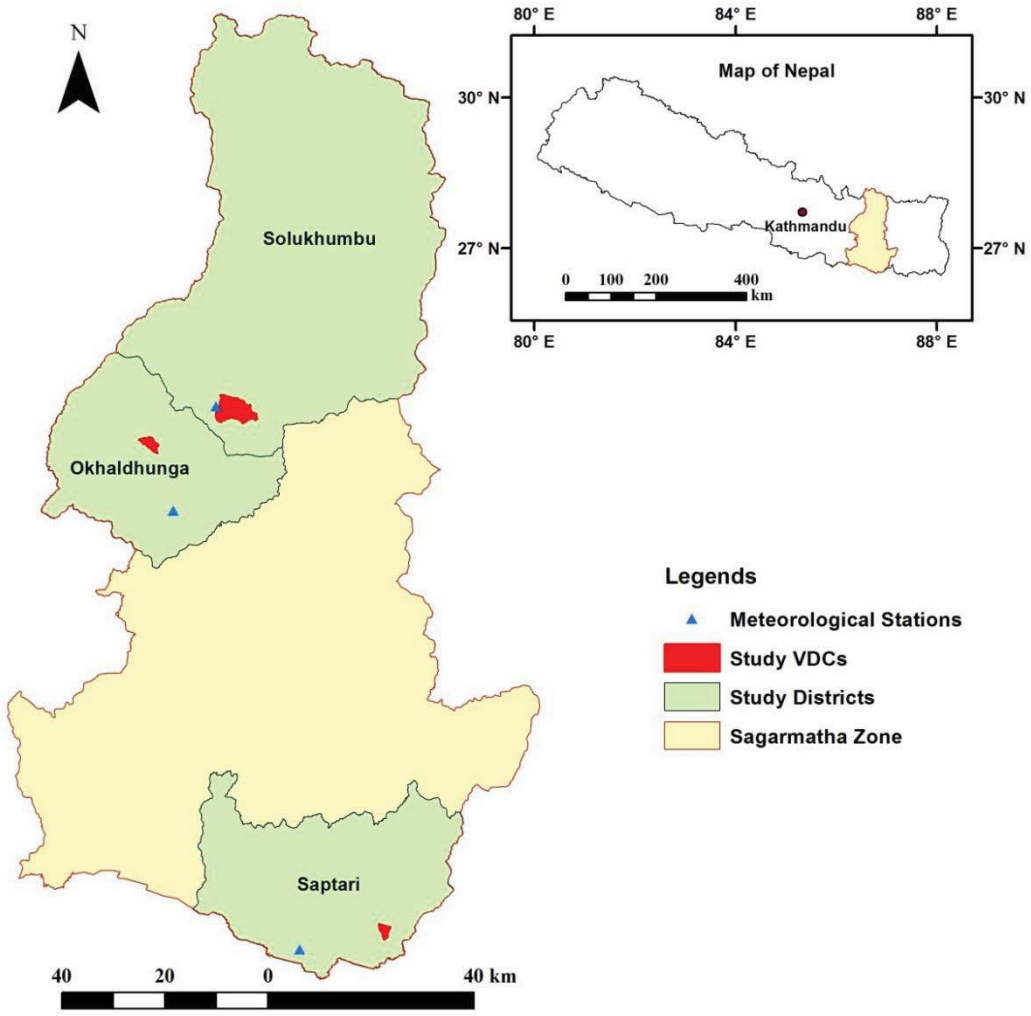

Figure 1. Location of the study area

2.3 Data Analysis

Data collected from questionnaire survey were coded and computed in MS-Excel and were processed and analysed using SPSS (version 19.0). Rates of changes in cereal yield (mainly for rice, wheat and maize) were analysed for three reference years, 1984, 1994 and 2014. These data were analysed using descriptive statistics (Frequency distribution, mean, standard deviation, percentage of frequency distribution), correlation analysis, and multiple comparisons of means. Similarly, the meteorological data obtained from the Department of Hydrology and Meteorology were computed in MS-Excel and analysed for calculation of mean, maximum, minimum for temperature, rainfall, and relative humidity.

3. Results

3.1 Historical and Recent Changes in Cultivation Practices

3.1.1 Changes in Crops Grown

According to focus group discussions and key informant interviews, farmers of Saptari district reported rice, maize, and wheat as the major crops, but they also grow mustard, pulses, flaxseed and vegetables. About 10 to 12 years ago, farmers grew *Aghani* varieties of rice such as *Jaspal*, *Prakiti*, and *Basmati* which are not cultivated anymore. The overall trade of rice has increased, as it is the main crop in the area. Farmers in Saptari also reported that mustard cultivation started 15 years ahead of wheat cultivation when the latter was introduced from India for the religious purposes. The main vegetables that farmers have newly introduced are cauliflower, tomato and green peas, while potato was introduced around a decade ago. Farmers generally believed that vegetable farming gave better economic benefits compared to cereal crop cultivation.

The major crops grown in Okhaldhunga district are rice, maize, millet, wheat, buckwheat, mustard and vegetables. Rice cultivation started as early as one hundred years ago when varieties such as Mansuli and *Junge* were cultivated; and 50 years ago, other varieties such as *Rambilash* and *Atte* started to be cultivated. Current varieties of rice that are being cultivated in Okhaldhunga are *Taichung*, *Radha*, and others. Wheat was introduced much later after a major drought occurrence in 1971, and its cultivation has been widely practised since 1975. The common traditional varieties of maize that are cultivated widely are *SetoPudko* and *Paheli* while high yielding varieties are grown in relatively small areas. Potato was introduced in 1969 after the region experienced a famine. During the focus group discussions, farmers reported that there was an increase in the production of rice and potatoes due to improved access to irrigation facilities and introduction of high yielding varieties of crops. In contrast, millet cultivation has declined due to the lack of market value. The main vegetable crops that farmers have recently introduced are tomato and chilli. However, during the key informants interview, it was revealed that increased pest infestation have resulted decline in chilli production. Among the pulses also, there is a decline in the cultivation of black lentil and *Masyang* which were common during the 1960s.

The major crops grown in Solukhumbu district are maize, millet, wheat, buckwheat, and barley while few farmers also practise mustard and rice cultivation. The traditional varieties of maize namely, *Pahelo* and *Seto* are being cultivated in different times of the year for the last 100 years, although high yielding varieties are also cultivated nowadays. For the last 10 years *Deuki* and *Ganesh* varieties of maize have also been grown. The cultivation of millet has declined, as according to farmers it is not economically profitable; and it is grown mainly as animal feeds in recent years. Meanwhile, millet is also grown in upland areas in recent years due to warmer temperatures. Wheat was introduced later than the other crops. The first variety cultivated was *Dolakhe* followed by a high yielding variety RR-21. Interestingly, the *Dolakhe* variety was not given to children due to fear of diarrhoea. Although, potato is considered as a vegetable, it is one of the main crops being cultivated in most of the places in Solukhumbu district for a long time. Farmers have reduced the cultivation of barley and buckwheat due to lack of manpower, while cultivation of chilli is growing. Farmers reported the cause for increase in chilli cultivation as it requires less labour compared to major cereal crops.

3.1.2 Changes in Irrigation Facility

The local farmers have been irrigating their fields mainly by means of canals from rivers or from streams and springs. The construction of irrigation canals in Saptari district has been expanded with support from district development committee for adopting a wider variety of crops. The primary source of water for irrigation in Saptari district is irrigation canal; however, a few farmers also have deep bore wells to draw water. Likewise, irrigation by means of stream and spring canal (*kulo*) is a fairly recent practice in Okhaldhunga district. Nonetheless, a majority of respondents from Saptari (63 % of the total respondents) and Solukhumbu (93 % of the total respondents) reported they do not have irrigation facility. On the other hand, a majority of the respondents (65 %) from Okhaldhunga reported that they have access to irrigation facilities.

3.1.3 Crop Production

The trend of cultivation and rate of production of different cereal crops (rice, maize and wheat) between the present as compared to 2004, 1994, 1984 are presented in table 1. The average yields of rice increased over the past 30 years by 37 %, 22 % and 19 % in Saptari, Okhaldhunga and Solukhumbu districts, respectively. The average yields of rice during 1984 were 487 kg/ha, 495 kg/ha and 403 kg/ha, and during 2014 were 2599 kg/ha, 1116 kg/ha and 1077 kg/ha in Saptari, Okhaldhunga and Solukhumbu, respectively. The average yields of maize have also increased during the past 30 years by 60 %, 78 % and 3 % in Saptari, Okhaldhunga and Solukhumbu districts, respectively. The average yields of maize during 1984 were 189 kg/ha, 157 kg/ha and 281 kg/ha, and during 2014 were 1496 kg/ha, 371 kg/ha and 426 kg/ha in Saptari, Okhaldhunga and Solukhumbu, respectively. The average yields of wheat, has likewise, increased during the past 30 years by 95 %, 71 % and 50 % in Saptari, Okhaldhunga and Solukhumbu districts, respectively. The average yields of wheat during 1984 were 12 kg/ha, 19 kg/ha and 80 kg/ha, and during 2014 were 157 kg/ha, 66 kg/ha and 235 kg/ha in Saptari, Okhaldhunga and Solukhumbu respectively. Farmers reported the increase in production of rice, maize and wheat was mainly due to high yielding varieties and that they could irrigate their agricultural lands easily. This study was carried out in eastern region of Nepal, which receives more rainfall and agro-inputs such as improved and good quality seeds, and affordable chemical fertilizers are also easily accessible compared to mid and far western region of Nepal. This partly justifies the increase in cereal production in the region although the country´s food production has been stagnant over the past few decades.

The multiple comparisons of means showed that there is a significant difference in the average production of rice and maize during the past 30 ($p<0.05$) in all three districts as shown in table 2. There was a significant difference in means of the average production of rice, maize and wheat during 2014 and 1984 for Solukhumbu district ($p<0.05$, 0.01). Likewise, in Okhaldhunga, there was a significant difference in means between 2014 and 1984/1994 for rice and maize ($p<0.01$). Furthermore, in Saptari district, there was a significant difference in means between 2014 and 2004, 1994, 1984 for rice and maize ($p<0.05$).

Table 1. Trend of rate of production change of cereal crops during various years (negative (-) sign indicated the decreasing trend).

Crops	Rate of change (%)	Saptari	Okhaldhunga	Solukhumbu
Rice	10 years	-5	-16	-14
	20 years	2	-37	-19
	30 years	37	22	19
Maize	10 years	31	-28	-38
	20 years	51	77	-45
	30 years	60	78	3
Wheat	10 years	48	30	-37
	20 years	75	68	-33
	30 years	95	71	50

Table 2. Multiple Comparison of means (t/ha) between recent (2014) and 10 years before (2004), 20 years before (1994), 30 years before (1984).

District	Crops	Years	Mean Difference
Saptari	Rice	10	959*
		20	1521**
		30	2112**
	Maize	10	558*
		20	1057**
		30	1307**
	Wheat	10	109
		20	125
		30	156
Okhaldhunga	Rice	10	73
		20	359**
		30	622**
	Maize	10	-19
		20	210**
		30	214**
	Wheat	10	20
		20	47
		30	49
Solukhumbu	Rice	10	9
		20	152
		30	673**
	Maize	10	-80
		20	-61
		30	146*
	Wheat	10	-59
		20	-34
		30	155**

Note. * and ** represents the significance at 95% and 99% level of confidence.

3.1.4 Pest Infestation and Pesticide Use

Farmers have reported pest infestation, which mostly occur during the summer season. Majority of the respondents (87% of the total respondents of Saptari district, 71% of Okhaldhunga district and 90% of Solukhumbu district) indicated that pest attack is increasingly seen. Pest attack also occur during rainy season in Okhaldhunga and Solukhumbu district, and during winter season (9% of the total respondents) in Saptari district. Furthermore, the majority of respondents reported the emergence of new types of pests (Figure 2), while some of the pests that existed before have now disappeared.

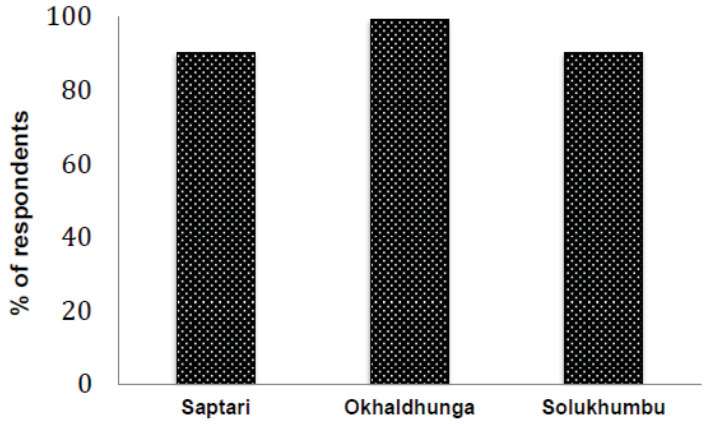

Figure 2. Emergence of new pests

Incidences of pest infestations in the three study districts was reported to be increasing compared to 20 years ago for all crops, i.e., rice (97% of the respondents in Saptari, 87% in Okhaldhunga, and 75% in Solukhumbu), maize (97% of the respondents in Saptari, 91% in Okhaldhunga, and 84% in Solukhumbu), wheat (100% of the respondents in Saptari, 76% in Okhaldhunga, and 74% in Solukhumbu) and vegetables (100% of the respondents in Saptari, 88% in Okhaldhunga, and 84% in Solukhumbu). Respondents from Solukhumbu (84%) and Okhaldhunga districts (52%) believed that the main reason for increase in pest attack is due to an increase in average temperatures, while respondents from Saptari district (73%) felt that it was due to a decline in pest predators. The pests that are seen during summer season are also reported to infest crops during winter season. The majority of the respondents (96%) of Saptari district use pesticides in their crops and vegetables, while the use is very low in Okhaldhunga and Solukhumbu districts (Figure 3).

Farmers in Saptari and Okhaldhunga district apply pesticides as per the prescribed dose(s) from the local agrovet stores, while in Solukhumbu, they apply the pesticides at random rates (Figure 4). The major pesticides used by farmers are: *Niraculan, Carbine, Mirakulin, Monosil, Metacid, Thimet, Cypermethrin, Mancozeb, Zinc phosphate,* and *Adosil*.

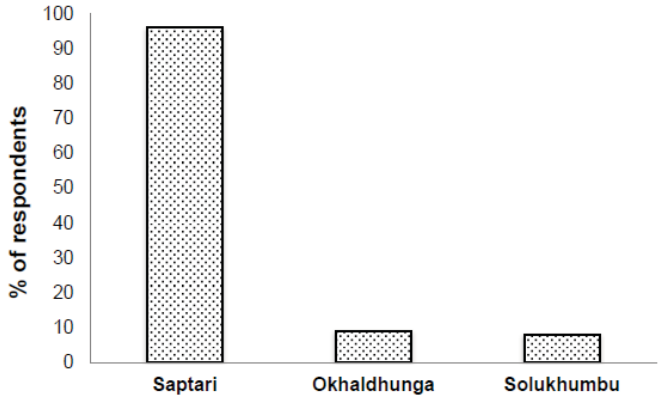

Figure 3. District-wise use of pesticides

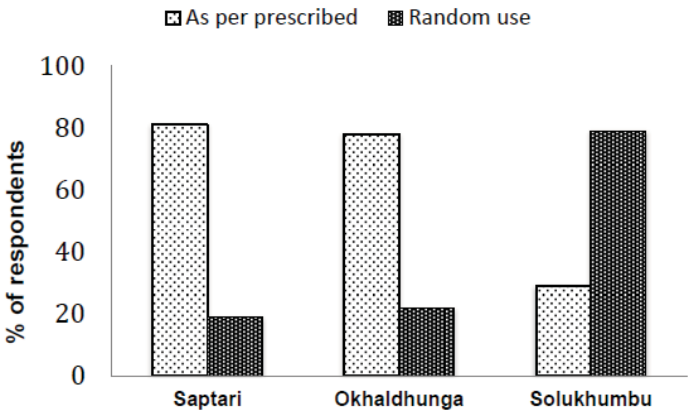

Figure 4. Pesticide application methods and rates

3.2 Linkages between Climatic Variables and Crop Production

Since the 1980s, average annual temperature and rainfall amounts for Saptari district is generally decreasing. However, the climatic data showed a negative correlation with the average production of rice, maize and wheat that has increased during the last 30 years. Such trend explains that farmers are managing to increase their production by adopting various practices. By contrast, in Okhaldhunga and Solukhumbu districts, the average production of rice, maize and wheat has shown a positive correlation with the climatic data. Thus, in the latter two districts, production has increased over the last 30 years with increasing trend of temperature and rainfall (Figure 5).

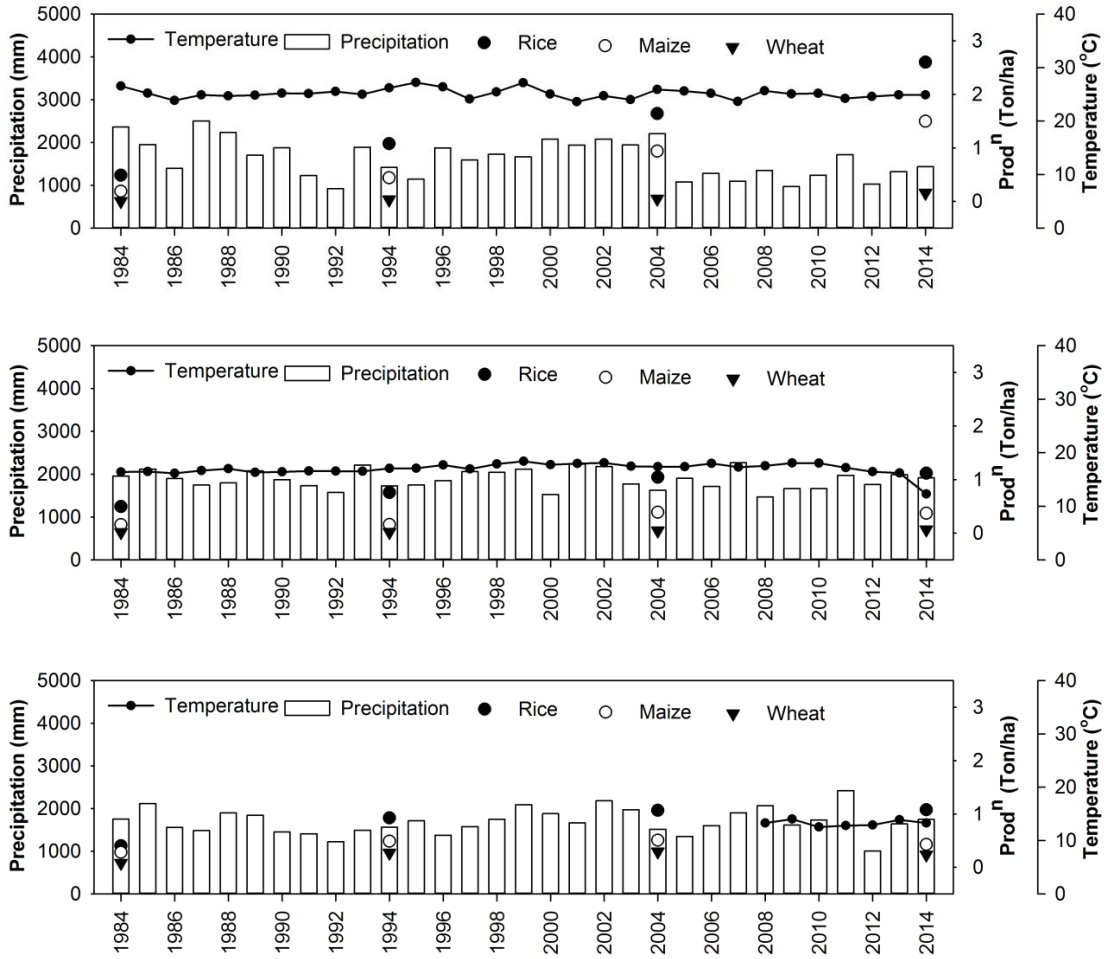

Figure 5. Linkages between climatic variables (temperature and precipitation) and crop productivity in three districts: a) Saptari b) Okhaldhunga and c) Solukhumbu

Farmers in Saptari district reported an increase in intense rainfall events, particularly during May to July, for the last 10-12 years, along with the late arrival of monsoon rains. Likewise, farmers in Okhaldhunga and Solukhumbu districts, who claimed they used to have monsoon by mid-June, also reported the arrival of monsoon to be typically delayed by about one month, with prolonged, partial and erratic rainfall events being more common. In general, farmers perceived the days to have become hotter. They have also reported more frequent incidences of drought. They claim that the events of frost have also decreased these days and fewer snowfall events occurred during the winter in the last three decades in Solukhumbu district.

In Saptari district, farmers have reported that the Koshi River has started significant damage since about 20 years ago, which has resulted in reduced overall productivity in the study area. Furthermore, the flood incidence in 2008 shifted the Koshi towards the west (present study area) that has further impacted the productive crop lands to this day. Farmers reported that the impacts of climatic variability have been felt on the quality of crops, overall productivity and also on crop biodiversity (fewer crop varieties being grown).

Farmers during focus group discussions and key informant interviews reported different adaptation measures they have adopted to minimize the impacts of climate change. These include re-plantation of trees and change in crop varieties such as cultivation of early maturing varieties, which ripen faster compared to the traditional varieties, so that they could plant and harvest within a shorter time. A few of the farmers were found to adopt the cultivation of rice varieties that can be grown at any time of the year, such as *Hardinath*. This variety can be harvested within a short duration and can be grown all year round. The survey also showed that high yielding varieties of rice are used mainly for two purposes: to increase the overall productivity and to combat the adverse climate change impacts on regular crops. For example, *Mansuli*, *Kanchhi-mansuli*, *Makawanpur* and *Sita* have been introduced coinciding with the use of chemical fertilizers and pesticides. Besides, adopting new varieties of

crops, some farmers have also been practising occasional calendar shift to coincide with the late arrival of the monsoon for the last 10 to 12 years, particularly for rice cultivation. Planting, weeding and harvesting times have been delayed. Through the focus group discussions farmers expressed their interest to participate in community sensitization programs if offered through workshops and seminars, which could help in mitigating the impacts of climate change to some extent.

4. Discussion

The major concerns emerging on the pathway from traditional to commercial farming are associated mainly with crop varieties and agricultural inputs. Rice is the major cereal crop in Terai and hill regions; and maize in mountain region. The introduction of other cereal crop especially wheat seemed to be influenced by external intervention for example Asian Green Revolution (GR) and intensification (Dahal et al., 2009). In this study, we found that introduction of wheat was either as a drought resistant crop or as a crop that is used for religious purposes. While few other crops were found not cultivated in those areas due to the lack of manpower, market and economic benefit. In contrast, the adoption of various crops and use of agro-inputs in farming were influenced by infrastructural development together with adoption of GR in other studies (Brown and Shrestha, 2000; Brown and Kennedy, 2005; Raut et al., 2011; Raut et al., 2012). With introduction of higher yielding varieties of crops and vegetables, the traditional varieties of rice and maize are in process of disappearing with few of the varieties already non-existent from these regions. Farmers have reduced the cultivation of barley and buckwheat due to lack of manpower, and they have neglected and underutilized food crops (NUFCs). The NUFCs are important for ensuring sufficient supply of micronutrients to the human body, as their nutritional values are comparable to advanced cereal (rice, maize and wheat) (NNS, 2011; Adhikari et al., 2017). Thus, changing local food systems, food habits, existing policies and lack of nutritional knowledge, farmers have compromised food and nutritional security along with the traditional crops.

Although decreasing cereal production over the past 30 years correlated with the declining rainfall and temperature in Saptari district, overall production has increased. Farmers perceive that the major reasons of increase in production of cereal crops were due to the use of improved agricultural technology, use of high yielding varieties, use of pesticides and irrigation facility. Moreover, farmers have also noticed that the decreasing trend of crop production in some years, are not only due to the decrease in rainfall but also because of irregular rainfall pattern and pests infestation and diseases. Furthermore, farmers have reported the incidences of drought for declining yield for specified years. The declining crop production will have severe impact on overall food security (Poudel et al., 2017). Studies in South Asian context also reported significant negative impacts on crop productivity and food supply due to extreme events, especially floods and droughts (Chhetri et al., 2012; Bandara & Cai, 2014). Although our study showed positive correlation between the crop yields and climatic data (temperature and rainfall) for hill (Okhaldhunga district) and mountain region (Solukhumbu district) of Nepal, the regional climate-model projections show temperature increases of 1.6°C–2 °C by 2030, 2.3°C–2.9 °C by 2050, and 3.4°C–5.0°C by 2080 (Ahmed & Suphachalasai, 2014). If, as expected, agricultural productivity is significantly affected, this could have severe negative impacts on the Nepalese economy, as agriculture is the mainstay of the country. Our finding is in accordance with those of Shumetie & Alemayehu (2017). As stated by Shumetie & Alemayehu (2017), rainfall inconsistencies and climatic variability are creating serious threat to smallholder households by impacting on overall agricultural productivity. Various modelling studies have already predicted and proved that Nepal is highly vulnerable to climate change, with agricultural productivity in Nepal likely to be severely affected by climate change (Joshi et al., 2011; Poudel & Kotani, 2013; Chalise et al., 2015).

The major coping strategies that farmers have been following appeared to be changing the crop varieties and shifting the crop plantation season especially for rice. Similar adaptation measures have been known to practise at farm-level in a recent study by Kabir et al. (2017). Changes in cultivation practices such as water conservation methods, changes in sowing time and introduction of cash crops have already been reported (Poudel et al., 2017). In this study, the adaptation in agriculture are mainly autonomous and it implies that individuals or communities undertaking adaptation to climatic risk to agriculture independently of outside intervention. Another study by Joshi et al. (2017) also reported that the increased incidence of droughts during rainy season is one of the main factors for farmers´ decision on adopting adaptation strategies.

5. Conclusions

Along the path from traditional to intensified agriculture, farmers have introduced high yielding varieties of crops and vegetables in the study areas, mainly because of enhanced production and increased returns. The cultivation of traditional varieties of rice and maize have vanished. Farmers have reduced the cultivation of

barley and buckwheat due to lack of on-farm labour. The pest infestation mostly occurred during summer season and the pest attack is reported to be increasing since two decades, while few pests disappeared. The majority of farmers in hill and Terai regions use pesticides as per prescribed dose(s), while in mountain region, pesticide use is random. The production of rice and maize has significantly increased since three decades in Terai, hill and mountain region. The rainfall and temperature data showed negative correlation with the average production of rice, maize and wheat that has increased in Saptari district during the past 30 years. In contrast, in Okhaldhunga and Solukhumbu districts, the average production has increased with increasing temperature and rainfall. With changes in climate variables, farmers have adopted coping strategies mainly on crop varieties and crop plantation season. Conversely, limited access to climate resilient crop varieties and poor extension services, despite farmers´ willingness to adopt adaptation measures, were the main barriers to climate change adaptation in the present context. Stronger agricultural research and support services, community-focused farming education and training are critically important for effective adaptation to climate change.

Acknowledgments

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Evaluation of Selected Advanced Spring Wheat Germplasm Lines In Eastern Canada

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Abstract

Twenty-three selected advanced spring wheat (*Triticum aestivum* L.) lines from Ottawa Research and Development Centre (ORDC) were compared with four known cultivars for agronomic performance at eight sites in 2016 (Ottawa CEF-C1, Ottawa CEF-C2, St. Isidore, Harrington, Palmerston, Princeville, Kincardine, Beloeil) in Eastern Canada, and for fusarium head blight (FHB). The reaction of these lines to six races of LR was determined in a growth cabinet and the LR susceptible cultivar 'Morocco' was included as the control for disease development in these trials. The majority of the selected lines showed no significant differences compared to four check cultivars, however ECSW05 and ECSW48, showed higher yield, moderate resistance to FHB and resistance to most of the tested LR races. Lines ECSW05 and ECSW48 will be advanced to grower's trials in eastern Canada in 2018 and may be used as sources of resistance to LR for future cultivar development in Eastern Canada.

Keywords: spring wheat, *Triticum aestivum*, fusarium head blight, *Fusarium graminearum*, leaf rust, *Puccinia triticina*

1. Introduction

Wheat (*Triticum aestivum* L.) is one of the worldwide staple foods in human life. It accounts for almost one-third of global grain production. Given that the world's population continues to grow and that wheat is one of the main crops cultivated in Canada. Wheat breeding programs aim to produce new high-yielding, high-quality cultivars with effective resistance to diseases, especially fusarium head blight (FHB) and leaf rust (LR), which occur annually and can lead to substantial yield losses.

Grain yield is one of the most important characteristics to wheat growers and many breeding programs aim to increase wheat yield in Canada (DePauw et al. 2011). Hucl and Baker (1987) found there is a correlation between crop grain yield and biological yield in those later-heading cultivars which had more kernels per spikelet, more total spikelets, and had higher grain yield. In addition, though some cultivars have significantly fewer spikelets per square meter, yet due to their heavier kernels, the crop yield still had increased 25%. (Hucl & Baker, 1987). They also found kernel weight had a correlation to grain yield by affecting test weight (Hucl & Baker, 1988). As we know, test weight represent the average weight of a cereal as measured in pounds per bushel, which is important to yield and flour extraction rate for wheat. The optimal industry standard for test weight is considered to be 55 to 60 lb/bushel (Darby, 2015). Also breeders have attempted to produce high-yielding wheat cultivars by using spring wheat hybrids, for which mean yields were found to be better than those of all controls (McKenzie & Grant, 1974). In addition, grain protein is also an important predictor of wheat yield and the optimal content is reported to be 12% to 14% as an industry standard (Darby, 2015). Bell and Anderson (1984) have studied superior performance of wheat protein in wheat cultivars and found some cultivars had the highest protein digestibility and superior protein rating. However, Löffler and Busch (1982).reported grain yield has a

negatively correlation to grain protein which makes it important to find a way to maintain the protein concentration while improving the yield

Apart from plant yield and other plant quality traits, resistance to fusarium head blight, caused by *Fusarium graminearum* Schwabe, is a key concern. This worldwide wheat disease occurs annually in Canada, causing yield losses by damaging wheat kernels. Every year, scientists use many methods to examine the wheat genome in hopes of identifying the gene segment that confers FHB resistance (Buerstmayr, Ban & Anderson, 2009). Unfortunately, there have been no explicit results yet, but some correlation between plant height and FHB severity has been reported (Moidu et al., 2015). In addition, *F. graminearum*, leads to high concentrations of deoxynivalenol (DON) in wheat kernels, a mycotoxin known to be harmful to humans (Xue, 2012). There is currently no single way to control FHB, but the use of resistant cultivars with appropriate fungicide application and suitable farming practices can help to overcome outbreaks (Gilbert & Tekauz, 2000). Leaf rust, caused by *Puccinia triticina* Eriks., is another worldwide disease that occurs in Canada and can easily be widely disseminated over large geographic areas by winds. In a warm, high-humidity environment, the uredinia erupt easily and release spores that infect wheat, making it difficult to prevent the disease from spreading (Kolmer, 2013). Annual virulence survey have been conducted on the wheat leaf rust pathogen, *Puccinia triticina* Eriks., in Canada since 1931 and revealing a diverse and constantly evolving population (McCallum et al. 2016a), such as in 2010 in which 41 different virulence phenotypes were found (McCallum et al. 2016b).

The objective of the present study was to evaluate the agronomic performance and susceptibility of selected spring wheat lines to FHB and LR in order to identify the best performers to be evaluated in grower trials.

2. Materials and Methods

2.1 Field Evaluation

Twenty-three hard red spring wheat germplasm lines, namely Eastern Cereal and Oilseed Research Centre advanced lines (ECAD) (ECO410.1.15, ECO410.1.7, 12NQW-300, 12NQW-303, 12NQW-734, 12NQW-754, 13NQW-73, 13NQW-454, 13NQW-979, 12CRF12-29, 12CRF14-94, 13Bou-64, 12BW0491, 13BW0426, BH33-47-4, ECSW05, ECSW43, ECSW48, ECSW49, ECSW16, ECSW72, ECSW69, and ECSW70) were evaluated in 2016 at eight sites in eastern Canada (St. Isidore, Ontario, 45°23′ N, 74°54′W; Palmerston, Ontario, 43°50′N, 80°50′W; Kincardine, Ontario, 44°10′N, 81°38′W; Princeville, Quebec, 46°10′N, 71°52′W; Harrington, Prince Edward Island, 46°21′N, 63°10′W; and Beloeil, Quebec, 45°34′ N, 73°11′ W) and two fields at the Ottawa Research and Development Centre (ORDC) Central Experimental Farm (CEF-C1 45°22′N, 75°43′W; and CEF-C2, 45°23′N, 75°43′W) and compared to four known varieties (AC Scotia, AC Carberry, Norwell and Sable) (Table 1). A randomized complete block design was used at all sites with three replicates. Depending on the location, the seeding date varied from April 20 to May 20, and the grain was harvested from late August to early September. Yield, test weight, height, protein content, thousand-kernel weight, days to head and FHB were measured at each site. DON analysis was conducted on 1gm representable samples using the in-house enzyme-linked-immunosorbent-assay (ELISA) procedure as described by Sinha et al. (1995).

Table 1. Pedigree of selected lines

Variety	Pedigree
ECO410.1.15	BA83-EC-23/3/ECO145.8.3.B (BW307/2*HOFFMAN HRF)
ECO410.1.7	BA83-EC-23/3/ECO145.8.3.B (BW307/2*HOFFMAN HRF)
12NQW-300	ERA52 / SWS403
12NQW-303	FL94R9 / SWS 416005
12NQW-734	FL94R9 / SWS 416005
12NQW-754	Sadash / FL54R1
13NQW-73	FL62R1 / TP-108
13NQW-454	06GG-294 / 06FL-94 (F7AB-143F8)
13NQW-979	06GG-294 / 06FL-94 (F7AB-143F8)
12CRF14-29	F5 PL223.C2C F6 / BA83-EC8 / F4 PL249.N1 F5 / BD76A*F0763
12CRF14-94	Glenn / 03TAB86A1 (5V55a1) / HD-22 (GS-0-EM0134) / 03TAB86A1 (5V55a1)
13Bou-64	F4 PL259.B1 F5 / BD76A*F0763
12BW0491	BW450/BD31-7-B-B-PNB-13-N
13BW0426	BW430/BD31-7-B-B-PNB-13-N
BH33-47-4	K2619=HF15*A0084/K2627&2628
ECSW05	AW 625/FL62R1/ZM24049/EC0017.8
ECSW43	AW 625/FL62R1/HOFFM/FL62R1
ECSW48	AW 625/FL62R1/HOFFM/FL62R1
ECSW49	AW 625/FL62R1/HOFFM/FL62R1
ECSW16	AW 625/FL62R1/AW 620/FL62R1
ECSW72	HOFFM/EC0017.8/AW 625/FL62R1
ECSW69	HOFFM/EC0017.8/AW 625/FL62R1
ECSW70	HOFFM/EC0017.8/AW 625/FL62R1
SCOTIA	AC Helena//Quantum/AC Walton
CARBERRY	Alsen/Superb
NORWELL	Max/PT742//Blue
SABLE	TG3S/B58664HCH

2.2 LR Growth Cabinet Evaluation

A randomized complete block design with four replicates was used to evaluate the susceptibility of the 23 lines against six common races of *P. triticina* (77-2 TJBJ, 06-1-1 TDBG, 12-3 MBDS, 74-2 MBGJ, Race 1 BBBD, 128-1 MBRJ) provided by Dr. McCallum (Morden Research and Development Centre, 101 Rte 100, #100, Morden, MB, R6M 1Y5), In addition to the four checks (AC Scotia, AC Carberry, Norwell and Sable), a known LR susceptible cultivar 'Morocco' was included as the control for disease development in these trials.

The urediniospores of *P. triticina,* used as inoculum, were stored in a freezer at −20 °C until use. The experiments were carried out in a growth chamber at a temperature ranging from 16 to 18 °C and 16 hour photoperiod. All test cultivar seeds were sown in 48-cell trays filled with normal soil and placed in a greenhouse. The plants were inoculated with the *P. triticina* isolates at the two-leaf stage. The inoculum was prepared immediately prior to use by suspending urediospores in a solution of Bayol oil provided by Ottawa Research and Development Centre and then place in the water bath at 45°C for 15 min to revive them. The mixed solution was sprayed with an atomizer (0.5 atm), and the inoculated plants were covered with a black plastic bag for 24 h to create appropriate humidity and encourage the urediospores to infect the plants. The growth chamber was maintained at 50% humidity during the disease development period (12–15 days) and watered every 2 days. Data were collected by rating the infection types described by McCallum et al. (2016)

2.3 Statistical Analysis

Analysis of variance was performed on the data sets using the SAS software program (version 9.1, SAS Institute Inc., Cary, NC), and the least significant difference (LSD) test was used to compare the means when the differences were significant.

3. Results

Generally, results from Table 2 show that all advanced lines performed as well as or better than the check varieties. Line AC Scotia had the highest yield (4091 kg/ha), and line ECSW16 (3306 kg/ha) had the lowest

yield but did not show a significant difference. Line ECSW43 had the longest days to head (60 d), which is significantly longer than lines AC Carberry, Norwell and Sable (50, 52 and 52 d, respectively) but not different from AC Scotia (56 d). Line 13NQW-979 had the highest test weight among all lines. Additionally, line ECSW16 (75.1 kg/hl) had the lowest test weight among all lines, but its test weight was not different from that of AC Scotia (75.2 kg/hl). Line ECSW72 had the highest thousand-kernel weight (39.9 g), followed by line ECSW69 (39.7 g), and it performed significantly better than AC Carberry, Norwell and Sable (32.9, 34.5 and 34.9 g, respectively) but not differently from AC Scotia (38.6 g). Line ECSW72 performed the best and had the highest mean value for plant height (101.5 cm), which was not different from that of AC Scotia (94.7 cm) but was significantly higher than those of AC Carberry, Norwell and Sable (72.9, 82.5 and 70.5 cm, respectively).

Table 2. Grain yield, days to head, test weight, thousand-kernel weight, plant height and protein of 27 spring wheat lines tested at eight sites in eastern Canada in 2016

Variety	Grain yield (kg/ha)	Rank	Days to Head	TSTWT (kg/hl)	TKW (g)	Height (cm)	PROT (%)
ECO410.1.15	3505	16	51	75.7	35.9	78.7	15.7
ECO410.1.7	3847	4	51	76.3	36.6	83.5	14.7
12NQW-300	3753	6	53	76.5	34.4	86.8	14.4
12NQW-303	3524	14	56	76.8	36.5	88.3	15.1
12NQW-734	3457	20	55	76.1	32.2l	86.9	14.6
12NQW-754	3756	5	53	77.7	37.1	89.9	13.4
13NQW-73	3502	17	55	78.0	31.3	5.6	15.7
13NQW-454	3392	23	52	78.7	30.9l	81.1	14.7
13NQW-979	3478	19	52	79.1	31.1	81.3	14.7
12CRF14-29	3542	13	52	77.0	36.1	5.4	14.7
12CRF14-94	3440	21	52	77.0	33.9	5.7	14.9
13Bou-64	3595	12	54	76.2	34.2	5.4	14.4
12BW0491	3360	24	52	76.5	34.9	5.5	15.1
13BW0426	3490	18	51	76.2	36.3	5.0	14.9
BH33-47-4	3342	25	52	75.9	33.5	82.4	15.6
ECSW05	3924	3	57	76.5	37.6	95.9	15.0
ECSW43	3635	10	60	75.4	37.7	98.7	14.0
ECSW48	3963	2	55	77.0	37.0	88.3	13.6
ECSW49	3401	22	59	75.6	36.0	95.6	14.5
ECSW16	3306	27	58	75.1	34.9	97.4	14.3
ECSW72	3630	11	58	76.6	39.7	101.5	14.1
ECSW69	3688	8	57	77.0	39.9	99.5	13.9
ECSW70	3511	15	55	76.8	37.8	93.8	13.8
SCOTIA	4091	1	56	75.2	38.6	94.7	14.2
CARBERRY	3320	26	50	76.7	32.9	72.9	15.3
NORWELL	3665	9	52	77.1	34.5	82.5	15.6
SABLE	3696	7	52	76.4	34.9i	70.5	15.6
LSD 0.05	**1324**		**7.07**	**3.52**	**3.34**	**16.22**	**1.74**

Abbreviations: TSTWT: test weight; TKW: thousand-kernel weight; PROT %: protein percent;
LSD: least significant difference at the 0.05 level.

When comparing yield parameter between the sites in Table 3, mean value in Beloeil location was found to be the highest (5880.8 kg/ha), which was significantly higher than the recorded for the CEF-C1, CEF-C2, St. Isidore, Princeville, Palmerston and Kincardine sites (2692.0, 2287.5, 3735.5, 4612.2, 2301.8 and 2133.6 kg/ha, respectively). However, CEF-C2, Palmerston and Kincardine did not differ significantly. With respect to the test weight, CEF-C2 had lowest mean value (73.2 kg/hl) and was significantly lower than that for the Beloeil site (80.7 kg/hl) but not significantly different from the mean values for the CEF-C1 and St. Isidore sites (73.3 and 73.6 kg/hl, respectively). As thousand-kernel weight parameter was compared among the seven sites, the highest mean value (39.5 g) is in Beloeil, which was significantly higher than the mean values for the CEF-C1, CEF-C2, St. Isidore and Princeville sites (34.9, 32.1, 35.4 and 32.7 g, respectively). Comparing the days-to-head parameter, CEF-C2 had lowest mean value (45.6 d), which was significantly lower than that for the CEF-C2, St. Isidore, Palmerston, Kincardine and Beloeil sites (45.6, 50.9, 57.8, 56.2 and 58.4 d, respectively), and none of the sites differed significantly from the mean values. With regard to the plant height parameter, Princeville had

the highest mean value (112.4 cm), which was significantly higher than the mean values recorded for the CEF-C1, CEF-C2, St. Isidore, Palmerston, Kincardine and Beloeil sites (69.9, 67.3, 74.9, 102.4, 91.4 and 89.2 cm, respectively). Additionally, the value for the CEF-C1 site did not significantly differ from CEF-C2 and St. Isidore sites, but CEF-C2 and St. Isidore were significantly different. Comparing the protein content parameter among the seven sites, the St. Isidore location had the second highest mean value (15.9%), which was significantly lower than the mean value for CEF-C1 (16.3%) and significantly higher than the mean values for the Princeville and Beloeil sites (12.5% and 15.6%, respectively) but not significantly differ from the mean value at the CEF-C2 site (15.8%).

Table 3. Grain yield, test weight, thousand-kernel weight, days to head, plant height, and protein of 27 spring wheat lines tested at seven sites in eastern Canada in 2016

Site	Grain Yield (kg/ha)	Rank	TSTWT (kg/ha)	TKW (g)	Days to Head (d)	Height (cm)	PROT (%)
CEF-C1	2692.0	4	73.3	34.9	49.0	69.9	16.3
CEF-C2	2287.5	6	73.2	32.1	45.6	67.3	15.8
St. Isidore	3735.5	3	73.6	35.4	50.9	74.9	15.9
Princeville	4612.2	2	77.4	32.7	-	112.4	12.5
Palmerston	2301.8	5	-	-	57.8	102.4	-
Kincardine	2133.6	7	-	-	56.2	91.4	-
Beloeil	5880.8	1	80.7	39.5	58.4	89.2	15.6
LSD	310.5		0.7	1.1	0.4	6.6	0.2

Abbreviation: TSTWT: test weight; TKW: thousand-kernel weight; PROT: protein percent; CEF-C1, CEF-C2: Ottawa Development and Research Centre Central Experimental Farm, Ottawa, Ontario; St. Isidore: Ontario; Princeville: Quebec; Palmerston: Ontario; Kincardine: Ontario; Beloeil: Quebec; '-': attribute not measured at that location; LSD: least significant difference at the 0.05 level.

The overall results for susceptibility to FHB and LR were presented in Table 4. In terms of mean values for FHB index, line ECSW69 shows an exceptional FHB resistance (7.8%), and lines ECSW05, ECSW16, ECSW48, ECSW49 and ECSW70 (10.7%, 13.3%, 10.0%, 13.3% and 11.7%, respectively) performed significantly better than AC Carberry, Norwell and Sable (50.0%, 38.3% and 76.7%). As for DON evaluation, the average of DON content among all the tested lines is ranged from 1.4 to 24.0 $\mu g\ g^{-1}$, and lines that performed the best were 13NQW-979, ECSW48 and ECSW49 (1.5, 1.4 and 1.7 ppm, respectively), their performance being significantly better than Norwell and Sable (8.7 and 24.0 ppm, respectively) but not different from AC Scotia and AC Carberry (4.7 and 5.5 ppm, respectively).

Table 4. Average test results for fusarium head blight and leaf rust for selected wheat lines or cultivars

Variety	INC(%)	SEV(%)	FHBi(%)	DON	Leaf Rust Races					
				ppm	128-1MBRJ	12-3 MBDS	74-2MBGJ	Race 1	06-1-1TDBG	77-2 TJBJ
ECO410.1.15	100	30.0	30.0	8.2	2-3	2	2-3	2-3	2-3	3-4
ECO410.1.7	100	30.0	30.0	4.9	2-3	3-4	3-4	2-3	3-4	3-4
12NQW-300	100	18.3	18.3	7.9	1-2	3-4	2	1	2-3	4
12NQW-303	100	16.7	16.7	4.1	3-4	4	3-4	1-2	3-4	4
12NQW-734	100	18.3	18.3	4.7	2-3	3-4	3-4	1-2	4	4
12NQW-754	100	16.7	16.7	5.0	2-3	3-4	3-4	3-4	2-3	4
13NQW-73	100	18.3	18.3	6.3	1	1	3-4	0	3-4	3-4
13NQW-454	100	18.3	18.3	4.3	0	1-2	4	2	0	2-3
13NQW-979	100	21.7	21.7	1.5	0-1	2	0	0	1-2	2-3
12CRF14-29	100	15.0	15.0	3.7	0-1	1-2	2-3	0	2	3-4
12CRF14-94	100	21.7	21.7	4.2	1-2	2-3	4	1	4	3-4
13Bou-64	100	20.0	20.0	13.7	0	2	1-2	0	2	2-3
12BW0491	100	15.0	15.0	4.0	0-1	0	1-2	1	2	3-4
13BW0426	100	23.3	23.3	6.6	0-1	0	3-4	1-2	3-4	3-4
BH33-47-4	100	18.3	18.3	3.1	0	0	2-3	1	3	2-3
ECSW05	90	11.7	10.7	4.3	1-2	2-3	3-4	1-2	2	3-4
ECSW43	100	15.0	15.0	3.2	2	2-3	2-3	1-2	3-4	3-4
ECSW48	83	11.7	10.0	1.4	1-2	1-2	2	1-2	1-2	4
ECSW49	100	13.3	13.3	1.7	2-3	1-2	3-4	1-2	3-4	3-4
ECSW16	100	13.3	13.3	3.4	1-2	1-2	4	1	2-3	3-4
ECSW72	100	15.0	15.0	6.4	2-3	3-4	3-4	0	2-3	3-4
ECSW69	67	11.7	7.8	2.0	3-4	4	2-3	1	3-4	3-4
ECSW70	87	13.3	11.7	3.3	2-3	2-3	3-4	2-3	2-3	3-4
SCOTIA	93	15.0	14.1	4.7	2-3	4	3-4	1-2	4	4
CARBERRY	100	50.0	50.0	5.5	1	0	1-2	1	4	4
NORWELL	100	38.3	38.3	8.7	2-3	2-3	3-4	1	3-4	4
SABLE	100	76.7	76.7	24.0	1	2-3	4	1	3	4
Morocco	-	-	-	-	4	3-4	3-4	3-4	3-4	3-4
LSD	7.77	5.89	6.04	5.44	-	-	-	-	-	-

Abbreviation: INC: incidence; SEV: severity; FHBi: fusarium head blight index = incidence × severity ×100%; DON: deoxynivalenol; leaf rust grade: 1 – small uredinia with necrosis; 2: small- to medium-sized uredinia with chlorosis that were considered a virulent; 3: medium-sized uredinia without chlorosis or necrosis; 4: large uredinia without chlorosis or necrosis; LSD: least significant difference at the 0.05 level.

The tested lines were most susceptible to leaf rust race 77-2 TJBJ, followed by 74-2 MGBJ, 06-1-1 TDBG, 12-3 MBDS, 128-1MBRJ and Race 1. Several lines, including 13NQW-979, 13Bou-64 and BH33-47-4, exhibited moderate resistance to the six tested rust races in the growth cabinet environment. Other lines, including 12BW0491 and ECSW48, had better resistance to races 74-2 MGBJ, 06-1-1 TDBG, 12-3 MBDS, 128-1MBRJ and Race 1, but lower resistance to race 77-2 TJBJ. Line 13NQW-454 showed higher resistance to 77-2 TJBJ, 12-3 MBDS, Race 1, 128-1MBRJ and 06-1-1 TDBG, however it has a lower resistance to race 74-2 MGBJ. Line ECSW05 showed higher resistance to 06-1-1 TDBG, 12-3 MBDS, 128-1MBRJ and Race 1, but has lower resistance to races 77-2 TJBJ and 74-2 MGBJ.

The correlations between yield, test weight, thousand-kernel weight, days to head, plant height, protein and FHB was shown in Table 5. The result shows that plant test weight, thousand-kernel weight and height have significant negative correlation with both FHB index and protein percent. In addition, yield does not have significant correlation with DON, but had a significant negative correlation with FHBi.

Table 5. Correlation between grain yield, test weight, thousand-kernel weight, days to head, plant height, protein and fusarium head blight

	FHBi	DON	HGT	Grain Yield	TSTWT	TKW	PROTEIN
DON	0.65*						
HGT	-0.46*	-0.41*					
Grain Yield	-0.29*	-0.16	0.74*				
TSTWT	-0.22*	-0.24*	0.55*	0.50*			
TKW	-0.38*	-0.22*	0.61*	0.64*	0.24*		
PROT	0.46*	0.33*	-0.57*	-0.58*	-0.52*	-0.50*	
Days to Head	-0.46*	-0.31*	0.47*	0.20	0.03	0.34*	-0.29*

Note. FHBi: fusarium head blight index = incidence × severity×100%; DON: deoxynivalenol; HGT: height; TSTWT: test weight; TKW: thousand-kernel weight; PROTEIN: protein percent; *: means significant.

4. Discussion

This study was carried out at eight test sites to evaluate the performance of 23 selected advanced wheat lines for yield, test weight, thousand-kernel weight, heading date, height and protein. However, due to the extreme outliers in some sites which represent the average values for ECAD lines among the test sites in Table 3, it can be highly possible that this effected the values shown in Table 2. For example, the high yield and days-to-head values for the Beloeil sites in Table 3 could explain the high per-line yield and days-to-head estimates shown in Table 2. Taking this situation into consideration, the values of yield and days-to-head for the ECAD lines would possibly be much lower than their estimated value shown in Table 2.

This FHB resistance experiment demonstrated that the ECAD lines showed moderate resistance to fusarium spores and performed very well compared to the checks. A negative correlation was observed between plant height and FHB morbidity which is similar to a previous study reported by Moidu et al. (2015). In addition, race 77-2 TJBJ showed the highest damage to wheat leaves among all LR races in the LR inoculation test, similar to what was reported by Chen et al. (2015).

Based on the overall results, several tested lines not only showed their improvement in agronomic performance but also outperformed the selected commercially available cultivars. The observed scores of FHB ranged from immunity to high susceptibility with LR scores ranging from nearly immune (0) to very susceptible (4). Lines ECSW05 and ECSW48 not only had reasonable yields but also showed moderate resistance to FHB and were resistant to the tested LR races, which suggests that they should be evaluated further at sites across the country to test their response to FHB and LR under different environmental conditions. In addition, the climatic factor also needs to be considered since FHB and LR can be affected by the environment. Therefore, for more precise knowledge of test lines field performance under different environmental conditions the test lines will be evaluated further in the coming years.

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Transitions in Cooperative Labour and the Constraints to the Adoption and Scaling-Up of Labour Intensive Agricultural Technologies

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Abstract

The research presented in this paper stems from a collaboration between researchers in the Benin Republic, Nigeria and Canada who are examining the opportunities to enhance the sustainable production of under-utilized indigenous vegetables through the micro-dosage of synthetic fertilizer. Because micro-dosing is a labour intensive technology, and is time sensitive in application, we sought to better understand how the availability of labour, as affected by changes in cooperative networks, might affect adoption and scaling up opportunities. The systems of cooperative labour described in this paper reflect the culture and traditions of the Betammaribe people, residing in the village of Koumagou B in northwest Benin. Our results indicate that cooperative labour systems among the Betammaribe are in transition and are being influenced by seasonal migration, the financial demands of formal education, the use of oxen by those with relative wealth, and off-farm employment. These pressures have led to the atomizing of Koumagou B households and a concomitant decline in the availability of cooperative labour. Interventions designed to improve the livelihoods of smallholder farmers must not inadvertently perpetuate social and economic inequalities or disadvantage those most vulnerable. It is this possibility that warrants careful consideration as we contemplate the benefits of adopting and scaling-up new agricultural technologies in the future.

Keywords: Benin, labour exchange, micro-dosing, socio-economic inequality

1. Introduction

The availability of agricultural labour has shown to be a critical factor for the adoption of new agricultural technologies and often serves as an operative constraint to farming systems in Africa (Larson & Gurara, 2013; Marenya & Barrett, 2007). This is particularly true during critical periods of production when labour is in most demand (Palm, Myers & Nandwa, 1997; Mignouna Manyong, Rusike, Mutabazi & Senkondoet, 2011; Bachman et al., 2016), or when adoption involves labour intensive technologies, such as organic or inorganic fertilizer applications (Palm, et al., 1997) and other soil conservation investments (Lee, 2005).

Some have argued that systems of cooperative labour are capable of overcoming short-term labour constraints in ways that facilitate the adoption of labour intensive technologies. Adapted over time, cooperative labour systems ease labour shortages and relax the labour constraints that can impede the adoption and scaling up of new agricultural technologies (Kirinya, Taylor, Kyamanywa, Erbaugh & Bonabana-Wabbiet, 2013). Such systems exist among smallholder farmers throughout the world and have been described in detail for Sub-Saharan Africa, including south-western Ethiopia (Bartels, 1977), south-eastern Cameroon (Geschiere, 1995), eastern Uganda (Shiraishi, 2006), Zimbabwe (Worby, 1995), Nigeria (Stone, Netting & Stone, 1990), Tanzania (Ponte, 2000), the Democratic Republic of the Congo (Suehara, 1983, 2006), and Sudan (Barth, 1967). These accounts often depict cooperative labour systems as driven by a sense a mutual aid and reciprocal behaviour.

Much of the current research conducted on cooperative labour has been influenced by the seminal works of Erasmus (1956) and Moore (1975), who both offered simple, yet useful, typologies of cooperative labour systems. For Erasmus (1956), cooperative labour can be divided into two types: exchange labour, which relies upon strict reciprocity of labour and sometimes the provisioning of simple meals; and festive work parties, which require the host to provide more elaborate food and drink but do not require reciprocal labour commitments. Moore (1975), while respecting this underlying typology, preferred to call these two types of cooperative labour simply

'reciprocal' and 'non-reciprocal', as he believed the true difference lay in the level of labour-based reciprocity.

In some regions of Africa, the prevalence of socio-economic inequality have altered or displaced traditional systems of cooperative labour. For example, Swindell (1985) suggests that a transition has been occurring in cooperative labour systems throughout Africa as a result of migration, a growing landless proletariat, the introduction of full-time, off-farm employment, and the commodification of the economy. In light of these changes, it is necessary to understand how these conditions affect the supply of local labour before proposing any new agricultural technologies or attempting to identify user groups with high adoption potential (Dreschsel, Olaleye, Thiombiano, Barry, & Vohland, 2005). If local labour supply is limited, or if new technologies demand intensive labour inputs, caution must be exercised before introducing new technologies that only add to the labour burden of farming households (Drechsel et al., 2005).

The research presented here stems from a collaboration between researchers in the Benin Republic, Nigeria and Canada who are examining the opportunities to enhance the sustainable production of under-utilized indigenous vegetables through the minimal use of synthetic fertilizer, a process referred to as Micro-Veg technology. Micro-dosing involves the placement of small amounts of fertilizer at the base of plants at the time of seeding or soon after germination. The aim of this project is to accelerate the adoption of fertilizer micro-dosing to enhance the production of indigenous vegetables (e.g., amaranth, African eggplant, fluted gourd, African basil) leading to improved food and nutritional security, while contributing to the economic empowerment of resource constrained farmers. The ultimate scaling up objective is to reach 250,000 farmers in 51 locations across Benin and Nigeria. Given that micro-dosing is a labour intensive technology, and is time sensitive in application (Camara, Camara, Berthe & Oswald, 2013), we sought to better understand how the availability of labour, as affected by changes in cooperative networks, might affect the scaling up of the Micro-Veg technology. Our analysis was motivated by an understanding that interventions designed to improve the livelihood conditions of farmers must not inadvertently perpetuate existing conditions of social and economic inequality. It was this possibility that warranted careful consideration as we contemplated the risks and benefits of scaling-up new agricultural technologies.

2. Study Area

The study area for this research was the village of Koumagou B, which is located within the commune of Boukombé, in the Atacora department of northwest Benin (Figure 1). Koumagou B is comprised of five hamlets - Koumagou Centre, Yatera, Koutannagou, Koucangou, and Kouyiéndagou - whose residents are united by kinship, and recognize each other as descendants of the original village founder (Joffroy and Djanguenane, 2005). The area surrounding Koumagou B consists of valleys and hills, rocky cliffs and plateaus (Avohou and Sinsin, 2009). The climate is Sudano-Sahelian, with a rainy season stretching from June to October and a dry season lasting from November to May (Aregheore, 2009). Climate change is affecting the timing and duration of the rainy season, creating unpredictability and stress for farmers who rely solely upon rain-fed irrigation. Farming in the village is primarily subsistence-based and includes the production of sorghum, millet, fonio, rice, beans and tubers such as yam. Most farm labour is done by hand, with little mechanization. Synthetic fertilizer is used to a limited extent on some crops (particularly maize), depending upon availability and affordability (Bachmann et al., 2016). The application of organic fertilizer (manure) is typically constrained by the size and number of animals owned by village households.

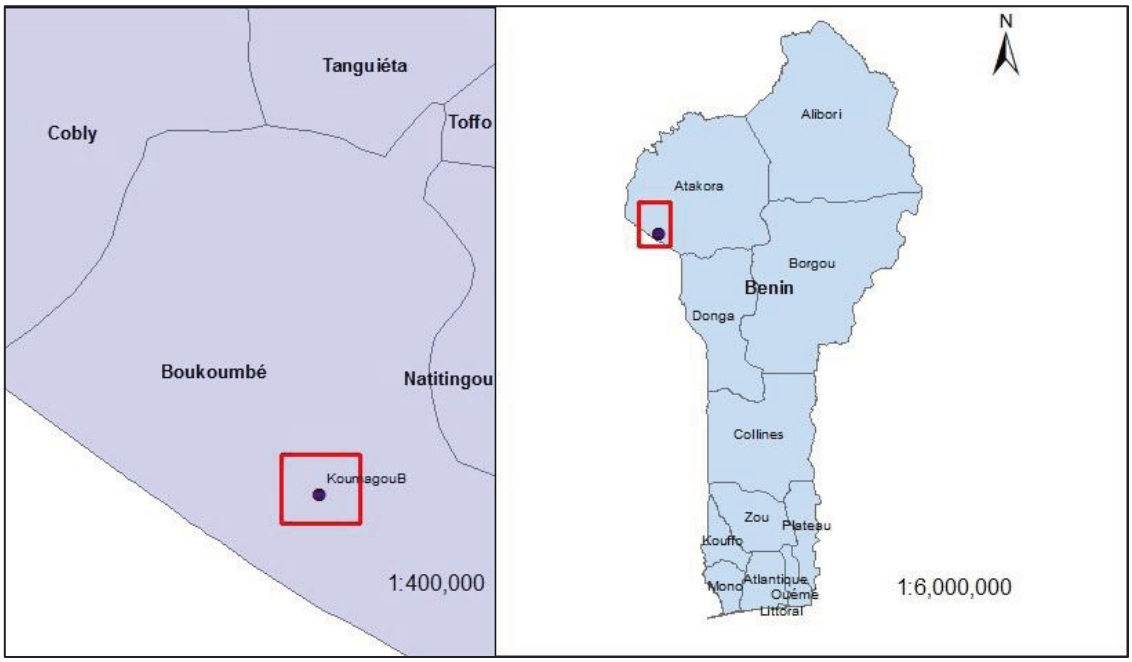

Figure 1. Location of Koumagou B, Benin

Field work was conducted during an initial 3-month exploratory field season between May and August 2014, followed by a second 11-month field season from June 2015 to May 2016. Our research was informed by grounded theory and involved a mixed methodology consisting of a village census, a Principle Component Analysis, key informant interviews, focus groups, and participant observation.

A village census was conducted with each head-of-household in the village. The census was used to enumerate household labour, assets, and education. Survey questions addressed the participation of household members in reciprocal and non-reciprocal labour activities. Both classifications were considered useful for understanding and qualifying the current state of cooperative labour at the village level. In total, 92 out of 98 households were surveyed (94 percent); representing a survey population of 768 residents.

To evaluate the potential impact of socio-economic status upon one's involvement in cooperative labour, a Principal Component Analysis (PCA) was used to develop a household index of socio-economic status. PCA is a multi-variate statistical technique that is used to reduce the dimensionality of a group of variables while still capturing variation among the group. For this analysis, the variables included household labour, land ownership, education, and durable household assets as proxies for socio-economic status. This approach has been used in various settings where income data are difficult to come by or simply unreliable.

Fourteen key informant interviews were conducted with village residents. An initial participant list was co-developed with our local research collaborators. However, a schemata was used to help ensure a representative cross-section of the village population according to age, gender, household composition, and marital status. This sample included male and female respondents who were married in polygamous households (3M,1F); male and female respondents who were married in monogamous households (2M, 2F); male and female respondents who had never been married (1M, 1F); and male and female respondents who were widowed (2M, 2F).

Two focus groups involving village farmers were also conducted. Focus group discussions explored the changes occurring in cooperative labour and the demands or drivers that are influencing those changes. In addition to these formal exchanges, 14 months of living in Koumagou B allowed for countless interactions and opportunistic conversations that further informed our analysis. However, the exchange of information between villagers and members of the research team was at times challenging. Because villagers often express information by way of parables, metaphors and allusions, the information being provided is best understood by someone with an emic knowledge of Betammaribe culture and society. In addition, the Ditammari language is intuitive where only a single word may be spoken but the rest of the phrase is understood at least by other Betammaribe. Accordingly, members of the Canadian and Beninese research team worked closely with village collaborators to ensure what

we were learning through our interviews and focus groups was not misconstrued.

It is also important to note that in general, the Betammaribe are reluctant to share information with outsiders. Padenou and Pastor-Barrué (2006), found this to be the case when studying the architectural significance of the *tatas*, and encouraged other researchers to consider this fact before conducting any research with the Betammaribe. This was indeed our experience, where gender and culture intersected to create unspoken barriers. This is where 14 months of participant observation and the less formalized, though equally important, aspects of sustained field work proved invaluable. The ultimate success of this research was based on the trust and personal relationships that developed through the course of the fieldwork.

3. Traditional Cooperative Labour Systems

Agricultural labour exchange not only in Koumagou B, but also more generally amongst the Betammaribe, is comprised of multiple systems organized according to age, gender, level of reciprocity, season, and time of day. Labour strategies are further differentiated by the social and economic status of households. One of the major systems of labour exchange in Koumagou B is referred to as *Tachaata* and stems from the traditional system of marriage within Betammaribe society. Historically, marriage was arranged soon after birth. A father would bring a white baby chick to the family of his potential daughter-in-law, who may have just been born. If the chick is accepted, the marriage arrangement was agreed upon. If the chick survived and produced eggs, the marriage was deemed to have a promising future. In the following years, the family of the prospective groom, along with extended kin, would work each year on a specific set of agricultural tasks for their future in-laws. In addition to providing labour, the groom's family would bring food stuffs to the girl's family, to ensure the child was well nourished. This system of exchange can last as long as 10 years.

For the general adult population in Koumagou B (i.e., those who have undergone their initiation ceremony), a system of reciprocal labour exchange occurs during the morning hours. This system is called *Tapikantouanta* (meaning morning mutual assistance) or alternatively, *Tanananta*. This is a small rotational group involving 2 to 5 people who take turns working each other's fields. For their efforts, the host provides a thin porridge to the workers during the work period. The relatively small size of the group means a more frequent work rotation with labour being available every few days. This particular system is closest to the pure exchange labour of Erasmus (1956) and the reciprocal cooperative labour system discussed by Moore (1975).

Group formation in the *Tapikantouanta* system is based on physical and relational proximity. Physical proximity allows for an early start time and relational proximity fosters productive work environments. For example, a young woman explained that for *Tapikantouanta*, a woman would choose her closest friend (in a relational sense) with whom to work.

…you choose your closest friend, and you work together, and another chooses their closest friend, and they work together. Because if there is someone among you who doesn't get along properly with the others, the work is not going to function well. If there are problems between you, the work will not move ahead.

The composition of the group may change for different reasons: it may be affected by seasonal work migration in the case of men, by pregnancy in the case of women, or by illness. However, the importance of trustworthiness in the composition of the work group is considered a determinant for cooperative group membership. Farmers choose to work with those who can 'keep the secrets of the small group', and will not divulge that which has been said while working.

In the afternoon, after workers have had time to rest following *Tapikantouanta,* and have eaten a mid-day meal at their own homes, workers would assemble into *Koutouangou* groups, which translates roughly to 'large mutual assistance'. *Koutouangou* is a type of rotational labour exchange that can involve between 10 to 20 workers. Like the *Tapikantouanta* system, *Koutouangou* is also reciprocal. However, in this system the host must also provide a basic meal at the end of the work day. Those with economic means would offer meat (ideally pork, goat or beef, with poultry as a secondary option) in addition to a grain. Those with less economic means tend to offer small dried fish or fried cheese. Both men and women participate in *Koutouangou*, although labour activities are gender specific.

Koutouangou is organized under the guidance of the eldest male or female in the group. While the personal autonomy of individual Otammari is highly revered, deference is offered to those who are older, i.e., those who have done their initiation ceremony before you. One villager described how the eldest directs the efforts of the group, ensuring that the work schedule aligns with other social obligations and is adjusted to the uncertainties of weather. However, this same villager made clear that the eldest was "not a chief" in the sense of being able to dictate the work of others, but rather, he or she was only put in charge of the schedule.

If the *Koutouangou* fails to satisfy the labour needs of the host, he or she can invite the *Koutouangou* group back for additional work by hosting a festive work party. This system is referred to as *Diyiyi*, meaning 'to invite', and is consistent with the 'festive work party' described by Erasmus (1956) or 'non-reciprocal cooperative labour' category of Moore (1974). Villagers described this process by using the analogy of the *tontine*, or the informal rotating savings and credit association that is popular throughout West Africa (see Sommerfeld, Sanon, Kouyate, and Sauerborn 2002, for an overview of such associations in the West African context). "*Koutouangou* is like a tontine. If your tontine had already passed and you still need something done, then you do *Diyiyi*." In this manner, they are distinguishing between the rotating 'investment' nature of *Koutouangou*, and the one-off, 'payment' nature of *Diyiyi* (even though in this case they will be working with the same working group members).

More commonly, *Diyiyi* is used by farmers as an ad-hoc way of gathering a large work party from throughout the village. In this case a farmer spreads word, often by going door to door, that he or she would be hosting a work party. Depending on the amount of work to be done, well over 20 people may attend, although not all contribute equally to the labour but rather may be used by some (e.g., very young and the elderly) as an opportunity to socialize with neighbours and enjoy the food and drink that are provided by the host. In contrast with the standard fare offered at the end of *Koutouangou*, the host is expected to provide a more lavish meal, as *Diyiyi* is not a form of reciprocal labour exchange. The special fare is acknowledgement of non-reciprocal cooperation. *Tchouc,* the traditional fermented sorghum beer, is a requisite offering, though stronger forms of alcohol, including imported liquors, have also become common. The socialization aspect also performs an important function in the coordination of the cooperative labour system in general. A *Diyiyi* provides the opportunity for people to meet, interact and discuss forming a *Koutouangou* group for the afternoons.

While meat, ideally pork, goat or beef is most valued, those with less means give what they have in hopes of attracting sufficient labour. Whether providing meat or less valued forms of sustenance, the host is expected to thank the participants for their labour; "thank you for yesterday" or "thank you for the other day" signifying their appreciation well after the work was completed. Verbal acknowledgement is important to signify the lasting impression and is considered essential for maintaining good working relationships.

Another form of cooperative labour is referred to as *Takinta* and is employed specifically for the harvest and processing of fonio in September/October. Fonio, a grain indigenous to West Africa, holds a special place in Betammaribe society, and its cultivation embodies very distinct responsibilities according to age and gender. Only men can sow the fonio (the seeds come from the 'male' granary which only the man has access to) and only men can cut the fonio at harvest time. Older women are considered specialists for weeding throughout the season. At harvest time, women of all ages gather and sort fonio sheaves into piles. After the fonio has dried in the fields and is brought to the threshing floor, children are enlisted to crush the fonio beneath their feet to release the grain. Women then pound the fonio to remove the husk and sift and wash the grain. The *Takinta* system demonstrates the unique age and gendered dimensions of cooperative labour.

It is also common for Betammaribe youth to participate in a system called *Tatouanta* (meaning mutual assistance) or more precisely *Tabikantouanta* (*Tatouanta* for the children). Prior to undergoing their initiation into adulthood, youth work the village fields. Boys and girls work separately, and receive informal instruction and education on their appropriate roles as adults in Betammaribe society. *Tatouanta* continues until one is initiated into adulthood, which is not fixed by age but determined by the size and health of the child, and the timing of initiation ceremonies, including those that mark permissible sexual relations.

4. Changes in Cooperative Labour

As early as the 1950s, Mercier (1968) found that the traditional form of arranged marriage was decreasing in prominence among the Betammaribe due to the growing influence of the European economic system that commoditized labour. An important example of this tendency is the manner in which young women in Koumagou B have used their system of labour exchange to gain purchasing power in the emerging monetary economy. A widowed woman, approximately 45 years of age, attributed the change to the advent of girls attending school in greater numbers and choosing to delay marriage. Others felt that *Tachaata* has been discontinued, or more accurately, "broken because one no longer pays a bride price for the wife."

The material demands of formal education-school supplies, school uniforms-requires cash. Young women have drawn upon the organizing principles of cooperative labour to harness their earning power and engage with the market economy, an economy that provides the financial means to purchase fabric for clothes, school supplies and the ubiquitous cell phone and corollary phone credit. Farmers are now expected to pay groups of young women for their labour. The amount paid is not necessarily determined by the work achieved, but rather is a set

amount, which at the time of this research was 4500 CFA. Adapted in this way young women are using cooperative labour to meet the current demand for wage income.

As the system of arranged marriages declined, *Tachaata* has also transformed into *Koutouangou.* While still maintaining many of its traditional qualities, including kin-based and reciprocal, the frequency that work groups are formed has declined as more households rely on oxen, and to a lesser extent, mechanized technologies to meet their tilling needs. Of the 92 households surveyed, 12 (13%) owned oxen. As oxen and plough offer a more efficient labour saving option, the use of Koutouangou in particular has become less common. Of the 92 households surveyed, 38 household (41%) reported participation in Koutouangou.

Table 1. Participation in Koutouangou

Participation in Koutouangou					
	Koumagou Centre (Hamlet 1)	Yatera (Hamlet 2)	Koutannagou (Hamlet 3)	Koucangou (Hamlet 4)	Kouyiéndagou (Hamlet 5)
N-Households	35	13	9	16	19
% of Koumagou B Households	38%	14%	10%	17%	21%
Number and (%) of households participating in Koutouangou	6 (17%)	2 (15%)	6 (67%)	11 (69%)	13 (68%)

It is not only oxen but also the advent of wage employment, which has also been attributed to the decline in the Koutouangou system. One man, in his early 50s, married with two wives and 17 children, noted that Koutouangou, and cooperative labour in general, has:

"…decreased… Because today people use machines to till the soil, the oxen as well. And lots of people don't like doing *Koutouangou* because they have money now. … They do jobs."

The pressure to earn cash from employment, as opposed to relying upon reciprocal labour exchange, has affected the general availability of labour and the perpetuation of reciprocal labour exchange. This is most pronounced among young men who have the additional pressures of paying for school. Unlike girls, boys in Benin are required to pay school fees for secondary grade levels. With few local wage earning opportunities, young men often migrate to neighbouring *communes*, particularly Natitingou and Bembèrèkè, to find employment. One young man, unmarried yet initiated into adulthood, attributed the 'rural exodus' to wage seeking opportunities:

"Our area here, there aren't jobs (*paa*). If I stay here, just until the end of the rainy season, I wouldn't have enough money to buy school supplies. Here, you can't work at someone's place and have money very quickly for your work. He [the employer\farmer] is going to say wait until he goes to sell his crops."

An older farmer similarly acknowledged this economic reality when admitting "we don't have the money here to pay people." With money in short supply, most farmers consider their opportunity costs, preferring to use the little money they have to grind millet and buy ingredients for sauce. After these expenditures, farmers acknowledge that there is rarely enough money left to pay people to work in the fields.

These changes have in many ways disadvantaged the relatively poor in the village who are now challenged to attract needed labour. For those farmers struggling with cash flow, or unable to afford lavish meals for work parties, using reciprocal exchange labour was their best option for attracting labour. For example, a young woman, when asked how she acquires agricultural labour, said that after having relied upon internal household labour, she would then look for cooperative labour, and only after these options were exhausted, would she look to hire someone and pay them, asking rhetorically "does one want to let go of money?"

Other farmers stated that with the decline of *Koutouangou, Diyiyi* (non-reciprocal exchange labour/festive labour) has become more common. As noted above *Diyiyi* requires a more lavish and expensive meal to attract labourers but does not require reciprocal labour obligations. Many farmers noted that in the past they would rely on *Koutouangou* to attract needed labour but now it is more common for those with the financial means to host a *Diyiyi.* Geschiere (1995) notes that this type of transformation in cooperative labour groups is akin to hired labour gangs that have become common in Cameroon. In that case, wealthier farmers have been able to manipulate what were reciprocal labour systems by providing a wage or lavish meals as compensation. Swindell (1985) also found that conditions of economic differentiation enable wealthier farmers to appropriate the labour of poorer farmers through the provisioning of meals. In these cases the socio-economic status of farmers influences the pattern of labour exchange with the more wealthy utilizing festive and wage labour, while economically disadvantaged farmers must rely on reciprocal labour exchange (Chibnik and de Jong, 1989). Research conducted in other parts of the world demonstrate similar transitional complexities (Barth, 1967;

Takasaki et al., 2014; Worby, 1995). In Peru, for example, the reciprocal labour system of *ayni* is decreasing in importance as the opportunity cost of cooperative labour increases (Mitchell,1991).

In our research, an elderly man neatly summed up the major changes regarding the system of mutual assistance:

"Yes, there really has been a change. The children don't work anymore. Some plow with oxen; others use invitation (*diyiyi*) only, and lots no longer organize themselves into groups to work."

When we divided the households into quartiles based upon socio-economic status (SES), the highest two quartiles did indeed show the lowest participation in *Koutouangou*. In fact, none of the households in the two highest quartiles used Koutouangou (Table 2).

Table 2. SES of Village Households

Socio-Economic Status of Village Households			
	Mean	Proportion	St Dev.
Household Demographics (*N*-92)			
Gender of Respondent/Head			
Male		0.90	
Female		0.10	
Age of HH Head	41.01		12.35
Household Labour	4.06		3.84
Total Cultivable land (ha)	2.41		1.11
Some education=1 Illiterate=0		0.30	
Socio-Economic Status	8.21	1.93 Min	18.28 Max

Off-farm earning opportunities for some households has created greater socio-economic differentiation within the hamlets. For those with greater financial resources or sources of income outside agriculture, the higher opportunity cost of their time and the lower opportunity cost of cash influences the extent to which the labour of others is reciprocated. In this case, non-reciprocal cooperative labour *(Diyiyi)* or hiring wage labour provides greater flexibility and allows wealthier landowners to pursue other more remunerative activities. A man with a job as a motorcycle taxi driver and two wives who both had sources of income outside of agriculture, noted:

"Someone can come and ask for some work, and you give a portion [of your field] and discuss the price. If he is satisfied, he works and I pay him."

In contrast, a young woman in a female-headed household with no off-farm income, explained:

"Before, you would invite people and lots of people came. But today, lots don't come. They always wait for you to find them something. Because, if they know that you are going to prepare them something to eat, certain people say to themselves "I have already eaten at my place, what am I going to find elsewhere?" They ask themselves the question "Am I going to work for the *pâte* or the sauce?" Those that are poor have difficulty working in their field."

Reciprocal cooperative labour is theorized to function best in groups with limited socio-economic differentiation (Erasmus, 1956; Swindell, 1985). At an intuitive level, the farmers in Koumagou B knew this. One woman, when asked who she works with in the system of cooperative labour, responded "One must choose someone who has the same difficulty as you." Whereas reciprocal cooperative labour once helped to ensure resources flowed from the relatively rich to the poor, promoting equality of productive resources within the society, now farmers, particularly widows and the economically marginalized, complain that the system no longer works for them. Many noted that in the past, the poorest of the village were helped through the system of mutual assistance.

"… the objective was to help each other. There were certain neighbours who didn't manage to work in their field. Or they didn't have the time to work in their field. Thus the system facilitated helping each other."

People now complain that other farmers are increasingly calculating regarding participation in cooperative labour systems. This was a sentiment shared across socio-economic groups. A married man of higher SES, when asked if the systems that existed before were designed to help each other:

"Yes, to help each other and that is what gave joy in the village. The poorest could benefit from services of their brothers in the village. Before, there was joy. The poor or the rich helped each other, without problem… [but now] if you don't have the means, you can't benefit from the services of others."

When asked about the changes that are occurring in cooperative labour, a middle-aged male farmer said that

people no longer want to work with their neighbours because they do not want their neighbours to have the same "riches" as them. Others similarly noted that due to economic inequality between households there is an unwillingness for villagers to work together:

"Because they think that by helping the other, the other becomes stronger. Whereas it's mutual. Normally, you should be at the same level, like our parents were. But presently, we have lost that."

5. Discussion and Conclusion

The systems of cooperative labour described in this paper reflect the culture and traditions of the Betammaribe people. These systems persist and continue to evolve under the influence of various globalizing processes. The transition that is occurring in their cooperative labour systems reflects the dynamism of Betammaribe culture and the engagement of Koumagou B households with the emerging demands of a monetary market system, formalized education, and general social change. These pressures will continue to shape the nature of cooperative labour among the Betammaribe. The system of *Koutouangou,* or the afternoon system of mutual assistance, reflects a time when arranged marriages and bride prices led men and their neighbours to rally together and work on the fields of the future in-laws. *Koutouangou* itself, however, is threatened by the increasing prominence of wage labour, oxen that plough the field where once men tilled together by hand, seasonal migration, and the increasing popularity among those with the financial means to host *Diyiyi*, festive work parties. *Tatouanta*, once reserved for youth destined to marry soon after initiation into adulthood, is now used by young women to earn money to pay for items required for their formal education. The remuneration offered to these young women straddles the traditional systems of mutual assistance and a new system based on gendered solidarity and the commodification of their labour. This trend may foreshadow a wider schism in the traditional labour system, as educated young women leave the fields to work in different sectors, as young men transition to wage labour (agriculture or otherwise), and as the elderly left in the village are no longer able to work the land in cooperative labour systems.

Others who have studied cooperative labour in Africa note the possible coexistence of cooperative labour systems and the commodification of labour (Netting, Stone & Stone, 1989; Takasaki, Coomes, Abizaid & Brisson, 2014; Worby, 1995). These authors stress the importance of avoiding the temptation to view the evolution of cooperative labour on a continuum from traditional reciprocal exchange to modern commoditized labour. One should not view these changes as abrupt breaks with tradition but rather a transition determined partly by localized and regional norms together with other societal pressures.

Yet cooperative labour systems that rely on mutual trust, reciprocity, and physical and relational proximity have traditionally bound Koumagou B households through webs of mutually supportive relationships. Viewed in this light, elements that disrupt these systems migration for seasonal work, the demands of modern schooling, the use of oxen privileged by the wealthier few, off-farm employment have nonetheless contributed to the atomizing of Betammaribe society. It is tempting to offer up cooperative labour as a means of harnessing the power of community solidarity for overcoming the constraints associated with the adoption and scaling-up of new agricultural technologies. However, as researchers and practitioners, we must remain cognizant of the rapidly changing nature of social cooperation in the face of market penetration, the commodification of labour, and the general complexity of gender and labour relations. These considerations are critical if we are to enhance rather than hinder the livelihoods of those we hope to aid through our research and extension efforts.

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Nutritional Efficiency of Forest Species in Natural Regeneration of Tropical Forest in Brazil

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Abstract

The knowledge of the nutritional aspects of native species, mainly in natural regeneration, may be important for understanding their establishment, particularly in areas with low nutrient availability soils, such as tropical soils. This study aimed to determine the biological utilization efficiency (BUE) of the nutrients N, P, K, Ca, and Mg of forest species of natural regeneration in a Lowlands Dense Ombrophilous forest fragment in Pernambuco, Brazil. A phytosociological study of the fragment was carried out and were defined the ten species with the highest absolute density (AD). Three individuals per species were selected. The N, P, K, Ca, and Mg contents were determined in the sample leaves of the species, and the foliar biomass was determined "*in loco*". Nine individuals of each species were collected according to the following diameter intervals at the base (DBs): DBs<5 cm; 5≤DBs<10 cm and 10≤DBs<15 cm. The content, stock and BUE of nutrients were calculated per species. The BUE of nutrients by species varied according to the following decreasing order: P>Mg>K>Ca>N. The highest BUE of nutrients was of the species *Protium heptaphyllum*. In tropical soils of low natural fertility, the use of these species can be recommended in environmental reforestation projects. The difference in the nutritional demand of the forest species can indicate the planting of those with greater capacity of absorption and BUE of nutrients, being more efficient in areas of soils with low natural fertility like in the tropical forests.

Keywords: forest nutrition, nutrient content, nutrient stock, biological utilization efficiency

1. Introduction

The Atlantic Forest is responsible for a significant portion of Brazil's biological diversity and has been impacted by constant anthropogenic pressures, endangering the richness of endemic species that make up the biome (Bosa, Pacheco, Pasetto, & R. Santos, 2015). According to A. Chaves, R. M. S. Santos, J. O. Santos, Fernandes, and Maracajá (2013), due to the high degree of anthropogenic disturbances in this biome, its conservation represents one of the greatest challenges of the Brazilian tropical regions.

Natural regeneration represents the interaction of natural processes of reestablishment of the forest ecosystem. It is part of the forest growth cycle and refers to the initial stages of its establishment and development (Gama, Botelho, & Bentes-Gama, 2002). It is considered the intermediate stage between the seedling and the adult vegetative or reproductive stage, fundamental for the maintenance of forest balance, since the failure of adaptive processes during this period may make it difficult to establish or even eliminate the species from the site (Amo-Rodríguez & Gómez-Pompa, 1976).

The biological utilization efficiency (BUE) of nutrients expresses the ability of plants to absorb and utilize nutrients (Barros & Novais, 1990), being considered an efficient plant those that produce the maximum biomass per absorbed nutrient (Stahl, Ernani, Gatiboni, D. Chaves, & Neves, 2013). Many factors contribute to the BUE of nutrients of the plants, such as: associations with beneficial fungi or bacteria (Jacoby, Peukert, Succurro, Koprivova, & Kopriva, 2017); nature of soils (Baligar, Fageria, & He, 2007); and taxonomic group e.g. Leguminosae (Fabaceae) (Baribault, Kobe, & Finley, 2012).

The evaluation of the BUE of nutrients of different forest species is an important parameter to assist in the choice

of material to be used in reforestation (Caldeira, Rondon Neto, & Schumacher, 2002); however, the studies that have been carried out emphasize mainly commercial species (Stahl *et al*., 2013; Batista, Furtini Neto, & Deccetti, 2015).

Information on BUE of nutrients of native forest species is scarce in literature, and when they exist, they refer only to the adult arboreal stratum, as in the works of Espig *et al*. (2008) and Bündchen, Boeger, Reissmann, and S. L. C. Silva (2013), which evaluated the BUE of nutrients in adult tree species in forest formations of the Atlantic Forest Biome. No studies were found to evaluate species in the natural regeneration phase. Young individuals (seedlings) are usually evaluated in experiments in a protected and controlled environment, with the objective of studying the BUE of nutrients in response to the fertilization of a certain nutrient, such as the studies developed by N. Souza *et al*. (2012) and N. Carnevali, Marchetti, Vieira, T. Carnevali, and Ramos (2016).

The distribution of mineral nutrients in the plant and its components is not homogeneous. However, the crow's biomass, although it represents a small part of the total biomass of the tree, has a high mineral nutrient content. It is concentrated mainly in the leaves, and is even higher in the initial stages of plant growth. Thus, the determination of nutrient content in the leaves is the most used way to evaluate their stock (A. C. Silva, A. R. Santos, & Paiva, 1998), if the biomass is measured or estimated. Therefore, with the stock and the biomass one can calculate the BUE of nutrients of the species of a forest stand (Espig *et al*., 2008).

The knowledge of nutritional aspects of native species is important in order to understand the establishment of these species in their origin sites, especially in areas with low nutrient availability soils, such as tropical soils (N. Souza *et al*., 2012). This information, when obtained specifically for natural regeneration species, which are in the initial phase of its development (Felfili, Rezende, Silva-Júnior, & M. A. Silva, 2010), combined with the knowledge of these species' autecology (Schorn & Galvão, 2006) may subsidize the indication for use in reforestation.

The hypothesis of this study is that in nutritionally balanced forests, BUE of nutrientes should vary between species by nutrient. The most efficient species to use N is not the same as most efficient to use P.

In this context, this work aimed to determine the BUE of the nutrients N, P, K, Ca, and Mg of forest species with the highest absolute density (AD) of natural regeneration in a Lowlands Dense Ombrophilous forest fragment.

2. Method

The study was carried out in a Lowlands Dense Ombrophilous forest fragment (L. Martins & Cavararo, 2012), of approximately 79 ha, in the municipality of Sirinhaém, Pernambuco, Brazil, under the coordinates UTM 25L 259089 and 9053293; 259604 and 9053741; 259727 and 9052723; 259920 and 9052956, with an mean altitude of 63 m. The region presents an Am monsoon climate, according to Köppen's classification with a mean annual temperature of 25.6 ºC (Alvares, Stape, Sentelhas, Gonçalves, & Sparovek, 2013).

The rainfall data of the Pernambuco State Agency for Water and Climate - APAC recorded an mean annual rainfall of around 1,800 mm (P. Oliveira *et al*., 2016). Soils found in the region are of Yellow Latosol, Yellow Argisol, Red-Yellow Argisol, Gray Argisol, Gleissol, Cambisol, and Fluvic Neosols (H. G. Santos *et al*., 2013).

For soil chemical characterization, particle size distribution and soil textural class of the forest fragment, four simple samples were collected and homogenized, giving rise to a composite sample. They were sampled in 40 plots (10 m x 25 m) that were distributed systematically in the fragment. Samples were collected at two depths (0.0-0.10 m and 0.10-0.20 m) (Table 1).

Table 1. Soil chemical attributes particle size distribution and soil textural class in the Lowlands Dense Ombrophilous forest fragment, Pernambuco, Brazil

Soil attribute	Depth (m)	
	0.0-0.10	0.10-0.20
pH (H_2O)	3.88 ± 0.23	4.15 ± 0.23
P (mg dm^3)	1.33 ± 0.52	1.20 ± 0.40
Ca^{2+} ($cmol_c$ dm^{-3})	0.47 ± 0.21	0.22 ± 0.13
Mg^{2+} ($cmol_c$ dm^{-3})	0.64 ± 0.32	0.52 ± 0.23
K^+ ($cmol_c$ dm^{-3})	0.07 ± 0.04	0.05 ± 0.03
Al^{3+} ($cmol_c$ dm^{-3})	1.41 ± 0.36	1.22 ± 0.25
(H+Al) ($cmol_c$ dm^{-3})[1]	6.10 ± 1.75	4.68 ± 1.39
TOC (g kg^{-1})[2]	25.2 ± 0.88	18.0 ± 0.53
SB[3]	1.18 ± 0.39	0.79 ± 0.29
$CEC_{effective}$ ($cmol_c$ dm^{-3})[4]	2.59 ± 0.42	2.01 ± 0.32
$CEC_{potential}$ ($cmol_c$ dm^{-3})[5]	7.28 ± 1.74	5.47 ± 1.36
m (%)[6]	54.44 ± 11.85	60.70 ± 10.74
V (%)[7]	16.21 ± 7.09	14.44 ± 7.25
Total Sand (g kg^{-1})	481.60 ± 6.96	432.90 ± 5.50
Coarse Sand (g kg^{-1})	384.80 ± 6.46	335.90 ± 4.91
Fine Sand (g kg^{-1})	96.80 ± 1.31	97.10 ± 1.58
Silt (g kg^{-1})	252.70 ± 6.21	270.80 ± 8.54
Clay (g kg^{-1})	265.70 ± 4.95	296.30 ± 7.70
Textural class	Sandy clay loam	Loam clay

[1]Potential acidity; [2]Total organic carbon; [3]Sum of bases; [4]Effective cation exchange capacity; [5]Potential cation exchange capacity; [6]Saturation by aluminum; [7]Base saturation.

The Ca^{2+}, Mg^{2+} and Al^{3+} were extracted by 1.0 mol L^{-1} KCl solution and determined by titration. P, K^+, Fe, Cu, Zn and Mn were extracted by Mehlich-1 solution. P was determined by spectrophotometry, K^+ by flame photometry and Fe, Cu, Zn and Mn by atomic absorption spectrophotometry. Potential acidity (H+Al) was extracted by 0.5 mol L^{-1} calcium acetate solution and determined by titration, and the total organic C (TOC) determination was performed by oxidation using the K dichromate method. With the results of these chemical analyzes, the sum of bases (SB), base saturation (V), saturation by Al (m), effective cation exchange capacity ($CEC_{effective}$), and potential cation exchange capacity ($CEC_{potential}$) were all calculated (Donagema, Campos, Calderano, W. Teixeira, & Viena, 2011).

For the sampling of shrub-tree species of natural regeneration, 40 subunits of 25 m² (5 x 5 m) were systematically allocated. These subunits were implemented on the right side of 40 sampling units of 250 m^2 (10 x 25 m) (Figure 1), previously permanently allocated for the study of the floristic composition of the adult shrub-tree community, equidistant by 25 m and interspersed to the right and left. The fragment is a permanent preservation area in accordance with the Brazilian legislation of an agricultural enterprise producing sugarcane.

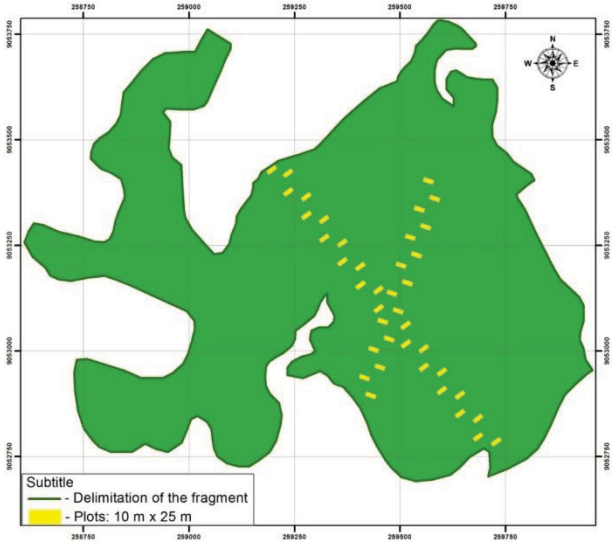

Figure 1. Schematic diagram of the plots distribution in the Lowlands Dense Ombrophilous forest fragment, Pernambuco, Brazil

Natural regeneration studies were established based on the inclusion level, proposed by Finol (1971) adapted by Marangon (1999), in which individuals who presented a diameter at breast height (DBH) < 15 cm and height ≥ 1 m were measured. Due to the height inclusion level, the diameter measurements were performed at the base, 30 cm from the ground (DBs).

Sampling of the leaves was performed between 6 and 9 h am during the hottest and humid period of the year. Sampling of the species was also performed in individuals with good phytosanitary status in shrub-tree with better morphological performance in the forest fragment.

The species identification was according to the Angiosperm Phylogeny Group - APG III (2009) classification system. With the data, the ten species of natural regeneration with the highest AD were defined using the following expression (Müeller-Dombois & Ellemberk, 1974):

$$AD = Ni/A$$

Where: AD is the absolute density (ind. ha^{-1}); N is the number of individuals of i species; and A is the sample area in hectares. The sampled individuals were counted in 40 plots of 5 x 5 m totaling 1,000 m^2. Subsequently the data were estimated to 10,000 m^2 (one hectare).

The ten forest species with the highest AD in natural regeneration of the fragment were classified as Ecological Group (EG) (Table 2). The EG classification followed the proposal of Gandolfi, Leitão Filho, and Bezerra (1995), who defined as: Pioneers (P) – light dependent species; Initial secondary (IS) – species that occur in conditions of medium shading or not very intense luminosity; and Late secondary (LS) – species that develop in the understory under light or dense shade conditions, and can remain in this environment for a lifetime or grow until reaching the canopy or emergent condition.

Table 2. Species with the highest absolute density (DA) in natural regeneration in the Lowlands Dense Ombrophilous forest fragment

Species	Family	Ecological group	Absolute density (Ind. ha^{-1})	DBs[3] (cm)
Brosimum rubescens Taub.	Moraceae	IS[1]	1,500 ± 82	3.2 ± 1.4
Thyrsodium spruceanum Benth.	Anacardiaceae	IS	580 ± 36	4.6 ± 2.8
Tovomita mangle G. Mariz	Clusiaceae	IS	560 ± 21	4.9 ± 2.5
Anaxagorea dolichocarpa Sprague & Sandwith	Annonaceae	LS[2]	340 ± 14	6.0 ± 3.7
Eschweilera ovata (Cambess.) Miers	Lecythidaceae	IS	340 ± 13	7.9 ± 2.0
Protium arachouchini March.	Burseraceae	LS	280 ± 11	6.4 ± 3.2
Caraipa densifolia Mart.	Calophyllaceae	IS	280 ± 18	4.7 ± 2.5
Talisia retusa R.S. Cowan	Sapindaceae	IS	260 ± 11	5.2 ± 3.2
Inga capitata Desv.	Fabaceae	IS	250 ± 10	5.2 ± 2.0
Protium heptaphyllum (Aubl.) Marchand	Burseraceae	IS	240 ± 10	6.7 ± 3.7

[1]Initial secondary; [2]Late secondary; [3]Diameter at base (medium).

For the foliar sampling, there were selected three individuals of each species with highest AD that presented DBs similar to the mean DBs of all individuals of the species. They were also selected for their phytosanitary status and good cup formation, which properly characterizes the species.

Fifteen leaves in the middle third of the plant were collected. The collected leaves were packed in plastic bags and stored in styrofoam boxes with ice. Subsequently, the plastic bags were replaced by paper bags and then taken to a forced air circulation chamber at 65 °C in order to dry the foliar material. After reaching constant weight, the material was milled, homogenized, and conditioned in previously cleaned and dried vials, for further analysis.

The nutrients P, K, Ca, and Mg were extracted by nitric-perchloric digestion (Bataglia, Furlani, J. Teixeira, Furlam, & Gallo, 1983). Next, Ca and Mg were determined by atomic absorption spectrophotometry, P dosed by colorimetry (Braga & Defelipo, 1974), and K determined flame photometry. N was extracted by sulfur-digestion and determined by distillation and titration by the Kjeldahl method (Tedesco, Gianello, Bissani, & Bohnen, 1995).

The mean fresh foliar biomass of each species (g $plant^{-1}$) was determined by collecting all leaves of three individuals, according to the DBs intervals: DBs<5 cm; 5≤DBs<10 cm and 10≤DBs<15 cm, totaling nine individuals per species. The leaves of each individual were weighed in the field to obtain the fresh matter weight.

The percentage of moisture of each species was determined by weighing three subsamples of variable size

(≥100 g) and subjected to a temperature of 65 °C to constant weight. Dry foliar biomass per species was determined by the fresh and dry weight ratio of the samples. To calculate the total dry biomass of each species per unit area (kg ha^{-1}), the mean dry biomass of the species was multiplied by AD (ind. ha^{-1}).

The nutrient stock in the foliar biomass of the species in kg ha^{-1} was calculated by multiplying the nutrient content (g kg^{-1}) by the foliar biomass (kg ha^{-1}). The BUE of nutrients was calculated as the ratio of the foliar biomass of the species and the nutrient stock in the biomass (Espig *et al*., 2008).

The statistical procedure used to study the data of content, stock, and BUE of the nutrients N, P, K, Ca, and Mg was the analysis of variance (ANOVA). Comparisons of means among the species using Scott-Knott's test at 5% probability were also used, when the effects were significant by the F test at 5% probability level. The Kolmogorov-Smirnov test was used to test the hypothesis of data normality (Fisher, 1990). The SAS software was used for the statistical analyses (Statistical Analysis System, version 8.2, SAS Institute, Cary, N.C., USA).

3. Results

The total foliar biomass by shrub-tree species of natural regeneration in the Lowlands Dense Ombrophilous forest fragment varied more than seventeen times between the species of lower biomass per area (*C. densifolia*) and those of highest biomass (*B. rubescens*) (Table 3).

Table 3. Foliar biomass per individual (g plant $^{-1}$) and per area (kg ha^{-1}) of the forest species with highest absolute density (DA) in natural regeneration in the Lowlands Dense Ombrophilous forest fragment

Forest species	Foliar biomass per individual (g $plant^{-1}$)	Foliar biomass per area (kg ha^{-1})
Brosimum rubescens	181.54 ± 87.39	272.31 ± 131.08
Thyrsodium spruceanum	66.30 ± 35.53	38.46 ± 20.61
Tovomita mangle	127.27 ± 43.08	71.27 ± 24.12
Anaxagorea dolichocarpa	94.62 ± 20.14	32.17 ± 6.85
Eschweilera ovata	69.17 ± 28.18	23.52 ± 9.58
Protium arachouchini	289.29 ± 74.40	81.00 ± 20.83
Caraipa densifolia	55.88 ± 19.88	15.65 ± 5.57
Talisia retusa	145.06 ± 14.31	37.72 ± 3.72
Inga capitata	63.42 ± 16.54	15.86 ± 4.13
Protium heptaphyllum	403.60 ± 212.24	96.86 ± 50.94
Total foliar biomass	-	684.81 ± 27.74

P. heptaphyllum and *P. arachouchini* were the species that presented the largest individual biomasses, possibly because they present composite leaves with larger dimensions and *C. densifolia* was the species that presented the lowest foliar biomass.

Foliar biomass per individual ranged from 55.88 to 403.60 g $plant^{-1}$ (Table 3). Despite the great difference between individual biomasses, it was verified that the total biomass per species is directly related to AD, because *B. rubescens*, even though it did not present the highest individual biomass, was highlighted due to the high AD (Table 2).

The nutrient content in the leaves of natural regeneration species, on mean, was distributed according to the following decreasing order: N>Ca>K>Mg>P (Table 4).

Table 4. Nutrient content (g kg^{-1}) and stock (kg ha^{-1}) in the species with highest absolute density (DA) in natural regeneration in the Lowlands Dense Ombrophilous forest fragment

Forest species	N	P	K	Ca	Mg
	g kg^{-1}				
Brosimum rubescens	15.31 ± 0.70b	1.47 ± 0.16b	3.27 ± 0.77b	5.05 ± 0.82b	2.98 ± 0.23b
Thyrsodium spruceanum	15.63 ± 1.68b	1.38 ± 0.15b	2.41 ± 0.24b	6.76 ± 2.12b	3.94 ± 0.28a
Tovomita mangle	17.03 ± 1.53b	1.33 ± 0.13b	5.27 ± 0.54b	12.20 ± 2.22a	4.18 ± 0.60a
Anaxagorea dolichocarpa	17.55 ± 0.82b	2.45 ± 0.11a	8.14 ± 1.76a	14.31 ± 0.96a	3.98 ± 0.24a
Eschweilera ovata	18.71 ± 1.90b	1.34 ± 0.09b	4.33 ± 1.12b	4.73 ± 0.76b	3.42 ± 0.62b
Protium arachouchini	15.59 ± 1.54b	1.37 ± 0.11b	4.84 ± 0.98b	5.01 ± 0.86b	1.67 ± 0.24c
Caraipa densifolia	15.59 ± 0.53b	1.51 ± 0.18b	3.66 ± 0.41b	3.58 ± 0.49b	1.61 ± 0.09c
Talisia retusa	15.03 ± 0.9b	1.47 ± 0.32b	5.16 ± 2.45b	10.76 ± 3.81a	4.29 ± 0.55a
Inga capitata	23.85 ± 2.71a	1.35 ± 0.12b	4.29 ± 0.17b	4.42 ± 3.71b	2.19 ± 0.13c
Protium heptaphyllum	15.17 ± 2.04b	1.27 ± 0.07b	3.11 ± 1.07b	3.24 ± 1.18b	0.98 ± 0.30d
Mean	16.94	1.49	4.45	7.01	2.92
$F_{calculated}$	80.80**	13.80**	5.60**	11.00**	31.22**
CV (%)[1]	9.34	10.74	26.27	29.42	12.96
	kg ha^{-1}				
Brosimum rubescens	4.17 ± 0.19a	0.40 ± 0.04a	0.89 ± 0.21a	1.37 ± 0.22a	0.81 ± 0.06a
Thyrsodium spruceanum	0.60 ± 0.06d	0.05 ± 0.005d	0.09 ± 0.005c	0.26 ± 0.08c	0.15 ± 0.01c
Tovomita mangle	1.22 ± 0.10c	0.10 ± 0.01c	0.37 ± 0.04b	0.87 ± 0.15b	0.30 ± 0.04b
Anaxagorea dolichocarpa	0.56 ± 0.02d	0.08 ± 0.005c	0.26 ± 0.05b	0.46 ± 0.03c	0.13 ± 0.01c
Eschweilera ovata	0.44 ± 0.04e	0.03 ± 0,00e	0.10 ± 0.02c	0.11 ± 0.02d	0.08 ± 0.01d
Protium arachouchini	1.26 ± 0.12c	0.11 ± 0.01b	0.39 ± 0.08b	0.41 ± 0.06c	0.14 ± 0.02c
Caraipa densifolia	0.24 ± 0.01e	0.02 ± 0.005e	0.06 ± 0.005c	0.05 ± 0.005d	0.03 ± 0.005e
Talisia retusa	0.57 ± 0.03d	0.06 ± 0.01d	0.20 ± 0.08c	0.41 ± 0.14c	0.16 ± 0.02c
Inga capitata	0.38 ± 0.04e	0.02 ± 0,00e	0.06 ± 0.005c	0.07 ± 0.05d	0.03 ± 0.005e
Protium heptaphyllum	1.47 ± 0.19b	0.12 ± 0.005b	0.30 ± 0.10c	0.31 ± 0.11c	0.09 ± 0.03d
Mean	1.09	0.10	0.27	0.43	0.19
$F_{calculated}$	353.86**	144.13**	24.82**	39.79**	198.14**
CV (%)	9.78	16.29	31.84	25.87	14.82

[1]Coefficient of variation = Standard deviation/Mean x 100.

Means followed by equal letters in the columns do not differ from each other at 5% probability level by the Scott-Knott's test.

** Significant at 1% probability by the F test. [ns]Not significant.

The N content in the leaves ranged from 15.03 g kg^{-1} to 23.85 g kg^{-1}, with a mean of 16.94 g kg^{-1} (Table 4). The species with the highest N content was *I. capitata*, the only leguminous species of the group of ten of greater DA (Table 2).

The Ca content was higher in the leaves of *A. dolichocarpa*, *T. mangle* and *T. retusa*. A second group with lower Ca content was formed by *T. spruceanum*, *B. rubescens, P. arachouchini, I. capitata, C. densifolia*, and *P. heptaphyllum* (Table 4). The Ca content in these species ranged from 3.24 to 14.31 g kg^{-1}, with a mean of 7.01 g kg^{-1}.

K content in the leaves of the studied species ranged from 2.41 g kg^{-1} to 8.14 g kg^{-1} and presented a mean of 4.45 g kg^{-1}, especially *A. dolichocarpa*, which presented the highest content of this nutrient (Table 4).

P. heptaphyllum showed the lowest content of Mg, which was 0.98 g kg^{-1}, while in the species *T. retusa*, *T. spruceanum*, *T. mangle* and *A. dolichocarpa* the Mg content was higher (Table 4).

P content foliar biomass of the species varied from 1.33 to 2.45 g kg^{-1}, with a mean of 1.49 g kg^{1}. P content in *A. dolichocarpa* was higher than of the other species (Table 4).

Nutrient stock in the foliar biomass of natural regeneration species followed the decreasing order: N>Ca>K>Mg>P. This decreasing sequence varied according to species: *T. spruceanum* was N>Ca>Mg>K>P; *C. densifolia* was N>K>Ca>Mg>P; and *P. heptaphyllum* was N>Ca>K>P>Mg (Table 3). The highest nutrient stock were observed in *B. rubescens* (Table 4), due to the amount of biomass per area of the species (Table 3)

N was the nutrient that presented the highest stock in the foliar biomass of the highest AD species, varying from

0.24 to 4.17 kg ha^{-1}, with a mean of 1.09 kg ha^{-1} (Table 4).

The mean P stock in the foliar biomass of the regenerating species was lower than the other nutrients evaluated, ranging from 0.02 to 0.40 kg ha^{-1} (Table 4), mainly due to the low content in the leaves (Table 4). *B. rubescens* was the species that accumulated more P in the fragment due to high foliar biomass (Table 3). The species *I. capitata*, *C. densifolia* and *E. ovata* presented the lowest stock of P (Table 4).

The species *B. rubescens* and *T. mangle* showed the highest Ca stocks (1.37 and 0.87 kg ha^{-1}, respectively) and Mg (0.81 and 0.30 kg ha^{-1}, respectively), and the lowest stocks of Ca were found for *C. densifolia*, *I. capitata* and *E. ovata*. For Mg the smallest stocks were found in *C. densifolia* and *I. capitata*. *B. rubescens* was also the species with the highest stock of K and *C. densifolia* and *I. capitata* the smallest (Table 4).

The BUE of nutrients by natural regeneration species varied between nutrients and species. When nutrients were grouped in order of decreasing efficiency, the following sequence was obtained: P>Mg>K>Ca>N (Table 5).

Table 5. Biological utilization efficiency of nutrients of the species with highest absolute density (DA) of natural regeneration in a Lowlands Dense Ombrophilous forest fragment

Forest species	N	P	K	Ca	Mg
	kg kg^{-1}				
Brosimum rubescens	65.43 ± 3.03a	687.08 ± 80.65a	317.14 ± 72.93a	201.39 ± 30.32b	337.00 ± 28.27c
Thyrsodium spruceanum	64.46 ± 6.91a	731.51 ± 73.49a	418.29 ± 40.92a	158.04 ± 49.14b	254.94 ± 18.82c
Tovomita mangle	59.01 ± 5.12a	754.16 ± 70.90a	191.02 ± 20.27b	84.01 ± 16.96b	242.34 ± 33.83c
Anaxagorea dolichocarpa	57.07 ± 2.60a	408.32 ± 19.09b	127.44 ± 31.65b	70.10 ± 4.93b	252.09 ± 15.19c
Eschweilera ovata	53.79 ± 5.24b	745.84 ± 48.27a	240.30 ± 54.37b	215.46 ± 37.67b	299.69 ± 60.90c
Protium arachouchini	64.58 ± 6.33a	734.62 ± 58.64a	212.98 ± 47.69b	203.68 ± 33.22b	606.95 ± 85.71b
Caraipa densifolia	64.21 ± 2.22a	670.49 ± 86.02a	275.29 ± 30.79b	282.90 ± 36.16a	622.15 ± 34.75b
Talisia retusa	66.71 ± 4.03a	701.59 ± 137.37a	220.10 ± 82.55b	103.76 ± 45.68b	235.66 ± 30.33c
Inga capitata	42.32 ± 5.15c	745.17 ± 64.40a	233.29 ± 9.91b	348.76 ± 234.67a	457.25 ± 27.13b
Protium heptaphyllum	66.79 ± 9.57a	786.50 ± 43.56a	352.11 ± 137.12a	345.57 ± 150.51a	1,099.95 ± 400.72a
Mean	60.44	696.53	258.80	201.37	440.80
$F_{calculated}$	6.03**	6.18**	5.31**	3.50**	12.76**
CV (%)[1]	9.02	10.68	24.53	46.40	30.18

[1]Coefficient of variation = Standard deviation/Mean x 100.

Means followed by equal letters in the columns do not differ from each other at 5% probability level by the Scott-Knott's test.

** Significant at 1% probability by the F test. [ns]Not significant.

N was the nutrient that species used less efficiently (Table 5) due to the high content of this nutrient in the leaves of the species (Table 4). *I. capitata* presented low BUE of N, but, as it is a leguminous species, it may present good growth and development under high or low N availability in the soil (Table 1) due to its ability to obtain N through the symbiosis with bacteria that perform biological fixation of N.

P was the nutrient with the highest BUE by species, ranging from 408.32 to 786.50 kg kg^{-1} (Table 5). *A. dolichocarpa* presented lower BUE of P than the other species.

The species that showed best BUE of K were: *T. spruceanum, P. heptaphyllum*, and *B. rubescens* (Table 5). *C. densifolia, I. capitata*, and *P. heptaphyllum* were the species most efficients for Ca; *P. heptaphyllum* was the most efficient for Mg (Table 5). Specifically for this nutrient, the species presented a very wide variation of efficiency. *T. mangle* was more than 4.7 times less efficient than *P. heptaphyllum*.

4. Discussion

Studies of nutritional efficiency in natural regeneration species may be difficult because requiring the collection of all the foliar biomass (destructive sampling). In this study, the total foliar biomass (684.81 kg ha^{-1}) presented a value similar to that found by Socher (2004) (778.47 kg ha^{-1}) in a natural regeneration study (individuals greater than 1.30 m in height and DBH less than 15 cm) in a Mixed Alluvial Ombrophylous forest in Paraná. For Barbosa (2012), methodological differences and other factors such as species specificity, stand's age, location climatic zone, soil fertility, and anthropogenic disturbances may influence the biomass of different forest fragments. Nutrient content data of this study were obtained in the warmer and wetter period of the year in which the nutrient absorption is higher than in the dry periods. With the nutrient content maximized, we can calculate the stock potential of the species and their biological utilization efficiency.

In this study the concentrations of N presented by the species were always higher than 15 mg kg^{-1}. According to Epstein and Bloom (2006), N content equal to or greater than 15 g kg^{-1} are considered normal for most plants. TOC levels were high in the surface layer (Table 1) showing that there was good N availability in the fragment and the species were benefited by this high availability with adequate N levels in the leaves. N is an essential nutrient at any stage of plant development and one of its functions is the formation of basic compounds in the plant's life cycle (amino acids, proteins, nucleic acids, among others) (Capaldi, 2002). Additionally, the amount of N in the plant influences the absorption of all nutrients, making it essential to maintain adequate concentrations of this nutrient for the plants (Epstein & Bloom, 2006). According to Bredemeier and Mundstock (2000), N availability is usually a limiting factor, influencing plant growth more than any other nutrient.

The highest N content was verified in the leguminous species. The legumes fix N through symbiosis with bacteria of several genera, being the most common with the genus *Rhizobium* sp. and this species of leguminous, that have ability to associate with microorganisms and allows the N of the air to be transformed into N compounds assimilated by plants, which can make the plant partially or totally independent of the external supply of this nutrient (Nogueira, O. Oliveira, C. Martins, & Bernardes, 2012).

The high N content in the leaves of *I. capitata* may be due the symbiosis of this leguminous with N-fixing bacteria. Although there is no record of specific symbiosis studies with the species *I. capitata* in tropical forests, the study performed by G. Almeida, Nascimento, A. Almeida, Cardoso, and Leal (2013) reported the potential for spontaneousnodulation or symbiotic relationship in different species of this genus.

Garay *et al*. (2003) evaluated the N content of two exotic forest species, one leguminous, *Acacia mangium* (Fabaceae), and another non-leguminous *Eucalyptus grandis* (Myrtaceae), used in agroforestry and reforestation. The authors observed that the N content in the leaf of the leguminous *Acacia mangium* (15.6 g kg^{-1}) were almost twice the value found in *Eucalyptus grandis* (8.6 g kg^{-1}). The N content determined by Espig *et al*. (2008) in the native forest leguminous *Parkia pendula* and *Dialium guianense* in a Dense Ombrophilous forest fragment were of 22.96 and 20.83 g kg^{-1}, similar to those found in this study.

On mean, the Ca content this study were lower than those found by Espig *et al*. (2008), but the result was compatible with the expected content for the evaluated natural regeneration stratum, because high Ca content may be related to the low mobility of this element in plant tissues and to leaf longevity. Thus, it is expected that the older the leaf, the higher its Ca content (Boeger, Wisniewiski, Reissmann, 2005). The study by Espig *et al*. (2008) was carried out in plants in the adult stage, but is the main reference for Lowlands Dense Ombrophilous forest nutrition in northeast Brazil. Additionally, the soil Ca content of the fragment was very low (Table 1). The fragment is located in a region of high rainfall and cationic nutrients are very vulnerable to leaching.

Plants of natural regeneration are young and soil/plant/atmosphere water relations are dependent on adequate K content in the leaves of the species. According to Epstein and Bloom (2006), the opening and closing of the stomata depend on the flow of K, and its adequate content in young tissues is indispensable for obtaining the cells turgor.

Boeger *et al*. (2005) studied the nutrients in leaves of tree species in three successional stages of Dense Ombrophilous forest in southern Brazil, and obtained mean K contents similar to those obtained in this study, ranging from 3.2 to 5.2 g kg^{-1}. However, the K content of this study are below those found by Golley *et al*. (1978) and Espig *et al*. (2008), because the authors found mean contents of 14.3 and 12.23 g kg^{-1}, respectively. The low K content for the evaluated natural regeneration species in this study can be associated with the initial phase of their development and with the ecological group of these species (Table 2). According to S. R. Silva, Barros, Novais, and Pereira (2002), in the initial phase of growth, species of the final groups of the succession have low K requirement, or are efficient in using this nutrient in low availability conditions. The authors also affirm that the effects related to K are very small for the growth of some native forest species. The K levels of the soil of the fragment were also very low, as well as Ca (Table 1). The K because it is a monovalent cation is more vulnerable to leaching than Ca and the intensity of the rains in the region contributes to its leaching.

The soil Mg contents did not correlate with the leaf contents of the species, especially when comparing the Ca/Mg ratio of soil and species. In the soil, the Mg contents were higher than Ca (Table 1) and in plants the Ca/Mg ratio was on mean 2.4/1 (Table 4). The plants absorbed more Ca than Mg, even when there is little availability of this nutrient in the soil. Mg is a nutrient with fundamental importance in photosynthesis because it is the central atom of the chlorophyll molecule (Viera & Schumacher, 2009). Its deficiency compromises this molecule's synthesis, which affects the constitution and stability of thylakoids and results in poor chloroplast formation (Epstein & Bloom, 2006).

The mean P content in this study was higher than the found by Espig *et al*. (2008), which was of 0.95 g kg^{-1},

possibly because P has ample mobility within the plant and, therefore, tends to focus on younger organs (Viera & Schumacher, 2009). In addition, soil P levels were very low (Table 1) and should have limited their absorption. In tropical soils, P is the most limiting nutrient, as found by Ellsworth *et al*. (2017).

In general, tree species have a high P absorption capacity in their initial stage of growth. Their availability in the soil favors mainly the pioneers' initial growth (Flores-Aylas, Saggin-Júnior, Siqueira, & Davide, 2003). According to C. Souza, Tucci, J. F. Silva, and Ribeiro (2010), P limits growth and interferes with other nutrients absorption.

Species that develop under the same soil and climate conditions may differ in relation to their nutritional requirements, because they tend to be more or less demanding of a given nutrient. This situation occurs in forest fragments with high floristic diversity. According to Bündchen *et al*. (2013), this behavior emphasizes the importance of mixed stands to satisfy the nutritional demands of the species, because, for a better use of soil nutrients, a species that is more demanding of a nutrient should be closer to a less demanding species.

The heterogeneity, both of species and nutritional, is essential for forest self-sustainability, because the release of nutrients from the phytomass by decomposition and mineralization processes supplies a large part of the nutritional demand necessary for the growth and adequate development of forest species (Bündchen *et al*., 2013).

The species presented different levels of nutrients even when exploring the same soil conditions. Some factors may have contributed to this, such as ability to fix N_2 atmospheric, such as legumes; greater capacity of lateral and deep rooting, increasing its capacity of absorption of nutrients; formation of more or less dense crowns with greater or lesser biomass production. In this case, the nutrient can be diluted or concentrated in a larger or smaller biomass.

Nutrient stock was strongly influenced by the amount of biomass per area. According to Caldeira *et al*. (2002), the stock of nutrients is a consequence of their content and the production of biomass. In fact, the species studied showed differences in nutrient stocks.

The litter in forest fragments is important for the biogeochemical cycling process of nutrients, mainly for N, P, and Ca, because it is the main transfer route of these nutrients to the soil (Cole & Rapp, 1980). As shown, these three nutrients presented the highest stocks in the studied natural regeneration species. Therefore, as its leaves are incorporated into the litter and decomposed material, they'll contribute to the supply of these nutrients to the soil, and, consequently, will be available to plants in subsequent cycles

According to Espig *et al*. (2008), the nutritional stock evaluation is important in commercial plantations, where it predicts the nutrients export during the interest compartments removal, as wells as in natural forests, to predict the capacity of the species to supply nutrients and evaluate its contribution to the ecosystem balance, especially when dealing with low natural fertility areas.

The species of natural regeneration showed a wide variation in the BUE of nutrients. According to Bündchen *et al*. (2013), these differences evidenced the existence of different strategies for the acquisition and use of nutrients by tree species in the same establishment site.

The nutrient content found in the foliar biomass of the species in tropical soils is generally very low. S. R. Silva *et al*. (2002) stated that the decrease of the nutrient content in the soil solution causes to its less absorption by plants, resulting in an increase in BUE of nutrient. For example, P was the nutrient with the highest BUE by the species. This result showed that in weathered soils with low levels of available P, the species could develop properly, because they presented high BUE of this nutrient to produce biomass. In tropical forest soils, the P content are very low, as in this study and the phosphate nutrition of the forests is very dependent on the P cycling (C. Souza *et al*., 2010). As the cycling amount of P is also small (Bizuti, 2011), the high BUE of P of the species is fundamental for these species establishment, mainly in natural regeneration.

BUE indicates the ability of the species to grow in nutritionally restrictive environments (Barbosa, 2012). In this study, the highest BUE of N, P, K, Ca and Mg of the species can indicate them to be used in areas where there is a diagnosis of low levels of these nutrients, which contributes to reforestation projects, especially in tropical forests. In addition, the use of native species in these reforestation projects should be encouraged, especially when the nutritional demand of these species is known.

5. Conclusions

The BUE of nutrients by species varied according to the following decreasing order: P>Mg>K>Ca>N. In tropical soils of low natural fertility, the use of these species can be recommended in environmental reforestation projects;

In environment with restricted K availability, *T. spruceanum, P. heptaphyllum*, and *B. rubescens* can be recommended, as well as *P. heptaphyllum*, which can also be indicated to populate areas with low levels of Ca and Mg in the soil, common in tropical environments;

The difference of the nutritional demand between species may indicate for planting those with greater capacity to absorb and use nutrients, being most efficient in areas of low natural fertility soils of tropical forests.

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Stakeholders' Perception and Preferences of Post-harvest Quality Traits of Tomato in Ghana

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Abstract

The high levels of tomato consumption coupled with wide production levels in Ghana make the crop economically viable. Food preferences vary among individuals and geographical locations. Traits to select during crop improvement therefore, depend on the target beneficiaries. Breeders sometimes fail to consider preferences of end users probably because they are oblivious of them. This study used Participatory Rural Appraisal (PRA) and surveys to identify preferences and perceptions of end users in tomato value chain, for making proper breeding choices according to the information collected. The strategy employed for this research was descriptive survey. The target population included tomato farmers, market players and consumers. A multi-stage sampling was used to select the study sample. More than half (57.3%) of the respondents had been involved in tomato production for over 10 years. Sixteen variables were discussed with each group. The first three principal components (PCs) with Eigen values greater than 1.0 together explained 100% of total variation in the data set. Scores for ranking popular vegetable and ranking causes for poor shelf life were not significantly associated with any of the components. The Focus Group Discussion (FGDs) also established that, seven main vegetable crops were cultivated and produced by the communities and ranked tomato as number one. Similarly, six important quality traits of tomato were mentioned by stakeholders as their favorite. Respondents showed extreme preferences for firmness and shelf life as the most important quality traits of tomato. Seventy-seven-point five percent (77.5%) of the consumers use tomatoes every day in their food preparation. The study revealed stakeholders' desire and plea for firmness and extended shelf life of tomato fruits in Ghana. Consequently, the survey validated the need to regulate tomato breeding goals to develop high yielding tomatoes with improved fruit quality and prolonged shelf life.

Keywords: tomato, post-harvest traits, PRA, FGD, descriptive study

1. Introduction

The high levels of tomato consumption coupled with wide production levels in Ghana make the sector appear economically viable. Consumption of tomato however, exceeds production in Ghana. In recent years, Ghana has been cited as the second largest consumer of tomato paste in the world. According to the Ghana National Tomato Producers' Federation, Ghana produces 510,000 metric tons (t) of tomato each year, while it imports up to 7,000 t per month from its neighbors, along with 27,000 t of processed tomato from Europe (Inusah et al., 2013). Tomato production serves as a source of income for most rural and peri-urban producers in Ghana. Despite these, many challenges are beset its production making it not very lucrative in Ghana. The challenges faced by producers and other stakeholders are in production, post-harvest, marketing or a combination of any of them. In addition, regional trade agreement policies have opened a market opportunity in Ghana for tomato farmers from Burkina Faso, presenting further challenges for local farmers. It is now an annual habitual usually between March and May for the tomato "market queens" to travel all the way to neighboring Burkina Faso to purchase tomatoes, encountering several hazards on the highways. According to Inusah et al. (2013) the tomato from Burkina Faso are of higher quality and sell more quickly than local varieties. They emphasized that "Burkina tomatoes are bigger, harder and superior in taste and last longer in storage". Combinations of the above factors created a restricted market monopolized by these so called 'market queens'. Their activities are facilitated by service providers who play various exploitative roles to the disadvantage of small-scale farmers in Ghana. It

must be noted however, that food preferences may vary among individual age groups, gender and sometimes cultures as well as geographical locations (Sugri *et al.*, 2012). Traits to select during crop improvement therefore, depend on the target beneficiaries (Sugri *et al.*, 2012). Even though emphasis in crop research is increasingly shifting from quantity to quality of production in recent times (Oko-Ibom & Asiegbu, 2007), there is still little improvement in the quality of commercially produced tomato varieties (Beckles, 2012), hence resulting in high amount of qualitative losses. However, qualitative loss in tomato production can have a negative impact on many parameters like consumer acceptability, nutrient status of fruits, and financial income to producers. An investigation into the possible factors that can affect the postharvest quality of tomatoes is therefore necessary. It is believed that some cultivars that have been released were not espoused because of lack of adequate consideration of farmers' (Derera *et al.*, 2006), and other stakeholders' preferences in the process of their development. Breeders failed to consider the special preferences of farmers (Toomey, 1999; Banziger & Cooper, 2001), probably because they are oblivious of them (Derera *et al.*, 2006). Breeding programmes must determine their breeding objectives and selection procedures to meet client needs. Effective breeding should be established on clear identification of stakeholders taking into consideration the constraints and preferences. These can be addressed through participatory plant breeding (PPB), participatory varietal selection (PVS) (Gibson *et al.*, 2007; Gasura *et al.*, 2008) and/or participatory rural appraisal. To identify the preferences of end users in the value chain and address them holistically, there is the need to carry out PRA and market surveys to collect the relevant information to make suitable breeding choices. The major objective of the survey was to become acquainted with tomato stakeholders' and ascertain on their varietal preferences, perception, opinions, attitude and knowledge of postharvest quality traits of tomato in Ghana.

2. Methodology

2.1 Description of Study Area

The study was carried out in nine communities which span in four agro-ecological zones (forest, forest-savannah transition, Guinea savannah, and Sudan savannah). The agroecological zones are found in the Ashanti, Brong Ahafo, Volta and Upper East Regions of Ghana. All the four regions are the major tomato growing areas in the country (Asante et al., 2013). The forest and forest-savannah transition zone have bi-modal rainfall regime of 1300 to 2200 mm per annum while Guinea and Sudan savannah have a uni-modal rainfall pattern (May to August) with an average of 1100 mm per annum. Major tomato growing districts and communities within these agro-ecological zones were selected for the survey (Table 1).

Table 1. List of study areas

Community	District	Region	Agroecological zone
Vea	Bongo	Upper East	Sudan savanna
Pwalugu	Talensi	Upper East	Sudan savanna
Bolgatanga	Bolgatanga	Upper East	Sudan savanna
Battor	North Tongu	Volta	Costal savanna
Adidome	Central Tongu	Volta	Costal savanna
Tuobodom	Techiman North	Brong Ahafo	Transitional
Derma	Tano South	Brong Ahafo	Transitional
Agogo	Asante Akim	Ashanti	Deciduous forest
Akumadan	Offinso North	Ashanti	Deciduous forest

2.2 Research Approach/Strategy

The strategy of this research is descriptive survey. It was used to determine the suitable quantitative and qualitative data, from a relatively large number of cases with the purpose of providing a systematic description and assessment of the perceptions of stakeholders (Field, 2000; Field, 2005; Kumar, 1999).

2.3 Study Population and Sample Selection of Respondents

The target population of the study included tomato farmers, tomato consumers, tomato whole sellers and retailers. These groups of people were targeted because they provided relevant information concerning post-harvest quality traits of tomato in Ghana. A multi-stage sampling procedure was used to select the study sample. The multi-stage sampling procedure was used because the target population structures were large and dispersed across the agro-ecological zones in the country. According to David and Sutton (2004) and Lewin (2005), it is more appropriate to initially select subgroups at various levels rather than randomly selection from the whole population when the population is large and widely dispersed. At the first stage of the multi-stage sampling

procedure, four agro-ecological zones in four regions were purposively selected from the list of six agro-ecological zones in Ghana. At the second stage, four (4) Districts were purposively selected from the selected four (4) Regions. The districts were purposively selected because they epitomized major tomato production, marketing and utilization areas in Ghana. At the third stage four communities (one of each from the selected district) were again purposively selected from the selected four districts. At the final stage, 157 tomato farmers were randomly chosen from the selected communities to constitute the desired study sample size. The distribution of the respondents by the regions is presented in Table 2.

One hundred and fifty-seven (157) Farmers, seventy seven (77) market players and forty (40) consumers were also purposively chosen from the selected communities to constitute the desired study sample size.

Table 2. Sample of respondents per region

Region	Respondents			
	Number of Participants			Total
	Farmers (%)	Market players (%)	Consumers (%)	
Upper East	51 (58.8)	19 (27.9)	9 (13.2)	79 (100)
Volta	29 (58.8)	18 (26.5)	10 (14.7)	57 (100)
Ashanti	38 (57.5)	20 (27.4)	11 (15.1)	69(100)
Brong Ahafo	39(55.2)	20 (29.9)	10 (14.9)	69 (100)
Total	157 (57.5)	77 (27.9)	0 (14.5)	274 (100)

2.4 Data Collection

The study used data from primary and secondary sources. The primary data was collected using Focus Group Discussion (FGD) and semi structured questionnaire. Four FGDs were conducted in four communities (Pwalugu, Adidome, Agogo and Derma) using an interview guide for the interaction (Table 3). Issues of relevance to the topic included in the guide were vegetables types grown, tomato variety grown and important postharvest quality traits of tomato, tomato shelf life and gender. In all 73 participants were involved with an average of 18 participants per community (Table 4). A team of three comprising one facilitator and two recorders led the FGD. In some communities where language was an obstacle, the Agricultural Extension Officer functioned as a translator. The study was conducted between February and March 2017. Observations of importance to the research were noted. The FGDs gave a collective and unanimous opinions on the issues presented.

Table 3. List of study areas for FGD

Community	**District**	**Region**	**Agroecological zone**
Pwalugu	Talensi	Upper East	Sudan savanna
Adidome	Central Tongu	Volta	Coastal savanna
Agogo	Asante Akim	Ashanti	Deciduous Forest
Derma	Tano South	Brong Ahafo	Transitional

Table 4. Sample size of FGD

Community	**Males**	**Females**	**Total**
Pwalugu	12	3	15
Adidome	17	4	21
Agogo	14	1	15
Derma	19	3	22
Total	62	11	73

A semi- structured questionnaire which included personal characteristics, production practice and harvesting, post-harvest including storage, marketing and consumer preference was used to gather data from 274 respondents made up of 157 tomato farmers, 40 tomato consumers, and 77 tomato whole sellers and retailers (Table 2). The designed questionnaire was first pretested in and around Kumasi Metropolis. David and Sutton (2004) recommended that survey questions should be pre-tested on a test group of cases from the target population to ensure its reliability. The survey was conducted between February and March 2017 as a supplement to the Focus Group Discussion (FGD).

2.5 Data Analyses

The summary of various statistical tools used in the analysis based on the objectives of the study is displayed in Table 5.

Table 5. Summary of statistical tools of data analysis

Objective	Statistical tools for Analysis
Describe the characteristics of tomato stakeholders (farmers, consumers, whole sellers and retailers) in the study areas	Frequencies, percentages, tables, graphs using the statistical package for social sciences
Obj. 1. Examine the role of stakeholders in tomato production and marketing	The data were converted to numerical values, standardized (Etzkorn, 2011), and analyzed using Genstat Computer package (Genstat, 2017).
Obj. 2. Assess the production, marketing and utilization patterns among tomato stakeholders in the study areas	Frequencies, percentages, tables, graphs using the statistical package for social sciences (SPSS, 2017).

3. Results

3.1 Demographic Characteristics of Respondents

3.1.1 Group Respondents (Focus Group Discussion)

Table 6a depicts male dominance of 84% of the total group respondents engaged in focus group discussion.

Table 6a. Demographic Characteristics of Group Respondents

Region	Males	Females	Total
Upper East	12	3	15
Volta	17	4	21
Ashanti	14	1	15
Brong Ahafo	19	3	22
Total	62	11	73

Table 6b indicates that majority (74%) of tomato farmers were in the age group of 30-50 years. More than seventy-eight percent of men also dominate tomato production. Majority (53.5%) of the farmer respondents had primary school education with 24.8% without any formal education. With regards to tomato production experience, more than half (57.3%) of the respondents had been involved in tomato production for over 10 years; 6.4% for 40 years. However 3.2% of respondents were not sure of the number of years they have cropped tomatoes. The table also show that 98.7% of market players (wholesalers (26%), retailers (65%) and market queens (9%) were females implying that females dominate the marketing of tomato in the study areas. More than 67% of the women fall within the age group of 31-50 years. Sixty percent of the respondents were aware of the varieties they sell to their customers. Major clients of the market players include household consumers (48%), retailers (43%), restaurants/chop bar operators/food vendors (6%) and other institutions (3%). More than half the consumers (53%) interviewed fall within the age range of 21-30 years. About forty-eight percent of the consumers were aware of the tomato variety they purchase or consumed being local or exotic.

Table 6b. Demographic characteristics of individual respondents

Variables	Farmers N=157		Market Players N=77		Consumers N=40	
Variables	**Freq**	**(%)**	**Freq**	**(%)**	**Freq**	**(%)**
Age (years)						
Below 20	-	-	-	-	4	10
21-30	35	23	18	23	21	53
31-40	-	-	26	34	12	30
41-50	80	51	26	34	2	5
51-60	42	27	5	6	-	-
Above 60	-	-	2	3	-	-
Gender						
Male	123	78.3	1.00	1.3	18	45
Female	34	21.7	76	98.7	22	55
Level of Education						
No formal education	39	24.8	31	40	3	7.5
Primary/JHS/Middle education	84	53.5	40	52	8	20
Secondary (SHS/Vocational) education	27	17.2	6	8	24	60
Tertiary education	7	4.5	-	-	5	12.5
Tomato Production/Marketing Experience (Years)						
< 5	-	-	-	-	-	-
1-10	90	57.3	36	47	-	-
11-20	40	25.5	30	39	-	-
21-30	12	7.6	9	11	-	-
31-40	10	6.4	2	3	-	-
Unknown	5	3.2	-	-	-	-
Tomato variety cultivated/ purchased/Consumed/marketed						
Local	96	61.1	55	71.4	19	47.5
Exotic	26	16.6	15	19.5	3	7.5
Local and exotic	15	9.6	5	6.5	8	20
Do not know	20	12.7	2	2.6	10	25
Major Clients						
Wholesale	76	48.4	-	-	-	-
Retailers	31	19.7	33	43	-	-
Consumers/households	14	8.9	37	48	-	-
Market Queens	36	22.9	-	-	-	-
Restaurants/Chop bars/Food vendors		-	5	6	-	-
Other institutions		-	2	3	-	-

3.2 Role of Stakeholders in Tomato Production and Marketing (Results of FGDs)

Sixteen variables (questions) were discussed (Table 7) with each group. The first three principal components (PCs) with Eigen values greater than 1.0 together explained 100% of total variation in the data set (Table 7). Scores for ranking popular vegetable and ranking causes for poor shelf life were not significantly associated with any of the components. Scores on the first two PCs accounted for 91.87% of the dissimilarity, and were related to all the questions with the exception of vegetables grown, most popular tomato varieties, important preferred quality trait, rank for important quality trait and causes of poor shelf life which were related to PCs 3 and PCs 4.

Table 7. Principal Component Analysis x questions used for the Focal Group Discussion

Variables	PC1	PC2	PC3	PC4
Vegetables grown	0.27658	0.26683	-0.19476	0.3656
Rank for popular vegetable	0.00000	0.00000	0.00000	0.00000
Reasons for ranking tomato high	0.09369	0.40769	-0.26934	-0.30659
Most popular tomato variety	0.15408	0.24851	0.66306	-0.38020
Reasons for variety popularity	0.35342	0.07036	-0.07544	0.30073
Reasons ranked high	0.19255	-0.34874	-0.28291	-0.29195
Important preferred quality trait	0.27352	-0.27732	0.15425	0.01366
Rank for important quality trait	0.27658	0.26683	-0.19476	0.27464
Reasons for the preferred trait	0.34655	-0.11440	0.04357	-0.04319
Opinion and attitude of quality	0.34655	-0.11440	0.04357	-0.00278
Farmers perception of tomato shelf life	-0.34655	0.11440	-0.04357	0.00278
Tomato shelf life	-0.12358	0.39892	-0.24507	-0.05866
Causes of poor shelf life	0.27658	0.26683	-0.19476	-0.55461
Rank of causes for poor shelf life	0.00000	0.00000	0.00000	0.00000
Farmers own way to increase Shelf life	0.07425	0.37879	0.44366	0.25210
Rank of farmers approach to Increase shelf life	0.34655	-0.11440	0.04357	0.00211
Eigen Values	7.752	5.110	1.138	0.000
Variance (%)	55.3	36.50	8.13	0.00
Cumulative (%)	55.37	91.87	100.00	100.00

Values greater than (>) 0.3 is significant

The distribution produced by PCs 1 and 2 is shown in Figure 1. All the regions are distinctly classified into different groups. Ashanti, Upper East, Volta and Brong Ahafo regions separately categorized in groups 1, 2, 3 and 4 respectively.

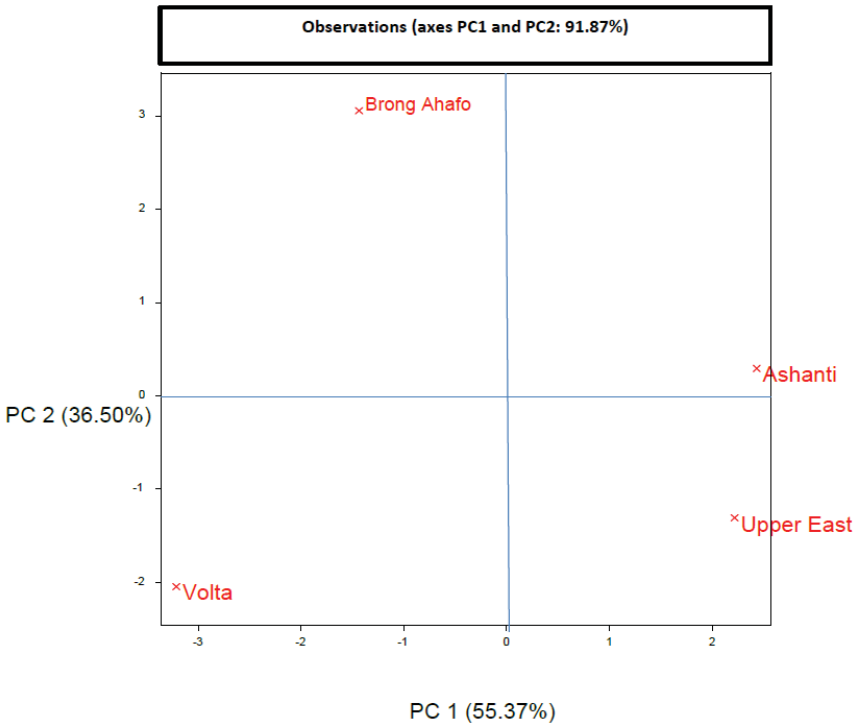

Figure 1. A biplot of PC1 and PC2 showing the distribution of communities involved in the focus group discussion

The hierarchical clustering (Fig. 2) demonstrates the association between responses among the communities. The communities were separated with Euclidean similarity distance from 1.0 to 0.6. Communities in Upper East and Ashanti regions were similar at about 0.85 whereas communities in Brong Ahafo and Volta regions were similar

at 0.6. However, they were all distinct at 0.83 levels. Two main clusters, A and B were identified at similarity level 0.52. Cluster A was composed of the Upper East and Ashanti Regions, whilst Brong Ahafo and Volta Regions were found in cluster B.

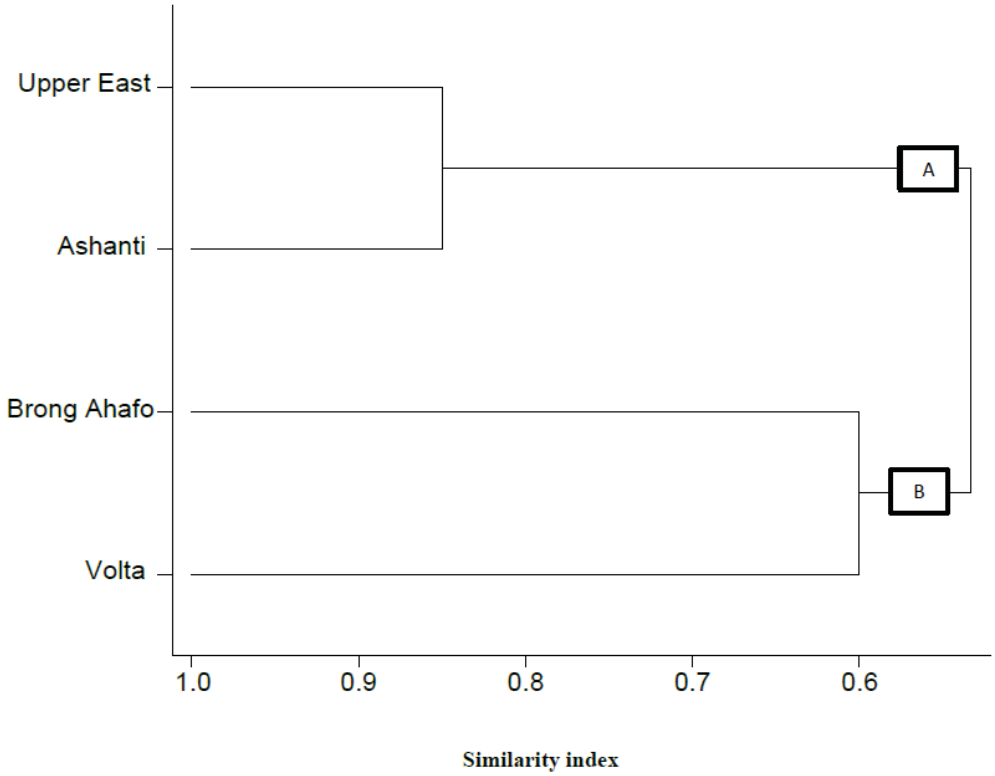

Figure 2. Dendrogram showing response of communities involved in the Focal Group Discussion

3.3 Vegetable Crop Initiative of the Communities

The FGDs established that, seven main vegetable crops were cultivated and produced by the communities (Table 8). The range of vegetables cultivated includes tomato, pepper, okra, garden eggs, onion and leafy vegetables. Tomato was ranked first among all the communities.

Table 8. Vegetable crop enterprise ranking within the communities involved in the focus group discussion

Rank position	Upper East	Ashanti	Volta	Brong Ahafo
1	Tomato	Tomato	Tomato	Tomato
2	Pepper	Pepper	Okra	Cabbage
3	Leafy vegetables	Cabbage	Pepper	Pepper
4	Onion	Garden egg	Garden egg	Garden egg

3.4 Postharvest Quality Traits of Tomato (Ranking)

During the FGD, six important quality traits of tomato were mentioned by stakeholders in the various communities as their favorite for any tomato variety (Table 9). They included fruit size, long fruit storage (shelf life), fruit colour, firmness and taste (brix). Ashanti region has the highest preferred quality trait whilst Upper East and Brong Ahafo regions had the least preferred quality traits. Shelf life/long fruit storage and firmness were ranked first in Upper East, Ashanti and Volta, Brong Ahafo regions respectively. The commonest trait across all the communities involved in the focus group discussion was fruit size and fruit colour though they were ranked second and fourth in their respective regions.

Table 9. Postharvest quality traits of tomato within the communities involved in the focus group discussion

Rank position	Upper East	Ashanti	Volta	Brong Ahafo
1	Shelf life/storage	Shelf life/storage	Firmness	Firmness
2	Fruit size	Firmness	Taste	Fruit size
3	Fruit colour	Fruit size	Fruit size	Fruit colour
4		Fruit colour	Fruit colour	
5		Taste		

4. Pattern of Tomato Production, Marketing and Utilization among Tomato Stakeholders

4.1 Tomato Production Preferences by Farmers

4.1.1 Postharvest Quality Traits of Tomato

The respondents had fairly uniform and near unanimous perceptions and opinions in their choice of postharvest quality traits of tomato. Respondents across the study areas showed preference for shelf life, firmness, fruit size, fruit colour and taste as an important postharvest quality trait of tomato. They however, showed extreme preferences for firmness and shelf life as the most important quality traits of tomato, and ranked fruit colour and taste as moderate preferences.

4.2 Farmers' Perception of Tomato Shelf Life and Firmness

Storage life of tomato fruits

Table 10 indicates the shelf life of tomato fruits as declared by farmers interviewed. They stated different storage life of their tomatoes. More than half (55.3%) of the respondents can store their tomato fruits for a maximum of six days. Only 5.9% of the respondents can store their tomato fruits for a maximum of 12 days. When respondents were asked about their satisfaction on the shelf life of their tomato variety, 87.9% mentioned that they were not pleased with storage period. Respondents who are not pleased with their shelf life of tomato outline several reasons such as reduces quantity and quality of tomato produce, reduces profit and limited life span (Table 11). Farmers on their own employ practice various ways to increase the shelf life of their tomato variety whiles waiting for market. About 30% of them apply fungicides few days before harvest and or harvest at breaker stage (just before ripen) (Table 12).

Table 10. Storage life of farmers' cultivated varieties

Storage period (days)	1-3	4-6	7-9	10-12
Percentage of farmers (%)	12.5	55.3	26.3	5.9

Table 11. Reasons for displeasure of the storage life of farmer's cultivated varieties

Reason	Percentage (%)
Reduces quantity and quality of produce (A)	30.1
Reduces profit (B)	35.3
Both (A and B)	33.1
Limited life span	1.5
Total	100

Table 12. Temporary measures employed by farmers to lessen poor storage life

Measures	Percentage (%)
Application of fungicides few days before harvesting	29.7
Application of calcium on the fruit before harvesting	2.9
Harvesting at breaker stage (just before ripen)	29.0
Harvesting at green stage of mature fruits	10.1
Cover fruits with dry grass	18.1
Spread fruits on the floor	10.1
Total	**100**

4.3 Farmers' Perceptions and Opinions about Tomato Shelf Life

Farmers' views and thoughts about the storage life of tomato fruits are presented in Table 13. They enlisted poor agronomic practices, poor handling of the tomatoes and characteristic nature as their observations and awareness as far as tomato shelf life is concerned. About 71% of poor shelf life was attributed to the characteristic nature of the tomato variety (genetic) while 8.5% was pointed to poor handling of the tomatoes. Preponderance of the respondents (72.5%) was of the opinion that absence of ready market intensifies the problem of poor shelf life. Others were of the view that improper packaging (13.4%), precarious transportation (12.7%) and heavy rainfall (1.4%) deepen the poor storage life of tomato (Table 14).

Table 13. Respondents perception about poor shelf life of tomato fruits

Causes of poor shelf life in tomato	Percentage (%)
Poor agronomic practices	20.6
Poor handling of the harvested tomato	8.5
Tomato variety (genetic)	70.9
Total	**100**

Table 14. Respondents opinion about poor shelf life of tomato fruits

Views	Percentage (%)
Lack of ready market	72.5
Improper packaging	13.4
Precarious transportation	12.7
Heavy rainfall	1.4
Total	**100**

5. Tomato Preferences by Market Players

5.1 Market Level Characteristics

5.1.1 Criteria of Grading Tomatoes for Sale

Market players consider number of standards to sell their tomatoes, such as: Fruit size, freshness, ripeness, firmness and colours. Among these benchmarks, firmness of tomato fruit constituted the highest response (38%) while, fruit colour recorded the least response (3%) (Figure 3).

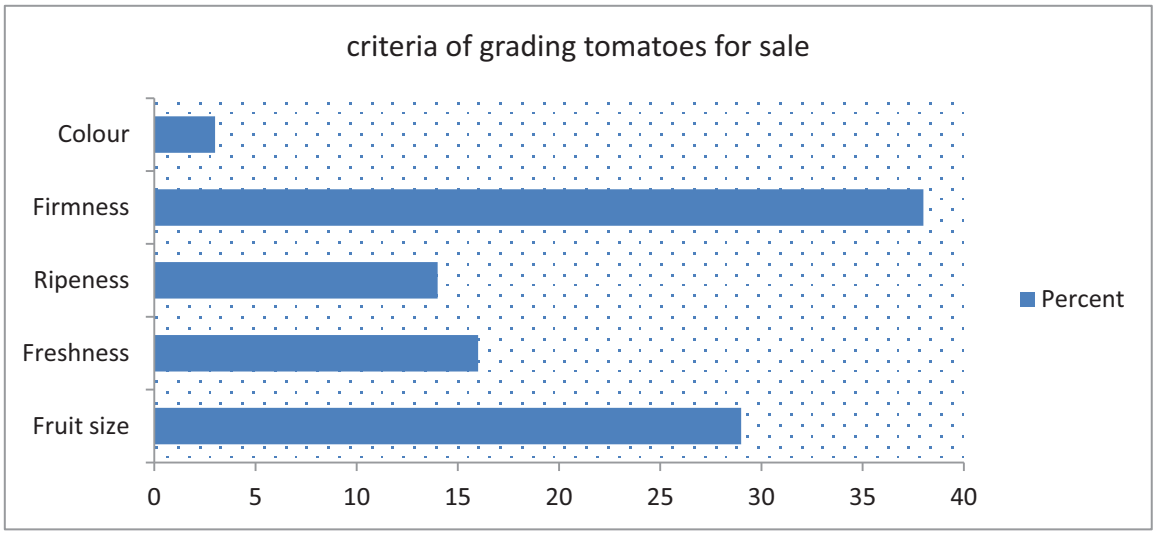

Figure 3. Criteria of grading tomatoes by market players

5.2 Market players' Perception and Opinion of Tomato Shelf Life and Firmness

Fifty respondents representing 65% indicated that their tomatoes for sale commence deterioration only after 1-3 days. Nonetheless only 3% of the respondents could keep their tomatoes for 10-12 days before they start to deteriorate. According to the market players especially the retailers, they employ several measures to prolong the shelf life but no avail. Some of these actions include putting tomatoes in a ventilated room (13%), spreading tomato fruits on the floor (21%), sorting out and cleaning during marketing (17%), putting them in a spacious container (19%), cold store (4%) and helpless (reduce price and sell out produce) (20%) (Figure 4).

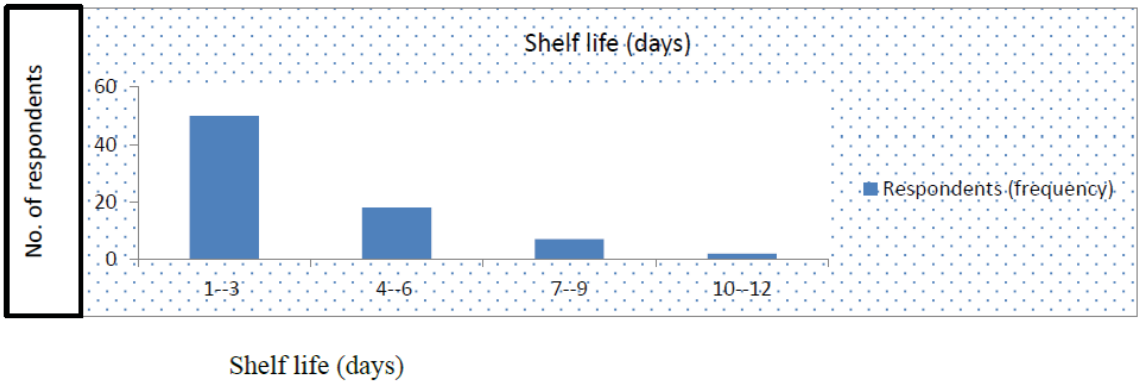

Figure 4. Shelf life of tomatoes as declared by market players

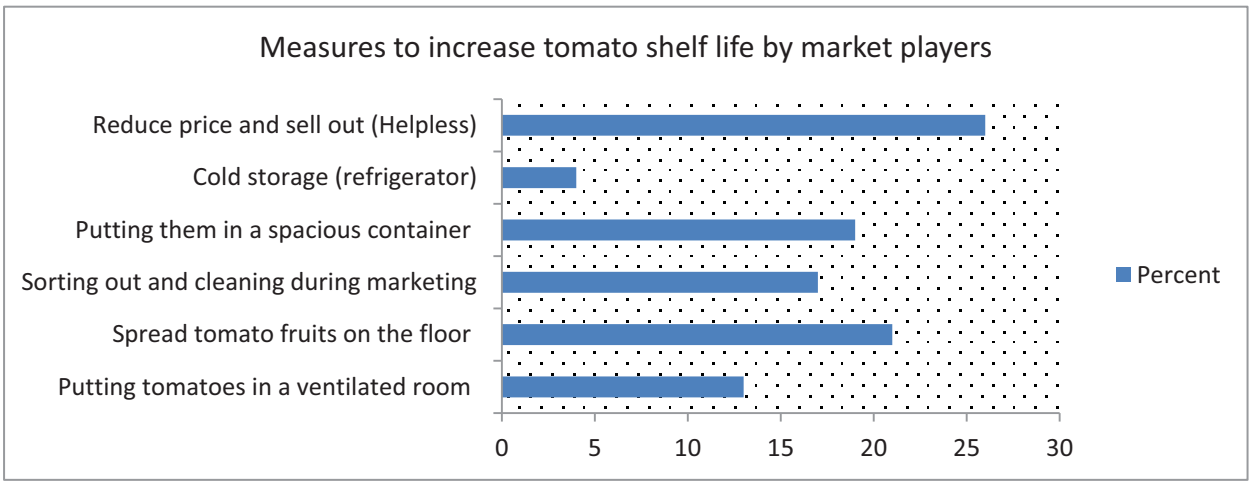

Figure 5. Measures employed by market players to extend shelf life

5.3 Tomato Utilization and Quality Preferences by Consumers

5.3.1 Consumer Level Characteristics

Tomato consumption pattern is presented in figure 6. Seventy-seven point five percent (77.5%) of the consumers use tomatoes every day in their food preparation whilst 10% and 7.5% consume twice and thrice a week respectively. Five percent of the respondents were however, not sure of how often they use tomato in their food preparation. Almost all the respondents use tomato in one way or the other. Figure 7 depicts the different forms in which tomatoes are used as mentioned by the respondents. About 93% of the respondents consume tomato by preparing stew or soup or both (Figure 7).

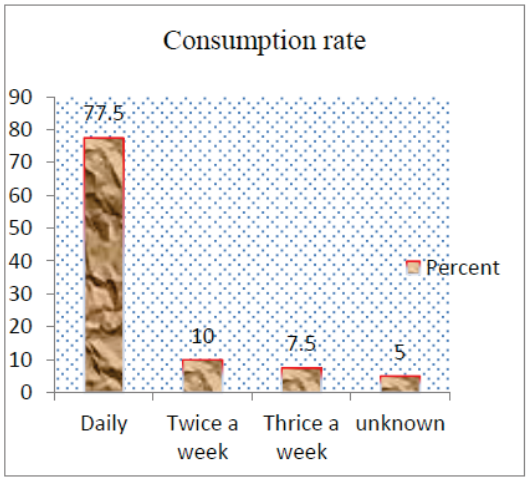

Figure 6. Consumption rate of tomato

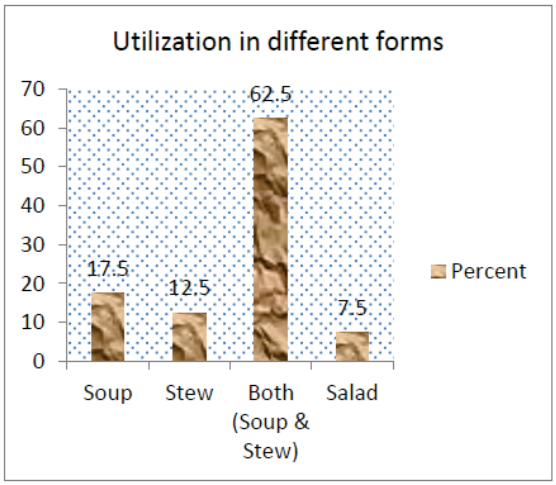

Figure 7. Use of tomato in different forms

The pie chart presents respondents' knowledge of the varieties they purchase from the market. Sixty-two percent of the respondents can identify the tomato variety they purchase (Fig. 8).

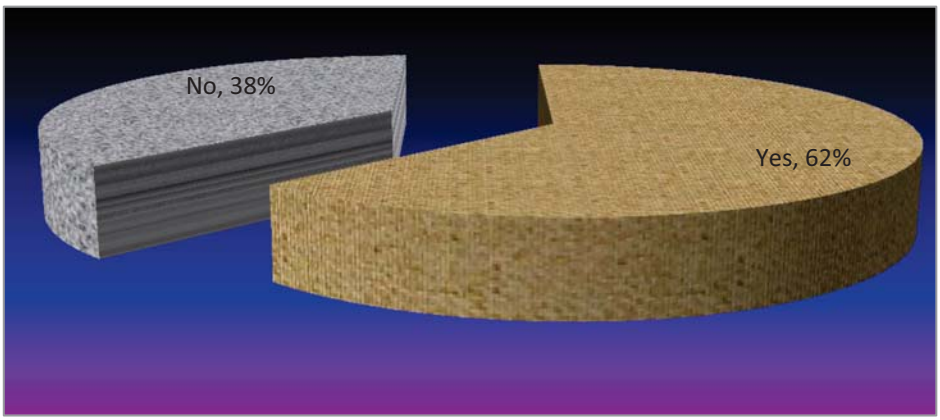

Figure 8. Consumers' knowledge of tomato variety purchased

Quality preference distribution of tomato indicated a response of 50% and 30% respondents for firmness and freshness/ripeness respectively (Figure 9). Half of the respondents prefer firmness to fruit size (15%) and colour (5%). Seventy-five percent of the respondents also place high premium on the shelf life and firmness of any tomato purchased for household use, whilst 15% put premium on the taste of tomato. Only 7.5% and 2.5% of the respondents lay premium on big fruit size and fruit shape respectively (Figure 10).

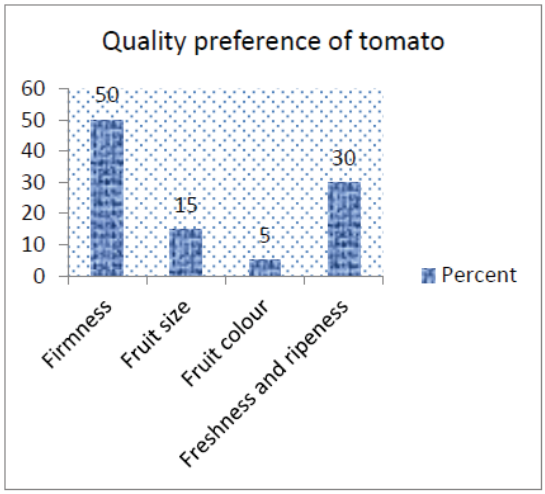

Figure 9 Consumer quality preference in tomato

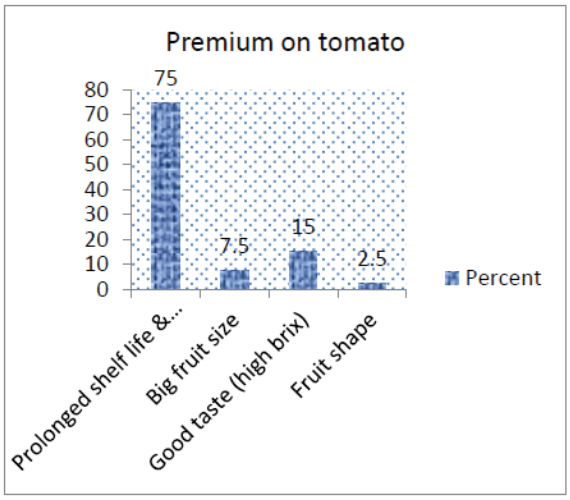

Figure 10 Premium placed by consumers in tomato

Consumers were asked to provide the number of days that they normally keep the tomatoes before deteriorating and from the figure below (figure 11), seventy-five percent of the respondents can store their tomatoes for only 1-4 days. Ten percent and five percent of the respondents can also store their tomatoes in the fresh stage for 5-8 days and 9-12 days respectively.

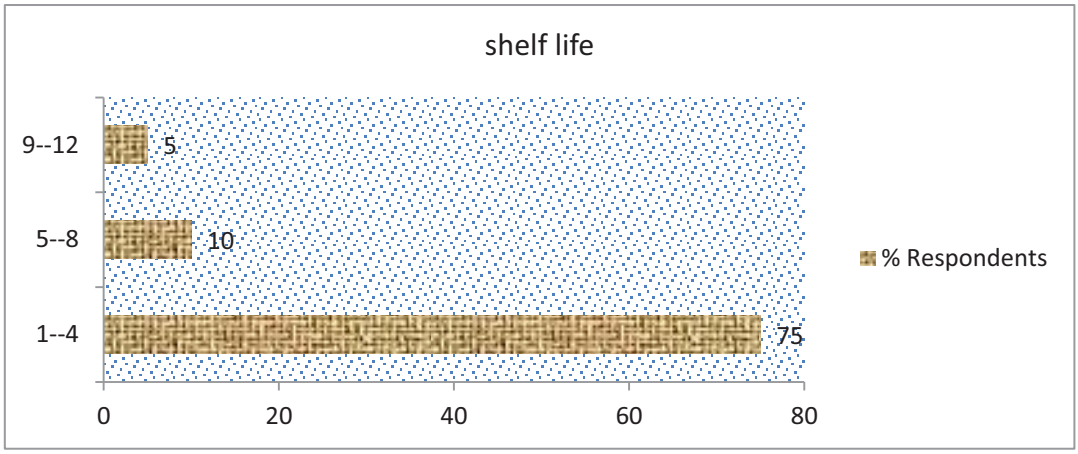

Figure 11. Shelf life of tomato as declared by households

6. Discussion

The variation obtained in the variables (questions) used for the Focal Group Discussion (FGD) suggests existence of a high degree of varying perception, knowledge and opinion of tomatoes in Ghana. The level of interest and involvement of participants were very high, indicating that dissimilarities observed may be ascribed to societal background since discussions were held at different communities in different regions. The future of tomato as a food security and an income generation crop was affirmed by the present study. This is fairly declared by the amalgam of stakeholders (farmers, marketers, consumers). Almost all the communities cultivate tomato and rated it as number one vegetable crop produced. The relative ranking position of tomato to other vegetable crops grown in the study areas as mentioned by the respondents confirms the high demand and income generating potential of the crop. This reason is true because according to Wolff (1999) tomato is consumed in almost every household daily. This agrees with Ochieng and Sharman (2004), who also reported that tomato cultivation +\- is a very significant economic activity in Ghana and more profitable than rice, maize, groundnuts, yam, pepper and diary. According to Clottey et al., 2009 as far back as the early 1960, market gardening of tomato had been very important dry season economic activity. In Ghana, production of the crop is an essential profitable activity for smallholder farmers who produce the bulk of the crop. A wide range of areas are suitable

for tomato production in Ghana. These include the forest, transitional and savanna zones (Norman, 1992). In contemporary years, even though domestic production has increased across the country, the level of production still falls short of domestic demand. As a result, fresh tomatoes are often imported mainly from neighboring Burkina Faso (Horna et al., 2006). This affirms the reason why Ghana imports over 7000 metric tons of fresh tomato per month from neighboring countries, along with 27,000 tons of processed tomato from Europe to meet its high demand (Inusah et al., 2013).

Stakeholders' ideal for postharvest quality traits of tomato included firmness, appearance (colour and shiny surfaces), fruit size, taste and long tomato fruit storage. Their most preferred quality traits are firmness and, prolonged shelf life. This could be due to the fact that firm tomatoes are less prone to damage and tend to have a longer shelf life. For instance, consumers buy tomatoes on the basis of appearance and firmness. Their approval and repeat purchases of the same tomato variety will be contingent upon good flavour quality and perhaps prolonged shelf life. As a matter of fact such tomato varieties are embraced by consumers and sell faster. Tomato is a perishable vegetable fruit and therefore varieties of such crop with increased life span are desirable. Mondal (2000) outlines shelf life as a period of time which starts from harvesting and extends up to the start of rotting of fruits. According to Shahnawaz et al., (2011) high quality tomato fruits have a firm, uniform and shiny colour, good appearance, without signs of mechanical injuries, shrinking and bruises. It is therefore no surprising why the stakeholders' desired for these quality traits. Likewise, for distant transportation, fruits should be firm to avoid physical damage. According to Dhall and Dhatt (2002), the firmness to tomato is provided by skin toughness, flesh thickness and locular area of the fruit. Even though stakeholders have established a positive correlation between firmness and long shelf life, it turns out to be deceitful sometimes. Firmness is an attribute of the tomato fruit when harvested. In other words, it is a general characteristic of the tomato fruit. However, in order to achieve long shelf life in tomatoes we must use specific tomato genes or other approach to inhibit fruit ripening. This implies that a firm tomato may not necessarily have a long shelf life. Dobrzanski and Rybezyski (1998) however, deliberated that firmness is a key characteristics of fruit that are important for quality, harvest, maturity, and shelf- life. According to Bosland (1993) fruit composition at the time of testing (degree of ripeness, size, post-harvest handling and internal temperature) can affect fruit firmness. He further stated that changes in firmness are highly correlated with surface appearance characteristics of tomatoes which associated to colour, shape and sense of feel to firmness.

There were varied responses on farmers' age, education and varieties grown. The age group indicates a mix of young and old people involved in tomato farming. The large number of young people involved in tomato production is an enthusiastic progress since the youth are noted to abandon farming in quest of other businesses in the cities. More young people can be encouraged to pursue tomato production to reduce the unemployment rate in the country and help to address the negative trend of the youth forsaking agriculture in general. The educational status of the farmers who attained up to primary/JHS/Middle school was more than half of the entire respondents indicating dominance by people with basic level education. This can thus be implied that respondents' level of education is satisfactory to offer them with the necessary professional expertise that will assist them to successfully accomplish their farm enterprise. This finding confirms with Seidu (2008), who stressed that education enables farmers to understand the social and economic conditions governing their farming activities and thereby increasing their output and also in confirmation with findings of Asante et al., (2013). He further emphasized that production or farming experience is positively related to technical efficiency. This implies that accumulated experiences can influence farmers to mobilize and use labour effectively coupled with appropriate record keeping. Farmers who are better educated are generally more open to innovative ideas and new technologies that promote technical change (Lapar & Ehui, 2003). The male dominance of tomato production implies the laborious nature of tomato farming operations right from nursing to harvest which their female counterparts cannot easily undertake.

Although respondents gave diverse shelf life of their tomato fruits, majority of the respondents could store their tomato fruits for few days (less than a week). According to Kader (1992), the high moisture content of tomatoes (above 95%) and its soft outer covering predisposes it to microbial spoilage and short shelf life, thus leading to high annual postharvest losses (PHL) (20–50%) of the crop. Fresh tomatoes are more traditional and culturally accepted in food application and as such farmers will want to employ various ways to increase the shelf life of their tomatoes. This is in agreement with Rozin and Vollmecke (1986) who indicated that cultural factors influence food choices because of the differences in both perception and preference. Respondents argue their displeasure in the reduction of their quantity and quality of produce therefore affecting their profit margin. As tomatoes are usually harvested over a limited period of time, it is thus required to provide storage for the fruits in order to regulate marketing and preserve high quality. As a matter of fact farmers employ temporary measures to

offset the poor storage life. According to Engindeniz (2007) because of the highly perishable nature of tomato, farmers attempt to store them in a variety of traditional structures which are greatly inappropriate thus resulting in substantial losses. The majority of respondents who harvest at breaker stage has confidence that by the time it gets to the buyer it would be in good condition and stays for some time prior to deterioration. Others who applied fungicides few days before harvesting also rely on the fungicides to make the tomato skin tough and thus prolonging the storage life. A lot of problems related to post-harvest life of tomato are associated with microbial and fungal deterioration of fruit. A number of fungal species have been described as contributory agents of tomato decay during storage (Singh et al., 2016).

Despite the seeming different opinions and thoughts of poor shelf life, respondents perceived to genetic or hereditary suggesting that they have certain knowledge of the characteristic nature of tomato. According to Norman (1992) tomato fruit contain about 93% moisture and the rest being solids. However, certain tomato varieties are able to delay or slow down ethylene production responsible for ripening thus ensuring prolonged shelf life. Majority of the respondents who were of the view that lack of ready market deepens the problem of poor shelf life is an absolute fact. Robinson and Shashi (2010) attest to the problem of unreliable market when they conducted a research on marketing; the case of tomato in the Upper East region of Ghana. This was also confirmed by Farida and Fariya (2014) who analysed the production and marketing of tomato and indicated lack of reliable market as important challenge in the tomato industry. They further mentioned that for production to be lucrative and serve as a motivation there should be ready market and a good price for the output. This is often impeded by the strong competition between imported and local tomato which somewhat regularly does not favor local production. Moreover prices of fresh tomatoes are unpredictable. Day-to-day prices may fluctuate due to transportation problems or adverse weather conditions in both supply and demand regions. According to Caballero (2008) profitability of tomato is not only determined by production cost and yield but also price. Prices determine income and define income levels for agricultural producers as well as their incentives to invest in new technology.

In general the distribution of agricultural food commodities in Ghana is controlled by women. It was therefore not surprising to see a predominance of the female market players in their early thirties to fifties. With nearly half of the market players having acquired more than 11 years in the tomato business was adequate enough to elicit palpable information on their preferences, perceptions and knowledge about postharvest quality traits of tomato. This further explains why a great number of the market players were aware of the varieties they sell to their clients or customers and could distinguish local from exotic varieties of tomato. The tomato market is one of the better organized sectors where each player has a well-defined function at specific stages in the marketing chain. In the tomato marketing chain it is easy to identify players in the categories of market queens, wholesalers and retailers. The trade is often undertaken by an association of women traders who are led by “tomato queen mothers” from the Southern parts of the Ghana. These queen mothers play protective roles in the markets as well as ensuring the welfare of their members. Buying at the farm gate is done by these queen mothers who sell to wholesale buyers and retailers. Other service workers include women who sort and package the tomatoes, drivers and loading boys, as well as middle men who bargain for the produce. Traders and middlemen have accumulated marketing strategies that enable them to bargain for lesser prices at farm gates. The goods are then sold at high prices in towns and city markets, benefiting the trader or the middleman rather than the farmer.

Market players desire firmness as an important quality trait for grading their tomatoes. This is because the fruit quality as it is directly related to fruit development, maturity; ripening and storage potential correlate with firmness. It is therefore not unimagined to hear market players classifying firmness as an important benchmark for grading their tomatoes. This is buttressed by Dobrzanski and Rybezyski (1998) who specified firmness as a key characteristic of tomato fruit essential for value. Even though Sargent and Moretti (2002) revealed that high quality fruits have firm appearance, Banaras et al., (1988) added that firmness of tomato fruits depends on the cultivar types and their morphological characteristics. Majority of the market players especially the retailers who experienced losing their tomatoes as a result of poor storage and absence of ready market resort to reducing the price of their tomatoes so as to clear them off. Similarly owing to lack of processing and storage facilities, farmers are compelled to sell at low prices rather than lose the entire product. The highly perishable nature of tomatoes therefore presents a market threat in the tomato industry. Traders especially retailers who faced this dilemma often compromise their moral values in order to make a profit. In many instances, they sell on credits to customers based on pure trust with the hope that they will be sincere enough to pay when they get the money but this drill has often resulted in defaults (Evers, 1994).

Tomato utilization and consumption varied among the respondents (consumers). Whereas tomatoes are used in different forms chiefly for soup and stew, consumption rate is daily according to majority of the respondents

interviewed. This confirms Wolff (1999) who indicated that tomato is consumed in almost every household daily. It is estimated that Ghana produces over 300,000 MT of tomatoes and 90% of the production is consumed locally. It also imports over 78,000 tons of tomato paste and puree per year to meet the ever increasing demand of the crop. Most of the consumers also desire firmness including freshness and ripeness for a good quality tomato. In another instance majority of the respondents (consumers) put premium on prolonged shelf life and firmness. This suggests that respondents have high preference for tomatoes with good firmness and extended shelf life, justifying the need for the present study.

According to Barret et al., (1994) the variation of shelf life in tomatoes is as a result of the changes in fruit ripening. A tomato with a good shelf life will allow consumers to buy more of such varieties and also reduce the number of times in going to the market to purchase tomato. Hence any time they visit the market they will buy enough of such tomato varieties with guarantee that the shelf life is good. The shelf life of tomatoes depends on the date picked or purchase since there is usually no sell by date, use by date or best before date attached anywhere to tomatoes. Fresh tomatoes will begin to get soft and then may leak liquid when they are going bad. They may also begin to mold, at which point they have gone bad and you will want to throw them out. A typical example is the loss of firm texture which is related to the structure and cell wall composition, mainly pectic fraction which, when degraded, causes softening of the tomato fruit. Another problem experience with having fresh fruit on the counter is the sudden presence of fruit flies.

7. Conclusion

The study acknowledged and established the potential of tomato as a food security and an income generating crop in Ghana. It identified and interrogated key tomato stakeholders from four agroecological zones representing major tomato growing areas in Ghana. It also revealed stakeholders' desire and plea for firmness and extended shelf life of tomato fruits in Ghana. Consequently, the survey validates the need to regulate tomato breeding goals to develop high yielding tomatoes with improved fruit quality and prolonged shelf life. It is imperative that breeding programmes of tomatoes should be tailored to accommodate particular community desires and preferences.

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