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Effective at the Margins: Outmigration and Economic Development in Rural North Carolina

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Abstract

This paper describes the economic and social challenges faced by Enfield, a small town in rural northeastern North Carolina, and the efforts by the Center for Competitive Economies at the University of North Carolina at Chapel Hill to assist the community in a strategic economic development plan to address these challenges. In particular, the paper outlines the challenges and tensions between place-based versus people-based economic development approaches and how these tensions are generalizeable to other rural small towns. Lastly, the paper concludes that even the most effective economic development strategies may only impact the community marginally given the larger confluence of events in the broader region, such as general population loss due to outmigration, declining traditional industries, and stagnant regional economies.

Keywords: Rural development, North Carolina, Population loss

1. Introduction

This paper describes the economic and social challenges faced by Enfield, a small town in rural northeastern North Carolina, and the efforts by the Center for Competitive Economies at the University of North Carolina at Chapel Hill to assist the community in a strategic economic development plan to address these challenges. In particular, the paper outlines the challenges and tensions between place-based versus people-based economic development approaches and how these tensions are generalizeable to other rural small towns. Lastly, the paper concludes that even the most effective economic development strategies may only impact the community marginally given the larger confluence of events in the broader region, such as general population loss due to outmigration, declining traditional industries, and stagnant regional economies.

1.1 Background

The Golden LEAF Foundation (Golden LEAF) was established by the North Carolina General Assembly to provide economic assistance in tobacco-dependent regions of the state, in accordance with the consent decree

signed by the State of North Carolina and cigarette manufacturers. North Carolina was one of 46 states to bring litigation against manufacturers of tobacco products. In accordance with this mission, Golden LEAF contracted with the Center for Competitive Economies (the Center) at the University of North Carolina at Chapel Hill to create an economic development strategic plan on behalf of the Enfield Partnership for Tomorrow (the Partnership). Based in the Town of Enfield in southern Halifax County, the goal of the Partnership was to encourage economic growth and development within the existing service area of the Halifax Electric Membership Corporation, a rural electric cooperative serving southern Halifax and Warren counties. To this end, the Partnership had brought together local business leaders and government officials to begin the process of identifying and prioritizing community goals. While the Partnership had reached out to the African-American community, the organization was largely ineffective in generating sustained, active participation from the minority community. The Town of Enfield's population is 75 percent African-American and representation from this community was critical to creating a sustainable plan.

2. Research Techniques and Approach

The research plan developed by the Center sought to combine a data-driven, objective assessment of feasible economic development opportunities identified by the Center with the desired economic development outcomes expressed by the broader community. Within this context, the Center designed a strategic planning process that centered on a comprehensive community engagement effort. The intent was to promote equitable representation of African American residents, community leaders, and elected officials in the identification and prioritization of community economic development objectives. This involvement occurred in the form of semi-structured interviews conducted with known community leaders and public meetings designed to inform residents and solicit input. Additional research tasks were introduced to collect relevant background statistics on regional socio-economic conditions. These included a review of contemporary demographic and economic trends, an assessment of potential retail market gaps, an inventory of workforce characteristics, and a review of the dominant regional industry clusters. Once these tasks were completed, the research results were compiled and ranked based on community input. This was then translated into a multi-phase implementation strategy designed to guide the development and monitoring of new programs.

Of the many demographic trends identified, residential outmigration was the most likely to have a significant long-term impact on the area's economic vibrancy. Anecdotally, this was readily apparent to many active in the community. Some of the most active participants were native residents that moved away and returned in their retiring years. However, their education and professional success had often occurred outside of the broader Enfield region. This challenge of rural depopulation and residential outmigration was also supported in the data analysis. Over the past decade, only seven counties in the State of North Carolina experienced negative population growth. Five of those counties were located in the northeastern region of the state, including Halifax. The Town of Enfield and other communities in the southern portion of Halifax County are at the forefront of the depopulation trend with rates of population loss that greatly exceed the regional average (U.S. Census Bureau, 2011). Population loss and outmigration can be particularly troublesome for rural communities, as these trends often result in an increased the local tax burden, contraction of the local labor force, and reductions in gross household consumption.

For the purpose of analyzing relevant demographic data, the research team used Geographic Information Systems (GIS) to define four study areas that highlight Enfield's unique location between two dominant urban centers. These study area geographies are depicted in Figure 1. A one-mile radius was chosen to capture demographic and consumer conditions within the Enfield community itself. Five- and ten-mile radii were selected to offer a perspective on the southern Halifax County community that takes into account the rural populations living in the area surrounding Enfield. These households could be considered part of the potential Enfield consumer and labor pools, and should thus be considered in the analysis. A twenty-mile radius was also chosen to provide a comparison to the other three study areas, since it includes the two dominant regional population and employment centers of Roanoke Rapids and Rocky Mount.

3. Population Loss and the Enfield Community

Population loss is a major issue facing rural communities throughout the United States. Of more than two thousand rural, nonmetropolitan counties nearly half lost population over the past two decades. In over seven hundred of those counties, the rate of population loss exceeded ten percent (McGranahan, Cromartie, & Wojan, 2011). This decline occurred through two distinct processes: natural change and outmigration. Natural changes in population occur when the birth rate and death rate diverge. All other things being equal, if the birth rate exceeds the death rate, the population increases. If the death rate exceeds the rate at which children are being born, the

population declines. Natural population change typically occurs quite slowly, perhaps with the exception of major conflict events and epidemic disease. Outmigration, by comparison, can occur quite rapidly as residents relocate to other areas seeking improved economic opportunity and a higher standard of living. Yet, the outmigration of individuals and households does not always result in a net loss of population. The outflow of residents must be large enough to offset the number of residents migrating into the area from outside, as well as any natural population growth that might occur. Much more volatile than natural population change, outmigration rates typically reflect the local conditions present in a community (McHugh & Gober, 1992). In addition to economic considerations, residential relocation choices are highly influenced by various quality-of-life factors. These can include the individuals place in the life-cycle, the quality of the local schools, the affordability of area housing, and access to a diversity of retail shopping outlets. It is this volatility and interrelatedness with other community characteristics that makes outmigration the primary focus of academic research and policy analysis (McGranahan *et al.*, 2011; Butmann, Deane, & Peri, 2005; McHugh & Gober, 1992).

3.1 Outmigration and the Life-Cycle

An individual's stage in the life cycle has a strong influence on their propensity toward outmigration (Plane & Jurjevich, 2009; Cromartie & Nelson, 2009). The highest rates of outmigration typically occur among young adults in their late teens and early twenties. These individuals, after graduation from high school, often migrate to major metropolitan cities to attend college, serve in the military, or pursue other career opportunities. As people age, the propensity for migration decreases and the geographic focus shifts from the urban core to the suburban fringe. By the time someone reaches their mid-forties, the likelihood of relocation has declined by around half. In addition to a reduced proclivity toward migration, older individuals and married couples with children have a greater preference for quality-of-life factors, like good quality schools, compared to their younger counter parts. This makes older households more likely to in-migrate to rural communities, often countering the outmigration of younger adults.

The challenge is that communities experiencing various types of economic and social distress are statistically more likely to lose young adults to outmigration faster than they can gain older adults and families through in-migration. McGranahan *et al*. (2011) reported that rural counties not experiencing any net population loss through outmigration, gained population at an average rate of one percent per year. While these counties still lost young adults, they experienced a net gain due to the in-migration of families and older individuals. Counties that experienced net outmigration, but that did not exhibit severe economic distress, also lost young adults, but at a much faster rate. These counties also failed to attract a sufficient cohort of young families and older adults. As these households are more sensitive to quality-of-life considerations, it can be inferred that low-poverty counties experiencing high net outmigration possess fewer desirable residential amenities. By comparison, rural counties that experienced severe economic distress and high net outmigration lost both young adults and young families, while also failing to attract older adults and retirees. What can be concluded from these findings is that the factors influencing relocation choices differ by age cohort and that adverse economic conditions can worsen trends of outmigration caused by a lack of desired amenities.

3.1.1 Life-Cycle Dynamics in Enfield and Southern Halifax County

Of the many demographic trends identified during the strategic planning process, residential outmigration was the most likely to impact the area's long-term economic vibrancy. Of the seven counties in North Carolina that lost population over the past decade, the Town of Enfield and other communities in the southern portion of Halifax County were at the forefront of the depopulation trend with rates of population loss that greatly exceed the regional average (U.S. Census Bureau, 2011). As previously shown in Table 1, the population of Enfield – as represented by the 1-mile radius – declined by ten percent between the year 2000 and 2010. Similar trends were evident in the 5- and 10- mile areas with a total decrease in population of 12 and 11 percent respectively. The 20-mile radius that included the cities of Roanoke Rapids and Rocky Mount showed a decline in population of only around one percent. This confirmed that while the county as a whole had lost population, urban areas were much less affected than rural ones.

Armed with this information, the research team investigated the distribution of population by age cohort. All four study areas showed similar proportional distributions. What was more telling was the rate at which the four study areas were gaining and losing population within each age group. Table 2 reports the absolute and annual average rate of change within each of the seven age groups. Within the 1-mile radius, there were significant losses in the under 18 and 35-44 age groups. These lost population at an average rate of 2.3 and 3.8 percent per year. Alternatively, there were two age groups that also exhibited modest gains. These included the 25-34 and 55-64

age groups. The rates of population growth in these two groups, however, were only around 0.9 and 1.4 percent per year. As the rates of population growth in these two categories were substantially lower than the rates of population loss in the remaining age groups, the net outcome within the 1-mile radius was a decrease in population. The 5- and 10-mile radii showed similar population changes, with high rates of population loss in the under 18 and 35-44 age groups. However, within these areas, the net positive population growth seen in the 25-34 age category had reversed sign, showing a negative growth trend. Lastly, the 20-mile radius showed a 1.1 percent decline in the under 18 age group, as well as a 0.7 percent decline in the 25-34 age group and a 2.4 percent decline in the 35-44 age group. The area showed modest gains in the 18-24 age range and substantial gains in the 45-54, 55-64, and 65 and over age groups.

What the age based population growth trends indicated was that Enfield and southern Halifax County were losing young adults, families, and older adults. Rapid declines in the number of residents in the under 18 and 18-24 age groups suggested that a large number of young adults were leaving the community. The fact that the proportional concentration of residents within the 18-24 age group did not change significantly suggested that the rate of population loss within the age group remained relatively stable over time. More concerning was the increasingly rapid loss of families, represented by the under 18 and 35-44 age groups. These households made up nearly 42 percent of the population in the year 2000. By 2010, this had decreased to 35 percent. Interviews carried out with residents located in and around the Town of Enfield confirmed that an under-performing and somewhat segregated school system, a lack of retail shopping outlets, and perceived problems of crime and juvenile delinquency were among the most important reasons why the area had failed to retain many of its families and older adults.

3.1.2 Population Loss and Racial Composition

One other important demographic shift related to population loss is the increasing prominence of the African-American population in southern Halifax County. As seen in Table 3, the racial and ethnic breakdown suggests a community that is primarily African American. The proportion of households in the 1-mile radius reporting as white decreased from around 28 percent in 2000 to 23 percent in 2010. This corresponded to an increase in the proportion of Households reporting to be African American, from 70 percent in 2000 to 76 percent in 2010. Data for the 5- and 10-mile radii report similar trends. The 20-mile radius, however, shows a more even split between white and African American households. In the year 2000, around 49 percent of households reported to be African American, while 47 percent reported to be white. By 2010, the mix shifted slightly to include roughly 51 percent African American households and 44 percent white households. What these figures indicate is that the rate of population loss was much higher among white households, resulting in a community that is increasingly African-American.

3.1.3 School Quality and Legacy of Segregation

The community engagement effort undertaken by the Center revealed a deep seated discontent among area residents with the quality of the local school system and other social conditions in the greater Enfield area. While research was being conducted for this project, the UNC Center for Civil Rights released a report discussing the impacts of the persistent racial and socio-economic segregation of Halifax County students (Dorosin, Haddix, Jones & Trice, 2011). The county is one of only a handful in the state with three separate school districts. The Roanoke Rapids Graded School District (RRGSD) and the Weldon City Schools (WCS) serve students in the urbanized areas of Roanoke Rapids and Weldon. The Halifax County Public Schools (HCPS) serve students in the unincorporated parts of Halifax County. The most striking difference between the three districts is that nearly 100 percent the students enrolled in the WCS and the HCPS in 2009 were African-American, while 70 percent of the students enrolled in the RRGSD were white. The WCS and the HCPS were also heavily low-income in 2009, with over 90 percent of students receiving Free and Reduced Lunch (FRL). In the RRGSD around 51 percent of students were enrolled in the program. While the percent of students enrolled in the FRL program in the RRGSD is still quite high, the percent enrollment in the WCS and HCPS is truly staggering.

This racial and economic segregation has had important impacts on educational outcomes in southern Halifax County. For example, the proportion of students in grades three through eight that scored at or above grade level on their End-of-Grade (EoG) reading exams during the 2009-2010 school year was only 37 percent in the HCPS and 47 percent in the WCS. This is compared to almost 68 percent in the RRGSD. While the percentage of students reading at grade level in all three districts is quite low, the magnitude of the difference between the RRGSD and the other two districts indicates a clear difference in school quality. The UNC study also measured three indicators of school quality, in addition to student performance. These were teacher turnover, teacher working conditions, and teacher quality. Table 4 reports teacher turnover rates for the three school districts. In

almost every measure, the HCPS and WCS experienced significantly higher rates of teacher turnover. This can be partially explained by a greater feeling of frustration among teachers within the two minority-majority school districts. Teachers in these schools identified a sense of tension within the community, a lacking sense of trust and respect within the working environment, and a feeling that the school environments were not "conducive to learning" (Dorosin *et al*., 2011). Some of these feelings of unease, however, may be related to the relative inexperience of many of the teachers in the HCPS and WCS school districts. The report indicates that between 25 and 30 percent of the teaching staff in these districts have three years or less of teaching experience. This is compared to only six percent in the RRGSD.

This relative inexperience – as well as the other issues within the two minority school districts – is likely a symptom, of funding disparities between the three districts. The annual budgets of the WCS and RRGSD are augmented by revenues drawn from local property taxes. The WCS receives revenue at a rate of 17 cents per $100 of value. The RRGSD, by comparison, receives 21 cents per $100. Due to the higher tax rate, as well as the higher value of property located in the City of Roanoke Rapids, the RRGSD receives substantially more supplemental revenue than the Weldon district. The majority of the funds received are used to pay wage supplements to teachers as a recruitment and retention incentive. In the 2009-2010 academic year, the RRGSD paid an average of $1,795 per teacher. The WCS paid only $373, while the HCPS could not provide such wage supplements (Dorosin *et al*., 2011). Because of these disparities between the districts, the HCPS have found it difficult to recruit and retain high quality teachers.

With less experience, lower test scores, less operational revenue, and a primarily disadvantaged student body, the HCPS has become one of the lowest-performing districts in the state. As such, it is also a major deterrent to the in-migration of potential residents who value high quality education. For instance, the 1996 Rural Manufacturing Survey identified labor quality as a major issue for rural manufacturers and indicated poor school quality as a barrier to the recruitment of upper level management. In terms of labor quality, worker reliability and attitude were the most frequently cited problems for manufacturers (McGranahan, 1998). This concern was echoed by Enfield area residents who described the challenges faced by recent high school graduates when they tried to secure employment. Many, it was noted, lacked even the basic soft skills necessary to be successful in the labor market. These included the ability to arrive on-time, to follow directions, and to groom one's self in a manner befitting a work environment. Thus, the local area schools fail to provide even the basic level of education necessary to serve area residents. Lacking this essential service, it is no wonder that the county remains unable to attract families in sufficient numbers to offset the loss of young adults.

3.1.4 Employment and Wages of Halifax County Workers

While high net outmigration in nonmetropolitan communities is strongly influenced by non-economic quality-of-life factors, research indicates that high rates of poverty and economic distress can exacerbate trends of outmigration (McGranahan *et al*., 2011). Halifax County, at the time of this research, was already one of the most economically distressed communities in the state. Between 2000 and 2010, the county lost over 2,400 jobs. The majority of these losses occurred in the goods-producing industries of manufacturing, construction, and natural resource extraction, which lost jobs at a rate of roughly six percent per year over the decade. Manufacturing experienced the most substantial losses with over 1,740 layoffs. Significant losses also occurred in the service-providing industries of trade and transportation, information technology, business services, and public administration. The net effect of these jobs losses was an increase in the county-wide unemployment rate from only six percent in 2000 to over 13 percent in 2010. This is compared to only 10.6 for the state as a whole.

While the county and state both experienced increases in the unemployment rate over the past decade, both appear to have experienced a moderate degree of nominal wage growth. Data collected from the Quarterly Census of Employment and Wages (QCEW) indicated that without adjusting for inflation, workers in Halifax County experienced an average annual increase in pay of roughly 2.1 percent (U.S. Bureau of Labor Statistics, 2011a). This raised the average annual wage from around $24,000 to over $29,600. At the industry level, the sectors that experienced the most rapid wage growth were mostly in the goods-producing sectors. In terms of high- and low-wage industry sectors, the goods-producing sectors also had the highest average wages at roughly $40,700 per year compared to only $27,500 per year on average in the service-providing sectors.

While positive nominal wage growth is an important indicator of labor market competitiveness, it is important to consider whether or not growth in local wages meets or exceeds the rate of inflation. In addition to nominal wage rates, the research team also calculated annual average wage figures that adjusted for inflation using the Bureau of Labor Statistics Consumer Price Index for the South Region (U.S. Bureau of Labor Statistics, 2011b). According to these figures, the average annual wage in Halifax County has actually declined in real terms by

almost $160. Goods-producing industries appear to have maintained positive wage growth equal to an increase in annual pay of nearly $4,400. Service-providing industries, however, experienced a drop in annual wage of almost $100 per year.

Together these trends in employment and wages suggest that Halifax County as a whole is under performing economically, compared to the state. It experienced employment losses in nearly all industry sectors over the last decade and only modest employment growth in the two industries that are not in decline. While employee wages have nominally increased over time, they have failed to keep up with inflation, leaving Halifax County at a competitive disadvantage compared to other parts of the state for worker recruitment and retention. The only industries that appeared to be wage competitive were the goods-producing sectors whose wages had remained at around 85 to 90 percent of the state average. Unfortunately, these are the same industries which were losing jobs at the highest rate.

3.1.5 Poverty and Income Dynamics

Symptomatic of prolonged unemployment, declining wages, and poor educational achievement, Enfield and southern Halifax County also experienced high rates of poverty and increasing income inequality between white and African-American residents. In Halifax County as a whole, roughly 24 percent of residents reported incomes at or below the federal poverty limit in both the 2000 Census and 2009 American Community Survey (ACS). Local level estimates for the Town of Enfield report a poverty rate of roughly 34 percent in both the Census and 2005-2009 ACS. This suggests that while poverty rates were high, they remained relatively stable over time, despite the recent recession.

In order to further illustrate the socio-economic disparities that exist between the African American and the white households, data were collected on median household income by race and ethnicity. Table 5 shows the inflation adjusted and non-inflation adjusted median household incomes for households by race of householder in 1999 and 2010. According to this data, the median African American household income in 1999 in the 1-mile radius was roughly 52 percent lower than that of white households. After adjusting to 2010 dollars, this was equal to a median white household income of over $48,000 per year, compared to only $23,000 per year for the median African American household. This disparity increased in 2010 where the median African American household income was roughly 54 percent less than the corresponding median white household income. The income disparity reported in the other three study areas for 1999 and 2010 was somewhat less than in the 1-mile area, but continued to reflect median African American household incomes that were between 42 and 48 percent lower than for their white counterparts.

To highlight another important characteristic of the Enfield community, Table 6 reports the number of households who received income from certain sources. What is important to recognize is that Enfield has a lower relative proportion of households drawing on traditional sources of income, such as wages/salary, self-employment, and interest, dividends, and rental income from real estate. Enfield also has a higher proportion of households that partake in various types of public assistance, like social security, public assistance, disability income, and unemployment income. The complicating factor was that the earnings source categories reported are not mutually exclusive. Households could feasibly be reported as drawing income or earnings from multiple sources.

4. Place-Based Versus People-Based Economic Development

The purpose of economic development has widely been accepted as raising standards of living for current residents, but economic developers have achieved little consensus on how these goals ought to be operationalized. In the 1960s, researchers and practitioners were divided over the best development methods to deal with spreading urban poverty and urban blight. The discussions raised questions about how economic development could best address poverty and whether the focus should be on people-based or place-based economic development strategies (Kain & Persky, 1969). Decades of economic projects and research have not resolved these divisions (Kraybill & Kilkenny, 2003).

4.1 What is Place-Based Economic Development

Place-based policies are distinctive from people-based development because the primary target is the locality, not just the individual residing there (Bolton, 1992). A development strategy that promotes the growth of the local economy also promotes its residents' living standards (Krayhill & Kilkenny, 2003). Proponents of place-based strategies argue that meaningful economic development strategies cannot occur without considering the context with which people live (Butler, 1991; Johnson, 2007). Policies such that enhance comparative advantages and location "uniqueness" enable a place to compete openly in a market for new industries, businesses, or residents

(Kraybill & Kilkenny, 2003) and are therefore are much more contextualized to the intricacies of its locality (Blank, 2005; Olfert & Partridge, 2010).

From this theoretical basis, place-based policies like industrial recruitment and industry cluster development have been attractive methods during the 1960s and 80s (Johnson, 2007) because they increase job growth rapidly in economically depressed areas, especially in areas where low-skill workforce and mobility are prevalent (Patridge & Richman, 2006). However, these policies may be costly and low yield, achieving only limited gains through primarily low-wage jobs. Critics also cite that harm stems from this type of quick-paced development (Crowe, 2006). Additionally, industrial recruitment strategies may lead rural communities to engage in a race to the bottom competition against each other, by offering expensive economic incentive packages at cost to greater community development.

The pure place strategy adopts a similar approach except applied to a larger geographical area, focuses on "improving the economic well-being of people in a geographic area extending well beyond the boundaries of the targeted area rather than to help only the residents of the targeted area" Ladd (1994). The belief is that if one community is able to flourish, its development will produce positive externalities for poorer neighboring communities. However, as was observable through this study, disparity across communities encourages out-migration from job-barren, economically distressed communities into their wealthier counterparts and may create a cycle of systematic preference where regional officials continue to invest their development programs into higher-performing communities. Moreover, such strategies are less ideally suited for long-term sustainable development for rural communities (Flora *et al*., 1992).

Alternatively, the place-based approach called "self-development" or "endogenous growth" approaches emerged in contrast to external growth stimulation. Self-development encourages and supports business development from within the community, drawing from local resources (Flora *et al*. 1992; Crowe, 2006). Such strategies can produce limited yields for a rural community – smaller numbers of jobs – while requiring large capital costs and technical assistance, which rural communities may not necessarily have. Furthermore, rural communities which were successfully able to implement self-development strategies were associated to also be successful with industrial recruitment strategies (Flora *et al*. 1992).

4.2 What is Place-Based Economic Development

The earliest forms of support for the person-based approach came from the urban development literature, where it was presented as an alternative to directly address the spatial dimensions of poverty, specifically the ghetto. Kain & Persky (1969) argued that place-based strategies overlooked the systematic factors which perpetuate poverty, such as disparate access to quality education, employment opportunities, and the psychological and social effects of living in low-income areas. People-based economic development focuses on developing human capital of poor, low-skilled individuals and increasing individual capability to compete in, and access formal labor markets. This may occur through education programs or skills training, transportation assistance to places of employment, or transfer payments and subsidies that enable them to leave their communities (Kain & Persky, 1969), but the ultimate goals is to promote the individual's labor capability, irrespective of locality, usually in a "spatially neutral," way to promote equitable access to resources (Olfert & Partridge, 2010).

Olfert & Partridge (2010) note that there is a "somewhat artificial distinction" between the types of policies. That is, the two development agendas have overlapping objectives that prevent a single, neat categorization of either policy. However, the greater lesson should not be in drawing distinctions, but that the bottom line of economic development is to raise living standards for members of a community. One strategy should not preclude another – the community cannot successfully thrive without considering the least advantaged members of its community. Persistent poverty is not simply inequitable, but leads to social and economic problems for the community; communities cannot succeed without thriving businesses and a strong tax base. Sound economic development must assume a balance of both approaches.

Furthermore, what these debates miss, and what critics on either side have come to realize, is that Intangible social goods, such as an educated workforce, social capital, e.g., a sense of community (Bolton, 1992; Crowe, 2006), and motivation for change are drivers for entrepreneurship and innovation (Olfert & Partridge, 2010; Faggian & McCann, 2009). Such intangible benefits are described as "security of stable expectations, and security of being able to operate in a familiar environment and to trust other citizens" (Bolton, 1992).

5. Conclusions and Recommendations

The Center's strategic economic development recommendations focused on both people-based and place-based strategies. The plan recognized that even the most successful economic development efforts likely would have

marginal effects on the broader Enfield community in the short term, but could set the stage for a better future for both the place and the people of the Enfield.

The Center first identified a set of industry clusters where the larger community had a potential competitive advantage. These focused heavily on the wood processing industries due to the abundance of timberland in the area and on small scale, value added food processing where the county has demonstrated recent and historical economic development success. It was suggested that Enfield not compete with the larger industrial sites in the region, but focus on niche, smaller scale businesses requiring less space.

Second, despite a relatively weak consumer market due to low incomes and a substantial population relying on government assistance programs, Enfield leaks much of its retail sales to the surrounding region. A list of retail development targets were identified for expansion into Enfield along with suggestions for how the local governments should provide assistance, concessions or incentives to promote retail location. These included financial assistance as retail sales or property tax breaks, concessionary financing (e.g. low-interest loans), and low-cost land, etc. The community may also offer non-financial forms of assistance, such as help creating a business plan or locating a store.

Third, the Center recommended that Enfield capitalize on its historic downtown commercial buildings historic residential structures. Several ongoing projects in the community included the renovation of a former historic home into a bed and breakfast and the restoration of a Masonic lodge into a theatre. It was recommended the Town pursue a formal historic district and identify historic properties to engage some pre-qualifying steps for current and future property owners to utilize federal and state historic rehabilitation tax credits to help finance their projects.

It was also recommended that the community leverage the inventory of existing historic homes for a “heritage housing” program to market these homes to potential newcomers, retirees, and others seeking relocation to North Carolina. This approach included using social networks and connections that already exist in the community, identify those individuals who have strong personal connections to the Enfield area, but who do not currently live here. In particular, efforts should focus on persons with the skills and assets that can provide important benefits to the community, such as entrepreneurs, educators, and professionals. Recruitment efforts should emphasize the availability of historic homes.

Several people-based strategies were also recommended to help the citizens of the Enfield area improve their lives and economic well-being. These included tackling the most prominent challenge of three school systems largely segregated on the basis of race and working to improve educational attainment in the community. Second, it was recommended that the community engage in recreational and vocation programs to engage youth, particularly in afterschool activities. Such programs will provide safe alternatives and address the youth delinquency and crime problems faced by the community. Third, it was recommended that the Partnership activity broaden participation and leadership opportunities for minority residents. This included reach out to local churches to encourage minority participation in the ongoing economic development planning and implementation efforts and inviting the mayor, town council members and town staff to participate in regular meetings and community events.

The challenged faced by Enfield are representative of the challenges faced by many post-agricultural and rural small town communities experiencing economic stagnation and depopulation. Communities facing these challenges are limited, especially in the short-term, in their options to address these challenges. Our findings suggest that communities should work to broaden public involvement to be inclusive and diverse in identifying community desires. Communities should also work to capitalize on their competitive advantages to retain and attract employment, even if these require pursuing nontraditional economic development approaches such as recruitment of retail stores or renovation of historic properties. Lastly, it is difficult for a small community facing broader trends of depopulation to buck the tide and continue to develop a strong place-based economic development strategy. Those communities should continue to work on people-based approaches to equip their citizens with the skills to allow them to out-migrate as needed to better employment options in other geographies.

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Table 1. Population Trends, 2000 and 2010

	2000	2010 (Est.)	Percent Change
1-Mile Radius	2,641	2,371	-10%
5-Mile Radius	5,457	4,790	-12%
10-Mile Radius	11,389	10,110	-11%
20-Mile Radius	138,166	136,889	-1%

Table 2. Population by Age Cohort, 2000 and 2010

Age Cohort	1-Mile Radius		5-Mile Radius		10-Mile Radius		20-Mile Radius	
	Absolute Change	**Annual Average**	**Absolute Change**	**Annual Average**	**Absolute Change**	**Annual Average**	**Absolute Change**	**Annual Average**
Under 18	-151	-2.3%	-325	-2.3%	-664	-2.4%	-3,882	-1.1%
18 - 24	-2	-0.1%	-23	-0.5%	-32	-0.3%	1,000	0.8%
25 – 34	24	0.9%	-40	-0.7%	-95	-0.7%	-1,284	-0.7%
35 – 44	-117	-3.8%	-241	-3.6%	-548	-3.8%	-4,667	-2.4%
45 – 54	-6	-0.2%	-19	-0.3%	-55	-0.4%	1,201	0.6%
55 – 64	37	1.4%	71	1.4%	210	1.8%	4,824	3.4%
65 and Over	-54	-1.2%	-90	-1.1%	-93	-0.6%	1,533	0.8%
Total Population	**-270**	**-1.1%**	**-667**	**-1.3%**	**-1,279**	**-1.2%**	**-1,277**	**-0.1%**

Table 3. Households by Race/Ethnicity, 2000 and 2010

Age Cohort	1-Mile Radius		5-Mile Radius		10-Mile Radius		20-Mile Radius	
	2000	**2010**	**2000**	**2010**	**2000**	**2010**	**2000**	**2010**
White/Caucasian	28%	23%	24%	21%	29%	28%	47%	44%
African-America	71%	76%	75%	78%	70%	71%	49%	52%
All Other Races	1%	1%	1%	1%	2%	3%	5%	6%

Figures may not sum to totals due to rounding.

Table 4. Teacher Turnover Rates, 2009-2010 Academic Year

Grade Level	Halifax County Public Schools	Weldon City Schools	Roanoke Rapids Graded School District
Elementary Schools	34%	25%	7%
Middle Schools	37%	19%	20%
High Schools	34%	N/A	13%

Table 5. Median Household Income by Race (2010 Dollars), 1999 and 2010

Age Cohort	1-Mile Radius		5-Mile Radius		10-Mile Radius		20-Mile Radius	
	1999	**2010**	**1999**	**2010**	**1999**	**2010**	**1999**	**2010**
White/Caucasian	$48,345	$44,844	$49,244	45,500	$49,969	$46,194	$54,236	$49,204
African-America	$23,034	$20,559	$26,070	23,577	$29,164	$26,514	$31,313	$28,548
Difference	**$25,312**	**$24,284**	**$23,174**	**$21,923**	**$20,805**	**$19,681**	**$22,923**	**$20,655**
Income Differential	**52%**	**54%**	**47%**	**48%**	**42%**	**43%**	**42%**	**42%**

Table 6. Median Household Income by Race (2010 Dollars), 1999 and 2010

Income Source	Town of Enfield		Halifax County		United States	
	1999	**2005-2009**	**1999**	**2005-2009**	**1999**	**2005-2009**
Wage or Salary	63%	61%	68%	65%	78%	77%
Self-Employment	4%	5%	7%	8%	12%	12%
Interest & Dividends	15%	15%	20%	15%	36%	25%
Social Security	36%	46%	34%	41%	26%	27%
Supplemental Security	18%	19%	11%	10%	4%	4%
Public Assistance	14%	5%	7%	2%	3%	2%
Retirement Savings	15%	13%	19%	18%	17%	17%
Other Sources	22%	18%	17%	17%	13%	14%
With Earnings	**65%**	**63%**	**70%**	**67%**	**81%**	**80%**
Without Earnings	**35%**	**37%**	**30%**	**33%**	**19%**	**20%**

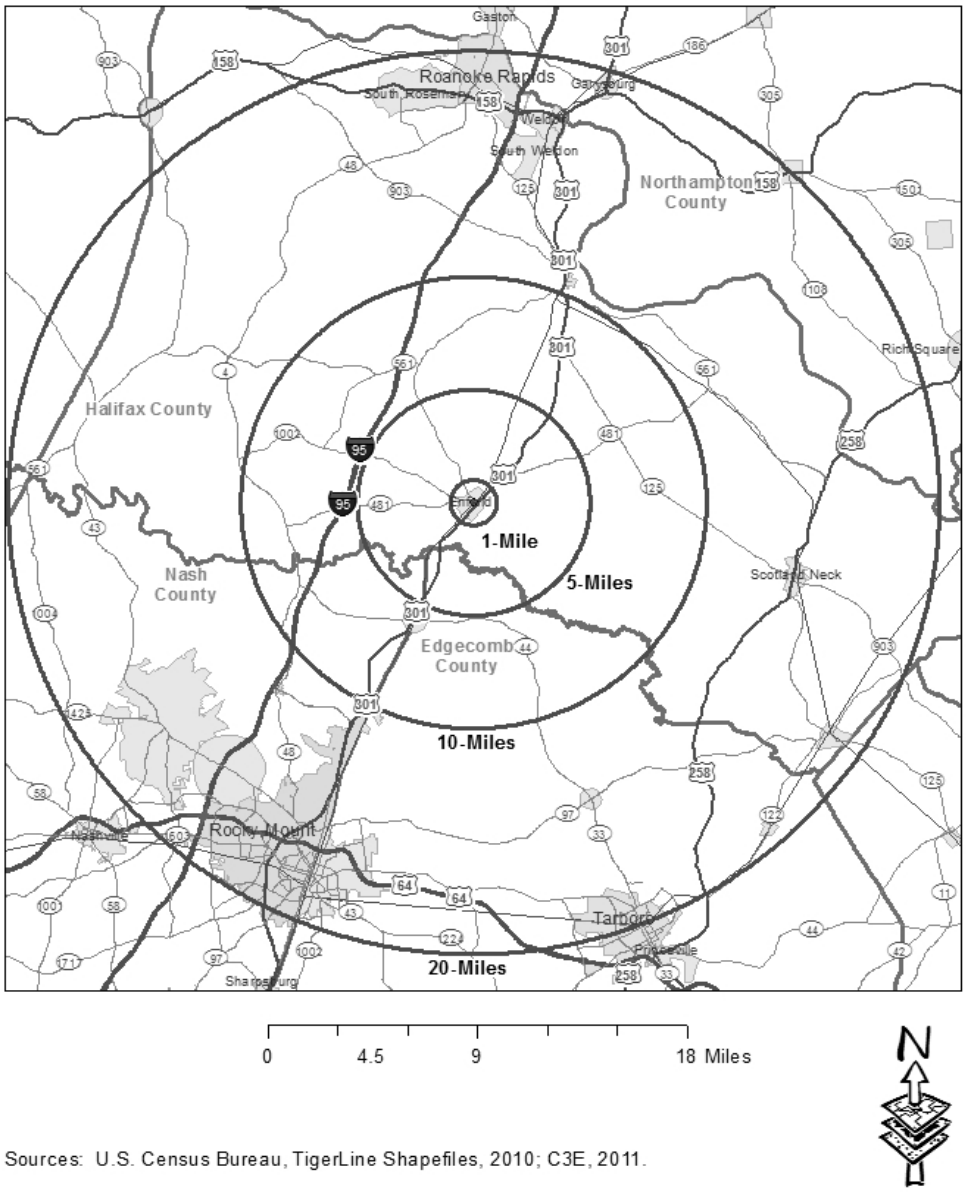

Figure 1. Study Area Geographic Boundaries

The Impact of Socio-Economic Characteristics on Coffee Farmers' Marketing Channel Choice: Evidence from Villa Rica, Peru

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Abstract

Villa Rica is one of the most important coffee-producing districts in Peru. In Villa Rica there are several marketing channels: intermediaries, private companies, cooperatives and associations. The intermediaries focus solely on higher prices while marketing organizations offer benefits to their members. The main aim of this paper is to analyze the socio-economic characteristics that influence coffee farmers to join a formal organization vs. those who distribute their product through intermediaries. A survey of 60 producers was carried out in June 2011 in Villa Rica. A binary logistic model was used in order to show how these characteristics affect farmers' choice of which marketing channel to use to distribute their product. The results demonstrated that farmers who are keen to receive technical assistance participate in the marketing organizations. These coffee marketing organizations should look for ways to improve the extension component through training and knowledge transfers to smallholder farmers.

Keywords: Socio-economic characteristics, Coffee marketing organization, Technical assistance, Logistic model, Intermediaries, Cooperative, Association, Private company

1. Introduction

Peru's main agricultural export item is coffee. Peru is the world's third largest coffee producer after Brazil and Colombia (Tulet, 2010), with over 160 000 farming families involved in coffee production (Peruvian Ministry of Agriculture, 2011). Even though 95% of the coffee beans production is destined for export markets, most coffee

producers live below the poverty line and manage agro-ecosystems in some of the world's most culturally and biologically diverse regions (Bacon, 2005). Villa Rica is one of Peru's most important coffee-producing districts due to its topography and climate which are ideal for this crop. The majority of farmers in this district are financially dependent upon coffee, and they only allocate a small portion of their land to growing subsistence crops or to diversifying crop mixes (Watson & Achinelly, 2008).

Over the past 20 years, domestic terrorist groups have frequently attacked the city of Villa Rica. Rural farmers lost their influence and found themselves isolated in the market due to the ruthless and violent tactics employed in this internal conflict. Small-scale farmers joined forces to form a union in an attempt to obtain economies of scale in marketing, pool their resources, and export their coffee (Bacon, 2005). Nevertheless, there is not a strong relationship between private coffee companies, associations, cooperatives and small-scale farmers (Yzaguirre & Saito, 2006). Small-scale farmers' land holdings are small. As their production volume is small and they can not commercialize individually, they market their coffee via a marketing organization (cooperative, association or private company). Many of the individuals have built links with a coffee marketing organization for the purposes of obtaining cheaper inputs and obtaining better access to marketing and capital equipment. Moreover, around 65% of the coffee is commercialized by these coffee marketing organizations which teach farmers production techniques and post-harvesting management (Table 1).

In Villa Rica there are two marketing channels (Figure 1): primary, there are the intermediaries who just focus on the prices, then, there are the coffee marketing organizations who for instance, give technical assistance to their members. In turn, they are subdivided into three sub-marketing channels: first of all, the private companies who monitor cocoa beans differentiation because of their participation in the international market. These private companies are composed of large-scale farmers who have the correct machinery to dry and ferment coffee beans and meet the quality that the international market demands. Subsequently, there are the cooperatives which distribute their coffee to the national and international markets. Finally, there are the associations who also distribute their cocoa as cooperatives. There are some differences between the associations and cooperatives: the latter share the income from the sales surplus at the end of the year with its members. After selling their high quality beans to the international market, these coffee marketing organizations sell their low quality coffee beans to the national industry.

Farmers from the same district who choose intermediaries may have very different holdings, practices, demographics, or outlooks from their counterparts who choose to participate in an organization (Arnould, Plastina & Ball, 2009). Measuring farmers' perceptions as well as studying the socio-economic characteristics and information-seeking behavior that influence those perceptions should be the preliminary step in developing extension programs to promote sustainability among farmers (Füsun Tathdil, Boz & Tatlidil, 2009a). Therefore, it is important to understand the socio-economic characteristics to make judgments about the effects of different policies on economic welfare. The main aim of this paper is to analyze the socio-economic characteristics that influence membership in a coffee marketing organization vs. coffee farmers who distribute their product through intermediaries.

2. Data

A survey of the coffee producers was carried out in June 2011 in Villa Rica, Pasco (one of the largest coffee producing region in Peru). Primary data was gathered by using a structured questionnaire at the study site with the CUNAVIR cooperative and the support of the local authorities in Villa Rica. This covered topics such as the socio-economic characteristics of households and marketing information. The CUNAVIR cooperative has approximately 200 members and is currently the largest association in Villa Rica. Interviews were conducted by the CUNAVIR cooperative which collected 30 completed surveys from its members. The Villa Rica authorities also contributed to this analysis by collecting 25 completed surveys from farmers who commercialize through intermediaries and also 5 surveys from farmers who use private companies. As we want to measure which personal characteristics were important in the decision-making process about which marketing channel were chosen by small-scale farmers for commercializing their product (coffee marketing organizations vs. intermediaries), those 5 farmers who use private companies were also added to the 25 CUNAVIR members sample. Consequently, for the purposes of analysis, there are 35 farmers in this sample who participate in an organization vs. 25 farmers who commercialize their coffee through intermediaries. An interview with a local government agronomist was also considered for qualitative description purposes.

3. Modeling Approach

To identify the factors which make farmers choose a given marketing channel to commercialize their coffee, a bivariate logistic regression was estimated. This helps examine the effect of different household factors on

membership in an organization or distribution of their coffee through intermediaries. As membership in a coffee marketing organization is a binary decision, a logistic model was used in order to determine what socio-economic factors influence the choice to sell coffee through a formal organization or through the intermediaries. The odds ratio related to each explanatory variable is reported in the results section, and the ratio can be interpreted as a multiplier of the odds of having the willingness to belong or not to the cooperative. If the value is greater than 1, then it indicates that as the predictor increases, the odds of cooperative membership increase and vice-versa (Field, A., 2009). The econometric model is given in Equation 1:

$$P(Y) = \frac{1}{1+e^{-(b_0+b_1X_1+b_2X_2+\ldots b_iX_i\ldots+b_nX_n+\mu)}} \quad (1)$$

Using the Binary logistic regression model equation (1) for the model purposes, Y is the marketing channel that the farmer chooses (if Y= 1, the farmer belongs to an organization; otherwise if Y=0, the farmer chose the intermediaries); $P(Y)$ is the probability of participation in a marketing channel, b_0 is the intercept, b_i (i= 1~n) are the estimated model coefficients; x_i (i= 1~n) are the independent variables and finally, μ is a random error term. Summary statistics for the variables included in the logistic model are given in Table 2.

Peruvian coffee family plots range from 3 to 5 hectares of land (Peruvian Ministry of Agriculture, 2011). Among surveyed households, both marketing organizations' members and non members have area plants above the national average. An important reason is that Villa Rica has fertile soils and also an appropriate climate to cultivate this crop.

It is expected that farmers see a positive effect from receiving technical assistance because they participate as a member in a coffee marketing organization. Bias was controlled by not considering the marketing organization in which the farmer is currently a member as an institution that gives technical assistance to the farmers (N.instcha-1). After all, if coffee farmers belong to this institution, then they will have free access to technical assistance, which gives its members advantages compared to non members, and thus becomes a potential source of bias in this model.

Socio-economic variables are commonly used by many researchers to study the influence of different factors on the behavior of a specific group of people (Füsun Tathdil, Boz & Tatlidi, 2009b). Socio-demographic variables such as gender, age, education and income influence people's opinions about farming (Boogard, Bock, Oosting, Wiskerke & van der Zijpp, 2011). Previous studies about Peruvian fair trade cooperatives found that members generally plant crops in slightly larger areas, which also encourages gender equality than in non-member households (Murray, Raynolds & Taylor, 2006a). Thus, female membership improves their process of economic development. Moreover, the more educated the farmers are, the more receptive they will be with regards to the adoption of new technologies. Nonetheless, being a member of a Peruvian cooperative for instance is not a significant predictor of education (Murray, Raynolds & Taylor, 2006b). Farmers who are married are generally involved in an organization compared to single farmers who commercialize through the intermediaries as the former are more likely to be under pressure to produce more, not only for family consumption but also for sale (Opara, 2010). In addition, age can be considered as an indicator of experience in farming (Gebremedhin, Jaleta & Hoekstra, 2009) which has relationship with agricultural activities because off-farm work first increases and then decreases with age (Lien, Kumbhakar & Hardaker, 2010).

4. Results and Discussion

Table 3 shows the results of the logistic model. Exp (B) is the exponentiation of the B coefficient, which is an odds ratio. A correlation matrix was previously used to detect the presence of co-linearity between the explanatory variables used in the model. The variables selected for the econometric model are not highly correlated, thus avoiding potential biases in the model estimation.

Estimation results show that when the number of institutions that give technical assistance to the farmers increased by a unit, the change in the odds of membership to an organization was 9.70; farmers who belong to a marketing organization are concerned about their knowledge and learning sustainable techniques so as to become competitive in the market. Farmers who distribute their coffee through intermediaries, meanwhile, do not receive any exposure to alternative production technologies as it is difficult for them to exchange ideas with other group members.

As expected, being older equates to more experience in cultivating coffee. Thus, it has a positive effect on the odds of joining an organization ($p<0.05$), making it more likely to participate in market, having better farming capacity and having access to information. Likewise, the number of members in a household has a significant but negative effect ($p<0.05$) because farmers who belong to an organization prefer to send their children to school

instead of having them help out on the farm. Thus, part time labor is hired especially during the harvest season and adult males with less than primary school education are the most common agricultural workers (Dammert, 2007). Married members seems to be more engaged in farm work ($p<0.05$) than non-members. The reason for this could be that the partner may choose to stay at home to care for their children, helping on the farm and also in domestic tasks. This could be an incentive to the married farmer to use agricultural information as it is their desire to produce greater quantities and better quality goods in order to obtain more income to improve their livelihoods.

5. Conclusions

Socioeconomic characteristics are found to be effective in predicting a farmer's marketing choice. Numerical results demonstrate that farmers who join an organization are particularly keen to gain technical assistance because they then can learn more techniques in order to improve their knowledge and improve their standard of living. Results also demonstrated that farmers who possess the following attributes were more likely to participate in an organization: 1) being older and 2) being married. Alternatively, farmers who commercialize through intermediaries require more household members to help in farm tasks.

A review of the analyzed socioeconomic features is important for farmers' organizations in order to make decisions so that they can empower themselves and encourage participation and unity among their members. Organizations should look for ways to improve the extension component so as to improve agricultural productivity through training and knowledge transfers to smallholder farmers. Moreover, compensation schemes such as the distribution of surplus income sharing among members act as an incentive to produce good quality coffee beans.

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Table 1. Breakdown of coffee selling percentage by marketing channel

Marketing channels	Intermediaries	Coffee marketing organizations		
		Associations	Cooperatives	Private companies
Coffee selling in metric tons (%)	35%	30%	5%	30%

Source: Proamazonia, 2003

Table 2. Summary Statistics

Variable	Description	Total (n=60)		Org member (n=35)		Intermediaries (n=25)	
		Mean	SD	Mean	SD	Mean	SD
Orgmembr	Member of an organization (yes=1, no=0)	0.58	0.50	1.00	0.00	0.00	0.00
N.inst-1	No. of institutions -1 that gives Technical assistance (number)	0.85	1.10	1.29	1.23	0.24	0.44
Coffeelnd	Coffee land (ha)	5.34	8.02	5.21	6.33	5.52	10.08
Age	Farmer's age (years)	47.62	12.86	50.77	14.18	43.20	9.32
Education	Education (years)	8.87	3.78	8.86	4.20	8.88	3.18
Fammbr	Family members that work on the farm	4.05	2.00	3.97	2.01	4.16	1.97
Occupat	Occupation (agriculture=1, other=0)	0.78	0.42	0.80	0.41	0.76	0.44
Sex	Sex (male=1, female=0)	0.88	0.32	0.86	0.36	0.92	0.28
Married	Married (yes=1, no=0)	0.80	0.40	0.83	0.38	0.76	0.44

Table 3. Results of the binomial logistic regression model

Variable	B (SE)	95% confidence intervals for odds ratio		
		Lower	Odds ratio	Upper
Intercept	-4.54(2.71)*		0.01	
N.instcha-1	2.27(0.70)***	2.45	9.70	38.49
Coffeelnd	0.06(0.05)	0.97	1.06	1.16
Age	0.84(0.04)**	1.00	1.09	1.18
Education	0.05(0.11)	0.86	1.06	1.30
Famemb	-0.52(0.25)**	0.37	0.60	0.99
Occup	0.55(0.94)	0.37	0.60	0.98
Sex	-1.17(1.08)	0.04	0.31	2.54
Married	2.27(1.18)**	0.17	9.68	97.39

R^2= 0.42 (Cox & Snell), 0.56(Nagelkerke), ***p<0.10, **p<0.05, ***p<0.01.

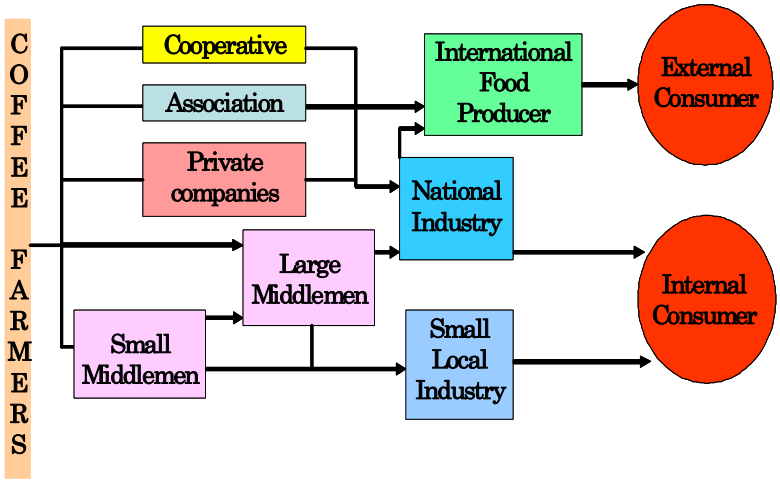

Figure 1. Peruvian coffee marketing channel

Source: Agromarketing, 2007

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Performance in the Production of Organic, Biofertilized and Conventional Guava in Zitacuaro´s Region, Michoacan, Mexico

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Abstract

The organic market is growing at a steady pace of 20 percent annually; this farming method can bring several advantages to the consumers and also to the farmers. Among other things organic farming does not have to rely on access to external inputs such as fertilizer and pesticides because the farmers make use of their own resources. This not only represents a friendlier environment to the farmer or the land but also can be cheaper. The aim of this study is to find out the yield differential between three productions systems (organic, biofertilized and conventional) of guava crops in Zitacuaro, Michoacan, Mexico.

The results indicated that the most profitable crop in terms of production costs and profits on Zitacuaro´s region is the biofertilized crop that takes up the sustainable practices combined with conventional practices in a lesser proportion. While organic and conventional crops shows a slide difference between them.

Keywords: Profitability, Yield, Regional production systems, Cost-benefit, Sustainability

1. Introduction

There is a strong trend towards the consumption of friendly products to the environment. The tendency of consumers around the world has been changing. The demand for healthier products has increased substantially in recent years; among these products include the strong demand for organic products. The main consumers of these products are the development countries such as U.S, Japan, Canada and European Union´s economies (Gomez, L. *et al*., 2001).

The demand for organic products has seen annual growth of 32 per cent and is expected that the consumption of organic products continue to rise in coming years (CIESSTAM, 2001, 2005). Over these years, the organic food sector underwent a transformation; by the time retail sales reached $21.1 billion usd in 2008, structural changes had revamped organic food marketing (Nutrition Business Journal, 2009).

Mexico has not lagged behind in this trend because nowadays some fraction of farmers begin to use different technologies to conventional farming, either partially or completely suppressed chemical inputs and allowing the introduction to the organic system. These products can be found crops such as coffee and avocado (FIRA, 2003). However there is a wide variety of products that begin to be cultivated by following these trends, as is the case of

Michoacan guava.

It is noteworthy that the province of Michoacan is currently the first producer of guava in Mexico with a share of the domestic production of 40 per cent of national production and harvested area of 8 726 tons with a growth rate of over 18 per cent in the last five years Susupuato, Juárez, Jungapeo, Tuxpan and Zitácuaro. These municipalities were selected for the research.

It is important that prior implement and promote a change on harvest in the province of Michoacan from the conventional agricultural system to an organic one is necessary know the yield differential between the different production system mentioned including the biofertilized (Note 1). In order to gives an accurate guidance to producers and decision makers being this the objective of this study.

The tool used in order to accomplish the objective is the Policy Analysis Matrix (PAM). This methodology has been applied to several countries (Barichello *et al*., 1998; Yao, 1997; Yao & Tinprapha, 1995; Nelson & Panggabean, 1991) because this methodology can show the profitability differential of each type of crops pointing out the possible problems on the production process.

2. Research Methods

In many countries have been defining food securities as grain security, bringing policymakers' active interference in grain markets and trade (Crook, 1997, 1999). The Policy Analysis Matrix (PAM) is methodology provides a tool for identifying the problems of the production process, with a systematic vision, stretching from the inputs obtaining until the product finally reaches the consumer's hands, this matrix allows us to measure effects on the economy and the effects of the economy in the production system; so it is useful for producing agents, implementers and decision makers (Monke & Pearson, 1989) and (Pearson *et al.*, 1991).

To construct the matrix, costs are classified in tradable and nontradable inputs. Economic valuation of the prices of the internal factors is done on the basis of respective opportunity costs, with the aim of estimating the values of scarcity that represent the net lost income, because the factor is not oriented towards its better alternative use (Hernandez, García, Valdivia & Omaña, 2004).

2.1 Accounting entities of the PAM

In the PAM are provided two accounting entities:

1) Earnings are measured as the difference between revenue and production costs.

$$Ganancias = \sum P_i X_i - \left[\sum P_j Y_j + \sum P_k Z_k\right]$$

Where:
Pi: price of product in the domestic market.
Xi: number of tons produced per hectare.
Pj: price of tradable inputs in the domestic market.
J: number of tradable and indirectly tradable inputs applied per acre.
Pk: price of domestic factors in the domestic market.
Zk: number of internal factors applied per acre.
The first accounting identity represented by $\sum P_i X_i$ (price of the product by the number of tons produced per hectare) represents the producer's income received by harvest a given product, and the second identity represented by $\sum PjYj + \sum PkZk$ (the sum of the price of tradable inputs by number of tradable inputs and the prices of domestic factors by the number of internal factors, everything in domestic prices) presents the costs borne by the producer in order to reap certain product (Kray, 2002) and (Winter and Aggrey, 2008) .

2) Measures the effects of policy and market distortions and is determined by the differences between the private evaluations, i.e. income, gains and costs incurred by the producer, and the economics of revenues, costs and profits (Ramanovich, 2002).

It is important to point out that this paper focus on the first accounting entity, corresponding with the valued at private prices. In order to get the information it was apply a questionnaire to the 80 per cent of the farmers of the region being in total 147 interviews. This stage of the research starts on october 2008 and finish early 2009.

3. Analysis Result

With the purpose of find out the profitability differential between the different production system the analysis of the results obtained is divided in five subsections the first one show the production per tree, the second one the average yield, the third one the cost of tradable inputs, the fourth the cost of internal factors and the fifth one the cost-benefit relation for the three methods of farming (organic, biofertilized and conventional).

3.1 Production per tree

The results shown (figure 1) that the average productions per tree are the highest in biofertilized crops, followed by the production per tree of conventional crops.

Organic guava crops show the lower average production for each tree; this production is comparatively lower compared to conventional crops in a 10.14 per cent and 29 per cent lower than production under biofertilized technique.

3.2 Avarage yield of guava production

Analyzing the yields obtained by crop type can be seen that on average the lowest yield is obtained from organic production is 13.2 tons per hectare, followed by conventional production 18.8 tons/ha. The crop with the highest yield is the biofertilized with a production of 22 tons per hectare. These results show that the guava production is lower in organic farming being 5.6 kg less than conventional farming and 8.8 lower than biofertilized farming. It is important to point out that on average in conventional or traditional farming there are 336 trees planted per hectare while in biofertilized and organic the planted trees per hectare are only 300.

3.3 Cost of tradable inputs by type of crops

The cost structure according to the PAM is divided into tradable inputs costs and internal factors cost.

Tradable inputs cost consists on costs of fertilizers, pesticides, supplies to fight plants disease and eliminate the weeds. It is important to note that herbicides were not counted because the population of the region that uses them is a very small fraction, being the brush cutters the most common method used.

The bigger spend on tradable inputs is occupied by the conventional crops, followed by biofertilized crops, so the organic farming is the one that have the lowest cost on tradable inputs. There is an important differences between the three types of crops in terms of tradable inputs as it show the figure 3, were the amount between organic farming and traditional farming is more than half.

3.4 Cost of internal factors by type of crops

The internal factors cost compose three items pruning, irrigation and harvesting, where the main factors are labor and water, regarding pruning and irrigation areas there were no technological differences.

In figure 3, can be seen that the cost of international factors once again the lowest costs is occupied by the organic crops with almost have the cost on biofertlized and conventional crops. The biofertlized and conventional crops cost in this items are almost the same being a little more expensive the biofertilized crops.

3.5 Cost-benefit relation

The cost/benefit relation could be the most important data in terms of profitability and gives a closer picture of the differences between the different technologies in the cultivation of guava, and which one is the most beneficial financially.

According to the data the results show (Figure 5) a big difference between each type of production. The most profitable type of production, with a clear advantage is the biofertilized production with 5.65 points, while organic and conventional crops shows a slide difference with values of 3.45 and 3.75 respectively. These results indicated that the most profitable crop in terms of production costs and profits of the farmer for the case of Zitacuaro region on the state of Michoacan is the crop that takes up the sustainable practices combined with conventional practices in a lesser proportion but without a complete elimination.

Worth noting that the organic farmers are not getting the premium paid by the final consumer at a premium ranging above conventional products by the cultivation of guava, factor that could be key for future conversion.

4. Discussion

Agricultural development can no longer do without sustainability. The different approaches to Sustainable Agriculture focus on: 1.giving greater consideration to the environment in agriculture, 2.reducing external input (but not generally rejecting chemicals in all cases), and 3.usually, an integration of local elements (Misereor, 1995, 2003).

Many factors have to be considered when comparing organic and conventional farming. Area productivity as a conventional measure is not meaningful on its own. There is plenty evidence in the literature review (Rosset, 1999), (Rosen, S. & Larson, B.A., 2000), (Röhm, O. & Dabbert, S., 1999), (FAO, 2002) y (UNDP, 1992) of yield increases having been attained with organic farming. However, in most cases, and in all local conditions, increases in income have been recorded for poor smallholders thanks to using local resources and not having to

rely on expensive external means of production decreasing the cost of tradable inputs as is the case of the present work.

Pimentel, Hepperly, Hanson, Douds and Seidel (2005) analyzed the environmental, energy and economic costs/benefits of growing soybeans and corn organically versus conventionally the study found that organic farming produces the same yield of corn and soybeans as does conventional farming, but uses 30 percent less energy, less water and no pesticides.

Some other works point out that farmers expend more in labor intensive, since farmers avoid chemical fertilizers, pesticides and herbicides relying on hand weeding for example, where the crop yield is usually lower being the production cost more expensive in the short term (Alvarez, 2008).

In the case of the present study in the short term the most profitable type of production is the biofertilized. This type of farming use sustainable practices and conventional ones. The results also show that the organic farming is cheaper in terms of tradable inputs cost this because the farmers instead of using external inputs use local resources like compost, labor work, etc. Being this an important factor of competitiveness when the international prices are increasing constantly and events as the present crisis could affect the stability of the crops yield. However the production per tree in the research area is lower than the biofertilized and conventional crops. This could represent a discourage to convert the crops into a more sustainable farming but the final results show in the cost-benefits relation that the sustainable practices and the reduction of the use of chemicals increase the profitability in guava crops of Michoacan, Mexico.

In the long run, organic farming can offers advantages compared to conventional farming because it not only promises higher yields but also ensures higher yield security, reduces dependence on external input and thus makes poor households less crisis-prone. However an important factor to achieve the increase on profits is that the farmers be able to get a good selling price instead of see how the brokers perceive all the yields.

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Note

Note 1. Biofertilized is term used for crops that implement sustainable practices and reduce the chemicals partially.

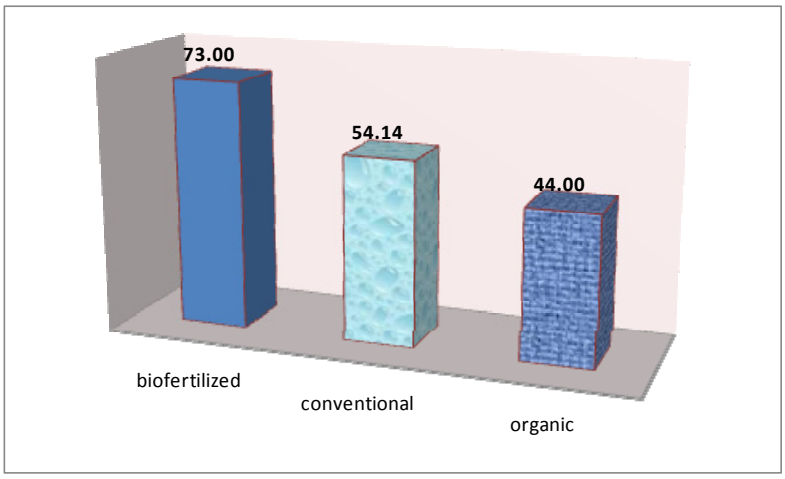

Figure 1. Production per tree (avarage in kilograms)

Source: Authors´s calculations based on data obtained from questionnaires

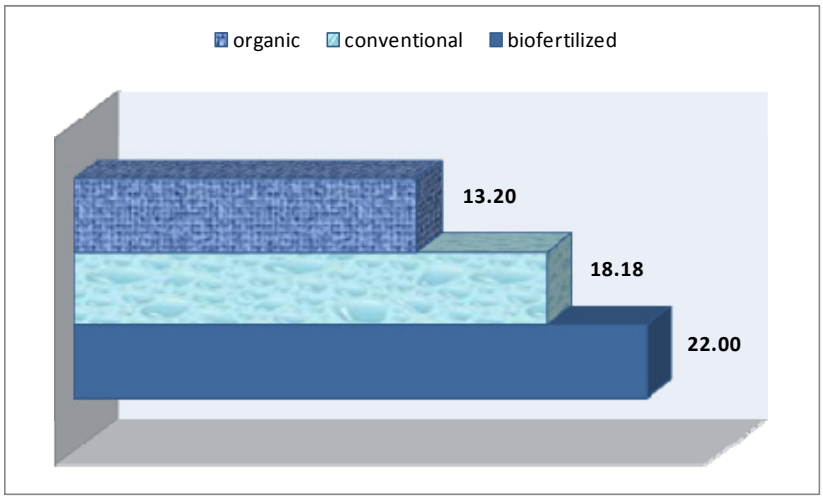

Figure 2. Avarage yield of guava production by crop type (Ton/ha)

Source: Authors´s calculations based on data obtained from questionnaires

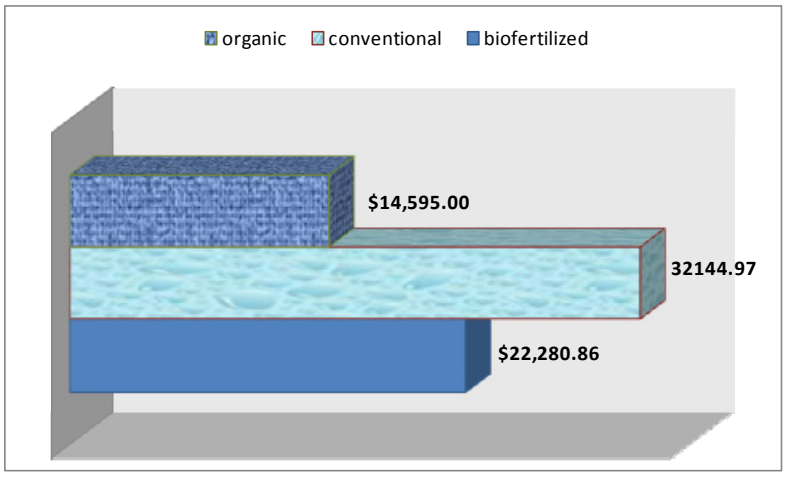

Figure 3. Cost tradable inputs type of crops (per hectare)

Source: Authors´s calculations based on data obtained from questionnaires

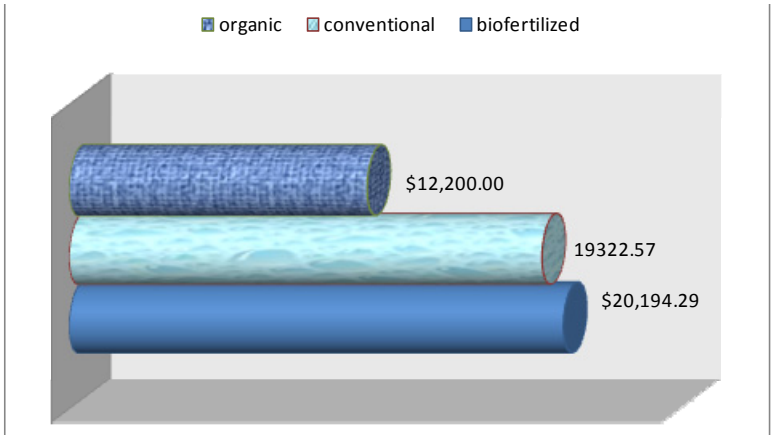

Figure 4. Cost per hectare internal factors by type of crops

Source: Authors´s calculations based on data obtained from questionnaires

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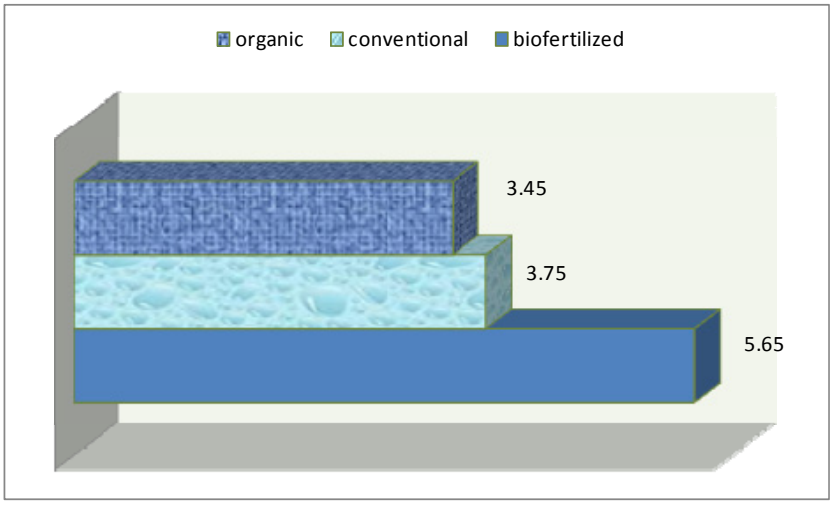

Figure 5. Cost-benefit relation by type of crop

Source: Authors´s calculations based on data obtained from questionnaires

Prospecting Antioxidant Capacities and Health-Enhancing Phytonutrient Contents of Southern Highbush Blueberry Wine Compared to Grape Wines and Fruit Liquors

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Abstract

Blueberry wines may have a multitude of health benefits, but few studies have quantified the health-enhancing antioxidants, total phenols, anthocyanins and flavonoids in blueberry wines, especially the Southern highbush blueberry wine, in comparison to grape wines and fruit liquors. This study was initiated to fill such a gap by measuring the antioxidant capacity and key phytonutrients of Southern highbush blueberry wine as compared to red, Rose and white wines and fruit liquors. The Oxygen Radical Absorbance Capacity (ORAC) of the Southern highbush blueberry wine tested in this study ranged from 18.54 to 25.48 mmol TE/L, with an average of 22.57 ± 2.92 mmol TE/L. This was higher than the ORAC values of over 80% of the red wines and 100% of the Rose and white wines reported in literature. A majority of the red wines were higher, but all the Rose and white wines and most fruit liquors were lower in total phenolic content than the Southern highbush blueberry wine. Anthocyanin contents of the blueberry wines were generally comparable to those of the red wines. Results show that blueberry wines could be more potent than most red, Rose and white wines in health enhancement and disease prevention from the antioxidant perspective.

Keywords: Blueberry, Wine, Antioxidant, Phenolic, Anthocyanin, Flavonoid, ORAC

1. Introduction

Blueberry (*Vaccinium spp*.) is a popular natural food product consumed worldwide. For centuries, native American tribes have used the leaves, roots, and fruits from the blueberry plant for medicinal purposes (Sanchez-Moreno *et al*., 2003), and blueberries continue to be used in many types of dietary health products as pharmaceutical or food supplements in modern society (Kalt & Dufour, 1997). In the U.S., blueberries rank only second to strawberries in terms of berry consumption, while in Canada, blueberry is the largest fruit crop grown nationally, accounting for over ½ of entire Canadian fruit acreage (Scrivener, 2008).

In North America, the most commonly cultivated species is the (Northern) highbush blueberry, but with adaption to the Southern U.S. climate, its hybrid like the Southern highbush blueberry, which was developed by crossing northern highbush varieties from Michigan and New Jersey with wild blueberries native in Florida and other southeastern states (Williamson & Lyrene, 2004), has been created and quickly spread to Florida, Georgia, California, and even the Mediterranean regions of Europe, Southern Hemisphere countries and China. According to the U.S. blueberry (cultivated and wild) production and utilization data (USDA, 2009), of the total utilized production of 204 million tons in 2009, 101 million tons were for fresh use, while 103 million tons were processed, including blueberry wine production.

Since blueberries are on the top of most everyday fruits grown or marketed in North America in terms of antioxidant capacities (USDA, 2010), blueberry wines also contain significant amounts of phenols and has significantly higher antioxidant activity compared to many other wine products (Saucier *et al*., 1999). Antioxidants are critical to health protection by their ability to combat the free radicals that can cause damages to cellular structures or DNA. Literature shows a multitude of health benefits of blueberries and blueberry wine.

Due to the presence of anthocyanin, blueberries can considerably improve cardiovascular health. The anthocyanin and resveratrol contents in blueberry, which have natural cardiovascular protective qualities, are comparable or higher than in red wine (Sanchez-morendo *et al*., 2003). Also, blueberry wine has marginally higher antioxidant ability than red wine and much higher antioxidant capacity than white wine (Sanchez-morendo *et al*., 2003), so blueberry wine may be more potent than red wine in preventing heart diseases.

Literature shows that blueberries have improved the learning capacity and motor skills in aging animals, thus reducing the chances of dementia or Alzheimer's (Robert *et al*., 1977; Joseph *et al*., 1999; Shukitt-Hale *et al*., 1999; Greenwell, 2000). Blueberries have also been found to offer protection from urinary tract infections caused by bacteria adhering to the mucosal lining of the bladder or urinary tract (Ofek *et al*., 1991; Jepson & Craig, 2007). Highly beneficial to the digestive and excretory system, antioxidants in blueberries help combat free radicals that can cause inflammation on the digestive pathways, and thus prevents occurrence of peptic ulcers **(**Watson, 2001**)**. Eating blueberries, drinking blueberry juice, or taking blueberry wine in an appropriate quantity may help heal the existing ulcer or hemorrhoid condition (Seeram *et al*., 2008).

In addition, blueberries can improve day or nighttime vision, reduce the restoration time after exposure to glare, and prevent weakness of eyes (macular degeneration) arising from aging. The various phytonutrients present in blueberries, such as anthocyanin, flavonoids and phenolics, part of which are carried forward to wine during fermentation, are known for their benefits to the eyes and canhelp protect against occurrences of "Cataracts" (Robert *et al*., 1977; Greenwell, 2000). Studies also show that some compounds, such as polyphenols (flavonoids, proanthocyanidins, ellagitannins, etc.), stilbenoids,lignans and triterpenoids, present in blueberries are capable of inhibiting cell proliferation in the human breast, colon and ovarian cancers (Damianaki *et al*., 2000; Seeram *et al*., 2008).

Blueberry wine is usually produced by fermentation through nontraditional methods. During blueberry wine processing, an initial press of the berries provides the juice used for fermentation along with its skin and seeds. Sulfur dioxide and pectin enzymes are usually added. After the primary fermentation, usually 2-3 weeks, wine is separated from the dregs on a free run basis and the residuals are lightly pressed to extract the remaining wine.

During fermentation, phenolic compounds including catechins and other components, flavonoids and anthocyanins are transferred from the juice, skins or seeds into the blueberry wine. Su and Chien (2007) reported that the blueberry wine making process did not really lower the anthocyanin content. There are only a few studies that have quantified the antioxidant capacity, anthocyanins and total phenols in blueberry wines, e.g., Sanchez-Moreno *et al*. (2003), Su and Chien (2007) and Johnson *et al*. (2011). However, no analytical quantification of the foregoing antioxidant activity and phytonutrients was found in literature for the Southern highbush blueberry wine. Therefore, the objective of this study was to prospect the antioxidant capacity and key phytonutrients of Southern highbush blueberry wine and systematically compare with grape wines and fruit liquors.

2. Materials and Methods

2.1 Southern Highbush Blueberry Wine Samples

Southern highbush blueberry wine was obtained from a local blueberry winery for two batches of experiments conducted at the University of Florida. The blueberries used to produce the wine were a mixture of several cultivars including Star, Windsor, Emerald, Primadonna and Jewel. In the first batch, three 750 mL bottles were obtained for each of the different processing conditions: low sulfite, unfiltered; sulfite, unfiltered; and sulfite, filtered. Low sulfite consisted of 30 ppm total sulfites, while normal levels of sulfite were 150 ppm total sulfites. Filtering was performed first with a crude filter (>1 μm) with subsequent filtration by a fine filter (>0.45 μm). Two 10 mL portions of wine from each bottle were sampled for analysis, making 6 total observations for each wine. In a second study, 12 liters of non-sulfite, filtered wine, which was eligible for labeling as "organic," were obtained from the same local winery.

2.2 Determination of Antioxidant Capacity

Antioxidant capacity of the Southern highbush blueberry wine was measured by the Oxygen Radical Absorbance Capacity (ORAC) method. The ORAC values were expressed as mmol Trolox equivalent (TE) per liter.

For the filtered blueberry wine with no sulfite added, the ORAC values were determined using a modified method per Huang *et al*. (2002). Briefly, 50μL ORAC Phosphate Buffer (75mM, ORAC-PB) and appropriately diluted samples were added to a 96-well black plate (Fisher Scientific, Pittsburg, PA). This was followed by addition of 100μL, 20nM fluorescein working solution to all filled wells. The mixture was incubated at 37^{o}C for

10 min before the addition of peroxyl radical generator 2,2'azobis (2-amidinopropane) dihydrochloride (140mM, AAPH). The rate of fluorescence decay was monitored over time by calculating the area under the fluorescent decay curve and quantified using a standard curve of TROLOX, using a Spectra Max Gemini XPS microplate reader (Molecular Devices, Sunnyvale, CA). The fluorescence was monitored at 485 nm excitation and 530 nm emissions for 40 min at 1 min intervals. The antioxidant capacities of the extracts were expressed as mmol TE/L of blueberry wine.

For the other wines, the ORAC procedure was basically the same as above, except for different dilutions as: 1:1000, 1:1500, 1:2000, and 1:3000.

2.3 Determination of Total Phenols

Total phenols were determined using a modification of Folin-Ciocalteu's method. To a 96 well clear plate (Fisher Scientific, Pittsburg, PA), 12.5µl of 2N Folin-Ciocalteu's phenol reagent was added to 50 µl of deionized distilled water (ddH_2O) and 12.5µl of wine sample. After 5 min, 7% sodium carbonate (Na_2CO_3) solution (125µl) was added to the mixture and incubated (90 min, 25°C). The absorbance of the sample was measured at 750 nm versus a reagent blank using a microplate reader. A standard curve for total phenolics was developed using gallic acid. The concentration was expressed as mg of gallic acid equivalents (GAE)/L of wine.

2.4 Determination of Total Flavonoids

A standard colorimetric assay (Kim *et al*., 2003) with slight modifications was used to quantify total flavonoid content. To a 96 well clear plate, 25µl of the wine sample was added to 125 µl of ddH_2O. Subsequently, 7.5µl of 5% sodium nitrate ($NaNO_2$) was added to the mixture and allowed to stand for 5 min. Fifteen microliters of 10% aluminum chloride ($AlCl_3$) was added to the mixture and incubated at ambient temperature for an additional 5 min. Following that, 50 µl of sodium hydroxide (1M, NaOH) were added to the mixture and immediately diluted by the addition of 27.5µl of ddH_2O. The absorbance of the mixture was measured at 510nm against a reagent blank and compared to a catechin standard using a microplate reader. The total flavonoids was expressed as mg of catechin equivalents (CE)/L of wine.

2.5 Determination of Total Anthocyanins

Total anthocyanins were determined by the pH differential method (Benvenuti *et al*., 2004). Two buffer systems, potassium chloride (KCl) (pH 1.0, 0.025 M) and sodium acetate ($NaC_2H_3O_2$) (pH 4.5, 0.4 M) were utilized. An aliquot of the blueberry extracts were diluted (1:10) and adjusted to pH 1.0 and pH 4.5 using the prepared buffers. Subsequently, the solutions were incubated at ambient temperature for 20 min. Absorbance was measured using a UV/VIS spectrophotometer (Beckman Coulter, Du 730, Life Sciences UV/VIS, Lawrence, KS) at 510nm and 700 nm at each pH, respectively. Results were calculated using equations 1 and 2 below and expressed as mg of cyanidin-3-glucoside/L of wine.

$$A = (A_{510nm} - A_{700nm})_{pH1.0} - (A_{510nm} - A_{700nm})_{pH4.5} \quad (1)$$

$$\text{Anthocyanins} = A \times MW \times DF \times 1000/(\varepsilon \times 1) \quad (2)$$

where A is absorbance, MW molecular weight [449.2]), DF dilution factor, ε molar absorptivity [26, 900] (Sellappan *et al*., 2002).

2.6 Statistical Analysis and Comparison

For the blueberry wine data obtained in this study, significant differences were analyzed using 1-way ANOVA, with means separated by the Tukey's Studentized Range test, using SAS version 9.0 at a 0.05 significance level. For the comparison among blueberry wines, grape wines and fruit liquors, a literature search was conducted to gather the reported data on ORAC, total phenols and anthocyanins and tabulate them together with the measured values from this study that were referenced as a benchmark value. A percentage was calculated for the wines or fruit liquors that were above or below the benchmark values of the blueberry wine.

3. Results and Discussion

3.1 Antioxidant Capacities, Total Phenols, Anthocyanins and Flavonoids of Southern Highbush Blueberry Wine

Similar to the USDA (2010) database for the ORAC values of selected foods, antioxidant capacity of the Southern highbush blueberry wine, with or without sulfite and filtration, was also determined by the ORAC method and expressed in the TROLOX equivalent (TE) values. The key phytonutrients (i.e., total phenols, total anthocyanins and total flavonoids) were measured for the filtered blueberry wine with no sulfite added to provide the benchmark information on the level of phytonutrients of the Southern highbush blueberry wine that is eligible for labeling as organic. The results are shown in Table 1.

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The ORAC values of the Southern highbush blueberry wines ranged from 18.54 to 25.48 mmol TE/L. The ORAC values of low sulfite, unfiltered wine appeared to be significantly lower than those of the rest samples ($p \leq 0.05$). The average of the ORAC values shown in Table 1 was 22.57±2.92 mmol TE/L, which reflected the overall antioxidant capacity of the Southern highbush blueberry wine tested in this study. This ORAC value ranked high compared to most blueberry wines listed in Table 2.

According to the literature, addition of sulfite to non-organic wine has two major purposes: to inhibit microorganisms and to prevent non-enzymatic browning (mainly, Maillard reaction) (Fleet, 1993). Non-enzymatic browning is a problem in wines that leads to a reduction in phenols, such as catechins, which are the major polyphenolic antioxidants in wines (Saucier and Waterhouse, 1999). The rate of Maillard reaction is enhanced by increasing the amount of reducing sugars and/or increasing the temperature (Eriksson *et al*., 1981). Thus, if blueberry wine, which is rich in reducing sugars (10-12%) and in polyphenols, is exposed to an environment of raised temperature for an extended duration, the Maillard reaction is favorable. As mentioned earlier, sulfite addition can combat this reaction. However, in the event of improper amount of sulfite, or in the case of aforementioned low-sulfite/unfiltered wine, antioxidant capacity might diminish.

Although Table 1 shows the effect of higher sulfite concentration on stabilizing the antioxidant activity of the blueberry wine, sulfite cannot be added to any blueberry wine destined for "organic" labeling, for which the sulfite limit is 10 ppm to reflect the naturally occurring sulfite in wine. The non-sulfite, filtered blueberry wine tested in this study, which could be claimed as organic, had an ORAC value of 23.49 mmol TE/L.

Table 1 also shows the total phenolic, anthocyanin and flavonoid contents of the filtered, non-sulfite Southern highbush blueberry wine. Anthocyanins are the major water-soluble flavonoids in blueberries, giving the red, purple and blue color to many fruits and vegetables (Espín *et al*., 2007), and considered biologically active compounds exhibiting a wide range of health benefits, e.g., antioxidant (Cao *et al*., 1997), antifungal (Benkeblia, 2004), and anti-carcinogenic properties (Ames, 1983). Flavonoids are naturally occurring phenols that are present in many plants including blueberries. Flavonoids and phenolics in general are strong protector against heart disease and cancer (Yao *et al*., 2004). The total phenols andanthocyaninsof the Southern highbush blueberry wine tested in this study are compared with those of grape wines and fruit liquors in section 3.3.

3.2 ORAC Comparison between Blueberry Wines and Grape Wines

The data presented in Table 2 reflect the ORAC values of most blueberry and grape wines reported hitherto in the literature. A small number of wines had their antioxidant activities measured by a different method from ORAC, e.g., TRAP in Campos *et al*. (1996), which were not included in Table 2. Grape wines are divided into red, rose and white wine types. The blueberry wines listed came from highbush or Southern Highbush varieties. Besides the specific cultivar of Elliot and Weymouth, most blueberry wines were produced from mixed cultivars. For example, Johnson *et al*. (2011) used 15 cultivars including Berkley, Blue Chip and Blue Haven, while in this study, the mixed cultivars were, as mentioned earlier, Star, Windsor, Emerald, Primadonna and Jewel.

To facilitate the comparison, the average ORAC value of the Southern highbush blueberry wine tested in this study, i.e., 22.57 mmol TE/L, was chosen as a benchmark. For the 20 red wines listed in Table 2, the ORAC values ranged from 5.25 to 39.9 mmol TE/L. Four of the 20 red wines (i.e., 20%) had ORAC values higher than 22.57 mmol TE/L, while 16 of the 20 red wines (i.e., 80%) had lower ORAC values than the Southern highbush blueberry wine.

The ORAC values of the 6 Rose wines listed in Table 2 ranged from 1.52 to 11.2 mmol TE/L, which were all much lower than that the Southern highbush blueberry wine tested in this study.

For the 13 white wine types listed in Table 2, the ORAC values ranged from 0.6 to 5.35 mmol TE/L, which were far below that the Southern highbush blueberry wine. The much lower antioxidant potentials of white wines than red wines or blueberry wines were attributed to the fact that there is no skin or seed contact during the fermentation of white wine, while most antioxidants and phytonutrients are contained in the skins or seeds (Rigo *et al*., 2000; Yilmaz & Toledo, 2004).

The foregoing comparison suggests that blueberry wine could be more potent than red wine in health enhancement and disease prevention as far as the antioxidant capacity is concerned.

3.3 Comparison of Total Phenols and Anthocyanins among Blueberry Wines, Grape Wines and Fruit Liquors

Similar to the ORAC comparison, the total phenolicvalue of the Southern highbush blueberry wine tested in this study, i.e., 929 mg GAE/L, was used as a benchmark for comparison. For the 26 red wines listed in Table 3, the total phenolic values ranged from 700 to 4059 mg GAE/L. A majority of red wines (24/26) had total phenols higher than that of the Southern highbush blueberry wine, with only 2 of 26 falling below. The total phenolic

contents of the Rose and white wines were all lower than that of the Southern highbush blueberry wine. Of the 8 fruit liquors, two had a comparable total phenolic value to that the Southern highbush blueberry wine, while the other 6 all fell below.

A limited number of wine's anthocyanin data were reported in literature. Listed in Table 3 are only 10 red wine types for which the total anthocyanin contents were reported. Except for the highbush blueberry cultivar Elliot that had a much lower anthocyanin value (i.e., 14.7 mg C3GE/L), most anthocyanin contents of the blueberry wines and grape wines listed in Table 3 were comparable.

4. Conclusions

The Oxygen Radical Absorbance Capacity of the Southern highbush blueberry wine ranged from 18.54 to 25.48 mmol TE/L, averaging 22.57±2.92 mmol TE/L. About 80% of red wines and 100% of Rose and white wines reported in literature had lower ORAC values than 22.57 mmol TE/L, with only 20% of red wines above this ORAC value. From the perspective of antioxidant activities, blueberry wines could be more potent than most red wines and all Rose or white wines in health enhancement and disease prevention. For total phenolic contents, an overwhelming majority of the red wines was higher than that of the Southern highbush blueberry wine, but all the Rose and white wines were lower than it. Most fruit liquors reported in literature had lower total phenolic contents than the Southern highbush blueberry wine. The anthocyanin contents of blueberry wines were generally comparable to those of the red wines.

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Table 1. The ORAC values, total phenols (TP), anthocyanins and flavonoids of Southern highbush blueberry wine with and without sulfite addition or filtration

Southern Highbush Blueberry Wine	**ORAC** (mmol TE/L)	**TP** (mg GAE/L)	**Anthocyanins** (mg C3GE/L)	**Flavonoids** (mg CE/L)
No sulfite, filtered	$^{*}23.49\pm8.71^{a}$	929±52	60.62±3.51	1233±166
Low sulfite, unfiltered	$^{\Psi}18.54\pm3.67^{b}$			
Sulfite, unfiltered	$^{\Psi}22.77\pm0.46^{a}$	Average ORAC value = 22.57 ± 0.46 mmol TE/L		
Sulfite, filtered	$^{\Psi}25.48\pm5.35^{a}$			

* Values are mean of triplicate measurements.

$^{\Psi}$ Values are mean of six measurements.

Values with the same superscripted letters are not significantly different ($p \leq 0.05$).

Table 2. Comparison of the ORAC values among the red, Rose, white and blueberry wines

Wine	**ORAC** (mmol TE/L)	Source
Red Wine		
Graciano	39.9	Davalos et al. (2004)
Cabernet Sauvignon	34.7	Davalos et al. (2004)
Tempranillo	30.8	Davalos et al. (2004)
Aglianico	12.14	Pellegrini (2003)
Chianti	11.43	Pellegrini (2003)
Sauvignon	8.95	Pellegrini (2003)
Aglianico	10.4-12.8	Fogliano (1999)
Guardiolo	8.4	Fogliano (1999)
Solopaca	7.6	Fogliano (1999)
Gragnano	7.0	Fogliano (1999)
LacrimaChristi	6.4	Fogliano (1999)
Villard Noir	27.20	Sanchez-Moreno *et al*. (2003)
Cabernet Sauvignon	10.06-21.22	Sanchez-Moreno *et al*. (2003)
Tempranillo	18.94	Sanchez-Moreno *et al*. (2003)
MontepulcianoSangiovese	18.66	Sanchez-Moreno *et al*. (2003)
Merlot	17.08	Sanchez-Moreno *et al*. (2003)
Chambourcin	14.67-16.00	Sanchez-Moreno *et al*. (2003)
Mendocino	9.74	Sanchez-Moreno *et al*. (2003)
Pinot Noir	9.52	Sanchez-Moreno *et al*. (2003)
Red Table	5.25	Sanchez-Moreno *et al*. (2003)
Rose Wine		
Garnacha	11.2	Davalos *et al*. (2004)
Tempranillo	10.0	Davalos *et al*. (2004)
Cabernet	8.95	Davalos *et al*. (2004)
Villa Torre	2.42	Pellegrini (2003)
Tamerici	2.18	Pellegrini (2003)
Bardolino	1.52	Pellegrini (2003)
White Wine		
Albarino	4.84	Davalos *et al*. (2004)
Verdejo	3.18	Davalos *et al*. (2004)
Vernaccia	1.94	Pellegrini (2003)
Pinot	1.68	Pellegrini (2003)
Greco di Tufo	1.61	Pellegrini (2003)
Coda di volpe	0.9	Fogliano (1999)
Solpaca	0.8	Fogliano (1999)
Falanghina	0.8	Fogliano (1999)
Lacrima Christi	0.6	Fogliano (1999)
Chardonnay	3.38-5.35	Sanchez-Moreno *et al*. (2003)
Vidal Blanc	3.33	Sanchez-Moreno *et al*. (2003)
Sauvignon Blanc	2.59-2.68	Sanchez-Moreno *et al*. (2003)
Pinot Grigio	2.28	Sanchez-Moreno *et al*. (2003)
Blueberry Wine		
Southern Highbush, Mixed	22.57	This study
Highbush, Mixed	4.5-25.1	Johnson *et al*. (2011)
Highbush, Mixed	16.67-24.39	Sanchez-Moreno *et al*. (2003)
Highbush, Elliot	18.80	Sanchez-Moreno *et al*. (2003)
Highbush, Weymouth	9.18	Sanchez-Moreno *et al*. (2003)

Table 3. Total phenol and total anthocyanin comparison amongthe red, Rose, white and blueberry wines and fruit liquors

Wine or Liquor	Total Phenols (mg GAE/L)	Anthocyanins (mg C3GE/L)	Source
Red Wine			
Graciano	1468	-	Davalos *et al*. (2004)
Cabernet	1428	-	Davalos *et al*. (2004)
Tempranillo	1302	-	Davalos *et al*. (2004)
Villard Noir	1850	59.02	Sanchez-Moreno *et al*. (2003)
Cabernet Sauvignon	1593-1804	59.06-60.23	Sanchez-Moreno *et al*. (2003)
Tempranillo	1932	72.33	Sanchez-Moreno *et al*. (2003)
MontepulcianoSangiovese	1817	94.81	Sanchez-Moreno *et al*. (2003)
Merlot	1637	52.61	Sanchez-Moreno *et al*. (2003)
Chambourcin	1256-1267	111.70-170.10	Sanchez-Moreno *et al*. (2003)
Aglianico	1300-2300	-	Fogliano (1999)
Guardiolo	1400		Fogliano (1999)
Solopaca	1200	-	Fogliano (1999)
Gragnano	900	-	Fogliano (1999)
LacrimaChristi	700	-	Fogliano (1999)
Cabernet Sauvignon	2164-3340	-	Frankel *et al*. (1995)
Merlot	1800-2133	-	Frankel *et al*. (1995)
Zinfandel	2000	-	Frankel *et al*. (1995)
Petite Sirah	2020-4059	-	Frankel *et al*. (1995)
Pinot Noir	2816	-	Frankel *et al*. (1995)
Tempranillo	1455-2446	-	Sanchez-Moreno *et al*. (2000)
Garnacha	1277-1530	-	Sanchez-Moreno *et al*. (2000)
Cabernet Sauvignon	2358	-	Sanchez-Moreno *et al*. (2000)
Pinot Noir	1037-2529	57-117	Rigo *et al*. (2000)
Enanito	1963-2063	255-294	Rigo *et al*. (2000)
Teroldego	1663-2352	246-443	Rigo *et al*. (2000)
Cabernet Sauvignon	-	261	Nyman & Kumpulainen (2001)
Reference red wine	1390-1600	-	Heinonen *et al*. (1998)
Rose Wine			
Garnacha	432	-	Davalos *et al*. (2004)
Tempranillo	439	-	Davalos *et al*. (2004)
Cabernet	389	-	Davalos *et al*. (2004)
Garnacha	419-486	-	Sanchez-Moreno *et al*. (2000)
Tempranillo	330-373	-	Sanchez-Moreno *et al*. (2000)
White Wine			
Albarino	214		Davalos *et al*. (2004)
Verdejo	186		Davalos *et al*. (2004)
Chardonnay	280-306	-	Sanchez-Moreno *et al*. (2003)
Vidal Blanc	220	-	Sanchez-Moreno *et al*. (2003)
Sauvignon Blanc	191-270	-	Sanchez-Moreno *et al*. (2003)
Pinot Grigio	191	-	Sanchez-Moreno *et al*. (2003)
Coda di volpe	120	-	Fogliano (1999)
Solpaca	150	-	Fogliano (1999)
Falanghina	140	-	Fogliano (1999)
Lacrima Christi	110	-	Fogliano (1999)
Sauvignon Blanc	165-193	-	Frankel *et al*. (1995)
Chardonnay	240-259	-	Frankel *et al*. (1995)
White Zinfandel	243-331	-	Frankel *et al*. (1995)
Malvar	139-265	-	Sanchez-Moreno *et al*. (2000)
Verdejo	178	-	Sanchez-Moreno *et al*. (2000)
Albillo	293	-	Sanchez-Moreno *et al*. (2000)
Chardonnay	201	-	Sanchez-Moreno *et al*. (2000)
Reference white wine	265	-	Heinonen *et al*. (1998)
Blueberry Wine			

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Southern Highbush, Mixed	929	60.62	This study
Highbush, Mixed	375.4-657.1	-	Johnson *et al*. (2011)
Highbush, Mixed	1514-1860	80.56-162.20	Sanchez-Moreno *et al*. (2003)
Highbush, Elliot	1470	14.70	Sanchez-Moreno *et al*. (2003)
Highbush, Weymouth	600	74.69	Sanchez-Moreno *et al*. (2003)
Rabbiteye (V. ashei)	1150	99.6	Su and Chien (2007)
Fruit Liquor			
Cranberry	500	-	Heinonen *et al*. (1998)
Cherry	1080	-	Heinonen *et al*. (1998)
Arctic Bramble	555-610	-	Heinonen *et al*. (1998)
Strawberry	410-525	-	Heinonen *et al*. (1998)
Rowanberry	545	-	Heinonen *et al*. (1998)
Cloudberry	450-500	-	Heinonen *et al*. (1998)
Cloudberry+Red Raspberry	415	-	Heinonen *et al*. (1998)
Red Raspberry+Black Current	1050	-	Heinonen *et al*. (1998)

Onion as a Pest Control Intercrop in Organic Cabbage (*Brassica oleracea*) Production System in Ghana

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Abstract

The use of chemical insecticides in the control of insect pests has left in its wake resistance of some pests to some of the conventional insecticides. Alternative methods of managing pests such as cultural control have to be employed to reduce pest infestation of crops. Onion was used in an intercrop as a non host crop to manage the pests of cabbage. The experiment was conducted in a Randomized Complete Block Design with four treatments; sole cabbage (T1), 2 rows of cabbage to 1 row of onion (T2), 3 rows of cabbage to 1 row of onion (T3) and 4 rows of cabbage to 1 row of onion (T4), each of which was replicated three times. Data were collected on pests' numbers, plant height, damaged leaves at harvest, canopy spread, number of damaged heads and fresh weight. Significantly fewer *Bemisia tabaci, Hellula undalis* and *Brevicoryne brassicae* infested the intercropped plants than the sole crop. However, intercropping cabbage with onion did not significantly reduce *Plutella xylostella* population on cabbage. Number of damaged heads, fresh weight and damaged leaves were significantly different ($P< 0.05$).

Keywords: *Brevicoryne brassicae*, Cabbage, Onion, *Plutella xylostella*, Intercropping

1. Introduction

Cabbage, *Brassica oleracea* L. is an exotic leafy vegetable grown in many tropical areas in Africa. It is a biennial potherb, but is usually cultivated as an annual. It grows best in mild to cool climates (Cabbage, 2010 Encylopaedia Britannica). Structurally, cabbage has a short thickened stem surrounded by a series of overlapping expanded leaves which form a compact head (Rice *et al*., 1986). Cabbage is often used in stews, boiled in soups and also eaten fresh as an ingredient of salads (Van der Vossen and Seif, 2004). According to Norman (1992), cabbage is nutritionally a rich leafy vegetable. Per 100g of raw cabbage, the nutritional values are: 21 cal energy, 1.2 g protein, vitamins and some minerals such as potassium, phosphorus, magnesium and sodium.

The nutritional value and succulent nature of cabbage has attracted many insect pests which feed on it. The insect pest complex associated with cabbage include aphids, *Aphis brassicae*, diamondback moth, *Plutella xylostella* , the cabbage webworm *Hellula undalis,* the cabbage looper, *Trichoplusia ni* (Chalfant *et al*., 1979; Shelton *et al*.,1982; Mochiah *et al*., 2011), and the white fly , *Bemisia tabaci*. These pests damage the cabbage head by making holes in the leaves, destroying the growing buds and tunnel into mature heads. The feeding activities of these pests reduce the quality of cabbage heads and subsequently its market value, leading to financial loss to the farmer.

The destructive nature of cabbage pests necessitates the application of control measures to minimize the effects of these pests. Chemical insecticides have been used against insect pests in vegetable crop production. However, several problems are associated with the use of chemical insecticides. These include the development of resistance, environmental contamination, and increased health hazards to applicators and dangers to consumers of high toxic residues. The rapid increase in the numbers of these pests necessitates the application of high doses of pesticides (Kim *et al*., 2001). The use of insecticides in vegetable production is on the increase despite the problems associated with their use. Insecticide resistance is the underlying cause of insecticide dependency among farmers. This has resulted in farmers using more powerful insecticides to be able to control these pests. Roush and Tabashnik (1990) stated that the use of insecticides has resulted in the evolution of resistance in more than 440 insect species and mites worldwide. Perez *et al*. (2000) assessed the insecticide resistance to several insecticides of five insect pests including *P. xylostella* and *Spodoptera exigua* attacking field and vegetable crops in Nicaragua and observed that *P. xylostella* showed resistance to cypermethrin, deltamethrin, thiocyclam and methamidophos.

The concept of intercropping involves the cultivation of two or more crops simultaneously on the same field. The rationale behind intercropping is that the different crops planted are not likely to be attacked by the same pests. The commonest goal of intercropping is to produce a greater yield on a given piece of land, making use of resources that would otherwise not be utilized by a single crop. Intercropping reduces pest population because of the diversity of crops grown. When other crops are present in the field pests movements are hindered. According to Sullivan (2003), if susceptible plants are separated by non- host plants that can act as a physical barrier to the pest, the susceptible plant will suffer less damage.

The use of synthetic chemical insecticides have been effective in controlling pests, but the continuous use pose harmful effects like residual contamination of the produce, environmental pollution as well as pest resistance. There is therefore the need to seek alternative methods of managing pests. Intercropping, in combination with organic farming provide an alternative means of managing pests. The study therefore assessed the role of intercropping and organic farming in the management of major pests of cabbage.

2. Materials and Methods

2.1 Study area

The experiment was conducted on an experimental farm of the Department of Theoretical and Applied Biology, Kwame Nkrumah University of Science and Technology, Kumasi from December 2010 to April 2011. The area falls within the forest zone of Ghana and is characterized by relatively high annual rainfall of about 730 mm and annual minimum and maximum temperatures of 21.5 ^{o}C and 32.1 ^{o}C respectively (Addo-Fordjour *et al*., 2007). The soil type is sandy loam and the topsoil is about 0.3 m deep.

Cabbage and onion seeds were obtained from an Agrochemical shop. They were nursed separately in the Greenhouse until ready for transplanting. The farming system used in the study was strictly organic. This system excluded the use of insecticides, growth hormones and any other synthetic chemical used in modern farming systems. No fertilizer was applied throughout the growth of the plants.

2.2 Experimental design

Twelve experimental beds each measuring 4.5 m x 1.5 m were raised, each separated by 0.5 m alley. The experiment was conducted in a Randomized Complete Block Design (RCBD) with four treatments each of which was replicated three times. The treatments were sole cabbage (T1); 2 rows of cabbage intercropped with 1 row of onion (T2); 3 rows of cabbage intercropped with 1 row of onion (T3) and 4 rows of cabbage intercropped with 1 row of onion (T4). Cabbage and onion seedling were transplanted 3 weeks after germination. The square planting distance was used. Distance between the cabbage plants, both within and between rows was 0.45 m and the row intercropping was used. There were 30 cabbage plants on each bed, both on the sole cabbage and any of the intercropping options. Management of weeds was done periodically by manually uprooting them.

2.3 Data collection

Data were collected on the following parameters on cabbage: pests' species and numbers, canopy spread, plant height, number of damaged heads at harvest, numbers of damaged leaves at harvest and fresh weight of cabbage heads. At each sampling for insect pests, five cabbage plants were randomly sampled from the inner row. The leaves of the sampled plants were carefully examined for insect pests. Insects collected were placed separately in Kilner jars sent to the laboratory, counted and their numbers recorded.

2.3.1 Canopy spread

Measurement of canopy spread was done at the time of harvest with a metre rule. The spread of canopy was measured as the horizontal distance from one end of the plant to the other i.e. the two most outspread and directly opposite leaves of the plant.

2.3.2 Plant height

Plant height was measured from the soil surface to the apex of the plant. The highest point reached by the plant was recorded as the height of the plant.

2.3.3 Number of damaged leaves and heads

At harvest the number of damaged leaves per cabbage plant were counted and recorded. Damaged leaves were removed from the rosette, one after the other until no damaged leaf was found. The numbers of damaged heads that were not able to form marketable heads were counted, recorded and the means calculated. Five cabbage heads were randomly sampled from each bed and weighed on a top pan balance. This was done for each treatment and the mean for each was calculated and recorded.

2.4 Data analysis

Data collected were analyzed using the general Linear Model (GLM) procedure of SAS (SAS, Institute, 2005). Number of insects count were log (x+1) transformed. Comparison of the means was done using the Student Neuman-Keul's (SNK) test. Significant difference was set at $P \leq 0.05$.

3. Results

3.1 Insect pests encountered on cabbage

During the growth of the cabbage plant a number of insect pests were identified attacking the plant. These include the diamondback moth *Plutella xylostella* (L), the cabbage aphid, *Brevicoryne brassicae* (L.), the cabbage webworm, *Hellula undalis* (F.), the whitefly, *Bemisia tabaci* (Genn.) and the cabbage looper, *Trichoplusia ni* (Hübner). These pests attacked the plant at different growth stages of the plant.

P. xylostella was observed on cabbage at 4 weeks after transplanting (WAT) and remained on the plant till harvest. *P. xylostella* numbers were largest on the sole cabbage plots (T1) which were the control plots and least on T4 plots (i.e. 4 rows of cabbage to 1 row of onion). However, the numbers of *P. xylostella* on the intercropped plots and the sole cabbage plots were not significantly different (P= 0.063) (Table 1). *B. brassicae* was observed at 2 WAT. Their numbers ranged from a mean of 34 on sole cabbage to 17.3 on 4 rows of cabbage to 1 row of onion (T4); the difference was significant (P= 0.004). However, *B. brassicae* numbers on sole cabbage (T1) and two rows of cabbage to one row of onion (T2) were not significantly different (Table 1).

Bemisia tabaci was observed at 6WAT. Their numbers decreased consistently from the sole cabbage, T1 to four rows of cabbage to one row of onion, T4. Even though generally low numbers were recorded on all plots, many more were recorded on the sole cabbage plots than the intercropped plot. Intercropping cabbage with onion significantly reduced and not reduce the numbers of this pest on cabbage (P= 0.002). Cabbage webworm *H. undalis* appeared on the plant at 6 WAT, which was relatively late in the growth of the plant. They were most abundant on the sole cabbage plots and completely absent on 4 rows of cabbage to 1 row of onion (T4).Significant differences in numbers existed among the intercropped plants and the sole cabbage plants.

The cabbage looper, *T. ni* was also observed on the plant at 6 WAT, with the largest number infesting the sole cabbage, whilst the T4 plots were least infested. However, the observed differences were not significant (P= 0.164). Thus intercropping did not reduce the population of this pest on cabbage.

3.2 Effects of intercropping system on growth, damage by pests and yield of cabbage

The effects of intercropping on growth parameters and damage by pests are shown in Table 2. Plant height ranged from a mean of 28.73 cm on four rows of cabbage and one row of onion (T 4) to 30.09 cm on the sole cabbage plots (T1). It was observed that intercropping did not significantly affect plant height (P=0.620). Mean canopy spread on the plots did not differ significantly (P=0.992). As a consequence of heavy pests attack, the mean number of damaged leaves at harvest was largest on the sole cabbage plots (T1) but least on 4 rows of cabbage to 1 row of onion (T4) (P=.021).There was however, no significant differences in leaf damage among the intercropped plants (Table 2). Mean number of damaged heads was least on 4 rows of cabbage to1 row of onion (T4) and largest on 2 rows of cabbage to 2 row of onion (T2). Mean fresh weight of cabbage heads were significantly heavier on the intercropped plots than on the sole cabbage plots (Table 2).

4. Discussion

Cabbage is an important leafy vegetable which forms an important component of the diets of many African countries. However increased production of this crop is being hindered by pests' attack. The stage of growth of the plant at which pests attack the crop is very significant to the survival of the crop. Cabbage plants that were infested early could not completely survive the attack and as a consequence produced smaller and lighter heads. Even though intercropped cabbages recorded lower numbers of *P. xylostella*, these were not significantly different from that recorded on the sole cabbage. This finding lends support to the report by Lingappa *et al*. (2006), who stated that intercropping is not reliable in controlling diamondback moth. Asare-Bediako *et al*. (2010), however, stated that intercropping cabbage with non-host crops such as onion and tomato significantly reduced *P. xylostella* numbers on cabbage. In their study however, the chemical insecticide Dursban (chloropyrifos) was used to spray the plants whilst in the current study the farming practice was purely organic where no insecticide was used.

Aphids attack the tender leaves of cabbage plants and secrete honeydew which accumulates on leaves leading to growth of sooty mould which affected the yield of cabbage (Blackman & Eastop, 2000). Thus the reduction of *B. brassicae* numbers on the intercropped plants subsequently led to a reduction in damaged leaves. The significantly lower numbers of *B. brassicae* on the intercropped plants was attributed to the confusing olfactory and visual cues offered by onion which reduced their ability to disperse. Sankar *et al*. (2007) stated that intercropping cabbage with garlic and onion significantly reduced the population of aphids on cabbage. Similarly, Said and Itulya (2003) indicated that the odour from onion is able to repel *P. xylostella* from settling on cabbage when in an intercrop. Garlic and onion produce a pungent alliaceous compound, allyl-epropyl-disulphide, which is responsible for its pest repellent attribute.

Intercropping also reduces pests attack because the non host crop act as physical barriers to the movement of insect pests (Sheehan, 1986). Studies conducted by Bach and Tabashnik (1990) in Hawaii found that cabbage interplanted with tomato contained lower numbers of *P. xylostella* larvae and higher levels of parasitism compared with monoculture cabbage. High temperatures and low rainfall promote the increase in numbers of *P. xylostella* and *B. brevicoryne*. However, during the months of February and March, there were unusually heavy rains which were an important mortality factor washing off the eggs, larvae and nymphs from the leaves. This phenomenon was thoroughly studied by and reported by Kobori and Amano (2003) who observed that 1 hour of stimulated rain resulted in 95.3% drop off of 1st instar, 72% of 2nd instar, 60.7% 3rd instar and 42.7% 4th instar of *P. xylostella*. This was an indication that heavy rainfall reported during those months resulted in heavy mortality. Warm and dry weather are particularly favourable for rapid development of cabbage pest such as aphids (Horna *et al*., 2006) and *P. xylostella*.

In cabbage one important factor that determines the marketability of the crop is the extent of damage to the head. Cabbage heads that are heavily infested by pests are less attractive to buyers. The intercropped cabbage recorded significantly lower numbers of damaged leaves. However, with the exception of T4 which recorded fewer damaged leaves, the other intercropped plots recorded numbers of damaged leaves which were not significantly different from the sole cabbage. In the study, the highest marketable yield was recorded on T4 and least on T1 (sole cabbage). In some instances, intercropping results in loss of weight in vegetable plantings (Theunissen e*t al.,* 1995). However, in the current study, intercropping resulted in increased weight in cabbage. According to Cerruti *et al*. (2002), from an economic point of view any increase in quality due to intercropping must be sufficient to compensate for lower number of heads or intercropping systems may only be practicable in systems where quality is of greatest importance. In the current study it was observed that as a result of reduction of pests numbers on the intercropped cabbage an increase in yield of 11.03% to 50.1 % were recorded compared with the sole cabbage. Lotz *et al*. (1997) however, reported a reduced yield of cabbage of 15-24% when intercropped with clover due to competition between the two crops. It therefore means that non-host crop in an intercropping must be carefully selected in order not to compete with the main crop for essential nutrients.

5. Conclusion

The results of this study indicated that onion can be used as an intercrop in the management of cabbage pests. The fact that reduction in pests' numbers and significant increase in yield were achieved without the use of insecticides was an indication that when adopted by the small to medium scale African farmer it would improve yield and increase the incomes of farmers. In the current study, it was observed that in an intercrop, the secondary crop needs not occupy much area of the available land to produce the desired effects. Hence intercropping every four rows of cabbage with one row of onion will serve as an effective pest management strategy and effective land use.

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Table 1. Effects of intercropping on the mean numbers (SE) of pests of cabbage

Cropping System	*P. xylostella*	*B. brassicae*	*B. tabaci*	*H. undalis*	*T. ni*
Sole cabbage	21.74^{a}± 3.75	34.0^{a} ± 2.10	6.73^{a} ±1.70	1.40^{a} ±0.52	0.80^{a} ± 0.39
2 rows of cabbage to 1 row of onion	19.73^{a} ± 3.50	26.3^{ab} ±2.60	4.73^{ab}±0 .30	0.60^{ab}±0.21	0.67^{a} ± 0.29
3 rows of cabbage to 1 row of onion	15.07^{a} ±2.95	21.3^{b}± 3.20	2.60^{bc}± 0.64	0.20^{b}± 0.11	0.27^{a} ± 0.15
4 rows of cabbage to 1 row of onion	10.20^{a} ± 2.49	17.3^{b}± 4.10	0.60^{c}± 0.19	0.00^{b}± 0.00	0.07^{a} ± 0.01
P-value	0.063	0.004	0.002	0.005	0.165

Within columns means with the same letter are not significantly different P > 0.05.

Table 2. Effects of intercropping systems on growth, damage and yield of cabbage

Cropping System	Plant height (cm) (SE)	Damaged heads at harvest (SE)	Damaged leaves (SE)	Weight of cabbage (kg) (SE)	Canopy spread (cm) (SE)
Sole cabbage	30.09^{a}± 0.96	2.67^{a} ± 0.33	16.33^{a} ± 1.7	1.05^{a} ±0.035	22.95^{a} ± 1.60
2 rows of cabbage to 1 row of onion	29.19^{a} ± 0.38	3.67^{ab} ±0.67	13.00^{ab} ±1.0	1.21^{a}±0.028	22.90^{a} ± 1.70
3 rows of cabbage to 1 row of onion	29.04^{a} ±0.51	3.00^{b}± 0.00	11.33^{ab}± 0.67	1.24^{a}± 0.105	23.10^{a} ± 1.67
4 rows of cabbage to 1 row of onion	28.73^{a} ± 0.94	1.33^{b}± 0.33	7.00^{b}± 2.52	2.14^{b}± 0.202	23.55^{a} ± 1.68
P-value	0.620	0.021	0.002	0.001	0.992

Within columns means with the same letter are not significantly different P > 0.05.

Chitin Nanofiber Membranes for Chiral Separation

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Abstract

Nanofiber membranes for chiral separation were prepared from chitin, which is the most abundant natural amino polysaccharide. The membrane showed chiral separation ability by adopting concentration gradient as a driving force for membrane transport. In other words, the chitin nanofiber membrane selectively transported the D-isomer of glutamic acid (Glu), phenylalanine (Phe), and lysine (Lys) from the corresponding racemic amino acid mixtures.

Keywords: Chiral separation, Chitin, Membrane, Nanofiber membrane, Optical resolution

1. Introduction

L-Glutamic acid (L-Glu), which is usually used as a seasoning in Japan, is tasty, while the corresponding D-glutamic acid (D-Glu) gives a different taste. This is one of familiar examples. A lot of optically active compounds show different physiological activities, depending on their mirror image isomers (Voet *et al*., 1990; McKee *et al*., 2003). From this, the production of optically pure compounds is an important process in various industries, involving pharmaceuticals, agrochemicals, food additives, fragrances, and so forth. Asymmetric synthesis is thought to be an ultimate way to obtain enantiometrically pure compounds from a standpoint of green chemistry. However, the development of asymmetric synthesis is not so fast. Chiral separations, such as crystallization resolution, kinetic resolution, chromatographic separation, membrane-based separation and so forth, are still mighty and promising methods to obtain optically pure compounds. Among those chiral separation methods, membrane-based separation is ecologically and economically competitive to other chiral separation methods. Membrane-based separation is continuously operated under mild conditions and process scale-up is relatively easy. From above, membrane-based separation can be called "green separation technology" not only in chiral separation but also in separations of other mixtures. Membrane-based separation with separation membranes fabricated from green polymer will surely become a green separation technology.

The authors research group developed membranes from various naturally occurring or 'green polymers', their derivatives, and wastes from food industries as resources for membrane material so that we can construct sustainable environment and society. To this end, the authors' research group developed membranes from various raw materials, such as cellulose acetate for optical resolution (Izumi *et al*., 1997; Yoshikawa *et al*., 1999), egg shell membranes for chiral separation (Kondo *et al*., 2001), agarose for pervaporation (Yoshikawa *et al*., 2000, 2002), gelatin for vapor permeation (Yoshikawa *et al*., 2004a), proteins from *Geobacillus thermodenitrificans* DSM465 for vapor permeation (Yoshikawa *et al*., 2004b) and molecular recognition (Yoshikawa *et al*., 2006, 2007a), DNA for gas (Matsuura *et al*., 2006) and chiral separation (Yoshikawa *et al*., 2007b, 2007c; Iwamoto *et al*., 2009), chitosan for chiral (Iwamoto *et al*., 2010a) and vapor permeation (Iwamoto *et al*., 2010b), optical

resolution with molecularly imprinted nanofiber membranes from cellulose acetate (Sueyoshi *et al*., 2010), and keratin for optical resolution (Sueyoshi *et al*., 2011).

Chitin, which is an abundant green polymer on the earth and is main component of exoskeletons of arthropods, such as crustaceans and insects, is one of promising green polymers as a membrane material. Chitin is a polymer of N-acetyl glucosamine and containing chiral environment, which is expected to discriminate absolute configuration of a given mixture of enantiomers. One of the authors has recently isolated chitin nanofibers from the exoskeletons of crabs and shrimps (Ifuku *et al*., 2009, 2010). The obtained chitin nanofibers have a highly uniform structure of 10-20 nm in width and a high aspect ratio. Furthermore, as chitin nanofibers consist of an antiparallel extended crystalline structure, they have excellent mechanical properties, including a high Young's modulus, high fracture strength and low thermal expansion. Given their characteristic nano-form and excellent physical properties, chitin nanofibers are strong candidates for a membrane for chiral separation. To this end, chitin nanofiber membranes were fabricated and their chiral separation ability was studied adopting racemic mixture of amino acids as model racemates.

2. Experimental Section

2.1 Materials

Chitin powder from crab shells was purchased from Nacalai Tesque. D-Glutamic acid (D-Glu), L-glutamic acid (L-GLu), D-phenylalanine (D-Phe), L-phenylalanine (L-Phe), D-lysine (D-Lys), and L-lysine (L-Lys) were used as received. Water purified with an ultrapure water system (Simpli Lab, Millipores S. A., Molsheim, France) was used.

2.2 Membrane Preparation

Chitin nanofibers were prepared from commercially available chitin powder derived from crab shells according to a previously described procedure (Ifuku *et al*., 2010). Fibrillated chitin nanofibers were dispersed in water at a fiber content of 0.1 wt%. The suspension was vacuum-filtered using a hydrophilic polytetrafluoroethylene membrane filter (Millipore, pore size: 0.2 mm). The obtained chitin nanofiber membrane was hot-pressed at 100 °C for 30 min to obtain a dried sheet. The thickness of the chitin nanofiber membrane thus obtained was determined to be 85 μm.

2.3 Enantioselective Transport

A membrane (area, 3.0 cm^2) was fixed tightly between two chambers of a permeation cell. The volume of each chamber was 40.0 cm^3. An aqueous solution of racemic mixture of amino acid was placed in the left-hand side chamber and an aqueous solution in the right-hand side chamber. Each concentration of racemic amino acid was fixed to be 1.0 x 10^{-3} mol dm^{-3}. All experiments were carried out at 40 °C. The amounts of the D- and L-isomers that transported through the membrane were determined by liquid chromatography (LC) [JASCO PU 1580, equipped with a UV detector (JASCO 1570)] employing a CHIRALPAK MA (+) column (50 mm x 4.6 mm (i.d.)) (Daicel Chemical Ind. Ltd.) for the analyses of racemic Glu's and Phe's, and a CROWNPAK CR (+) column (150 x 4.0 mm (i.d.)) for the measurement of racemic Lys's. An aqueous copper sulfate solution was used as a mobile phase for Glu and Phe analyses, and a perchloric acid solution as eluent for Lys analysis.

The flux, J (mol cm cm^{-2} h^{-1}), is defined as:

$$J = Q\delta/At \tag{1}$$

where Q (mol) denotes the amount of transported amino acid, δ (cm) membrane thickness, A (cm^2) the membrane area, and t (h) is the time.

The permselectivity, $\alpha_{i/j}$, is defined as the flux ratio, J_i/J_j, divided by the concentration ratio ([i-AA]/[j-AA]):

$$\alpha_{i/j} = (J_i/J_j)/([\text{i-AA}]/[\text{j-AA}]) \tag{2}$$

The subscripts D and L refer to the D-isomer of amino acid and the L-isomer of amino acid, respectively.

2.4 Adsorption Selectivity

The membrane was immersed in a 1.0 x 10^{-3} mol dm^{-3} racemic amino acid solution and the mixture was allowed to equilibrate at 40 °C. A 0.02 wt. % sodium azide was added as a fungicide. The amount of amino acid in the supernatant subtracted from the amount initially in the solution gave the amount of the amino acid adsorbed by the membrane. Quantitative analyses were done as above.

Adsorption selectivity, $S_{A(i/j)}$, is defined as

$$S_{A(i/j)} = ((\text{i-AA})/(\text{j-AA}))/([\text{i-AA}]/[\text{j-AA}]) \tag{3}$$

where (i-AA) and (j-AA) denote the amount of enantiomer of amino acid adsorbed in the membrane, and [i-AA] and [j-AA] are the concentrations in the solution after equilibrium had been reached, respectively.

3. Results and Discussion

Three types of racemic amino acid were adopted as model racemates. Among nineteen types of amino acid, racemic glutamic acids (Glu's) with very polar anionic side chains, racemic phenylalanine (Phe's) having aromatic side chain, and racemic lysine (Lys's) with very polar cationic side chains, were adopted as model racemates in the present study.

Concentration gradient was adopted as a driving force for membrane transport of above amino acids. As an example, time-transport curves of racemic mixture of three types of amino acid are shown in Figure 1. The D-isomer of Phe was transported in preference to the corresponding L-isomer. The permeselectivity toward D-Phe was determined to be 1.16. As for other amino acids, such as Glu and Lys, the D-isomer was preferentially transported through the present chitin nanofiber membrane like Phe. The permselectivies were determined to be 1.04 for racemic Glu's and 1.07 for racemic Lys's, respectively. The permselectivities for the present chitin nanofiber membranes were not so high comparing with membrane performances previously reported (Maier. *et al*., 2007; Xie *et al*., 2008; Higuchi *et al*., 2010).

Adsorption selectivities of those membranes toward three types of racemic amino acid were studied so that the mechanism for the expression of permselectivities could be elucidated. In Table 1, the amounts of amino acids adsorbed in the membrane and adsorption selectivities are given. The L-isomers of Glu and Phe were incorporated into the membrane in preference to the corresponding antipodes, while D-Lys was selectively adsorbed in the membrane. Especially, the adsorption selectivity toward L-Phe reached 2.33. From permselectivity and adsorption selectivity, diffusivity selectivity, $S_{D(i/j)}$, can be determined by equation (4).

$$S_{D(i/j)} = \alpha_{i/j}/S_{A(i/j)} \ (= D_i/D_j) \tag{4}$$

where D_i and D_j are diffusion coefficients of i-isomer and j-isomer, respectively. The diffusivity selectivities for those three types of amino acid are summarized in Table 2 together with flux values and other selectivities, such as permselectivity and adsorption selectivity. As for the transport phenomena of Glu and Phe, the enantiomer, which was less incorporated into the membrane, was quickly diffused within the membrane. In other words, the diffusivity of enantiomer preferentially adsorbed in the membrane was retarded. This retarded diffusion might be due to a relatively strong interaction between the enantiomer selectively adsorbed and the membrane as often observed in chiral separation (Yoshikawa *et al*., 2003, 2007c; Masawaki *et al*., 1992; Aoki *et al*., 1995; Tone *et al*. 1996). On the other hand, the diffusivity selectivity for Lys gave same tendency like adsorption selectivity even though the value of selectivity was not so high.

From the intercept of the steady-state portion of time-transport curve in Figure 1, the time lag, for a given enantiomer is determined (Mulder, M., 1996). Using those time lags, diffusivity selectivity can be estimated by equation (5).

$$S_{D(i/j)} = \theta_j/\theta_i \tag{5}$$

As can be seen in Figure 1, the time lag for the D-isomer was shorter than that for the L-isomer. This leads to the conclusion that the diffusion coefficient for D-amino acid was higher than that for the corresponding L-isomer. As a result, it was qualitatively concluded that the diffusivity selectivity toward D-amino acid was over unity. It was revealed that the D-isomer diffused within the membrane faster than the L-isomer. The diffusivity selectivity qualitatively elucidated from time lag data coincided with that determined from permselectivity and adsorption selectivity.

In our previous study of enantioselective transport of racemic amino acids through molecularly imprinted membranes (Yoshikawa *et al*., 2003), applying an optimum potential difference as the driving force, the permselectivity, reflecting adsorption selectivity, was attained. In other words, applying enantioselective electrodialysis, permselectivity, which corresponds to the adsorption selectivity, was attained. In the present study on optical resolution of racemic Phe's, additional potential difference was applied by electrodialysis to obtain permselevctivity, reflecting adsorption selectivity. Against expectation, permselectivity was hardly observed. This might be due to the fact that enantiomers non-specifically dragged by applied potential difference diffused through the mesh between chitin nanofiber, which was still too large to express permselectivity. Narrowing mesh size between chitin nanofibers or plugging the mesh with some polymeric materials would enhance permselectivity.

4. Conclusions

Nanofiber membranes for chiral separation were prepared from chitin, which is the most abundant natural amino polysaccharide. The membrane showed chiral separation ability by adopting concentration gradient as a driving force for membrane transport. In other words, the chitin nanofiber membrane transported the D-isomer of glutamic acid (Glu), phenylalanine (Phe), and lysine (Lys) from the corresponding racemic amino acid mixtures faster than the corresponding L-isomer.

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Table 1. Adsorption of racemic mixture of amino acids in chitin nanofiber membrane

Amino Acid	(Amino Acid)/mem.		$S_{A(D/L)}$	$S_{A(L/D)}$
	10^5mol/g-mem.	10^3mol/CRU[a]		
D-Glu	5.18	9.27	0.96	1.04
L-Glu	5.41	9.68		
D-Phe	1.57	2.81	0.43	2.33
L-Phe	3.66	6.55		
D-Lys	3.01	5.38	1.04	0.96
L-Lys	2.90	5.18		

[a] Constitutional repeating unit of chitin.

Table 2. Results of chiral separation with chitin nanofiber membrane[a]

Amino Acid	J_D	J_L	$\alpha_{D/L}$	$S_{A(D/L)}$	$S_{D(D/L)}$
	mol cm cm^{-2} h^{-1}	mol cm cm^{-2} h^{-1}	. $\alpha_{L/D}$)	($S_{A(L/D)}$)	($S_{D(L/D)}$)
Glu	7.93 x 10^{-10}	7.59 x 10^{-10}	1.04 (0.96)	0.96 (1.04)	1.08 (0.92)
Phe	1.25 x 10^{-9}	1.08 x 10^{-9}	1.16 (0.86)	0.43 (2.33)	2.70 (0.37)
Lys	1.18 x 10^{-9}	1.10 x 10^{-9}	1.07 (0.93)	1.04 (0.96)	1.03 (0.97)

[a] $\alpha_{i/j} = S_{D(i/j)}$ x $S_{A(i/j)}$ [i = D, j = L or i = L, j = D]

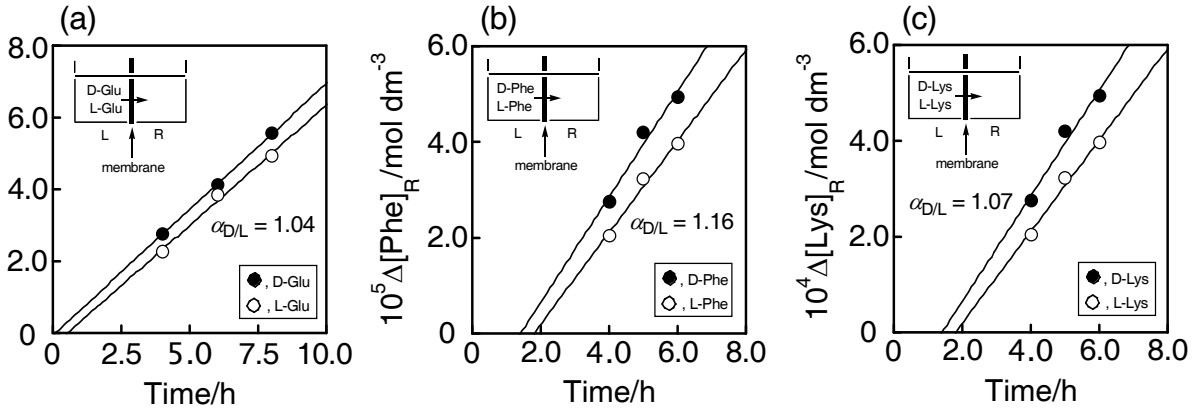

Figure 1. Time-transport curves of racemic mixtures of Glu's (a), Phe's (b), and Lys's (c) through the chitin nanofiber membrane at 40 °C

([D-AA]$_0$ = [L-AA]$_0$ = 1.0 x 10^{-3} mol dm^{-3}; AA: Glu, Phe, or Lys.)

Why and How to Make Plant Conservation Ecosystem-Based

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Abstract

Compared to other groups of organisms, plants require distinctive approaches in their conservation because of their keystone roles in ecosystems and economies. The state of the whole plant cover of the Earth should be of concern to conservationists – for its capacity to ensure the survival of plant species, deliver ecosystem services (locally to globally) and provide produce from plants in ecologically sustainable ways. The primary targets of attention in ecosystem-based plant conservation are the relationships between people and plants, as relevant to every locality, rather than the species-centric approach of conventional plant conservation. Moving plant conservation to an ecosystem-based approach will require the development of training programmes for field practitioners and of information systems for their use.

Keywords: Plant conservation, Ecosystem-based, Evidence-based conservation

1. What is Ecosystem-based Plant Conservation?

We believe that the ecosystem-based approach is appropriate for plants and that plant conservation should be a consideration in all places where the land has, or potentially could have, a covering of plants. It is an approach requiring urgent development, given that many species of plants are under threat, large areas of vegetation are

ecologically degrading and there are severe declines in those many ecological services whose quality is closely linked to the plant cover on the land. According to a 2010 estimate, twenty-two per cent of plant species are threatened with extinction (www.kew.org/plants-at-risk).

Ecosystem-based conservation has been stipulated as the primary framework to be used for implementation of the Convention on Biological Diversity (CBD) (www.biodiv.org). The precise meaning of the ecosystem approach *sensu* CBD is debateable, but broadly it encourages conservationists to think in terms of systems and to keep in mind that people are major elements of ecosystems in nearly every case. A set of twelve guiding principles has been provided (www.biodiv.org/programmes/cross-cutting/ecosystem). Nevertheless, none of the sixteen targets of the Global Strategy for Plant Conservation, developed under the CBD, refers specifically to the delivery of ecosystem services, a fundamental part of the ecosystem approach.

We consider the ecosystem-based approach to have three purposes - conservation of plant species, delivery of ecosystem services and the ecologically sustainable supply of produce from plants (A.C. Hamilton & Hamilton, 2006; Pei, Huai, Hamilton & Hamilton, 2009). The conservation of plant species and their genetic diversity is the principal purpose of conventional plant conservation, targeted species by species. The methodology used includes the identification of species under threat (Red Lists) and the localities where they are found, and then trying to secure the continuing existence of the species, especially through the use of protected areas and *ex situ* facilities (Given, 1994; Heywood & Iriondo, 2003; Krupnick & Kress, 2005; Schemske *et al*., 1994).

The nature of the land's plant cover has a strong influence on the functioning of ecosystems, acting on various scales (e.g. (Haslett *et al*., 2010; IPCC, 2007; Nicholson *et al*., 2009; Cao, Chen & Yu, 2009; Zheng *et al*., 2002). One of the reasons why the conservation of tropical forest is important is because its existence contributes substantially to carbon sequestration, moderating global climate change. More locally, the plant cover can have a major influence on the local climate, the provision of water supplies, control over soil erosion and flooding, and the availability of habitats for animals, including insects that pollinate crops. These are provisioning and regulating ecosystem services. There are two other types (Millenium Ecosystem Assessment, 2005): cultural services, such as aesthetic appeal and spiritual value, which are important in the implementation of plant conservation (see next section), and supporting services, such as nutrient cycling, which are concerned with the internal functioning of ecosystems.

All types of production systems involving plants should be targets in ecosystem-based plant conservation. They include agriculture, livestock grazing in more natural habitats and resource harvesting from wild plants (timber, fodder, medicines, etc). Much progress must be made. Intensive, chemical-based, agriculture is a major cause of loss of biological diversity (Mabey, 2010). Extensive areas of savannah and other rangelands are over-grazed (He, 2009; Perrings, 2000). Livelihoods in developing countries have commonly been made more precarious by the overharvesting of resources gathered from wild plants, such as firewood (Dounias, Rodrigues & Petit, 2000). Even with protected areas, the inclusion of sustainable use as a major management objective is often unavoidable. Many protected areas, supposedly under strict protection, suffer from unregulated harvesting of their plants (Nagendra, 2008).

2. The Frontline: the Locality

The locality is the critical place for the pursuit of ecosystem-based plant conservation. This is where plants live and where conservationists can interact directly with those people who have the most immediate influence on their fate. In rural settings, such people may include farmers, herders, collectors of wild plant produce and the managers of protected areas, according to the site. Urban settings too are relevant to ecosystem-based plant conservation, for instance for the contributions that their plants can make to ecosystem services. Grass-covered, rather than hardtop, driveways permit the recharge of aquifers and reduce flooding (White, 2008), while plants in gardens can provide habitats for threatened wildlife (Osborne *et al*., 2007).

The locality is where the integration of all three aspects of ecosystem-based plant conservation must be practically achieved. An initial step is the evaluation of the special conservation features of the place with respect to plants (Fig. 1). Analyses should be forward-looking, taking account of anticipated environmental change, for instance in the climate. Questions to ask include: how does (or could) the locality contribute especially to conservation of plant species?; how does (or could) the cover of plants at the locality contribute to the provision of ecosystem services?; what types of ecologically sustainable produce from plants does (or could) the locality provide?

Of course, actions taken away from the locality are often needed to achieve much conservation advance. They may include new laws and regulations, awareness-raising campaigns on plant conservation and steps taken to encourage environmentally responsible purchasing of plant-based products. However, any actions taken in

favour of conservation away from where the plants grow must result in better conditions for the plants on the ground to be of real use. The relationship between field projects and policy development can be synergistic. Progress at field level can be highly dependent on advance in policy. In turn, field examples can provide case studies useful for ensuring that policies are realistic.

Cultural services, the third type of ecosystem services, are of great importance for the delivery of plant conservation. It is normal in human societies for people to hold religious or other cultural beliefs that help protect certain features of the natural world from destructive exploitation (A.C. Hamilton, 2001). Examples include the beliefs and related practices that protect the Sacred Landscapes of the Tibetans, the Holy Forests of the Dai and numerous sacred groves in Africa and India (e.g. Xu *et al*., 2005). Similarly protective beliefs are found in western societies. Americans are attracted to 'wilderness', the British to 'old fashioned countryside' and Germans to 'forest' (Schama, 1995).

3. Developing Plant Conservation as a Service

Plant conservation requires development as a service to deliver its full potential. We see a parallel with medicine, which similarly is an art applied to practical problems and which likewise is strongly influenced by science. The same form of social organisation seems appropriate for both, that is with a frontline of general practitioners delivering services to the public, backed up by information systems and other specialist support. However, there is a major difference between conservation and medicine. Medicine (dealing with human health) is much better supported financially than conservation (dealing with environmental health), even though the latter is just as essential in the longer term for human welfare.

There are many hurdles to overcome in building capacity for ecosystem-based plant conservation: gaining acceptance by government agencies and conservation groups of the validity of the approach, developing training programmes for field practitioners, developing information systems targeted at field practitioners and, most fundamentally, winning more public support. Plant-based sciences, such as botany and forestry, have been in decline as university subjects in many countries over recent years (Disney, 1998; A.C. Hamilton *et al*., 2003). Plants tend to be poor relations to animals in the public's conservation consciousness, despite their keys roles in ecosystems and economies. With the possible exception of the 'medicinal plant', no-one has yet come up with an image of plant conservations as iconic as the panda.

The key competencies required of field practitioners must be established. They will certainly include knowledge relating to all three purposes of the ecosystem approach, the social skills necessary to work constructively with partners, especially communities, and the acumen to know when to ask for help. These are demanding requirements, though in principle not much different from the cross-disciplinary understandings and inter-personal skills required of any practical conservationist. Previous educational experiences should be helpful for devising training programmes, for instance those of the People and Plants Initiative (PPI, 1992-2005), an international programme to build global capacity in applied ethnobotany (A. C. Hamilton, 2004). This experience is relevant, because applied ethnobotany, like ecosystem-based plant conservation, straddles the boundary between the social and botanical sciences and centrally involves working with communities. One lesson learnt from PPI is the value of extensive period of mentored field research by trainee professionals. As with the acquisition of other practical skills, there is much to be gained from an apprenticeship approach.

Knowing how conservation can best be pursued can be problematic, given its multidimensional nature with many influencing variables. An 'evidence-based approach' and 'participatory action research' (which is rather similar) have been proposed as useful for its development, the former inspired by its success in medicine (A.C. Hamilton & Hamilton, 2006; Song & Vernooy, 2010; Sutherland, Pullin, Dolman & Knight, 2004). There have already been some attempts at an evidence-based approach, for example a programme of WWF to identify best practice in integrated conservation and development projects (ICDPs) (McShane, 1999) and another of Plantlife International to identify how communities can best conserve their medicinal plants (A.C. Hamilton, 2008; Pei *et al*., 2010).

An evidence-based approach involves periodic reviews of the evidence relating to the success or failure of practical efforts to deal with particular issues, followed by the formulation of recommendations on best practice. These recommendations can then be disseminated for wider practical adoption or treated as hypotheses for further testing. If properly applied, the evidence-based approach should not lead to 'cookbook' solutions, but rather to the integration of the expertise of the individual practitioner with the best external evidence (Sackett, Rosenberg, Gray, Haynes & Richardson, 1996).

4. Ecosystem Thinking Can Boost Species Conservation

The ecosystem approach is not a threat to conventional plant conservation, which is mainly concerned with saving species. Rather, by providing a wider conceptual framework - through broadening the purposes seen for plant conservation and rooting the discipline in people-plant relationships - it should increase the effectiveness of many activities associated with the conventional approach.

Success at achieving delivery of ecosystem services or sustainable use can result in relatively immediate and tangible benefits appreciated at local level. Therefore, emphasising these aspects of plant conservation can be helpful for gaining public support. Habitats that are good providers of ecosystem services are often good for species' conservation too (Dobson *et al*., 2006; Duffy, 2009; Hector, Joshi, Lawler, Spehn & Wilby, 2001; Hooper *et al*., 2005).

An example off how attention given to a prized ecosystem service can help deliver species' conservation is provided by the history of forest conservation on the Eastern Arc Mountains of Tanzania. These forests are of great global significance for the conservation of plant species (Lovett & Wasser, 1993). Here, the delivery of water supplies from the mountains is closely linked to the presence of forest. It was threats to water supplies, in particular, that led to the government strengthening its control over these forests during the 1970s (A.C. Hamilton & Smith, 1989). Later, it was the hydrological, more than the biodiversity, case that was critical in the decision to create Amani Nature Reserve on the East Usambara Mountains, a prime Eastern Arc site (AH, pers. involvement).

An example demonstrating the value of focusing on sustainable use is provided by the history of conservation of Bwindi Impenetrable National Park in Uganda (A.C. Hamilton, Cunningham, Byarugaba & Kayanja, 2000). The small forest contained within this park is of prime national and international value for the conservation of plant species (Davis, Heywood, Herrera-MacBryde, Villa-Lobos & Hamilton, 1994, 1995; Howard, 1991). It is home to half the world's mountain gorillas. The creation of the park in 1991 was accompanied by the imposition of strict rules prohibiting all access to its plant resources. This, in turn, generated local hostility and fires were set within the forest and threats made against the gorillas. A major contribution to avoiding disaster was a field evaluation of the values of the plant resources of the park to the local people (Cunningham, 1996). The results of this survey were instrumental in the drawing up of agreements between the park and local communities, allowing defined rights of access to plant resources (Wild & Mutebi, 1996). Tensions were reduced.

Placing more emphasis on ecosystem services and sustainable use should be useful for saving plant species away from protected areas, the desirability of which is widely acknowledged today. Many endangered species of plants are not confined to protected areas (e.g. about 40% of Chinese species – CSPC, 2008), certain aspects of plant diversity, such as traditional crop varieties, are closely associated with people and not readily amenable to a protected area approach (Pei *et al*., 2009) and protected areas will lose much of their effectiveness for conservation with predicted climate change unless attention is given to conservation elsewhere (Ackerly *et al*., 2010; Manning, Gibbons, & Lindenmayer, 2009).

It has become recognised that the *ex situ* conservation of threatened plants should not be conceived as an end in itself (Schulman & Lehvävirta, 2011), a view endorsed by the ecosystem approach with its *in situ* focus. Recognising this, it follows that the usefulness of *ex situ* plant collections for conservation purposes should be gauged by their effects on the *in situ* world. *Ex situ* plant collections are not *a priori* necessarily beneficial to conservation. Many serious plant invaders have spread out from collections in botanic gardens (Mabey, 2010) and the introduction of modern crop varieties (bred from the germplasm of crop landraces in seedbanks) is ironically one of the principal reasons why such landraces have been disappearing (Song & Vernooy, 2010; Veteläinen, Negri & Maxted, 2009).

The ecosystem approach has some democratic advantages. It is inclusive in seeing roles in plant conservation for people everywhere. It inherently acknowledges the value of geographically-based cultural diversity, since every locality requires the presence of people with an interest in its particular plants. The ecosystem approach incorporates a social model that offers the potential to develop greater equality in distributing the costs and benefits associated with conservation. A fair distribution of costs and benefits is likely to be instrumental for achieving long-term success in conservation – another parallel with medicine (Wilkinson, Pickett & De Vogli, 2010).

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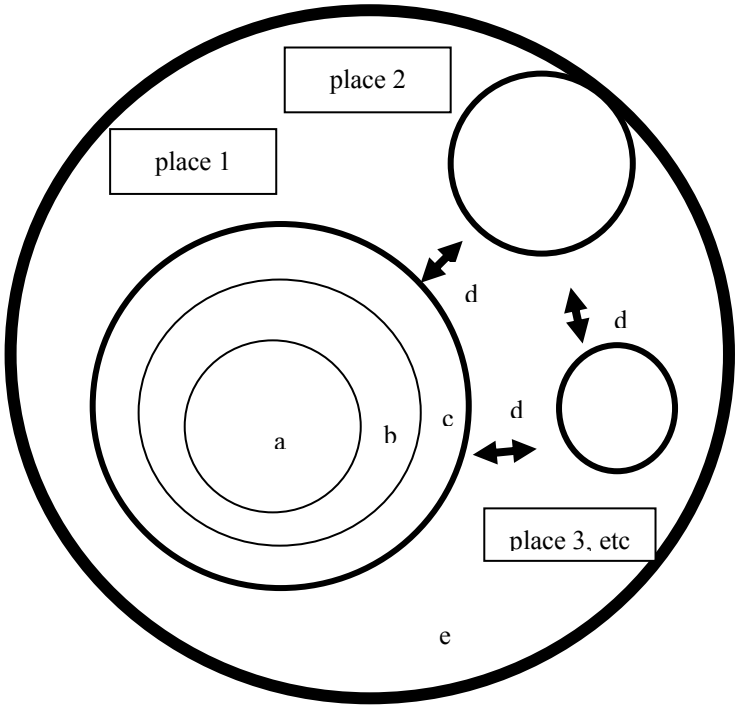

Figure 1. Representation of Ecosystem-based Plant Conservation

a. The inner circle represents the plants of any place. These plants may contribute to one or more of the three purposes of plant conservation (species conservation, ecosystem services, sustainable use). Alternatively, the plants may deliver few or no conservation benefits (e.g. with much intensive agriculture) or be replaced by a plant-free surface (e.g. where the land is covered by buildings).

b. The inner ring represents those people who do (or could) influence the plants directly, such as farmers, gardeners, collectors of wild plant resources and reserve managers.

c. The outer ring represents those people who do (or could) influence the plants, though only indirectly, such as lawmakers, consumers, contributors to climate change and conservation biologists.

d. Places vary in their relative (actual or potential) contributions to plant conservation. Therefore, the optimal delivery of conservation benefits from plants entails trade-offs between places (indicated by the two-way arrows).

e. The outer circle represents the Earth's limit of ecological sustainability, setting a minimum long-term requirement for conservation achievement. The current level of exploitation of Earth's ecosystems already exceed the limits of global sustainability (Hails, Humphrey, Loh, & Goldfinger, 2008).

Regulation, Knowledge Transfer, and Forestry Policy Implementation: Different Strokes for Different Folks?

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Abstract

Knowledge transfers from the public to the private sector about the substance and necessity of regulatory rules are critical for effective regulatory compliance. With groups of professionals that share specialized training the overall problems are minimized. Yet what happens when regulators contend with non-professionals? Using a case of forestry policy in Washington State we find that professional-to-professional exchanges are relatively effective, but that non-professional forest owners were less responsive, which reduced the effectiveness of the knowledge transfer and program compliance. We also find that one way to overcome this implementation barrier is to have regulators use an adult-based learning method.

Keywords: Regulation, Knowledge transfer, Forestry policy, Adult learning, Ways of knowing, Policy implementation

1. Introduction

By definition, a private forest owner's ability to provide good forest management is linked to appropriate knowledge about forest ecology and stewardship practices. Additionally, where private forest practices are regulated by government, forest owners need to understand not only the regulatory policies, but also the rationale behind regulations; otherwise they are less likely to willingly comply with regulatory directives (Creighton & Baumgartner, 2005, 197). Consequently, in order to facilitate effective forest management natural resource professionals advising and/or otherwise regulating private forest owners must have the capacity to not only convey such knowledge, but to do so in a manner in which it is accepted and applied by those being regulated. Traditionally, especially in regulatory arenas defined by science and technical issues, the passage of knowledge from the public to the private sector has been treated as a fairly simple, technical transfer of a set of facts, rules, and policies across the public-private boundary (Nicolini *et al*., 2003, 6). Success requires the creation of a common language, computer or information technology compatibility, a common set of training guidelines and procedures, and so on (Carlile, 2002). The emphasis is on *sending* information, or finding ways to standardize or make compatible methods of communication to facilitate the transfer of knowledge from one participant or organization to the next, and to identify the barriers that slow this process or the structural components of the regulatory relationship that might speed this process (Podolny & Page, 1998).

Such an approach to knowledge transfer makes sense if the senders and receivers of such knowledge share an occupational profession. Within each separate group of professional economists, lawyers, engineers, or silviculturalists (foresters), for example, individuals have been shown to adhere and respond to professionally defined career-based incentives for advancement, and to be shaped profoundly by their specialized training (Mosher, 1982). The net result is that professional groups tend to direct their attention to, and give more credence to, certain types of information, while also showing a preference for distinctive problem recognition and problem-solving methods (Katzmann, 1980; Scott, 1998). Clearly, for many regulatory realms that primarily, if almost exclusively, require interactions between similarly trained experts on both sides of the regulatory puzzle (e.g., securities regulation/securities law; finance and tax regulations), this approach to knowledge transfer is adequate.

However, there are many regulatory arenas where the professionals (experts) in government agencies are not always complemented by similarly trained professionals in the private sector. What happens then? How do regulators ensure that their knowledge is accepted and applied when the regulated community may be responding to different cues, perhaps more social than technical in nature, or perhaps closely related to their own on-the-ground decision-making experiences, as they decide what constitutes valid knowledge for problem solving purposes? Moreover, what happens to the knowledge transfer dynamic when the regulated community is *not* reasonably monolithic, or homogeneous, in its composition? Do regulators need to adapt their approach to the knowledge transfer puzzle in such cases?

These questions have become more central to policy and regulatory debates in recent years with the growth of private-public partnerships and other collaborative governance arrangements that regularly and integrally engage a broad variety of publics and professionals in policy decision-making and implementation processes (Bingham & O'Leary, 2008; Sirianni, 2009; Weber, 2003). As well, we have learned more about distinctive, value laden "ways of knowing" that directly affect people's perspectives on information, problems and solutions (Feldman *et al*., 2006), and as researchers have started to understand knowledge and knowledge transfer from a "pragmatic view of knowledge" that treats it as "localized, embedded, and invested in practice" (Carlile, 2002) (Note 1). It is not enough from this perspective to highlight differences between participants, for sometimes that will only heighten the difficulties of transferring knowledge. Rather, there is a need to recognize the connections between knowledge and practice, or the premise that what people and organizations know is deeply embedded in what they practice. This view of knowledge has a "situated" dimension to it, in that knowledge must be understood in the context of practice that is situated in a geographic setting, a particular point in time, or within a particular set of social relationships (Nicolini *et al*., 2003). In other words, in order to get effective regulatory compliance in some, perhaps many cases, regulatory professionals must understand the individuals and business/landowners they are regulating as well as the technical specifics found in the scientific and regulatory rationales for particular rules (Cartmell *et al*., 2006; Downing & Finley, 2005).

To help forest policymakers and regulators better understand the dynamics of knowledge transfer, we examine the process of knowledge exchange between private forest owners and natural resource management professionals (regulators) in the State of Washington. The research is part of a larger study of Washington's innovative "Alternate Plan option," (Note 2) a policy instrument developed by the State to render its Forest Practices Rules (WAC 222) more responsive to individual properties and owners. Study participants were

asked to describe and compare their various knowledge sources, and to discuss which types they most preferred and why. The private forest owners of importance to the segment of the study discussed in this paper belonged to two groups -"professional" non-industrial private forest (NIPF) owners and smaller "non-professional" non-industrial private forest (NIPF) owners. The variation within the regulated community allowed us to examine the differences, if any, in the way that professionals and non-professionals approached the transfer of knowledge from regulators and the broader implications from any such differences.

Our findings confirm that forestry professionals, whether public or private, hold similar views toward knowledge and credible sources of knowledge, and that this helped to facilitate a relatively easy exchange of knowledge across the public-private organizational boundaries as well as the application of that knowledge to forest practices by the private "professional" foresters. Yet we also discovered that "non-professional" NIPF owners viewed knowledge differently than professional foresters, and tended not to use the same criteria as professionals to determine the credibility of information. Non-professionals relied more heavily on social cues, as opposed to scientific validity, and the degree to which they felt their own experientially based forest expertise was respected as part of the conversation over whether and how the state's regulators would permit them to develop an Alternate Plan for their forest property. For this part of the regulated community "knowledge is practice." In short, this group plays by a different set of rules that require acknowledgement on the part of natural resource managers if the knowledge they are imparting is to be heard, accepted and applied to the public problem at hand. Put differently, the disjuncture in the approaches to knowledge reduced the effectiveness of the knowledge transfer to non-professionals because Washington State regulators did not correctly understand what many forest owners needed from their knowledge providers.

2. Study Area and Research Method

We studied forest owners throughout the State of Washington who had considered or participated in the Alternate Plan program. The Alternate Plan option enables a forest owner to request departures from any of the prescriptive regulations that arise from the state's Forest Practices and Forest Practices Rules, as long as the forest owner can demonstrate to the satisfaction of a team of state natural resource professionals that the owner's proposal can be expected to produce a level of ecological protection at least equivalent to that obtainable under the prescriptive rules. The forest owner, often assisted by one or more privately hired consultants, works collaboratively with land management agency experts to finalize the accepted provisions of the Alternate Plan. The program requires extensive communication and knowledge exchange between forest owners, consultants, and agency professionals, and consequently provides an excellent forum for studying the process of knowledge transfer between professionals and non-professionals. Private forest owners receive information and regulatory supervision from the State Department of Natural Resources, Department of Ecology, and Department of Fish and Wildlife. In cases involving federally listed threatened or endangered species, the United States Fish and Wildlife Service or National Marine Fisheries Service may also become involved. On sites where sensitive soils are a concern, the federal Natural Resource Conservation Service may participate. Forest owners also often turn to the Washington State University Extension Service, forest ownership organizations, and peer networks for information and advice.

Forests and forest management are integral to the culture and economy of Washington State. Forests comprise approximately half of the state's land base, and about 42% of the 22 M total forested acres are privately owned (Washington Department of Natural Resources, 2005, Erickson & Rinehart, 2005). Of the privately held forests, about 1.3 million acres are owned by Washington's 34 Native American tribes, another 2.5 M acres are owned by the industrial forest ownership sector (Erickson & Rinehart, 2005; Mason, 2007). The remaining approximately 5.5 million acres are owned by an estimated 215,000 non-industrial private forest (NIPF) owners (Washington Department of Natural Resources, 2001; Rogers & Cooke, 2009).

We conducted an inductive, qualitative study, collecting data through in-depth interviews with 109 diverse stakeholders involved in the design, administration, and use of the Alternate Plan program. As is typical in inductive studies, the interview group was selected on the basis of theoretical rather than statistical sampling. Theoretical sampling was purposive, rather than random or statistically selective. Interviewees were selected by means of chain referral based upon their knowledge or experience in the subject under study. The sample size was determined by the emerging data: new interviewees were sought until additional interviews yield only repetitive, rather than new, data. The interview group included forest owners, policy advisors, state and federal land management agency personnel, natural resource consultants, forest business consultants, and special interest group representatives. Most interviews lasted at least two hours, but a few lasted as long as three or four. Most all study participants were interviewed in person, although six were interviewed by telephone at their request. All interviewees were promised anonymity. The interview process was ongoing from August 2004 through June

2007, with follow-up phone calls taking place into 2008. The interviews were semi-structured to ensure that each covered the same material. As part of their discussion of their overall experience with and perceptions of the Alternate Plan program, interviewees were asked to discuss their information sources, their perceptions of and reactions toward those sources, and their reasons for choosing or rejecting the information offered.

The interview data were analyzed using the constant comparison technique (Glaser & Strauss, 1999, 101-116). This technique enabled the researchers to progressively compare the data from each interview with all of the previous ones. Emergent themes were identified and coded (Clarke, 2005), and related quotations and observations of patterns were compiled in a process described by Maykut and Morehouse (1994) as the discovery stage.

3. The Variation in Contexts: Professionals versus Non-Professionals

Diverse regulated communities can pose a challenge for regulatory officials. In the case of private forestlands in Washington State, there is a major difference in the types of NIPF forest owners government officials must deal with. On one side there are the *professional* IPF's and NIPFs, while on the other are the non-professional NIPFs. The distinct contexts within which these forest owners operate can be characterized along three dimensions-degree of integration into the policy network, educational/professional backgrounds, and perception of personal efficacy in the regulatory process.

Professional IPF's and NIPFs in Washington State are well integrated into the forestry management policy network. They are typically long-term players in the forest ownership arena. Many professional NIPF's have followed in the footsteps of other family members engaged in forestry management. In other words, they belong to a multi-generational stewardship and management tradition of private forests that has been passed down along with the professional expectations associated with effective management practices and interaction with public officials. They are more likely to be members of the Washington Farm Forestry Association, the primary statewide organization representing non-industrial forest owners. Some have personally engaged in political activities such as lobbying government officials and attending forest management conferences involving both private and public officials. Many thus have well- established working relationships with existing and former regulators as well as other IPF and NIPF professionals.

By contrast, non-professional NIPFs are usually on the outside looking in at the policy network. They rarely come from an established lineage of private forest owners and typically have limited contact with forestry agency officials as well as with other NIPFs, professional or otherwise.

The same differences abound when it comes to educational/professional backgrounds. Whereas professional NIPFs typically have specific, high level technical training in natural resource and forestry sciences and practices, non-professional NIPFs come from diverse educational and professional backgrounds that tend to have no direct relationship to forestry or natural resource management. Given this, professional NIPFs are advantaged because they speak the same language as their regulatory overseers who share their intensive training and focus on all things forestry, while non-professionals are at a distinct disadvantage given their lack of familiarity with concepts, terms, acronyms, and practices. Moreover, given that non-professional NIPFs almost always manage their lands for multiple goals (e.g., recreation, nature-based retreat or haven, as well as forestry) and pursue other full-time professions, most NIPFs we interviewed agree that there are definite limits on the ability of non-professionals to overcome this disadvantage. Finally, professional NIPFs tend to identify themselves as members of a recognizable occupational group or community, in this case, forestry professionals, while non-professionals, given their diversity, do not.

These key differences among professionals and non-professionals factor into forest owners' sense of their own personal efficacy in the regulatory process. As might be expected, professional NIPFs are experienced and therefore can more easily adapt to the requirements of regulatory planning and implementation exercises, and possess a high degree of confidence in their own "expert" ability to evaluate knowledge, plans, and regulatory directives. Non-professionals, on the other hand, are uncomfortable and inexperienced in the regulatory planning and implementation spheres, and although they may feel a close personal attachment to their forest they tend to have a low degree of confidence in evaluating regulatory information and directives on their own. As well, non-professional NIPFs experience a low sense of efficacy, given that weak integration into the policy network and the lack of forestry background leaves them discouraged and feeling out of their depths when they do interact with government officials. Moreover, part of this discouragement and diminished efficacy stems from the fact that non-professionals encounter considerably higher costs in their attempts to gather and verify information vis-à-vis professional NIPFs.

3.1 Results and Discussion: Evaluating, Accepting and Applying Knowledge: Different Strokes for Different Folks

The descriptive differences in the professional versus non-professional contexts alone are not of significance. The critical significance lies in the connections between the context, decision and problem-solving practices, and, ultimately, outcomes (Katzmann, 1980; Khademian, 1992). With respect to professional and non-professional NIPFs in Washington State, the differences in context are correlated to distinctive approaches to decision-making as they relate to receiving and incorporating forestry management knowledge from regulatory officials. The professional NIPFs rely heavily on what we call a "technical, merit-based" approach to how knowledge from regulators is treated, while non-professionals adopt a radically different approach grounded in social relationships and a strong sensitivity to the manner in which regulators treat them when discussing forestry management plans and regulatory options. The variance in approaches directly affect whether the knowledge regulators are seeking to transfer is heard, understood, accepted, and applied to public problems by private forest owners.

Professional NIPFs, by contrast, approach knowledge in much the same way as their professional counterparts in the regulatory agencies. They focus tightly on the credibility, or merit, of the science employed for a particular decision or plan and accept criteria such as "professional reputation", "scientific credibility", and "peer review" (personal interviews). If the plan is firmly grounded in good science, then the likelihood increases that professional NIPFs will understand, accept, and apply the new knowledge. As one large, industrial forest owner notes: "We rarely get sideways with the agency professionals, and, in fact, we find them generally easy to communicate with and work with" (personal interview, 2/10/05). Similarly, professional NIPFs tend to treat knowledge providers - the person delivering the information--in the same way. What is the "technical" reputation of the provider? Do they have the appropriate professional or technical pedigree(s) in terms of education and experience to be credible? In this way, professional NIPFs do not lean heavily on personal relationships. Instead they treat providers as interchangeable as long as they meet the technical standards associated with the provisions of credible, science-based information.

Non-professional NIPFs, on the other hand, generally respect science and know that it is necessary to many regulatory decisions governing forest management (personal interviews). Yet they also seek a more level playing field in which experiential knowledge related to their particular forest is treated as a valuable component of decision-making, particularly when the science being used is derived from models rife with uncertainty or from unique, non-local landscapes that do not clearly correspond with the management and ecosystem realities of their own forest. For example, an owner of riverfront forest property states:

These new riparian regulations have just been a nightmare. We're really limited in what we can do in terms of timber harvest on our place now, even though my wife's family has been here for generations and we've always managed the place sustainably. There wouldn't even be a riparian forest still here if we hadn't always taken pretty good care of it (personal interview, 10/10/05).

A non-professional NIPF expresses this broader sentiment with respect to science: "Science-based agencies won't take social risks, they won't admit that their science isn't always accurate," while another laments that "I get frustrated over scientists who have tunnel vision. They can't see the whole picture, they don't know my history or the environmental history of my piece of land" (personal interviews, 10/4/04 and 11/9/04). This difference in approach also leaves agency "professionals" frustrated. As one puts it, "the science speaks for itself. I don't really understand why so many of them the non-professional NIPFs want to keep arguing about it" (personal interview, 3/10/05). Another adds, "We're going where the science takes us. I'd like to see more landowners understanding the science and pleased about using it It's hard to get most of the small forest owners to accept it" (personal interview, 2/16/05**)**.

At the same time, non-professionals rely heavily on personal social relationships and individualized trust when deciding whether the knowledge on offer is appropriate. Thus, their subjective impressions of the person or institution delivering it becomes critical, especially the perceived attitude and intent of the individual(s) delivering the information. For example, "most NIPF's are very wary of the agencies and do not particularly trust them to be objective. Our Cooperative Extension forester, though, was great. He really helped us" (personal interview, 9/17/04). Others are concerned that too many agency professionals in the forestry arena "know a lot about fish and forests, but not so much about people" (personal interview, 9/17/06). This means that knowledge providers are *not* interchangeable based on their technical competency. Instead, providers are far more likely to meet with success in transferring knowledge to the extent they appreciate that "it's all about relationships," especially personal, trust-based relationships (personal interviews, 12/22/06; 3/10/05; see also Weber &

Khademian 2008). Thus it matters when agency professionals give the impression that "forest owners are bad," or that in-house agency scientists "are getting too self-important," or, on a more positive note, whether "they really wanted me to be successful in my forest. I wish more of the people from the agencies were like that" (personal interviews, 10/4/04; 12/21/05; 4/6/05**).**

If no such personal relationship exists, whether because of scarce agency resources or otherwise, then the tendency of non-professional NIPFs is to rely on other sources for knowledge and advice (although relative to professional NIPFs, these networks are weak and small). Given this, it then becomes important for regulators to make the attempt to better understand how non-professionals are linked together so that they can build positive, trust-based relationships with critical influencers within the non-professional network, leaving the influencers to positively impact the rest of the network. In some instances these influencers may be professional forestry consultants, but for the subset of NIPF owners who cannot afford or prefer not to work with a consultant, the influencers are likely to be other, trusted non-professional NIPF owners.

Another key difference in the decision on whether to accept and apply knowledge from regulators is grounded in the approach to knowledge assessment. Both professionals and non-professionals expressed frustration with the tendency of forestry agencies in Washington State to give inconsistent advice on management recommendations and regulatory interpretations, thereby making it imperative that they verify and reconcile government information and recommendations. Given their own educational backgrounds/expertise and strong sense of efficacy, professionals tend toward self assessment and/or a reliance on other professionals' assessments of knowledge. But non-professionals, perhaps because of mistrust as well as a weak sense of efficacy and lack of forestry training, tend to go much further. They commonly check the veracity of the knowledge being imparted across a much broader range of sources. Chief among these are Washington State University Cooperative Extension (WSU Extension), private consultants, and informal networks. As one non-professional NIPF noted, "I always hope I'm getting good guidance from a particular agency employee, but I really like having my forestry consultant as a backup. I know he's looking out for me" (interview, 4/20/06). Others in this category said they prefer to rely on information from their informal personal networks than on scientific information from an institution or another professional. This was particularly the case if they did not have a strong, positive working relationship with the regulatory agencies or its employee representatives (personal interviews, 9/04 through 5/07).

Finally, non-professionals focus on the amount of empathy regulators display toward them and their personal situation. Of critical importance are questions such as: Do government-based knowledge providers treat such private forest owners with respect given their non-professional status and unique problem sets that involve more than forestry as a management goal for the land? Do regulators make a reasonable effort to show non-professional NIPFs how a new rule or plan can benefit them and their land? Is knowledge exchange a two-way street in which both science and experiential knowledge are integral to decision-making and in which landowners' concerns, whether economic, aesthetic, or ecological, are given a fair hearing? Few were tolerant of a professional whom they did not believe respected them, their personal situation, or their experience. As one non-professional forest owner who had won awards for good forest management said, "It offends me that they seem to assume I'm likely to mismanage my land without their direct supervision. It's almost as though they expect that I don't want to or know how to do the right thing" (personal interview, 10/05/04). In another case, a landowner frustrated with a particular agency employee said, "That guy was the weakest link throughout all of this effort to design a timber harvest on his property. Finally, though, we got to the right people and we could hardly believe what a difference that made" (personal interview, 10/10/05). In other cases, non-professional NIPFs noted that that they sought communications with agency professionals that clearly signaled "respect, respect, respect" (personal interview, 10/4/04), whether it was in the style of communication-"talk with us, not at us" (personal interview, 3/10/05), or in the appreciation for the different decision dynamics confronting a forest landowner/manager as opposed to agency regulators and scientists.

There's a crucial difference between the way most forest owners and most scientists make decisions. For forest owners and operators, adaptive management is essential or they wouldn't be able to successfully make a living. They need to be able to make decisions and take action quickly. Pure scientists, though, are distanced from temporal pressure and the causes and effects of decisions. They can view scientific rigor as the prime decision point (personal interview, 11/23/04).

In short, failure to recognize the importance of this empathy dynamic for non-professionals lessens the likelihood that knowledge will be transferred and applied.

3.2 The Regulatory Approach, Adult Learning Theory, and the Knowledge Transfer Problem

The differences in the context--degree of integration, educational backgrounds, and sense of efficacy-and in the evaluative criteria, or decision-making style used to decipher and decide which knowledge is worthy of being transferred and used in forest management practices are clear. The problem, as Creighton and Baumgartner (2005), Katzmann (1980), Khademian (1992), and others have found, is that the differences in evaluative criteria can also have direct implications for policy and management outcomes. Our findings agree, yet add an important additional element to the policy implementation mix - we found that there is a match, or correspondence, between the decision styles in the regulated community and the approach to the regulated community by regulatory officials. In cases where the regulatory interaction is between agency and private sector "professional" NIPFs, knowledge is more likely to be transferred successfully because regulatory policies and the rationale that drives them are more likely to be well understood. Both regulators and professional NIPFs operate according to the same decision criteria described above-science is key and both sides of the regulatory transaction speak the same language and are part of the same recognizable occupational community of natural resource professionals.

Core elements of an effective atmosphere for adult learning are inherent in such horizontal, peer-to-peer, transactions. These core elements include a shared cognitive background, mutual understanding, mutual interpersonal respect, and a readiness for a multi-directional dialogue receptive to the knowledge and opinions of all who are party to the exchange of information (Vella, 1994; Merriam *et al.*, 2007). We found that regulators consciously or unconsciously employed techniques that enhance adult learning when interacting with this group of professional private foresters. As noted by Daniels and Walker (2001) in their work on collaborative learning in natural resource policy settings, "adults bring more experience, less patience, and little tolerance for being 'taught'; they want to learn actively while they are working on the issues that are important to them. They need to be co-learners or peers much more than pupils" (79). Regulators tended to set the stage for effective adult learning by embracing a dynamic of reciprocity in which regulatory 'experts' respected the professional NIPF 'learners' prior knowledge, offering a peer-to-peer, horizontal (as opposed to hierarchical) learning dynamic (Keen & Mahanty, 2006; Vella, 1994). The peer-to-peer interaction accepted that a successful "cycle of discovery, integration, application, and transmission of new knowledge is dynamic and non-hierarchical" (McGrath, 2006, 5), and led, according to those interviewed, to a learning atmosphere in which they experienced 'membership' status and a high degree of collegial respect within the professional network. This peer status also translated into a greater willingness on the part of regulators to give greater credibility to professionals' practical forestry management experiences, the type of pragmatic, contextually oriented subject material that adult learners typically desire (Extension Committee on Organization and Policy, 1985), in cases where the science and empirical outcomes clashed (Knowles, 1984; Rogoff, 1984).

The congruence between the professionals', both regulators and NIPFs, decision styles, along with the regulators' provision of a respectful atmosphere conducive to effective adult learning, led to higher satisfaction on the part of the professional private forest landowners and often a greater willingness to comply with regulatory directives (less resistance), hence more effective forest management/plan implementation. From this perspective there is no knowledge transfer conundrum and policy implementation success improves because of it.

A substantial problem often surfaces, however, when the interaction is with non-professional forest landowners, not because they are naturally resistant to new knowledge and/or regulatory requirements and management plans, but because the knowledge exchange process between regulatory professionals and non-professional, layperson NIPF forest owners often fails to embody a positive atmosphere for effective adult learning. The problem is exacerbated by the fact that, for non-professional forest owners, the degree and type of necessary learning is often far more difficult to achieve. For a professional forest owner, any necessary new learning about forest stewardship principles or forest regulations is likely to be comparatively minor and incremental, since the professional owners begin their new learning from an already high platform of prior knowledge. Non-professional forest owners, by contrast, often begin from a relatively low or even non-existent platform of prior relevant knowledge. Many of them must therefore engage in a much more challenging process, one which typically involves a steep, long learning curve and may also involve a need for 'transformative learning' (Mezirow, 1978; Cranton, 2006) that substantially changes their understanding of their fundamental relationship with their land. Instead of adapting their knowledge transfer approach to accommodate the different learning context and decision-making style of the non-professional forest owners group, however, regulatory professionals tended to forge ahead with their same technical, merit-based "scientific professional" style of information delivery and failed to cultivate the core elements associated with a successful adult learning environment. First, regulators did not offer the potential for peer-to-peer interaction and/or relationships

mimicking the more typical close, neighborly relationships of value to this group. Instead they fostered a more conventional, hierarchical professional/non-professional relationship which reinforced the intellectual distance, hence separateness between regulators and regulated. As Mellow (2005) and Clover (2002) have previously noted, this is a recipe for dissatisfaction and resistance. The hierarchical 'expert to non-expert' approach creates an inevitable tension between the presumption of the professional 'experts' that *formal* education and science are most relevant, and the opposing presumption on the part of many non-professionals that their *informal* education and experience with their forestland deserves a similarly high level of respect and credence (Merriam *et al*., 2007). We found that this apparent lack of respect from certain natural resource professionals was especially objectionable to non-professional forest owners who had earned awards for good forest management, or who were accustomed to receiving a high level of professional courtesy and respect in other job settings.

Second, many of the regulatory professionals bypassed critical early phases of the learning cycle (Kolb, 1984; Daniels & Walker, 2001) by failing to adequately explain or otherwise demonstrate the relevance of new concepts or regulations to non-professional forest owners before requiring implementation. Since "knowledge acquisition is a gradual process (MacEachren, 1992), and "the order in which learning occurs is essential to its effectiveness" (Vella, 1994, as quoted in Daniels & Walker, 2001), this type of omission hampers the knowledge acceptance and application process.

Third, regulators typically failed to demonstrate empathy, or "situational cognition" in their interactions with the non-professionals. Situational cognition means that adults want evidence that the knowledge provider relates to and understands their circumstances "from the inside out" (Rogoff, 1984). Because adults are reluctant to engage with educators who do not appear to be situationally cognitive, knowledge is unlikely to be adopted unless conveyed through personnel and media attuned to its recipients (Keen & Mahanty, 2006). In fact, this agrees with Kittredge (2004), who found that many forest owners gravitate strongly toward empathetic knowledge providers, rather than those who simply try to inform, teach, or regulate them.

The fact that many natural resource professionals are unfamiliar with and do not employ precepts of effective adult education is not surprising. The available research and information linking adult learning theory to environmental contexts is so widely dispersed in interdisciplinary literature that it is difficult for researchers or practitioners to locate and conceptualize (Meyer, 2006). Furthermore, despite the fact that their work frequently involves the need to educate stakeholders about environmental concepts, the formal training of natural resource professionals focuses on ecology and typically omits any discussion of educational theory. As a result, although well-informed about ecological concepts, many natural resource professionals are not well equipped to convey those concepts to the public. The overall effect in the case of non-professional NIPFs in Washington State was a poor understanding of regulatory policies, misconceptions about forest ecology and management, and disillusionment with many of the professionals and institutions advising them. Importantly, and perhaps unsurprisingly, these outcomes of the knowledge transfer process led to greater resistance to the knowledge on offer, which ultimately resulted in less effective implementation of forest management regulations and plans (Gootee, 2009). Given the fact that the vast majority of forest owners-over 90,000 in Washington alone-fall into this category of non-professional NIPF's, the failure to take account of their different decision-making style is likely to have significant negative consequences for forest health, while also increasing citizen distrust of government agencies more generally (which makes future knowledge transfers that much more difficult). Similar outcomes may be expected to follow the continued emergence of collaborative environmental governance opportunities, wherein professionals and non-professionals must necessarily be closely engaged in an ongoing process of information transfer (Rickenbach *et al*., 2004).

4. Conclusion

This research highlights the significant variation in the approach to knowledge within the world of Washington State forest management policy. The variation means that the transfer of knowledge and the tendency to more willingly comply with the new forest program in question went relatively smoothly between agency forestry professionals and private sector forestry professionals. Such was not the case, however, when the transfer of knowledge involved agency professionals to non-professionals. A key reason that this latter case did not work well is that the non-professional receivers of information relied much more on socially grounded, value laden "ways of knowing" and the context of their own practice-based experiences, rather than the "science" of forestry preferred and emphasized by agency professionals. The difficulties of knowledge transfer and policy compliance were further compounded by the way in which Washington State forestry officials approached non-professional forest owners. These owners were treated to a conventional, hierarchical expert/non-expert relationship instead of a more appropriate adult learning approach offering a peer-to-peer, horizontal (as opposed to hierarchical) learning dynamic.

The problem with the hierarchical approach today, of course, is that scholars and many others now recognize that society's view of science and scientists is in transition (Ozawa, 1991; Kuhn, 1996). Forest management, once primarily a technical matter of improving commodity production, now encompasses far more diverse social interests (Smith, 1997). As well, society and scientists are increasingly aware that scientific discovery is a dynamic, open-ended process wherein any current knowledge is not necessarily conclusive (Jasanoff & Martello, 2004). Consequently, the public is increasingly unwilling to view natural resource professionals as omniscient regarding appropriate environmental management strategies, and is often resentful of professionals who attempt to retain hierarchical "expert/non-expert" relationships with stakeholders (Luckert, 2006; Winter *et al*., 2004).

All of which leads back to the importance of adult learning theory as a potential key tool for regulators faced with the challenge of multiple approaches to knowledge within the regulated community. More studies are needed that test the ability of adult learning theories, properly applied, to overcome the barriers faced by regulators in such situations. Another implication of this research is that regulatory agencies might find greater success to the extent they employ professionals with both adequate science credentials and considerable training in the social sciences, including more specifically, communications, education, dispute resolution, economics, sociology, psychology, and/ or political science. Familiarity with the fundamentals of transformative learning and adult education would substantially improve the preparedness of natural resource professionals for their critically important role as public educators by helping them recognize the limitations and risks associated with the conventional, hierarchical 'expert-to-non-expert' paradigm of information transfer.

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Notes

Note 1. Scott (1998) develops a similar concept that he terms "*metis"*--a wide array of practical skills and acquired intelligence developed in response to the dynamic environment (313).

Note 2. The Alternate Plan option (WA RCW 76.09; 76.13; and WAC 222-12-040) permits forest owners to suggest management alternatives that differ from the State's prescriptive Forest Practices Rules (WAC 222), if the alternative can be expected to result in equivalent or better levels of protection.

Yield of Sesame (*Sesamum indicum* L.) as Influenced by Organic Fertilizers in the Southern Guinea Savanna of Nigeria

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Abstract

Field experiments were carried out during the rainy seasons of 2008 and 2009 at the teaching and research farm of Nasarawa State University, Keffi, Lafia campus in the southern Guinea savanna agro-ecological zone of Nigeria to assess the effects of poultry manure, cow manure and sheep manure on the performance of sesame crop. Manure application was found to have significantly increased both yield and yield attributes of sesame compared with non application at all. Application of 2.5 t ha^{-1} of poultry manure produced the highest value for all the yield attributes measured. The seed yield per hectare in both years were also optimized with the application of 2.5 t ha^{-1} of poultry manure (1914.07 and 1933.20 kg ha^{-1} in 2008 and 2009 respectively) compared with any other applied rates of sheep and cow manure and is therefore recommended.

Keywords: Number of capsules, Capsule weight, Seed yield per plant, Seed yield per hectare, Sheep manure, Poultry manure, Cow manure

1. Introduction

Sesame (*Sesamum inducum* L.) also known as beniseed in West Africa, Sim-sim in East Africa is an oil crop belonging to the family *Pedaliaceae* grown in both tropical and sub-tropical regions of Africa, Asia and Latin America. It is the most important crop from which semi-drying vegetable oils are obtained and perhaps the oldest crop cultivated for its oil (Onwueme & Sinha, 1991). In 2007, Asia produced 2.4 million metric tons; Africa produced 1.2 million metric tons and Nigeria 110,000 metric tons of sesame (UN/FAO, 2008).

Sesame is produced mainly in the savanna agro-ecological zones of Nigeria by small holders' farmers on relatively poor soils with limited inputs, thereby resulting in low average yield of 300 kg ha^{-1} compared with 1,960 kg ha^{-1} in Venezuela and 1,083 kg ha^{-1} in Saudi Arabia respectively (Abubakar *et al*., 1998).

Sesame oil is considered to be of high quality oil and is often referred to as the "queen" of vegetable oil. This is due to its stability and high keeping quality as well as resistance to rancidity. Sesame oil is used in the production of paints, soaps, cosmetics, perfumes, insecticides, canned sardine and canned beef as well as for pharmaceutical and ethno botanical uses (FAO, 2002; RMRDC, 2004). The whole seed is high in calcium, phosphorous, iron and are well supplied with essential vitamins such as thiamin, riboflavin and niacin. The whole seed is used on top buns and snack foods, fried and eaten with sugar, unfried or ground and used in making soup. The leaves are used for vegetable soup (Onwueme and Sinha, 1991).

Traditional sesame growers in Nigeria rarely apply fertilizer on this crop because it is considered that it perform well even on poor soils (Haruna & Usman, 2005). However, nutrition studies in the tropics have shown that the crop perform well with the applications of organic or inorganic fertilizers (Olowe & Busari, 2000; Okpara *et al*., 2007; Haruna *et al*., 2011).

Manure is a key fertilizer in organic and sustainable soil management. It contains many of the elements that are needed for plant growth and development. Apart from increasing soil fertility, manure serve as soil amendment by adding organic matter to the soil. Organic manure has also been reported to greatly improve water holding capacity, soil aeration, soil structure, nutrient retention and microbial activity (Anon, 2007a) Manure application results in increased pH, water holding capacity and decrease in bulk density when used on long term basis (Anon, 2006).

Considering the low yield of sesame obtained in most growing areas as a result of non application of fertilizers and the poor fertility status of savanna soils, there is the need to assess the performance of sesame using different organic manure, which is the objective this study seeks to achieve.

2. Materials and Methods

Field Experiments were conducted during the rainy seasons of 2008 and 2009 at the Teaching and Research Farm of Nasarawa State University, Keffi, Lafia campus in the southern Guinea savanna agro-ecological zone of Nigeria 08^0 $30^/$ N and $30^/$ E, 18 m above sea level. The soil of the experimental site is sandy loam, well drained characterized by moderate pH (5.0 – 6.0), low in organic matter (0.06 -0.07%), available phosphorus (10.5 – 11.1ppm) and nitrogen (0.03 – 0.05%). The plot had not been cropped for three years.

The experiment consisted of factorial combinations of three levels each of sheep manure (0, 2.5 and 5 t ha^{-1}), poultry manure (0, 2.5 and 5 t ha^{-1}) and cow manure (0, 2.5 and 5 t ha^{-1}) respectively. The twenty seven (27) treatment combinations were laid out in a split-plot design and replicated three times. Cow and poultry manure levels were assigned to the main-plot, while sheep was assigned to the sub-plot. The gross plot size was $18m^2$ (4.5m x 4m) while the net plot size was $9m^2$ (3m x 3m). The experimental area was disc-ploughed and harrowed twice to a fine tilt. This was then followed by ridging at 75cm apart (between rows) and the field marked into plots and replications. The plots were separated by 1.0m unplanted boarder while replications were separated by 2.0 m unplanted boarder. The organic fertilizers were incorporated two weeks before sowing.

The planting material used was Ex-Sudan; it is white in colour, of medium height and medium maturity (85 to 90 days) (RMRDC, 2004). Sesame was planted on the 29^{th} and 30^{th} August in 2008 and 2009 respectively. Six to ten seeds of sesame were sown at 15cm intra-row spacing on ridges spaced 75cm apart and was later thinned to two plants per stand at three weeks after sowing. Manual hoe weeding was done at 3, 6, and 9 WAS to keep the experimental plots weed-free.

The crop was harvested at physiological maturity when the leaves and the stems changed colour from green to yellow with a reddish tint on them. Harvesting was manually done with the aid of a sickle by cutting the plants at the base close to the ground. Plants from each net plot were placed in a sack to dry so as to minimize seed loss when capsule dehisces. When the harvested plants were adequately dried, the sacks were gently beaten with sticks in order to release all the seeds from the capsules. The seeds were then separated from the chaff by winnowing. Ten randomly selected plant samples from each plot were used at harvest to determine the yield attributes such as number of capsule per plant, capsule yield per plant, seed yield per plant while, the entire plant in the net plot were used to obtain the seed yield per hectare.

2.1 Data Analysis

The data collected were subjected to analysis of variance using the 'F' test to estimate the significance in the effects of the treatments as described by Snedecor and Cochran (1967). Comparisons of treatment means were done using Least significant difference.

3. Results

Data on the yield attributes comprising of the number of capsules per plant, capsule weight per plant, seed yield per plant, 1000 seed weight at harvest showed that application 2.5 t ha^{-1} of poultry manure produced significantly higher number of capsules per plant, capsule weight per plant, seed yield per plant compared with other rates of applied poultry manure and other manure types used (Table 1). Increasing the rate of applied poultry manure from 2.5 t ha^{-1} to 5.0 significantly decreased all the yield attributes measured. Applications of 5 t ha^{-1} of cow and sheep manure significantly increased number of capsules per plant, capsule yield per plant, seed yield per plant and 1000 seed weight compared with other rates of application.

Seed yield per hectare of sesame was significantly increased by the application of 2.5 t ha^{-1} of poultry manure in 2008 and 2009 compared with other rates of applied manure (Table 2). Applications of 5 t ha^{-1} of cow and sheep manure produced significantly higher sesame yield per hectare compared with zero and application of 2.5 t ha^{-1} in 2008 and 2009. In both years of study, the highest yield of sesame per hectare (1914.07 and 1933.20 in 2008 and 2009 respectively) was produced by the application of 2.5 t ha^{-1} of poultry manure. Interactions between the treatments tested, were however, not significant.

4. Discussion

From the results obtained, it was seen that yield and yield attributes of sesame were significantly increased by the application of poultry manure, cow and sheep manure. This could be attributed to the low nutrient status of the soil and the ability of manures to supply nutrients contained in them gradually to support crop growth which

later translated to high yield and yield attributes (Aliyu, 2003 & Anon., 2007a). Both yield and yield attributes of sesame were optimized at 2.5 t ha^{-1} of poultry manure application while, optimum yield were obtain with the applications of the highest applied rate of cow and sheep manure probably because the poultry manure used during the experiment has higher nutrient content compared with cow and sheep manure (Table 3).

Application of poultry manure produced the highest yield of sesame compared with sheep and cow manure. This could be attributed to the fact that poultry manure has a low carbon to nitrogen ratio which mineralizes faster to release its nutrients hence its effect was superior to other manure tested.

5. Conclusion

From the fore going, it can be concluded that though both yield and the yield attributes of sesame were significantly increased with the applications of all the nutrients tested compared with non application at all, application of 2.5 t ha^{-1} of poultry manure produced the highest yield and yield attributes in both years and is therefore recommended.

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Table 1. Effect of treatments on the number of capsules per plant, capsule yield per plant, seed yield per plant and 1000 seed weight (data pooled for 2008 – 2009)

Treatment	Number of capsules per plant	Capsule yield per plant (g)	Seed yield per plant (g)	1000-seed weight (g)
Poultry manure t ha^{-1}				
0	28.57c	12.94c	10.21c	3.10b
2.5	49.65a	19.95a	15.24a	3.50a
5.0	36.40b	15.64b	12.48b	3.25b
S.E±	0.449	0.353	0.114	0.066
Cow manure t ha^{-1}				
0	35.77c	14.29c	11.20c	3.10b
2.5	37.28b	15.93b	12.72b	3.26b
5.0	41.57a	18.31a	13.99a	3.47a
S.E±	0.449	0.353	0.114	0.066
Sheep manure t ha^{-1}				
0	37.07c	14.34c	11.77c	3.12b
2.5	37.98b	15.48b	12.88b	3.25b
5.0	39.57a	18.71a	13.27a	3.48a
S.E±	0.432	0.354	0.098	0.055

Means followed by different letters within the same treatment group or column are statistically different at 5% level of probability.

Table 2. Seed yield (kg ha^{-1}) of sesame as influenced by organic manure in 2008 and 2009

Treatment	Grain yield (kg/ha)	
	2008	2009
Poultry manure (t ha^{-1})		
0	1134.35c	1191.06c
2.5	1914.07a	1933.20a
5.0	1339.35b	1406.32b
SE±	3.416	3.587
Cow-dung manure (t ha^{-1})		
0	1318.05c	1383.95c
2.5	1416.60b	1487.43b
5.0	1653.13a	1669.13a
SE±	3.416	3.587
Sheep manure (t ha^{-1})		
0	1173.32c	1231.99c
2.5	1581.40b	1660.47b
5.0	1633.05a	1649.38a
SE±	2.373	2.492

Means followed by different letters within the same treatment group or column are statistically different at 5% level of probability.

Table 3. Composition of organic manure used during the experiment

Manure type	2008					2009				
	% N	% P	% K	% Ca	% Mg	%N	% P	% K	% Ca	% Mg
Poultry manure	3.00	1.76	2.30	3.72	0.58	3.83	1.93	2.54	3.54	o.55
Cow manure	1.74	0.40	1.10	0.30	0.40	1.32	0.38	1.11	0.30	0.40
Sheep manure	1.9	1.4	2.9	0.25	0.30	1.81	1.50	2.75	0.22	0.31

Quality of Vermicompost Obtained from Residues of Forestry and Livestock

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Abstract

The forestry-livestock waste materials represent a serious ecological problem if they are not handled properly in agricultural activities. Vermicomposting is a biotechnological process with potential to transform such materials into products that can be safely used as soil enhancers. The objective of this study was to evaluate the nutritional characteristics of organic fertilizers obtained from forestry-livestock organic waste materials when they are processed through vermicomposting using "Red Californian Earthworm" (*Eisenia fetida*). A completely randomized experimental design with four treatments and eight replicates was performed. Treatments (mixtures) included: leaf litter + sawdust (LS), bovine manure + sawdust (BS), rabbit manure + sawdust (RS), and ovine manure + sawdust (OS). Total nitrogen, pH, carbon/nitrogen ratio, organic carbon and nitrates from vermicompost samples were measured and statistically analyzed using SAS v8.2. At the end of the study, all mixtures showed similar characteristics according to the analyzed variables. Carbon/nitrogen ratios decreased in three mixtures to values considered as within the vermicompost maturity stage. Contents of nitrates and total nitrogen were

increased. Final pH showed statistical difference among all mixtures. Results indicate that vermicomposting is a viable process for recycling forestry-livestock organic waste materials since it improves their chemical and nutritional characteristics.

Keywords: *Eisenia fetida*, Vermicompost, Agricultural amendment, Biotechnological process, Recycling, Organic waste

1. Introduction

Forestry-livestock organic residues represent a serious ecological problem if they are not handled properly in agricultural activities. Agriculture, cattle farming and forestry are important economical activities in the state of Chihuahua, Mexico. In accordance to official information, Chihuahua has recorded 1 708 887 bovines; 79 050 hogs; 1 808 335 poultry (INEGI, 2007); 203 757 goats; 131 712 horses and 86 621 sheep (INEGI, 2004), which generate significant quantities of manure. Also, the timber industry has enormous losses due to the low efficiency in the transformation processes, being sawdust one of the most important by-products (Zaragoza, 2004). These economical activities produce large quantities of waste materials that can be transformed into pollutants, causing ecological problems as a consequence (i.e. soil salinization, nitrate and phosphate lixiviation to underground waters and accumulation of lignin, aromatic oils and resins).

Although agricultural and forestry waste materials constitute a potential source of contaminants causing human health problems, they can also be seen as a new industry with extensive applications. An alternative for diminishing the environmental impact when using organic waste materials is their treatment by means of vermicomposting with "Red Californian Earthworm" (*Eisenia fetida*) which carries out a constant mixing and ventilation of materials, provides digestive enzymes and influences the decomposition characteristics of organic matter (Santamaría-Romero *et al.*, 2001; Domínguez *et al.,* 2003).

In the vermicomposting process, organic residues are decomposed by earthworms, diverse microorganisms and environmental factors. Carbon dioxide, water, mineral ions and stabilized organic matter are the most important products, the latter an enriched material with humic substances (Ulle *et al.*, 2004). It has been demonstrated an increase on the nitrogen (N) mineralization velocity as well as on the ammonium ($N\text{-}NH_4^+$) to nitrate ($N\text{-}NO_3^-$) conversion index by the action of earthworms (Atiyeh *et al*., 2000a; Moreno, 2004). Diverse mixtures of organic residues processed by earthworms have been published, namely hog manure mixed with food remainders and bovine manure mixed with fruit fibers of oil palm, among many others (Hernández *et al*., 2008). Nogales *et al*. (2005) point out that vermicomposting is an excellent biotechnological process to produce agricultural amendments and that vermicompost is a chemically and biologically enriched material.

As a result of the vermicomposting process, organic waste materials are recycled into stabilized products that can be applied to soils as a relatively dry, odorless source of organic matter with the ability to meet the soil's organic fertility requirements in a safer and more efficient way than the incorporation of untreated materials (Soto & Muñoz, 2002; Hernández, 2002). Nutritional properties of vermicompost can vary due to the different types and proportions of materials used, decomposition stage of such materials, vermicomposting conditions, and maturity and storage periods (Durán & Henríquez, 2007).

Vermicompost from forestry-livestock residues seems to provide useful characteristics as a soil-improving material in ecological agriculture. In addition, vermicomposting process allows the elimination of pollution caused by manure, sawdust and leaf litter.

The objective of this study was to evaluate the nutritional characteristics of organic fertilizers obtained from forestry-livestock organic waste materials when they are processed through vermicomposting using "Red Californian Earthworm" (*Eisenia fetida*).

2. Materials and Methods

The study was conducted at the Agrotechnology Sciences Department, Universidad Autonoma de Chihuahua, Mexico. The decomposition process was undertaken for sixteen weeks (February to June, 2007). As nitrogen (N) source, four organic residues were used: bovine manure, rabbit manure, ovine manure and leaf litter. Pine's sawdust was used as carbon (C) source. Four treatments (mixtures) were prepared: leaf litter + sawdust (LS), bovine manure + sawdust (BS), rabbit manure + sawdust (RS), and ovine manure + sawdust (OS). All mixtures had an initial carbon/nitrogen (C/N) ratio of 25/1, considered as an optimum ratio to initiate composting and vermicomposting processes (Hansen *et al*. 2001; Soto y Muñoz, 2002). To determine the required quantity of waste materials, the program "Moisture and C/N Ratio Calculation" developed by Richard (1995) was used.

The mixtures were deposited in 2-L plastic containers with 10-mm orifices in the bottom side to assure the draining of excessive humidity (Nogales *et al*., 2005; Santamaría-Romero *et al*., 2001). Initially, the mixtures were

subjected to a 15-day pre-composting process to avoid possible damage to earthworms due to a temperature increase (Castillo *et al.*, 2002). Later on, ten adult Red Californian Earthworms (*Eisenia fetida*) per liter per experimental unit were inoculated (Hernández *et al*., 2002). The study was conducted under laboratory conditions at 25ºC temperature (Nogales *et al*., 2005) and 70-80% humidity (Soto & Muñoz, 2002).

Samples of vermicomposts were collected at weeks 4, 8, 12 and 16 to quantify organic carbon (organic-C), total nitrogen (total-N), nitrates ($N\text{-}NO_3^-$) and pH which are parameters needed to determine if a vermicompost fulfills the required standards for its use like a soil enhancer (García, 2006). To measure these parameters 200 grams of vermicompost were sampled, dried out in stove at 60ºC, sifted in No. 20 mesh and placed into polythene bags. Organic carbon was quantified by the ASTM method (2000), total-N by Micro-Kjeldahl method (APHA, 1992), $N\text{-}NO_3^-$ by Brucine and UV-visible Spectrophotometry method (APHA, 1992) and pH by pHmeter (Fisher Scientific Accumet AB15, US®) using a water dilution of 1:5 (w/v).

A completely randomized experiment with four treatments and eight replicates was designed, which included the treatments and time as fixed effects. The results were statistically analyzed and means were compared by Tukey test ($P \leq 0.05$) using the software SAS version 8.20 (2004).

3. Results and Discussion

Vermicomposting significantly modified the observed characteristics of the initial mixtures. In general, vermicomposts obtained from the 16-wk decomposition process were more homogeneous, darker in color and odorless. These findings are similar to those previously published by other researchers (Soto & Muñoz, 2002, Nogales *et al*., 2005).

The statistical analysis on the total-N evolution did not show effect on the treatment*time interaction ($P \leq 0.4467$) nor the treatment factor ($P \leq 0.1339$) (Figure 1). Nevertheless, the time factor showed a significant effect ($P \leq 0.0320$) on total-N concentration. The RS treatment showed the highest level of total-N at weeks 8 and 12 with values of 1.63 ± 0.49 and 1.84 ± 1.41 respectively, while OS treatment showed the highest level of total-N at weeks 4 and 16 with values of 1.63 ± 1.05 and 2.06 ± 0.62 respectively.

Total-N content of 16-wk vermicomposts showed no statistical difference ($P < 0.2662$) (Table 1) but it increased as compared to its initial content, behavior expected as a result of: i) production of N-containing metabolites by earthworms; ii) mucosity production, an N-enriched fluid excreted by earthworms; iii) N-enriched dead tissue; and iv) the mineralization process during vermicomposting (Del Aguila *et al*., 2011).

Castillo *et al*. (2002) observed total-N concentration of 1.25% in vermicompost obtained from bovine manure and means from 1.02 to 1.11% in mixtures of bovine manure + food remainders, while Barbados (2003) pointed out that the optimum interval for a vermicomposting process product is 1.0 to 2.6%, as seen in the four treatments under study. Melgarejo *et al.* (1997) suggest an N content higher than 2% to allow the organic fertilizer for continuing its humification and mineralization process in the soil. According to Castillo *et al*. (2010), a 29-wk storage period without earthworms can increase the N content of recently elaborated organic fertilizers.

In the transformation process, organic-C content showed an effect on the treatment*time interaction ($P \leq 0.0166$) (Figure 1). As indicated before, this study started with mixtures containing 25% of initial organic-C which increased to values between 28 to 38% in a fluctuant fashion from week 4. These findings coincide with Castillo (2002) who obtained 29.72% of organic-C content when using cattle and bovine manures. Such a behavior has been published by several researchers (Mondini *et al*., 2003) stating that the increase of organic-C concentration can be a result of the C usage from the initial organic residues by microorganisms in order to build new cellular materials, which can be re-used in the vermicomposting process later on, although such an increase do not coincide with Nogales *et al*. (2005) and Santamaría–Romero *et al.* (2001) who observed a decrease in organic-C content due to losses in the form of CO_2 in the process.

At the end of this study, the organic-C content did not show statistical difference among treatments ($P < 0.0923$) (Table 1). Del Aguila *et al*. (2011) stated that the organic-C decreases at the end of the vermicomposting process because of diverse factors: i) the organic-C consumption by earthworms; ii) the transformation in CO_2 by respiratory activity; and iii) formation of the humic fraction which gives place to the mature vermicompost.

According to Barbados (2003), the optimum ranges for organic-C content vary between 30 to 40%; nevertheless, other values must be taken into account to determine the maturity of vermicomposts, such as the C/N ratio.

The C/N ratio of the treatments under study did not show any effect on the treatment*time interaction ($P < 0.0739$) (Figure 1), but there was a difference in the treatment factor ($P < 0.0145$) and time factor ($P < 0.0393$) because the LS treatment showed the highest means in weeks 4 and 12 with C/N ratio of 50.04 ± 14.6 and 66.73 ± 5.06, respectively. The BS treatment showed the lowest mean at week 4 with 23.66 ± 8.79 value. RS and OS treatments

showed mean values of 25.93 and 25.99 respectively. No difference existed among treatments on the C/N ratio in the 16-wk transformation period ($P \leq 0.1005$) (Table 1).

The described changes of organic-C and total-N caused a decrease of the C/N ratio in the LS, BS and OS treatments towards the end of the experimental period. The high C/N values found in vermicompost of rabbit manure are possibly due to the high amounts of fiber surplus found in the animal diet which also remains in high quantities in the used raw material.

In accordance to several researchers, a compost is considered to be stable and mature when the C/N ratio is lower than 20 (Nogales *et al*., 2005) or close to 15 (Acosta *et al*., 2004; Defrieri *et al*., 2005). In this study, the C/N ratio values indicate that the vermicompost maturity began towards the week 16 of the decomposition process.

The evolution of $N\text{-}NO_3^-$ showed an effect in the treatment*time interaction ($P < 0.0478$) (Figure 1). These significant differences were observed because the BS, RS and OS treatments initiated with $N\text{-}NO_3^-$ contents of 135 to 170 mg kg^{-1} at week 4, increased at week 8 and finally decreased at weeks 12 and 16. In comparison, LS treatment showed 226.75 ± 43.17 mg kg^{-1} at week 4, increased at week 8 to values of 317 ± 27.92 mg kg^{-1}, diminished at week 12 to 185.75 ± 75.87 mg kg^{-1}, and finally increased back again to 226.75 mg kg^{-1} at week 16.

The $N\text{-}NO_3^-$ content increase during the vermicomposting process suggests that the earthworms stimulate nitrification. For Atiyeh (2000b), such an increase suggests a higher maturation of the organic residues and it must be considered when incorporating organic residues to soils because $N\text{-}NO_3^-$ is a negatively-charged ion which is not absorbed into the organic substrate or soil particles and can be leached out, contaminating water bodies as well as soils.

At the end of the experimental period, statistical significance in $N\text{-}NO_3^-$ concentrations in vermicomposting treatments was not observed. $N\text{-}NO_3^-$ concentrations showed values close to those seen in compost obtained from bovine manure and sawdust at the 99^{th} day with concentration of 330 mg kg^{-1} (Hao *et al.,* 2004).

Values of pH for the four treatments showed an effect in the treatment*time interaction ($P < 0.0001$) (Figure 1). The LS treatment, although it had a similar behavior, always showed less alkaline pH values in the four sampling periods, as compared to the other treatments. The OS treatment showed the highest pH mean, with value of 9.91. OS and RS treatments showed mean values of 8.99 and 9.30, respectively. The four treatments showed significant differences in their final pH average values ($P < 0.0001$) (Table 1).

Treatments showing pH values higher than 9 were those containing manure. In accordance to Barbados (2003), the pH of the substrate in the vermicomposting process plays a very important role on the earthworms because it has a direct influence in their feeding and reproductive functions, being pH values close to 7.0 (in a range from 5 to 8.5) preferred by earthworms.

On the matter, Santamaría-Romero *et al.* (2001) stated that earthworms die in substrates having pH values below 5 and above 9. In vermicompost, they also found an increase of pH values up to 8.7 at week 4 and 8.6 at week 16. Several researchers explain that such an increase is due to the ingestion of decomposed organic residues by earthworms, which are chewed with their gizzards and then passed to the esophagus where calcareous glands are found with the function of excreting calcium carbonate to neutralize organic acids of the food (Ramirez, 2002).

These results are in accordance to Gutiérrez *et al*. (2007) who obtained pH values of 9.3 in bovine manure and 9.2 in ovine manure when evaluating the development of *Eisenia fetida*. In this study, a pH value higher than 9.0 seemed not to influence other variables since any statistical significance was found among the four treatments under evaluation.

4. Conclusions

The results of this laboratory study demonstrate that vermicomposting is a viable biotechnological process for recycling forestry-livestock organic waste materials because it decomposes and stabilizes such residues, contributing to diminish environmental problems. With regards to total-N, organic-C, C/N ratio and $N\text{-}NO_3^-$ significant differences among the four mixtures under study were not observed; however, there was an increase in total-N and $N\text{-}NO_3^-$ content. Three treatments (LS, BS and OS) reduced their C/N ratio to values between 18.03 and 19.81, which are considered to be within the interval for mature vermicomposts. In addition, difference in pH values existed with highest values corresponding to mixtures containing bovine, rabbit and ovine manure. These changes provide added value to forestry-livestock residues since vermicomposts can be utilized as enhancers for soils, especially for those with low content of organic matter.

Finally, more research is suggested in this field, since the parameters can vary depending on the season of the year, type of organic residues and mixtures used, as well as on the period of time that such residues are subjected to the vermicomposting process.

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Table 1. Chemical characteristics of vermicomposts with a process of 16 weeks.

Vermicompost		Total-N	Organic-C	C/N	$N\text{-}NO_3^-$	pH
		%			mg kg^{-1}	
Leaf litter + sawdust	LS	1.68 a	31.1 a	19.34 a	222 a	8.16 c
Bovine manure + sawdust	BS	1.58 a	31.1 a	19.81 a	235 a	9.10 b
Rabbit manure + sawdust	RS	1.46 a	38.0 a	26.80 a	235 a	9.44 a
Ovine manure + sawdust	OS	1.46 a	35.1 a	18.03 a	249 a	9.26 a

[ab] Averages with same letter in same column do not differ statistically (Tukey $P \leq 0.05$).

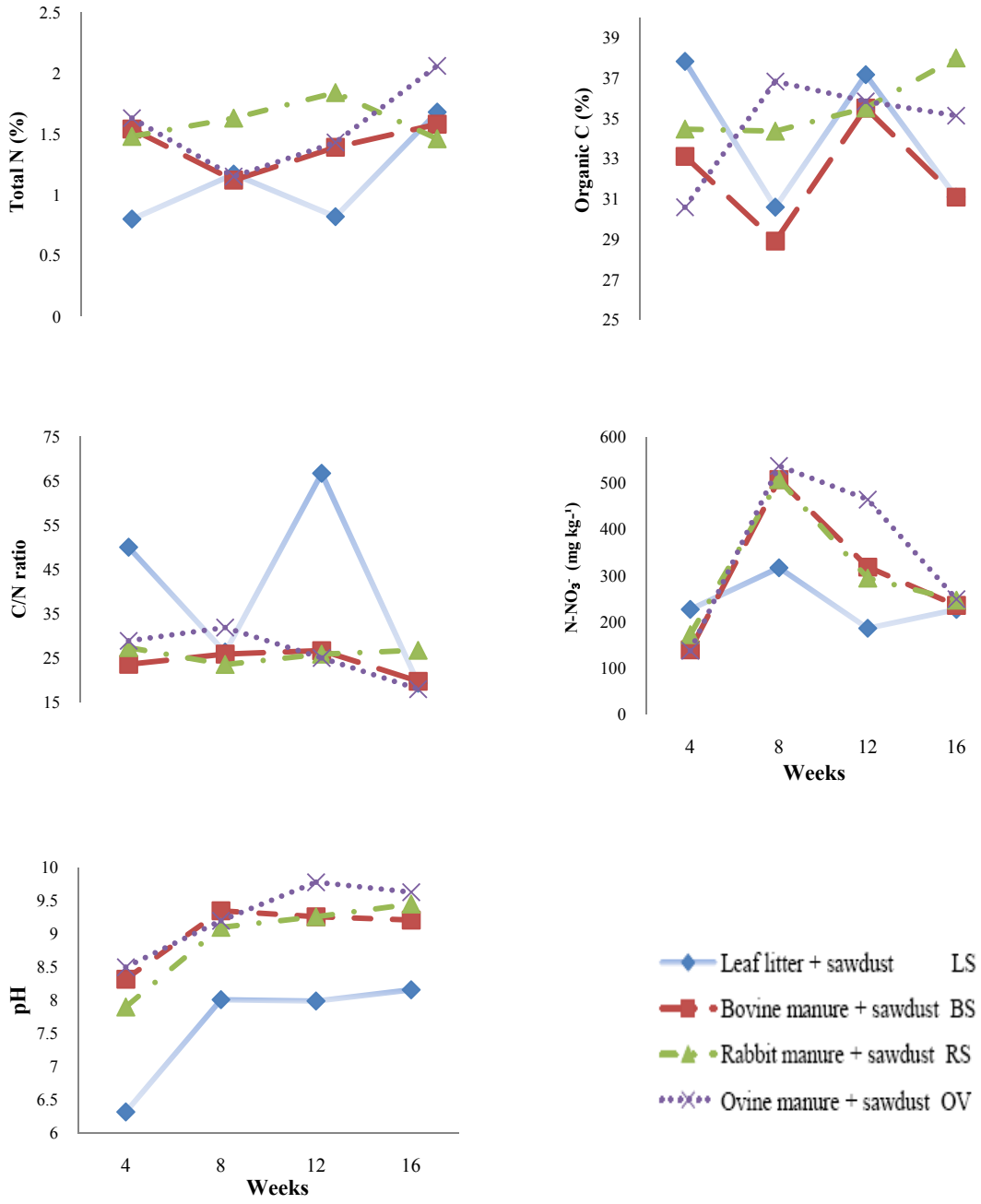

Figure 1. Dynamics of value averages for: a) total-N, b) organic-C, c) C/N ratio, d) $N\text{-}NO_3^-$ and e) pH, for vermicomposts under study

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Agricultural Diversification in the Garhwal Himalaya: A Spatio-Temporal Analysis

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Abstract

The Garhwal Himalaya represents a traditional agricultural society where more than 74% population largely depends on the cultivation of subsistence cereal crops to run their livelihood. Over the time, with the increase in human population and decrease in per capita land, the traditional subsistence agriculture could not fulfill food requirement. This was resulted in food insecurity and thus agricultural diversification began with the cultivation of cash crops - fruits, off-season vegetables and also of medicinal plants. Although, agro-ecological condition favours diversification of crops and agro-biodiversity is very high in the Garhwal region, the pace of diversifying cash crops for commercialization is tremendously low. Diversity in crops varies spatially - horizontal and vertical and temporally - rabi and kharif seasons. The highlands characterize high agro-biodiversity in comparison to the mid-slopes and the valley regions. Crop diversification index (CDI) of cereals and cash crops was calculated separately from the secondary dada. A case study of six villages was done to calculate cost-benefit analysis of cereals and cash crops. The purpose of this study is to investigate the potential of diversification – cereals as well as cash crops for livelihood sustainability in the Garhwal Himalaya.

Keywords: Diversification, Agro-ecology, Subsistence agriculture, Cash crop, Livelihood, Garhwal Himalaya

1. Geo-Environmental and Socio-Economic Background of the Study Area

The Garhwal Himalaya is located in the Indian Central Himalayan Region (ICHR), a part of Uttarakhand Himalaya, constitutes one of the most fragile ecosystems. The area ranges from 400 m to above 7000 m but human settlements are limited upto 3200 m. Landscape constitutes four eminent features - valley regions, mid-altitudes, highlands, and perpetual snow area with varying degree of climatic conditions ranging from subtropical to temperate, alpine, and frigid. The major perennial rivers - the Ganges, Yamuna, and their numerous tributaries originate from this part of the Himalaya. Administratively, it is a division of Uttarakhand State, comprises seven districts - Chamoli, Rudraprayag, Pauri, Tehri, Uttarkashi, Dehradun, and Haridwar. In this paper, only five districts of the Garhwal Himalaya such as Chamoli, Rudraprayag, Pauri, Tehri, and Uttarkashi are included. These districts are mountainous and known as the mainland of the Garhwal Himalaya. Agriculture practices continue to be the main occupation of people of the Garhwal Himalaya as about 70% population gets direct and indirect employment from agriculture (2011). Agricultural development holds the key to provide livelihood to a significant segment of population and the overall development of the region by way of creating employment, generating income, and ensuring food security to the rural people. Here, agriculture is characterized by low yield due to traditionally cultivating cereals, inadequate capital formation, low investment, inadequate irrigation facility, and uneconomic size of the holdings. Cropping pattern has shown a changing trend in the Garhwal during the recent past. The area under paddy and wheat crops has increased in the mid-altitudes and the valleys. There is a marginal increase in the area under cash crops. The Garhwal Himalaya is an economically underdeveloped and ecologically fragile region of the country. Due to high proportion of area under perpetual snow, steep slops, forest, pasture, grazing and waste lands, only 12 % area is put under cultivation. Low agricultural yield reflects the small size and scattered land holdings, difficult terrain, unfavorable climatic conditions for some crops, inadequate availability of improved inputs and technology, and lack of credit and marketing facilities (Dewan & Bahadur, 2005). While, the state can sustain forestry and agriculture for the survival of the people, live in this rural and hilly area (Bisht, 2006). Per capita net sown area

in the region is 0.089 ha compared to 0.166 ha at all India level. Small and marginal holdings below 1 ha constitute more than 85% of total holdings. Cropping pattern is dominated by the traditional and low productivity crops (mostly cereals), which occupy about 99% of the crop area, providing basic livelihood for a vast majority of the population. The scope to raise employment and income through industrialization is very little because of the fragile landscape and poor infrastructure. Due to this prevailing situation, the income and employment at small farms are not adequate. This is worsening over time due to increase in population and non-availability of other sources of prominent livelihoods. However, the region is endowed with certain climatic advantages which offer numerous opportunities for production of a variety of high value horticultural crops. The landscape features provide a greater opportunity to the agricultural diversification that is prominently essential for sustainable livelihood. It also leads for cultivation of varieties of cash crops including fruits of various kinds in all altitudinal zones. The present study examines the scope for raising income and employment from various categories of land holdings by diversification through cultivating off-season vegetable. The specific objectives are: (i) examining the extent, nature and pace of crop diversification, (ii) quantify role of diversification in agricultural growth, (iii) identifying the key drivers of crop diversification, and (iv) document policy constraints in accelerating the speed of agricultural diversification. This study was conducted through the collection of primary and secondary data from March 2008 to Feb 2009. District wise data on the area and the production of cereals and cash crops were gathered from secondary sources of the government records. Crops diversity was calculated through crop diversification index (CDI) i.e. %age of total cropped area under ‘n’ crops divided by number of ‘n’ crops. Where 'n’ denotes those crops which individually occupied at least 2% or more of the total cropped area in the districts. Primary data were gathered through case study of 6 villages located in the various altitudes. Households involving in growing cash crops were interview and semi-structured questionnaire was prepared for interview.

2. Agricultural Diversification

Agricultural diversification refers to the development of greater variety of agricultural crops within space and time. It takes place with an increase in population and a decrease in per capita cropland. A sustained economic growth, rising per capita income and growing urbanization are ostensibly causing a shift in the consumption patterns in favour of high-value food commodities like fruits, vegetables, dairy, poultry, products from staple food such as rice, wheat and coarse cereals. The demand for and supply of these commodities have grown much faster than those of food-grains (Kumar *et al*., 2003; Joshi *et al*., 2004a). Such a shift in consumption patterns in favour of high-value food commodities even among the poorest strata of the Indian society depicts an on-going process of transformation that is leading towards a ‘silent revolution’ of agricultural diversification. This revolution or process of transformation is also reflected in the rising exports of high-value agricultural products (Government of India 2003). The changing scenario of agriculture has forced the farming community and policy makers in agriculture to search for a more remunerative and viable crops. The diversification of agriculture towards non-food-grain and high value commodities has been the right answer for it, because these commodities have potential of income augmentation, employment generation, poverty alleviation and export promotion (Von Braun, 1995; Pingali & Rosegrant, 1995; Jha, 1996; Ramesh Chand, 1996; Vyas, 1996; Delgado & Siamwalla, 1999; Ryan & Spencer, 2001 & Joshi *et al*., 2004b). It is, therefore, important to diagnose the production-consumption linkages in the context of agricultural diversification. It will enquire identification of the driving forces that can alter production and consumption pattern. It is also important to understand how the production pattern is evolving itself in response to changes in the consumption pattern, in a scenario where smallholders dominate agriculture and a majority of them live in the rural areas (Joshi, n.a.).

3. Patterns of Agricultural Diversification in Garhwal Region

Garhwal Himalaya represents a hotspot in agro-biodiversity. Here, agricultural diversification is slowly picking up momentum in favour of high-value food commodities primarily to augment income rather than the traditional concept of risk management. The nature of diversification differs across regions due to existence of wide heterogeneity in agro-climatic and socio-economic environments. It was considered interesting to delineate the key regions and sub-sectors of agriculture where diversification was catching up fast. Crops, livestock, and forestry constitute the core sectors of agriculture. The crop sector is the principal income-generating source in agriculture followed by the livestock sector. It is depicted a steady diversification here with replacement of food-grain crops with nonfood-grain crops. Several non-food-grain crops such as fruits, vegetables, and medicines have substituted mainly coarse cereals in the farmers’ pursuit for higher income. The government-supported programmes had promoted the cultivation of fruits and vegetables. Among others, watershed program had facilitated conservation of rainwater and gave higher priority to the cultivation of fruits and vegetables. Rice and wheat have replaced coarse cereals and pulses in this region and it is diversifying only

marginally towards non-cereal commodities. Fruits and vegetables have been the traditional route for agricultural diversification in the Garhwal Himalayan Region. Whereas fruit cultivation has been adopted in a big way in the temperate belt, the same does not appear to enjoy any comparative advantage in non-temperate belt. Moreover, the fruits being grown in the non-temperate belt are losing market to substitute fruits grown in the plains. Within horticulture, diversification through off-season vegetables seems to possess great potential in most of the areas in both temperate and non-temperate belts of the Garhwal Himalayan Region. Climatic conditions in many parts of the Garhwal Himalaya are suitable to produce crops like tomato, peas, beans, cabbage, and capsicum in summer season (April to October). The price advantage makes it worthwhile to incur high production cost and transport off-season vegetables to distant consumer markets. There are many small pockets, which have attained economic progress by diversification through off season vegetables cultivation. During the post-green revolution period, fruits and vegetables performed impressively in the Garhwal Himalaya. It was due to the greater thrust to these commodities. To encourage the horticulture sector through coordinating production and processing of fruits and vegetables, National Horticultural Board was constituted in 1984 on the lines of National Dairy Development Board (NDDB). To strengthen food processing and promote their export, the Government of India, established the Agricultural and Processed Food Products Export Development Agency (APEDA). The main aim was to build links between Indian producers and the global markets. It yielded promising results. Table 1 shows district wise CDI of traditional and cash crops in the hill districts of Garhwal region. In terms of CDI in traditional crops, there is a slightly variation. The three districts – Chamoli, Rudraprayag, and Uttarkashi have comparatively less diversity i.e., 7.69 CDI while Pauri Garhwal and Tehri Garhwal have 7.14 CDI. In cash crops, CDI vary from 6.67 (highest) in Chamoli district to 9.09 (lowest) in Rudraprayag and Tehri Garhwal districts. Pauri Garhwal and Tehri Garhwal have 7.14 and 7.69 (moderate) CDI respectively.

4. Spatio-Temporal Factors and Agricultural Diversification

Spatio-temporal factors have a great impact on the agricultural diversification in the Garhwal Himalaya. On the other hand, diversity of crops varies according to an altitude and the cropping seasons. Generally, crops are grown in all three altitudinal zones - valleys, mid-altitudes, and the highlands and in the two cropping seasons - rabi and kharif. Highest diversity of crops is found in the highland during the kharif season. The highlands produce traditional subsistence crops nomenclature as *'Barahnaza'* (literally, '12 seeds') during the monsoon season when enough water remains available for growing various crops. It is further characterized by the vertical distribution of crops - valley regions, mid-altitudes and highlands, and provides support in maintaining agro-biodiversity. Until today, this system controls the livelihood of about 70% of people in the region. The traditional agricultural systems are the reservoirs of many crops and cultivars, most of which are still little known to the mainstream societies, and are better adapted than modern agricultural systems to environmental and social conditions (Altieri, 1995; Ramakrishnan & Saxena, 1996). Recently, global changes can be noticed in the crop diversification as the practice of cultivating '*Barahnaja'* has decreased particularly in the mid-slopes and low-lying areas. Distribution of major crops according to the agro-ecological zones is as follows:

4.1 Valley Regions

The valley regions comprise < 1000 m altitudes. Settlements and agricultural lands are found on the river terraces and along the roads. Area under farmlands is considerably low. Crop seasons fall one month earlier than to the mid-altitude and the highlands because of comparatively high temperature. Among cereal crops, wheat, barley, gram, *masur*, and mustard are grown during the rabi season – Oct/Nov to March/April and rice and maize are grown during kharif season – April/May to Sept/Oct. Similarly under cash crops, lemon, elephant citrus, ginger, garlic, and green leaves are grown during rabi season and onion, tomato, cucumber, pumpkin, beans, and green vegetables are grown during kharif season. Crops diversity under cash crops is higher than the cereals.

4.2 Mid-Altitudes

This region comprises between 1000 and 1600 m altitudes. Wheat, barley, gram, masur, and mustard crops are grown under the rabi season while rice, *manuwa* (finger millets), *koni, jhangora, kulthi, bhatt, urd, tour, naurangi, rajama, sawa*, and *cheena* are grown under the kharif season. Under cash crops, lemon, elephant citrus, mandarin, orange, ginger, garlic, and green vegetables are grown during the rabi season. During the kharif season, potato, cucumber, pumpkin, beans, pears, peach, nut fruits, and green vegetables are grown.

4.3 Highlands

The highlands are located > 1600 m. Here, diversity in crops – cereals and cash crops are tremendously high. They maintain agro-biodiversity. Sowing and harvesting periods for rabi and kharif crops in the highlands slightly go one month late than the valley region. Under rabi crops, there are fourteen crops grown out of them five are cereals. Under kharif season, the total number of crops is twenty five and out them cereals are thirteen.

The highest number of crops grow under kharif season in all agro-ecological zones shows that agriculture is rainfed. During the monsoon, enough rainwater is available in this region thus, maximum crops are grown. Table 2 shows agro-ecological zones, altitudes, main cropping seasons and major crops – cereals and cash crops grown in the Garhwal Himalaya.

5. Traditionally Cultivating '*Barahnaja*' and Agro-Biodiversity

The practice of *Barahnaja* is the name of a sophisticated intercropping system of rain-fed hill farming. *Mandua* (finger millet), *ramdana/chua* (amaranthus), *rajma* (common kidney beans), *ogal* (buckwheat), *urad* (black gram), *moong* (green gram), *naurangi* (mix of pulses), *gahath* (horse gram), *bhat* (soybean), *lobiya* (French beans) *kheera* (cucumber), *bhang* (cannabis) and other crops are grown together in a mix which is finely balanced to optimise productivity, maintenance of soil fertility, conservation of crop-diversity, and is geared towards meeting diverse household requirements. Zardhari (2000) describes it as a traditional mixed farming system in which central Himalayan farmers grow about 100 varieties of paddy, 170 varieties of kidney beans, eight varieties of wheat, four varieties of barley and about a dozen varieties of pulses and oil seeds each year. In such traditional cultivation, farmers have to spend almost nothing on inputs, since seeds, organic fertilizer, and pest control are virtually free. Whenever they see that conditions are suitable, they would start planting. Crops are grown between 400 and 3,200 metres. Wheat, rice, *mandua,* and *jhangora* are the common crops in three ecological zones, while wheat is grown in almost all the four ecological zones with highest productivity in comparison to the other crops. Various pulses (e.g., "*masur*", *Ervum lens* "*kulat*", and *Dolichos biflorus*) are grown in the intercropping system during the two harvest seasons – early winter after the rainy season (millet) and mid-summer before the hot dry season (barley and wheat). Dry and wet rice, taro, pumpkins, beans, corn, ginger, chili, cucumbers, leafy vegetables, and tobacco are also grown. Potatoes have become an important cash crop, growing in areas unsuitable for other plants. In the upland areas, above 1,500 metres, the practice of cultivating '*Barahnaja*' is common. The mid-slopes and the low-lying river valleys have undergone tremendous changes in cropping patterns as cultivation of paddy, wheat, and cash crops are recent trends. This has reduced agro-biodiversity in these areas.

In the Garhwal Himalaya, *Barahnaja* is conserved by the practice of crop rotation (Sati, 2009). In a year, more than twelve crops are grown in the different seasons. Under the cropping pattern, the total agricultural land is divided into two parts: *Talli* and *Malli Sar*, which is called *Sar*-system (Sati, 1993). From April-May till September-October, kharif crops are grown in the *Talli sar*. The main crops are paddy, *Koni*, and *Jhangora*. The millets are grown in the *Malli sar* in the same period under the kharif season. The millets are *mandua* (finger millet), *ramdana/chua* (amaranthus), *rajma* (common kidney beans), *ogal* (buckwheat), *urad* (black gram), *moong* (green gram), *naurangi* (mix of pulses), *gahath* (horse gram), *bhat* (soybean), *lobiya* (French beans) *kheera* (cucumber), *bhang* (cannabis), and J*war-Bajura*. After harvesting the kharif crops in the *Talli sar*, the rabi crops, wheat, barley and oilseeds are sown during October-November. From October-November till March-April after harvesting the millets, the land is given up to fallow in the *Malli sar*. The cropping pattern under these s*ars* will be in reverse in the second year. Besides the *Talli* and *Malli sar*, in and around the settlements, the vegetables: cucumber, pumpkin, potato, egg plant, lady's finger, garlic and maize is planted during the rainy season. The fields are known as *Bada* and *Pelwara* (Sati, 1993b).

6. Area and Production Patterns of Cereal Crops

Garhwal region represents high diversity of crops with comparatively less area under it and low production. Major crops are wheat, rice, cereals, and maize. These crops characterize highest area and production and major food staples of the inhabitant of Garhwal region. In all the five hill districts of Garhwal region, these crops represent equal proportion in area and production. Table 3 shows area and production patterns of 13 crops in the hill districts of Garhwal. These crops are rice, wheat, barley, *bhat, gahat, maize, manduwa, sawa, rajama, chana, massor, urd, arhar,* and peas. It reveals that out of 13 crops, rice and paddy have highest area and production in all districts. This is followed by *manduwa*. The other crops are sparsely grown with low per ha yield.

6.1 Cultivation of Cash Crops

Cash crops represent a highly valuable commodity and have a high economic viability but in the study region, area under cash crops is considerably less even some areas represent no land under these crops. It is observed from table 4 that potato has highest area under cultivation in all hill districts of Garhwal region followed by rapeseed and mustard and than by chili. The area under these crops varies from one district to another, depending upon the availability of cropped land and agro-ecological conditions. There are more than fifteen cash crops grown in Garhwal region. These crops are chili, ginger, garlic, mango, citrus, apple, potato, onion, sesamum, rapeseed and mustard, soyabeen, tea, drugs narcotics, and plantation crops. Table 4 shows area under cash crops

during 2003-2004.

6.2 Why Diversification of Cash Crops?

The Garhwal Himalaya provides a great scope for production of off-season vegetables. The vegetable farming varies from the valley regions to the mid-altitudes and the highlands according to terrain, slope, soil contents, and availability of water. On the mid-slope and highlands, potato is grown extensively, while on the terraces of valley regions, onion is the main vegetable. Besides, almost all variety of vegetables is grown in the entire basin, which has high economic value. The vegetable farming can be divided into two vertical zones according to the altitude. Potato is the main vegetable of the highlands, which is grown between 1500 m and 2200 m. It is mostly grown on the gentle slope of the mid-altitudes and the highlands (10-15^{o}). During the 1980s, the farmers of the region started intensive cultivation of potato and they are now able to export potato to the regional market. Along with cultivation of potato, the other vegetables and spices such as beans, ginger, cucumber, pumpkin, turmeric, and chili are also grown in this zone. These vegetables are locally consumed. Onions are grown in the lowlands, where the availability of water is ample. It is grown during the summer in different localities along the river terraces. Presently, the farmers are able to export onion in the regional markets (foothills of *Shivaliks*). These localities are found between 800 m and 1200 m.

6.3 High Production and Per Ha Yield of Cash Crops

The author conducted a case study of the six villages (Table 5). These villages were selected on the basis of their altitude, varies from 550 m to 2200 m. Comparative study of cereals (millets, wheat, and rice) and off-season vegetables (onion and potato) were carried out, which reveals area, production, and productivity of the cereals and off-season vegetables. It further denotes that off-season vegetables have high production and productivity both in the lowlands and the highlands than to the cereals (varies from 11.7 to 2.5 per ha yield respectively) while, the area under cereal crops is three folds than to the area under off-season vegetables. In contrast to the low proportion of land, production and productivity of off-season vegetables is notably high. For instance about 460 ha agricultural land is under cereal crops in Kulsari village (1150 m) productivity is 4.7 whereas, the land under cultivation of onion is 85 ha, productivity is 7.1. The proportion of land under off-season vegetables is comparatively high in the highlands with high productivity. In a highland village (Kwarad - 2200 m), land under cereals is 380 ha and its productivity is 2.5 whereas, 180 ha land is devoted for off-season vegetables, which productivity is 10 (Sati, 2009).

6.4 Comparatively High Income Earnings from the Cash Crops

As it is well known that the region possesses suitable agro-ecological conditions for the production of off-season vegetables therefore, high variety of vegetables such as onion, ginger, garlic, capsicum, cauliflower, ladyfinger, cucumber, pumpkin, tomato and potato are grown here but the proportion of land under off-season vegetables is considerably low. With the efforts done by the government agencies and introduction of modern innovation on the farmlands, the land under cereal crops is being transformed either into the cultivation of off-season vegetables or under fruit crops. Table 6 shows income of the farmers from both cereal crops and off-season vegetables.

7. Discussion and Conclusions

Farmers are the principal actors in management of diversity. Decision making by the farmers in choice of component for their farms is influenced by environmental, socioeconomic, and cultural factors as well as political climate (Morin *et al*., 1998). Mixed crop-livestock systems may have the potential to maintain an ecosystem's healthy functioning and enable it to absorb not only the shocks to the natural resource base (Holling, 1995; Prein *et al*., 1998) but also those brought about by sudden changes in the economic environment (Luu, 1999). In the Garhwal region, the farming community has responded to the changing consumption patterns of consumers by diversifying its production towards high-value food commodities. Experiences from many developing countries have revealed about the changing production at the farm level due to altering dietary patterns (Barghouti *et al*., 2003; Dorjee *et al*., 2002). Besides rising income levels, the increasing infrastructural development has been identified as factors that triggered the process of agricultural diversification out from the arena of staple food production (Joshi *et al*., 2005; Pingali, 2004). As economies grow, there is a gradual movement out of subsistence food-crop production to a diversified market-oriented production system. The process of diversification out of staple-food production is triggered by rapid technological change in agricultural production, by improved rural infrastructure, and by diversification in food-demand patterns. The slowdown in income-induced demand growth for staple foods is accompanied by a shift of diets to higher-value foods such as meats, fish, fruits, and vegetables. Since agricultural diversification includes horizontal, regional, and vertical diversifications, Karama *et al.* (1992) identified several potential benefits of agricultural diversification: (1) As

the results of agricultural diversification, increasing quantity and quality of foods and raw materials produced in diverse agro-ecological zones will provide more income for farmers, improve diet for the people, and reduce import demand; (2) Agricultural diversification will results in better utilization of natural resources; (3) Handling, marketing, and processing of more foods and raw materials resulting from diversification will increase value added, employment, and therefore alleviate poverty; (4) The increasing income and diversified sources of foods will reduce the demand for rice; (5) Quality processed products, resulting from vertical diversification and integration, will enhance the potential for exports and therefore will increase foreign exchange earnings. Development of the fruits and vegetables is highly dependent on technological change (Weinberger & Lumpkin, 2007). Unfortunately, the Garhwal region is lacking in farmland technology. Modern innovation in the farming system could not be established here due to the fragility of terrain and remoteness of the areas whereas the region is highly endowed with diverse agro-ecological conditions. As a result of this, only one-tenth of total agricultural area is devoted to fruits and vegetables. Diversification may also have a beneficial effect on the environment, as it usually breaks existing cereal cropping practices, which are of questionable sustainability (Ali, 2000; Cassman & Pingali, 1995). Furthermore fruits grown from trees and perennials are associated with permanent crop cover which limits soil erosion and land degradation. Agricultural diversity, including diversity in cash crops, can be noticed in the highlands throughout in the Garhwal Himalaya while it is comparatively low in the mid-altitudes and the low-lying river valleys. Currently, the changes in cropping patterns seem more pronounced in these two vertical landscapes. Low output from cereals, substantial cultivation of wheat, paddy, and off-season vegetables, high rate of population growth and literacy, large-scale emigration etc. are the major trends that marginalized cereals and subsequently reduced agro-biodiversity. On the other hand, the traditional practice of cereals is suitable in the prevailing agro-ecological conditions of the region. It is sustainable even in the adverse climatic conditions such as drought. In 1987, when there was drought throughout India, the Garhwal Himalaya enjoyed substantial production of subsistence crops (Sati, 2004). Cash crops, on the other hand, provides sustainable livelihood thus, able to augment employment, generating more income and controlling emigration. A sizeable proportion of agricultural land can be devoted to the cultivation of cash crops – fruits and off-season vegetables, particularly along the perennial streams' terraces where water for irrigation is available. Keeping agro-ecology and suitability in view, these crops need to be conserved in a balanced proportion of land so that the agro-biodiversity and food security can be maintained.

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Table 1. CDI in the Garhwal Region

S. No.	District	CDI		Cropped land (ha)	
		Traditional Crops	Cash Crops	Traditional Crops	Cash Crops
1	Chamoli	7.69	6.67	51730 (15.1)	3744 (20.8)
2	Pauri Garhwal	7.14	7.14	124388 (36.4)	3151 (17.5)
3	Rudraprayag	7.69	9.09	32980 (9.6)	745 (4.1)
4	Tehri Garhwal	7.14	9.09	44143 (12.9)	5582 (31.0)
5	Uttarkashi	7.69	7.69	88953 (25.9)	4780 (26.6)

Source: Raw data were collected from the District Statistical Diary (DSD) 2008

Note: figures in parentheses are %ages

Table 2. Spatio-Temporal Distributions of Major Crops

Agro-ecological zones	**Altitudes (m)**	**Main cropping season**	**Major crops grown**	
			Cereals	**Cash crops**
Valley regions	< 1000	Rabi (Oct/Nov – March/May)	Wheat, barley, gram, masur and mustard	Lemon, elephant citrus, ginger, garlic, and green leaves
		Kharif (April/May – Sept/Oct)	Rice and maize	Onion, tomato, cucumber, pumpkin, beans, and all green leaves
Mid-altitudes	1000 -1600	Rabi (Nov/Dec – April/May)	Wheat, barley, gram, masur, and mustard	Lemon, elephant citrus, mandarin, orange, ginger, garlic, and green leaves
		Kharif (May/June – Oct/Nov)	Rice, manduwa, koni, jhangora, kulthi, bhatt, urd, tour, naurangi, rajama, sawa, and cheena (Panicum miliaceum)	Potato, cucumber, pumpkin, beans, pears, peach, nut fruits, and all green leaves
Highlands	> 1600	Rabi (Nov/Dec – April/May)	Wheat, barley, rai, and mustard	Lemon, elephant citrus, mandarin, orange, ginger, garlic, arbi, green leaves
		Kharif (May/June – Oct/Nov)	Rice, jhangora, kodo, Phaphra, chaulai, ogal, kauni, (Fagopyum esculentum), sawa, urd, bhatt, naurangi, tour, uva, (Hoycleum himalayanse)	Potato, cucumber, pumpkin, beans, egg plants, chili, pears, peach, almond, apple, almond, and nut fruits

Source: Primary collection

Table 3. Area and production patterns of crops (%age of cropped area)

Crops	Chamoli		Pauri Garhwal		Rudraprayag		Tehri Garhwal		Uttarkashi	
	Area	Prod	Area	Prod	Area	Prod	Area	Prod	Area	Prod
Rice	23.60	23.21	20.46	21.07	32.28	34.26	22.39	19.60	17.85	29.06
Wheat	29.50	22.30	29.45	24.76	32.33	28.81	35.43	28.12	28.19	32.44
Barley	3.08	3.03	4.91	4.03	3.89	3.29	0.39	1.29	1.75	0.35
Bhatt	0.05	0.02	0.01	0.01	1.13	0.71	0.10	0.01	0.04	0.06
Gahat	0.87	0.58	2.50	1.40	0.57	0.32	1.36	1.75	2.96	0.77
Maize	15.84	17.43	2.54	3.09	0.57	0.59	13.55	3.15	2.48	14.05
Manduwa	21.04	26.64	21.78	27.61	20.48	24.41	12.77	18.95	18.76	12.89
Sawa	4.49	6.12	14.87	16.38	7.49	7.22	5.91	25.17	23.41	4.89
Rajma	0.06	0.04	0.30	0.22	0.29	0.05	4.97	0.41	0.97	4.35
Chana	-	-	0.06	0.05	-	-	0.01	0.01	0.18	0.01
Masur	0.37	0.17	0.09	0.05	0.07	0.03	0.54	0.31	0.71	0.17
Urad	0.80	0.26	2.54	0.95	0.69	0.18	1.34	0.48	1.59	0.37
Arhar	0.22	0.13	0.42	0.28	0.14	0.06	0.40	0.43	0.78	0.15
Peas	0.01	0.01	0.02	0.02	0.01	0.01	0.77	0.27	0.27	0.37

Source: DSD 2008

Abr. Prod = Production

Table 4. Area under cash crops (%age of Total Area) 2003-04

Commodities	Chamoli	Pauri Garhwal	Rudraprayag	Tehri Garhwal	Uttarkashi
Chilies	4.81	22.31	15.57	8.78	1.84
Ginger	0.16	0.86		3.87	0.02
Garlic	1.31	1.30	2.013	0.63	0.23
Mangoes	0.05	1.78		0.08	
Citrus fruits	0.19	0.03			0.04
Apples	0.03	0.03	0.54		8.77
Others fruits	0.08	0.44	0.81		1.63
Potatoes	66.77	19.42	16.64	23.52	44.94
Onions	1.36	15.26	2.95	2.26	0.52
Others vegetables	2.69	7.52	4.03	19.37	4.92
Sesamum	0.72	3.68	2.28	8.29	14.14
Rapeseed & mustard	14.20	16.03	45.64	22.75	20.86
Soybean	6.65	11.04	9.39	10.39	2.07
Tea	0.29				
Drugs, narcotics and plantation crops	0.67	0.29	0.13	0.05	0.02

Source: DACNET website, Ministry of Agriculture, Government of India

Table 5. Production (quintal) and Productivity of Traditional Crops and Vegetables (2003)

Name of case study village	Altitude (M)	Traditional crops (millets, wheat and rice)			Vegetables (potato and onion)		
		Area devoted	Production	Productivity	Area devoted	Production	Productivity
Dimri	550	465 (ha)	1600 (Rice and wheat)	4.4	55 (ha)	400 (Onion and other seasonal vegetables)	7.2
Kulsari	1150	460 (ha)	1700 (Rice and wheat)	4.7	85 (ha)	600 (Onion and other seasonal vegetables)	7.1
Kewer	1200	510 (ha)	1850 (Rice and wheat)	3.6	65 (ha)	500 (Onion and other seasonal vegetables)	7.6
Lolti	1800	370 (ha)	1005 (Millets)	2.7	136 (ha)	1600 (Potato and other seasonal vegetables)	11.7
Khainoli	2100	385 (ha)	970 (Millets)	2.5	165 (ha)	1745 (Potato and other seasonal vegetables)	10.5
Kwarad	2200	380 (ha)	945 (Millets)	2.5	180 (ha)	1800 (Potato and other seasonal vegetable)	10

Source: Sati, 2009a

Table 6. Income from Cereal Crops and Off-Season Vegetables

Name of village	Altitude (M)	Number of families involving with growing off season vegetables	Income from cereal crops (Indian INR.)*	Income from off-season vegetables (Indian INR.)
Dimri	550	38	2000-2500 per season per family	3000-3500 per season per family
Kulsari	1150	29	2000-2500 per season per family	3000-3500 per season per family
Kewer	1200	13	2000-2500 per season per family	3000-3500 per season per family
Lolti	1800	22	1000-1500 per season per family	4000-4500 per season per family
Khainoli	2100	26	1000-1500 per season per family	4000-4500 per season per family
Kwarad	2200	28	1000-1500 per season per family	4000-4500 per season per family

Source: Sati, 2009b

* 45 INR is equal to 1 USD (as per the rate in May 2010)

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Minimising Insecticide Application in the Control of Insect Pests of Cowpea (*Vigna Unguiculata* (L) WALP) in Delta State, Nigeria

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Abstract

Many commercial cowpea farmers control insect pests on cowpea with synthetic chemicals and may sometimes spray their farms during the growing season as many as 8 to 10 times. This leads to health hazards and environmental pollution. The present study was conducted to reduce the number of times, cypermethrin (conventional chemical) is applied before harvest and still, produce the expected cowpea grains. The experiments were carried out in two agro-ecological zones - Asaba and Abraka of Delta State during the late cropping season. The experiments consisted of 4 treatments - cowpea plots sprayed 4 times (at 7 days' intervals), cowpea plots sprayed 5 times (at 10 days' intervals), cowpea plots whose insect infestation were monitored before chemical application and control plots (without chemical treatment). Each treatment was replicated 3 times. The experiments were organised into a randomised complete block design (RCBD). The results indicated that cypermethrin controlled the major insect pests of cowpea. Second, grain yield was high at both locations; significant differences did not exist ($P>0.05$) in insect number and grain yield among the treatments. The study provides the evidence that (i) high cowpea grain yield is obtained at reduced number of chemical application of 4 or 5 times during the growing season (ii) Grain yield was significantly ($P<0.05$) higher at Abraka with1400.60kg ha^{-1} than Asaba (714.40kg ha^{-1}) during the late cropping season.

Keywords: Late cropping, Cowpea, Insect pests, Cypermethrin, Grain yield, Asaba/Abraka

1. Introduction

One of the food crops that has become very popular in recent times in Africa, particularly Nigeria is the legume crop - Cowpea (*Vigna unguiculata* (L) Walp). It is intensively and widely grown in the humid and semi-arid regions of the world (Jackai *et al.*, 2001). The main production belt in Nigeria is the drier Northern states - in the Sudan savannah region (Rachie, 1985). The cultivation, however spread lately to southern Nigeria and it is being cultivated successfully in the West and East (FOS, 1995; Emosairue *et al*., 2004).

The popularity of cowpea is due to its importance in the diet of man. It is a cheap source of plant protein (Alabi *et al.*, 2003) since protein obtained from meat, fish and eggs have gone out of his reach. Appropriately, Aykroid and Doughty (1982) described cowpea as the poor man's meat. Besides, cowpea is rich in vitamins, minerals and fats and oils. In some African communities, it is consumed as vegetables (Duke, 1981). Other usefulness of cowpea is in fodder production (Job *et al.*, 1983), fibre production (Rachie, 1983) and erosion control (Okigbo, 1978).

Though highly valued and intensively grown, yields are generally poor in Africa at the farm level, hardly above 300kg ha^{-1} (Omongo *et al.*, 1997). This is due to heavy decimation by a wide spectrum of insect pests, and attack by diseases while in the field (Taylor, 1964). The key insect pests of cowpea clearly identified as field pests are the cowpea aphid, *Aphis craccivora* Koch, the flower bud thrips, *Megalurothrips sjostedti* Tryb, the legume pod

borer, *Maruca vitrata* Fab and a complex of pod sucking bugs which include *Clavigralla tomentosicollis*, Stal, *C. shadabi* Doll, *Anoplocnemis curvipes* Fab, *Riptortus dentines* Fab. (Jackai *et al*., 1988). Sixty to eighty percent (60 - 80%) of grain losses due to their activities have been reported (Singh & Allen, 1980; Jackai & Daoust, 1986). For meaningful grain yield, control must be carried out (Suh *et al*., 1986) and the most reliable and effective control method is the application of synthetic chemicals and yield increase, several fold has been recorded (Jackai, 1993). Sometimes however, insecticides are excessively and unwisely applied (Omongo *et al.*, 1997) leading to environmental pollution (Alabi *et al.*, 2003), toxicity to mammals, destruction of beneficial organisms such as predators, parasites and parasitoids. Other problems associated with chemical usage are cost of insecticides and equipment (Afun *et al*., 1991). A growing awareness of the dangers of chemicals in pest control has resulted in the recommendation that chemical application should be minimized but not to be discarded (Stern, 1973) since such move would reduce crop productivity. Ecological approach to insect pests management in some parts of the world, particularly in African countries to reduce pesticide usage tends to receive the attention of farmers. Such approach include cultural control practices such as species diversification, manipulation of planting dates (Omoloye *et al.,* 2000; Tobih *et al.,* 2011; Tobih, 2011) intercropping (Olaniyan *et al.,* 2001; Okonman & Emosairue, 2005) use of crop varieties (Agbaje *et al.,* 2002*;* Adamu *et al.,* 2007*)*, use of trap cropping, mulching (Ikeorgu & Igwilo, 2002) and host evasion. With cultural control practices, several crops have been successfully protected (Jackai, 1983b). However, many cowpea farmers would prefer chemical usage to cultural approach and they apply insecticides more often weekly, starting from a few days after planting to control cowpea insect pests. This may require as many as 6 to 8 times and above before harvest (Omongo *et al*., 1977). Consequently, any control method that tends to reduce the number of insecticide application and still produce the desired yield should be encouraged / adopted.

This study aims at minimising the number of times insecticides are applied, in the control of insect pests and yield of cowpea in two locations in Delta State during the late cropping season.

2. Materials and Methods

The trials took place during the late planting season at Asaba and Abraka (two locations about 135 kilometres apart). The study was conducted in Asaba in the Teaching and Research Farms of the Agronomy department while at Abraka, on a plot of land, adjacent to Campus 2, Delta State University. For Asaba, the global position system (GPS) is 06^0 4^1; 06^0 49^E and the weather data for 2005 were, annual mean rainfall (mm) 163.70, annual relative humidity 80.41 and annual mean temperature 28.81^{0C}. For Abraka, the location statistics are GPS-$05^0 47^1$N, annual mean rainfall 232.46; annual relative humidity 83.00 and annual temperature 30.51^{0C}. The experimental beds were prepared manually in both locations with hoes and shovels. Each plot measured 5x3m and in between plots was 1.5m. The seeds – Ife brown (obtained from the International Institute of Tropical Agriculture Ibadan, Nigeria) were planted. Three seeds per hole were planted, at spacing of 60 x 30cm (Remison, 1978e). Planting took place on 17th September, 2005 at Asaba and in Abraka on 29th September, 2005. Seeds that failed to sprout were replaced four days after planting. Thinning to 2 per stand occurred 10 days after plant emergence. Each experimental plot consisted of 6 rows of 36 plants. The experiments consisted of 4 treatments and 3 replicates, organised into a complete randomised block design. The treatments were:

(i) Calendar spray at 7 days' intervals, CA.S7 (carried out 5 times)

(ii) Calendar spray at 10 days' intervals, CA.S10 (carried out 4 times)

(iii) Monitored spray, carried out only when insect pest infestation/damage reached the action threshold (AT)

(iv) Control – no chemical application

The AT for the study insects was arrived at, following the method reported by Afun *et al*. (1991). Mean scores of the insect pests observed in the field were calculated and served as the AT. The AT for *A.craccivora*, *M.sjostedti* and pod sucking bugs were 3,3 and 2 respectively. Damage of 40 percent and above, of flowers, was used as the AT for *M.vitrata.*

Chemical application commenced 25 days after planting (Afun *et al*., 1991).

2.1 Insect Observations and Data Collection

The effect of chemical treatment on 4 major insect pests and grain yield of cowpea was determined.

Aphis craccivora: This was determined weekly from the two middle rows of each plot between 8 and 10 a.m. when the plants were 26 days after planting (DAP). Twenty cowpea stands, tagged randomly were carefully inspected for aphid colony and the size rated visually (Table 1). The mean for the 20 stands was then calculated and recorded. Six observations were made.

Megalurothrips sjostedti: Assessment of thrips damage to cowpea in the field was done at 30 DAP. Damage symptoms such as browning/drying of stipules, leaf or flower buds and abscission were used to visually score 20 stands randomly tagged in the 2 middle rows of each plot. The rating was carried out in the morning between 8 and 10 a.m. and the mean score for the 20 stands was calculated and recorded. Four observations were made at the intervals of 6 days.

Maruca vitrata: This was done by counting. Twenty flowers randomly chosen from the 2 outer rows were opened each, between 3 and 5 p.m. and each was inspected on the spot for *Maruca* damage. Holes on the flowers and larval presence were the damage index by *Maruca*. Population of flower bud thrips in each flower was also counted.

Five observations were made at the intervals of five days. The mean for the 20 flowers was then calculated and recorded.

Pod sucking bugs (PSBs): The number of PSBs that rested on cowpea in the two middle rows of each plot was recorded in the morning (8 to 10 a.m.) at 45 DAP. Pod sucking bugs have similar damage and thus all were counted together. Four observations were made at 7 days' intervals.

Grain yield: This was done at the age of 65 to 70 days when the pods were matured. They were harvested and kept in polythene bags labelled according to treatments. The pods were dried by means of sunlight for 7 days and then shelled with hands. Grains in each treatment were weighed with triple beam balance (Haus model) and the weight recorded. Mean of replicates for each treatment was then calculated. The yield was extrapolated to kilogram per hectare.

2.2 Yield Related Components

Number of pods per plant: This was assessed in the field from the 2 middle rows of each plot when the pods were 60 DAP. Two sticks were used to mark out 1 metre long distance in the 2 central cowpea rows. All the pods and their stands that fell within this distance were then counted. The number of pods was divided by the number of stands:

$$\text{Number of pods / plant} = \frac{\text{No. of pods}}{\text{No. of plant stands}}$$

Pod load (PL) and **Pod damage (PD):** Assessment was done at 60 DAP. From the 2 middle rows of each plot, the PL was rated visually on a scale of 1-9 points (Table 3). For the PD, holes and frass on pods and sticking of pods were the *Maruca* damage index.

Pod evaluation index (Ipe): This was determined by the formula – PL x (9 – PD),

where PL is pod load and PD, pod damage (Jackai *et al*., 1988).

Pod length and **seed damage:** At 65 DAP, matured pods were harvested from the 2 central rows of the plots into black polythene bags. The pods were then dried under sunlight for 1 week. With a flexible thread, each pod was measured to determine its length. Each was carefully opened with hand, and the number of seeds per pod was counted. The seeds in each pod were classified into aborted seeds per pod, wrinkled seeds/pod and seeds with feeding lesions per pod.

The data for insect observation, yield and yield related components were subjected to analysis of variance (ANOVA) and significant means separated by Fisher's Least Significant Difference Test (LSD), at 5% level of significance.

3. Results

When compared with control, the major insect pests (except PSBs) were significantly reduced in the chemically protected plots at Asaba (Table 4). There was no significant difference with respect to PSBs among the insecticide protected plots and control. At Abraka, in the same season, *A. craccivora*, flower bud thrips and *M. vitrata* were significantly reduced in all the insecticide protected plots when compared to control. Conversely, *M. sjostedti* and PSBs were statistically similar in the treatments and when compared with control (Table 5).

Comparing the two locations, during the late cropping season of cowpea, the population of *A. craccivora* was significantly ($P<0.05$) higher at Abraka than Asaba. With *M. sjostedti* damage, flower bud thrip population, *Maruca* damage and coreid bugs, their incidence were significantly ($P<0.05$) more pronounced at Asaba than Abraka location (Table 6).

Grain yield at Asaba (Table 7), during the late season was high. All the plots treated with insecticide produced grains that were significantly ($P<0.05$) higher than grains from control. The insecticide treated plots were

statistically similar. On yield related components, 100 seed weight, pod length, aborted seeds/pod and wrinkled seeds/pod were not significantly different among the treatments. However, all other yield related components such as; number of pods/ plant, number of seeds/pod, pod load, pod damage and pod evaluation index showed significant differences among the treatments.

At Abraka (Table 8), in the same season, grain yield was significantly ($P<0.05$) higher in all the chemically treated plots when compared with control. Grain yield in the insecticide treated plots were not significantly different; yields were highest in CA.S10 (1,814.00 kg ha^{-1}) and least was in MOS (1,577.00 kg ha^{-1}). Yield related components manifested variations in values, as effect of chemical spray in the different treatments. Number of pods/plant, pod load, pod damage, pod evaluation index and wrinkled seeds/pod were significantly different among the treatments. Conversely, 100 seed weight, pod length, aborted seeds/pod and seeds with feeding lesions had values that were not significantly different among the treatments.

Effect of location on grain yield and yield related components under cypermethrin application in the late season in the study areas is presented in Table 9. Dry grain yields were significantly ($P<0.05$) higher at Abraka (1,400.60kg/ha^{-1}) than Asaba (714.40kg/ha^{-1}). There was no significant difference between the locations with respect to one hundred seeds weight, so also were pod load, pod damage, pod evaluation index, wrinkled seeds per pod and seeds with feeding lesions. However, seeds from Asaba weighed slightly more than the seeds from Abraka. Pod production was more and significantly ($P<0.05$) higher in Abraka than Asaba. Similarly, pod length were significantly higher in values at Abraka than Asaba. Conversely, number of seeds per pod and aborted seeds per pod, were significantly higher in Asaba than Abraka location.

4. Discussion

During the late cropping season, all the major insect pests were encountered in the study areas - an observation which tallied with the reports of Jackai *et al*. (1988) and Singh and Jackai (1985) that the major insect pests of cowpea occur wherever the crop is cultivated in Nigeria. The occurrence and distribution of insect species in this study in the two locations followed different trends. The insect species except *A. craccivora* were significantly more at Asaba compared to Abraka. Asaba campus, formerly College of Agriculture, inconsistently cultivated cowpea for consumption in some years back and this could have been a major factor which possibly contributed to the abundant occurrence of cowpea pests before the present study was carried out. Abraka on the other hand, had never been known to cultivate cowpea. Other possible factors for the variation of insect species in the two agro-ecological zones were climatic and environmental changes. Asaba which is located in the drier Northern part of the state had the mean annual rainfall, temperature and relative humidity of 163.70mm, 28.81^{o}C and 80.4% respectively in 2005. Abraka, which is close to the Niger Delta region, the annual mean rainfall in the same year was 232.46mm and annual mean temperature was 30.51^{o}C. These could have influenced occurrence and distribution of insect species in locations that are widely apart (about 135 kilometres apart) in Delta State. Tobih (2007) reported higher yam tuber damage by beetles at Ugbolu than Anwai. This study has made similar observations between Asaba and Abraka.

Cypermethrin (conventional chemical) effectively controlled the major insect pests in the various treatments at both locations, to conform with reports of earlier cowpea researchers (Jackai & Singh, 1986; Jackai, 1993). On grain yield, both locations recorded high yield, 714.40kgha^{-1} at Asaba and 1,400.60kgha^{-1} at Abraka. The values for grain yield in the study areas compared favourably with yield from some other cowpea growing areas of Nigeria such as Bauchi (Degri & Hadi, 2000) Kamboinse, Badeggi, Mokwa, Samaru, Kano and Ilora, (IITA, Annual Report, 1986) and Calabar (Emosairue *et al*., 1994).

The significantly higher grain yield at Abraka (compared to Asaba) may be attributed to less insect damage to cowpea in this region and probably too, soil and favourable climatic factors which prevailed during the study period. Yield differences due to locational effects have been reported earlier for some other crops such as cassava (Akparobi *et al*., 2002), maize (Agbogidi, 2006) and yam (Tobih, 2007).

Though cypermethrin effectively controlled the major insect pests of cowpea in the two agro-ecological zones and grain yield was high at both locations, this chemical, like most other conventional chemicals has adverse side effect such as environmental pollution, toxicity to mammals, users and consumers (Alabi *et al*., 2003). From Uganda, it is reported that commercial farmers in this country spray their farms from 8 to 10 times during the growing season (Omongo *et al.,* 1997). However, if this is the practice in Uganda, what about the cost of chemicals or are these chemicals supplied to farmers free of charge? Certainly, the high number of chemical application would increase the cost of production and chemical residues in cowpea grains which ultimately would not be healthy for human consumption. Excessive and unwise use of chemicals have ultimately, serious environmental consequences as noted above. The present study which employed 5 or 4 times spray before

harvest or monitored insect infestation/damage before spraying has advantages of reducing the number of chemical sprays and still produce the desired grain yield, and environmental pollution is minimal. Findings in this study support the report of Afun *et al.* (1991) who stated that significant differences did not exist in calendar spray(CA.S7 and CA.S10) and monitored sprays (MOS) in terms of insect number and grain yield.

The present study provides preliminary reports on the following:

(i) That environmental pollution is reduced, if farmers spray their farms 4 times (at 7 days' intervals or 5 times (at 10 days' intervals) before harvest or monitored insect damage before spraying; grain yield is appreciable.

(ii) Grain yield is much higher (highly significant) at Abraka than Asaba.

(iii) The study areas are suitable for large scale cowpea production.

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Table 1. Scale for rating aphid infestation on cowpea

Rating	Number of aphids	Appearance
0	0	no infestation
1	1-4	a few individual aphids
3	5-20	a few isolated colonies
5	21-100	several small colonies
7	101-500	large isolated colonies
9	>500	large continuous colonies

Source: Litsinger *et al*. (1977)

Table 2. Scale for rating flower bud thrips infestation on cowpea

Rating	Appearance
1	no browning/drying (i.e scaling) of stipules, leaf or flower buds; no bud abscission
3	initiation of browning of stipules, leaf or flower buds; no bud abscission
5	distinct browning/drying of stipules and leaf or flower buds; some bud abscission
7	serious bud abscission accompanied by browning/drying of stipules and buds; non elongation of peduncles
9	very severe bud abscission, heavy browning, drying of stipules and buds; distinct non-elongation of (most or all) peduncles.

After Jackai and Singh (1988)

Table 3. Scale for rating *Maruca vitrata* damage to cowpea

	Pod load (PL)	Pod damage (PD)	
Rating	Degree of podding	Rating	%
1	most (<60% peduncles bare (i.e. no pods)	1	0-10
3	31-50% peduncles bare	2	11-20
		3	21-30
5	16-30% peduncles bare	4	31-40
		5	41-50
		6	51-60
7	Up to 15% peduncles bare	7	61-70
		8	71-80
9	Occasional bare peduncles	9	81-100

After Jackai and Singh (1988)

Table 4. Effect of cypermethrin on the major insect pests of cowpea during the late cropping season at Asaba Egho (2011)

Treatments	*Aphis craccivora* (rating)**	*Megalurothrips sjostedti* (rating)	Flower bud thrips* (actual counting)	*Maruca vitrata** (actual counting)	PSB** (actual counting)
CONTROL	1.22	2.17	8.39	0.18	3.00
CA.S7	0.00	1.33	3.61	0.08	3.33
CA.S10	0.44	1.33	3.92	0.08	3.78
MO.S	0.44	1.33	4.76	0.10	2.22
LSD(0.05)	0.78	0.53	1.47	0.08	NS

N.S - Not significant, CA.S7 - Calendar spray at 7 days' intervals

CA.S10 - Calendar spray at 10 days' intervals, MOS - Monitored spray

* Means of 20 flowers ** Number per 2-middle rows

Table 5. Effect of cypermethrin on the major insect pests of cowpea in the late cropping season at Abraka Egho (2010)

Treatments	*Aphis craccivora* (rating)**	*Megalurothrips sjostedti* (rating)	Flower bud thrips* (actual counting)	*Maruca vitrata** (actual counting)	PSB** (actual counting)
CONTROL	1.89	1.50	3.33	0.07	0.02
CA.S7	1.22	1.00	1.85	0.02	0.04
CA.S10	1.00	1.00	2.25	0.02	.0.02
MO.S	1.11	1.00	2.83	0.04	0.04
LSD(0.05)	0.42	NS	1.37	0.05	NS

N.S - Not significant, CA.S7 - Calendar spray at 7 days' intervals

CA.S10 - Calendar spray at 10 days' intervals, MOS - Monitored spray

* Means of 20 flowers ** Number per 2-middle rows

Table 6. Effect of location on the major insect pests of cowpea under the application of cypermethrin in late cropping season at Asaba and Abraka

Location	*Aphis craccivora* (rating)	*Megalurothrips sjostedti* (rating)	Flower bud thrips* (actual counting)	*Maruca vitrata** (actual counting)	PSB** (actual counting)
Asaba Late	0.53	1.54	5.17	0.11	3.08
Abraka Late	1.31	1.13	0.05	0.05	0.03
LSD (0.05)	0.31	0.23	0.45	0.05	0.55

* Means of 20 flowers ** Number per 2 middle rows

NS-Not significant

Table 7. Effect of cypermethrin on grain yield and yield related components from cowpea in the late season at Asaba

Source: Egho (2011)

Treatments	Dry Grain yield (kg ha^{-1})	100 seeds wt(g)	Number of pods/ plant (approx)	Pod length (cm)	Number of seeds/pod	Pod load	Pod damage	Pod evaluation index	Aborted seeds/pod	Wrinkled seeds/pod	Seeds with feeding lesions
CONTROL	238.40	16.10	4.93	12.59	11.78	4.33	6.67	19.00	2.50	2.43	0.05
CA.S7	843.90	15.20	8.61	12.33	12.62	8.33	2.33	60.00	2.67	0.78	2.25
CA.S10	940.20	16.07	10.88	12.54	12.90	9.00	2.00	63.00	2.80	1.18	0.08
MO.S	835.00	15.57	11.65	12.71	13.25	9.00	2.00	63.00	2.40	0.65	0.02
LSD(0.05)	172.00	NS	3.58	NS	1.45	2.40	0.74	22.23	NS	NS	NS

N.S - Not significant, CA.S7 - Calendar spray at 7 days' intervals, CA.S10 - Calendar spray at 10 days' intervals, MOS - Monitored spray

Table 8. Effect of cypermethrin on grain yield and yield related components from cowpea in the late season at Abraka

Source: Egho (2010)

Treatments	Dry Grain yield (kg ha^{-1})	100 seeds wt(g)	Number of pods/ plant (approx)	Pod length (cm)	Number of seeds/pod	Pod load	Pod damage	Pod evaluation index	Aborted seeds/pod	Wrinkled seeds/pod	Seeds with feeding lesions
CONTROL	424.10	12.37	11.82	12.94	10.37	3.00	7.33	7.67	0.37	1.88	0.10
CA.S7	1787.40	15.60	11.67	12.80	11.02	8.67	2.00	60.67	0.43	0.70	0.00
CA.S10	1814.00	15.63	9.09	13.01	11.28	9.00	2.00	63.00	0.82	0.48	0.00
MO.S	1577.00	16.23	13.52	13.46	11.52	7.67	4.00	38.00	0.35	0.85	0.02
LSD(0.05)	963.15	NS	4.34	NS	NS	2.40	2.08	13.33	NS	0.87	NS

N.S - Not significant, CA.S7 - Calendar spray at 7 days' intervals, CA.S10 - Calendar spray at 10 days' intervals, MOS - Monitored spray

Table 9. The effect of location on cowpea yield and yield related components under the application of synthetic insecticides at Asaba and Abraka in the late season

Season	Dry Grain yield (kg ha^{-1})	100 seeds wt(g)	Number of pods/ plant (approx)	Pod load (cm)	Pod length (cm)	Pod damage	Pod evaluation index	Number of seeds per pod	Aborted seeds/pod	Wrinkled seeds/pod	Seeds with feeding lesions
Asaba Late	714.40	15.73	9.02	7.67	12.54	3.25	51.25	12.64	2.59	1.26	0.10
Abraka Late	1400.60	14.96	11.53	7.08	13.05	3.83	42.33	11.05	0.49	0.98	0.03
LSD(0.05)	336.46	NS	1.44	NS	0.44	NS	NS	0.62	0.72	NS	NS

NS = Not significant

Technical Efficiency Analysis of Fisheries: Toward an Optimal Fleet Capacity

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Abstract

Technical efficiency analysis has a vital role in fishing management and decommissioning programs. In this context, ignoring the variation across the regions in the field of natural endowment and level of economic development may lead to biased estimates of efficiency scores. Therefore, efficiency analysis in the southern coastal provinces of Iran, which is the aim of this study, was investigated by a common metafrontier production function that was identical for all studied provinces. The required data was obtained from a random sample of 520 fishery vessels. The results of the estimating metafrontier showed that mean technical efficiency for selected provinces varies between 0.408 and 0.542, while ranging between 0.650 and 0.728 when assessed based on the regional frontier. The highest mean technical efficiency based on metafrontier is devoted to Sistan-va-Baluchestan, while Bushehr has the lowest mean technical efficiency. The results also indicated that the main reasons, beyond the fact that Sistan-va-Baluchestan has the highest technical operation in comparison with other provinces are access to more suitable vessels and especially, access to the deeper water in the Oman Sea and Indian Ocean to fish the big pelagic species.

Keywords: Technical efficiency, Metafrontier, Fishing management, Decommissioning program, Iran, Pelagic species

1. Introduction

Iran is the largest fishing nation in the region with a coastline of 2700 km, of which 1800 km is in the Persian Gulf and the Oman Sea. Despite these potentials and a diversified climate suitable for various types of aquaculture systems in the land area, the fisheries sub sector contributed only 0.19 % of the GDP in 2006 and catch from wild natural resources is limited due to resource misallocation, low efficiency, overexploitation of fish resources (especially shrimp, silver pomfret and demersal species) and illegal fishing. In order to improve matters and balance between fish landed and living marine resources, the major remedial measures suggested are: fish conservation and enhancement, deep sea fisheries development, improved aquaculture efficiency, the promotion of fishing management and a buy-back scheme for reducing fleets to an appropriate size given the available fishing opportunities. In this context, knowledge of the technical efficiency at fleet level and its determinant factors would be valuable information not only to obtain the maximum output from a set of inputs or to produce an output using the lowest possible amount of inputs, but also for a decommissioning program (Idda *et al*., 2009; Lindebo *et al*., 2007; Maravelias & Tsitsika, 2008) In fact, the success of a decommission program depends both on the variation and the level of efficiency within the fishing fleets. The actual reduction in fleet capacity will be less than expected if fleets with lower than average efficiency levels are decommissioned. Further, if the remaining fleets improve their technical efficiency it may even further offset the effects of the decommissioning program (Hakan, 2001; Lindebo *et al*., 2007). Due to the key role of technical efficiency and its determinant factors in fishing management and a decommissioning program, there is a growing interest in the measurement of technical efficiency and the factors determining it at fishing fleet level (Esmaeili, 2006; Garcia del Hoyo *et al*., 2004; Hjalmarsson *et al*., 1996; Huang & Wang, 2002; Idda *et al*., 2009; Kirkley & Squires, 1999; Kirkley *et al*., 2002; Lindebo *et al*., 2007; Maravelias & Tsitsika, 2008; Pascoe *et al*., 2001; Reid *et al*., 2003; Reinhard *et al*., 2000; Squires *et al*., 2003; Tingley *et al*., 2005; Vestergaard *et al*., 2003).

The fishery manager may reduce technical efficiency by constraining the use of certain inputs or alternatively,

they may improve it by expanding these inputs or by taking measures that properly define the property rights of the fisheries (Esmaeili, 2006; Hoyo *et al*., 2004; Maravelias & Tsitsika, 2008). All of the aforementioned studies measure the technical efficiency of fleets within the region based on the regional frontier production function. The regions differ from each other in geography, natural endowment and level of economic development, therefore ignoring the variation across the regions may lead to biased estimates of efficiency scores, and hence misleading policy implications. However, for making efficiency comparisons across regions, which is the aim of this study, frontier for different regions must be identical. In this study, we do this by measuring technical efficiency relative to a common metafrontier production function(Battese *et al*., 2004). A metafrontier methodology is an overarching function that encompasses the deterministic components of the frontier production functions operating under different technologies involved. Comparable efficiencies and technology gaps under different technologies relative to the potential technology available to the economy as a whole can be estimated by this model. The studied regions then may be ranked based on their technical operation by technology gaps ratio (Battese *et al*., 2004).

2. Method

2.1 Methodological Framework

The basic method for measuring fishery vessel level efficiency is to estimate a frontier production function that envelops all the input-output data, with those vessels lying on the frontier curve being described as technically efficient. Any vessel that lies below the frontier curve is considered to be inefficient; this vessel could either reduce its input use whilst maintaining output or it could use the same amount of input and increase output. Differences in available stocks of physical, human and financial capital, economic infrastructure, and resource endowments have led efficiency researchers to estimate separate production frontiers for different regions and different groups of firms. After estimating a frontier production function for a region, it is common and straightforward to measure the technical efficiency of firms within the region (e.g., Hormozgan fishery vessels) based on the regional frontier production function. However, for making efficiency comparisons across regions (e.g., comparing efficiency levels ofHormozgan fishery vessels with efficiency levels of Sistan-va-Baluchestan fishery vessels), the frontier for different regions must be identical. In this study, this is done by measuring efficiency relative to a common metafrontier production. Metafrontier production function can be estimated using data envelopment analysis (DEA) or stochastic frontier analysis (SFA). There are several reasons for using DEA analysis to estimate technical efficiency. The main reasons are that DEA does not require a parametric specification of a function form to estimate the frontier production function, and it can also accommodate multiple outputs into analysis (Sharma & Leung, 1998; Tingley *et al*., 2005). Apart from measuring efficiency, applications using DEA have been recommended by FAO (1998) to also measure fishing capacity (Garcia del Hoyo *et al*., 2004; Kirkley & Squires, 1999; Kirkley *et al*., 2002; Pascoe *et al*., 2001; Reid *et al*., 2003; Vestergaard *et al*., 2003). A disadvantage of the DEA, however, is that it does not account for random variation in the output, and therefore attributes any apparent shortfall in output to technical efficiency.

2.2 Data Envelopment Analysis

If province k consists of data on L_K vessels, a convex metafrontier can be identified using the DEA to the inputs and outputs of all $L=\sum_{k=1} L_k$ fishery vessels in all studied provinces. The structure of metafrontier linear programming is as follows:

$$\max_{\phi_i,\lambda_i} \phi_i$$

$$\text{s.t.} \quad \phi_i y_i - Y'\lambda_i \le 0,$$

$$X\lambda_i - x_i \le 0,$$

$$j'\lambda_i = 1$$

$$\lambda_i \ge 0,$$

Where

y_i is the catch quantity of i-th vessel;

x_i is the N × 1 vector of input quantities for i-th vessel;

Y is the L × 1 vector of catch quantities for all L vessels;

X is the N × L matrix of input quantities for all L vessels;

j is an L×1 vector of ones;

λ is an L × 1 vector of weights; and $1 \le \phi_i < \infty$ is a scalar and $\phi_i - 1$ is the proportional increase in output that could be achieved by i-th fleet, with input use held constant. Therefore, $\frac{1}{\phi_i}$ which takes values between 0 and 1 is an estimate of the technical efficiency measure. To derive a set of N technical efficiency scores, the problem needs to be solved N times, one for each fleet. In practice, the tedious work of solving a different linear programming (LP) for every fleet is usually undertaken using loop command in software packages such as GAMS (Brooke *et al*., 1998). The above model can be used to construct a convex province- k frontier by applying the DEA model to the observed inputs and output of vessels in a province. Finally, having estimated the technical efficiencies of fishery fleets with respect to the metafrontier and province frontier, the technology gap ratio (TGR) for province-k fleets is calculated as:

$$TGR^k = \frac{TE}{TE^k}$$

Where, TE and TE^k are the technical efficiency with respect to the metafrontier and province-k frontier, respectively. This ratio shows the maximum output that could be produced by a vessel from province k as a percent of the output that is feasible using the metatechnology. This ratio indicates the technical operation and the studied provinces can be ranked based on their technical operation by this ratio. Due to the flexibility that GAMS offers, the DEA model was written in this software. Modification GAMS code to account for changes to the standard DEA is easy and can exert greater control over output formats. These features are important in fishery studies where efficiency analysis often differs from that available with the standard DEA model.

2.3 Data

Four coastal provinces of Iran have important fisheries on their side of the Persian Gulf and the Oman Sea. Total fish landing of these provinces have been, for the most part, stable in the period 1992-2001, but have increased since 2001 with exception of year 2006 (Figure 1). As shown in Table 1, Hormozgan is the largest province and about 37 % of the total landed in 2006 on the Iranian southern fishery came from this province. But, Sistan-va-Baluchestan has the highest fish landing per fisherman. In this study a random sample of 520 wooden fishery vessels was selected using stratified random sampling method from Bushehr, Hormozgan and Sistan-va-Baluchestan. These provinces are the major fishery provinces and account for roughly 86 percent of total fish landed in 2006 on the Iranian side of the Persian Gulf and the Oman sea. Since the application of DEA requires vessels to keep their number of input and output variables at a reasonable level, five important input variables are considered as follows: x1, the number of labor (the number of crew) employed in the i-th vessel; x2, number of fishing days by the i-th vessel in the studied year; x3, the engine horsepower of the i-th vessel; and x4, the number of nets (gear) used by the i-th vessel, and dependent variable or output variable is the catch quantity of i-th vessel.

3. Results

Estimated technical efficiencies with respect to the regional frontier production function and the metafrontier production function, together with estimated TGRs, are presented in Table 2. According to Table 2, the average technical efficiency score for Hormozgan province is 0.728; indicating fish landed is increased by about 73% of the potential, given its regional frontier. In other words, the mean gap between the best fisherman and other fishermen is about 27% in this province. However, the mean technical efficiency of Hormozgan is 0.479 when assessed based on the metafrontier production function. Therefore, the technology gap ratio for Hormozgan is 0.665 (0.479/0.728). This means that, given the input vector, the potential fish landed for this province is about 67% of that represented by the metatechnology. As indicated in Table 2, mean technical efficiency estimate based on the regional frontier for Sistan-va-Baluchestan province is very close to the score reported for Hormozgan, while based on this frontier; Bushehr has the lowest mean technical efficiency. Average technical efficiency for the studied provinces ranges between 0.408 and 0.542 when evaluated based on the metafrontier production function. The highest mean technical efficiency based on metafrontier is devoted to Sistan-va-Baluchestan, while Bushehr has the lowest mean technical efficiency. The value of the technology gap ratio for Sistan-va-Baluchestan and Bushehr is 0.763 and 0.641 respectively. Therefore, DEA scores from metafrontier and technology gap ratio show that Sistan-va-Baluchestan has a higher technical operation amongst the selected provinces. Also, the results obtained from regional frontiers indicate that the gap between the best fisherman and other fishermen is at its maximum in Bushehr while it is at the minimum in Hormozgan and Sistan-va-Baluchestan. The distribution pattern of technical efficiency estimates of fishing vessels from the metafrontier for the studied provinces is depicted in Figure 2.

4. Discussion

Technical efficiency, its measurement and determining factors are of crucial importance in production economic and decommissioning program. While technical efficiencies of fleets obtained with respect to a given frontier are comparable, this is not normally a valid case among fleets that operate under different technologies. Such problem arises when the comparison of fleets from different provinces or regions of a country are involved. In fact, apart from the regional frontier analysis, the metafrontier analysis divides the technical efficiency into two groups: one due to the inefficiency relative to the subgroup, and one due to the technology gap between the subgroup and full sample. The empirical outcomes provide more policy suggestions. This study utilized the concept of the metafrontier production function to explore provincial differences in fish landed technologies of Iran.

4.1 Inefficiency Relative to Subgroup

Results of estimating regional frontier production function showed that mean technical efficiency for selected provinces varies between 0.650 and 0.728. This means that, there are possibilities for either increasing total fish landing using the same inputs or decreasing input for the current level of fish landing, or a combination of both by filling the gap between the best fisherman and other fishermen. This possibility is higher in Bushehr, while it is lower in Hormozgan and Sistan-va-Baluchestan. It is worthwhile to compare the results obtained by this study for Hormozgan province with the results reported by Esmaeili (2006). However, this comparison should be made cautiously because his technical efficiency scores were obtained using stochastic frontier analysis (SFA), while the results of this study were estimated using DEA. Esmaeili (2006) found the mean value of technical efficiency of a wooden vessel for Hormozgan province to be 0.85, which is based on an expectation higher than the score obtained by this study. The studies in both fisheries and other sectors have generally found that DEA efficiency scores are correlated with, but lower than, those estimated using SFA. Technology gap values between Hormozgan fishery vessels and metatechnology were not reported in Esmaeili's study (2006) because he used only regional frontier analysis.

4.2 Inefficiency Due to Technology Gap

The value of technology gap ratio for the studied provinces ranges between 0.624 and 0.763. This ratio indicates the maximum fish landing by a vessel from province k as a percent of the fish landing that is feasible using metatechnology (we define the metatechnology as the totality of the regional technologies). Therefore, total fish landing can be increased considerably if fleets use the metatechnology or access to better natural endowment. The rank of studied provinces based on their technical operation is as follows: Sistan-va-Baluchestan, Hormozgan and Bushehr. The main reasons, beyond the fact that Sistan-va-Baluchestan has the highest technical operation in comparison with other provinces are access to more suitable vessels and especially, access to the deeper water in the Oman Sea and Indian Ocean to fish the big pelagic species, e.g. tuna. The combination of capture fisheries in selected provinces in 2006 is presented in Table 3. As shown in Table 3, more than 78 percent of total fish landing in Sistan-va-Baluchestan pertain to big pelagic species especially tuna fish (about 59%), while the share of tuna fish species in the total fish landing of Hormozgan and Bushehr in this year is 19.08% and 13.27% respectively. Furthermore, about 55 % of big pelagic species (about 70% of tuna fish) captured in 2006 on the Iranian southern fishery came from the Sistan-va-Baluchestan. Also, the share of demersal species which is under overexploitation in the total fish landing of Bushehr, Hormozgan and Sistan-va-Baluchestan is 49.57, 36.3 and 21.43% respectively. Therefore, it seems Sistan-va-Baluchestan and to some extent Hormozgan, are where policy makers must execute their deep sea fisheries development policy and a buy-back scheme for reducing fleets to an appropriate size given the available fishing opportunities must be executed in Bushehr province. In this context, the findings of this study can help policy makers to determine the optimal reduction or increase fleet capacity.

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Table 1. Number of fishermen and fishing vessels and amount of fish landed and fish landed per fisherman in southern coastal provinces of Iran

Province	Fishermen	Fishing vessels			Fish landed (Mt)	Fish landed per fisherman (Kg/person)
		Boats	Launch	Ship		
Bushehr	13209	1731	635	22	48113	3642.44
Hormozgan	27319	3075	873	35	120499	4410.81
Khozestan	37503	1552	722	0	45707	1218.76
Sistan-va-Baluchestan	23500	1707	1108	1	115353	4908.64
Total	101531	8065	3338	58	329571	3246.01

Table 2. Mean (±SD) of technical efficiency based on regional frontier and metafrontier and technology gap ratio estimates for southern coastal provinces of Iran

Province	Regional frontier	Metafrontier	Technology gap ratio
Bushehr	0.650 ± 0.156	0.408 ± 0.077	0.641 ± 0.104
Hormozgan	0.728 ± 0.110	0.479 ± 0.069	0.665 ± 0.089
Sistan-va-Baluchestan	0.727 ± 0.119	0.542 ± 0.064	0.763 ± 0.108

Table 3. Amount (Mt) and percent of type of captured fish in 2007 in selected southern coastal provinces of Iran

Fish type	Bushehr	Hormozgan	Sistan-va-Baluchestan	Total
Big pelagic	23419 (48.67)	52445 (43.52)	90524 (78.54)	166388 (58.62)
Tuna fish	6384 (13.27)	22997 (19.08)	68204 (59.18)	97585 (34.38)
Others	17035 (35.41)	29448 (24.44)	22320 (19.37)	68803 (24.38)
Small pelagic	843 (1.75)	24634 (20.44)	24 (0.00)	25501 (8.98)
Demersal	23581 (49.57)	43420 (36.03)	24704 (21.43)	91705 (32.31)
Total	48113 (100)	120499 (100)	116252 (100)	283864 (100)

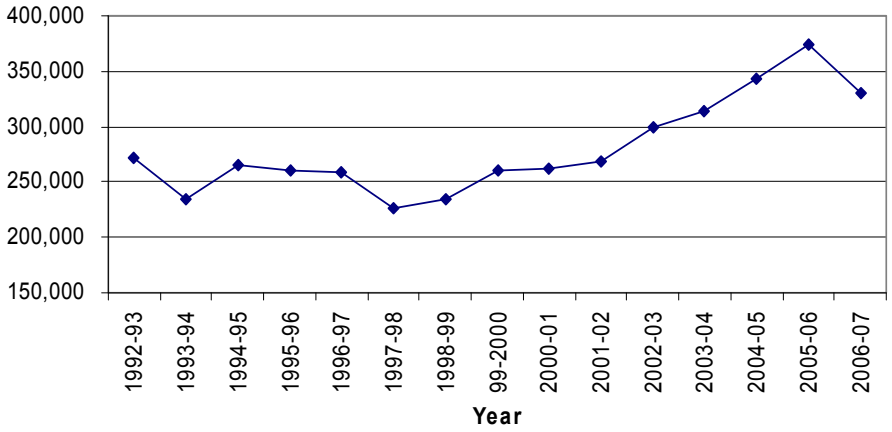

Figure 1. Total fish landed in southern Iran (1000 tons)

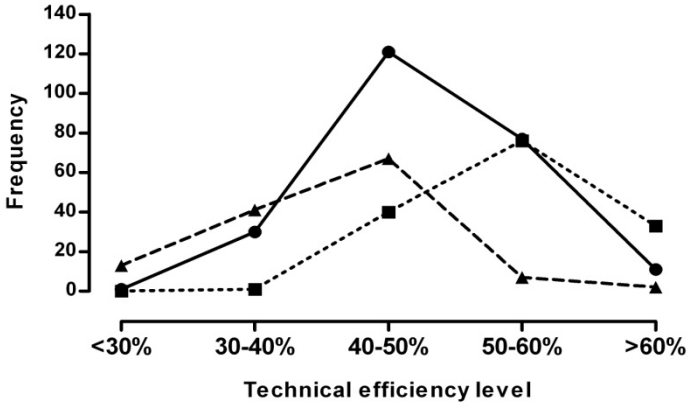

Figure 2. Distribution pattern of technical efficiency estimates of fishing vessels in southern coastal provinces of Iran; Hormozgan (–●–), Sistan-va-Baluchestan (–■–), and Bushehr (–▲–)

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Adoption of Some Cocoa Production Technologies by Cocoa Farmers in Ghana

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Abstract

Adoption of the cocoa (*Theobroma cacao*) production technologies recommended to cocoa farmers by Cocoa Research Institute of Ghana (CRIG) had been low, leading to yield and production levels below potential. To investigate this issue, a formal socio-economic sample survey of 300 cocoa farmers selected randomly, by a multi-stage sampling technique, from all the cocoa growing regions of Ghana was conducted with a structured questionnaire for the individual interviews. The adoption rates of CRIG-recommended technologies such as control of capsids with insecticides, control of black pod disease with fungicides, weed control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application were 10.3%, 7.5%, 3.7%, 44.0% and 33.0%, respectively. Adoption models indicated that credit, number of cocoa farms owned by the farmer, gender, age of the cocoa farm, migration, cocoa farm size, and cocoa yield affected the adoption decisions of cocoa farmers concerning the CRIG-recommended technologies analyzed in this study.

Keywords: Cocoa, Survey, Technology, Adoption, Ghana

1. Introduction

Cocoa technology could be defined as the total stock of knowledge including traditional skills necessary for cocoa production, processing and marketing (Laryea, 1981). The Cocoa Research Institute of Ghana (CRIG) was established to investigate into problems militating against cocoa production in Ghana. As such, research of the institute has been tailored to the development of technologies such as improved farm practices that address constraints to cocoa production such as pests, diseases and other poor agronomic practices. The technologies were previously handed over to the then Extension Division of Ghana Cocoa Board (COCOBOD), Cocoa Services, currently known as Cocoa Swollen Shoot Virus Control Unit (CSSVDCU) to disseminate to cocoa farmers to enhance productivity and production. Despite the dissemination of the CRIG-recommended technologies to farmers, the adoption levels of these technologies over the years by the cocoa farmers have been low (Henderson and Jones, 1990; Donkor, *et al.,* 1991; MASDAR, 1998). The reasons given by farmers for their low adoption of the technologies involve lack of resources such as money and labour to apply the technologies, and technical difficulties (MASDAR, 1998). The government then intervened with national programmes such as the Cocoa Diseases and Pests Control Programme (CODAPEC or mass spraying of cocoa farms) and the Cocoa High Technology Programme (Hi-tech) which provides free inputs and labour for the control of capsids and black pod (CODAPEC), and insecticides, fungicides and fertilizer (Hi-tech) to cocoa farmers on credit. This is because the spraying frequency of the CODAPEC programme is inadequate and farmers are expected to do additional sprayings.

CRIG has established that due to the additive and interactive nature of the recommended technologies, the full package must be adopted for the total impact to be realized (Asante, 1992). However, the main practice of cocoa farmers in Ghana tends to be a 'stepwise' mode of adoption of the innovations (World Bank/FAO, 1986). The high cost of some of the component technologies and the apparent non-adoption of these high-cost technologies suggest that farmers, who are risk-averse, may be reacting directly to the possible negative effects on their already low income (Asante, 1992).

To support the dissemination of recommended packages, a cocoa farmers' newspaper project was initiated under a collaborative effort of Cocoa Research Institute of Ghana (CRIG) and Cadbury International Limited. It was

aimed at disseminating CRIG-recommended technologies to cocoa farmers for adoption to increase cocoa output. As part of the newspaper project, a baseline socio-economic survey was conducted on cocoa production practices of the farmers. Also, this survey was aimed at generating insights that would contribute to improving the reliability of technology development and transfer, as well as designing agricultural policies conducive to widespread adoption of CRIG-recommended technologies. The main purpose of this study was to determine generally the adoption levels, and the socio-economic factors of adoption of the cocoa production technologies by cocoa farmers in Ghana. Consequently, the research questions one would want to ask are: what is the nature of adoption of these technologies by the cocoa farmers? What are the current determinants/constraints to their adoption?

2. Methodology

2.1 Study Areas

The study was conducted in six (6) cocoa growing districts: Nkawie (Atwima Mponua). Goaso (Asunafo North), Enchi (Aowin/Suaman), Oda (Birim South), Twifo Praso/Assin Fosu and Hohoe (Fig. 1). The land areas ranged from 894.2 km^2 to 2 638 km^2. The average rainfall in the selected districts ranged from 1 077 mm to 1 784 mm and the mean temperature ranged from a minimum of 22 ^oC to a maximum of 34 ^oC. Altitude ranged from 61m to 890 m above sea level. The vegetation was moist semi-deciduous rain forest and savanna. The main socio-economic activities in the districts were farming, trading, logging, small-scale mining and quarrying. Key crops grown in the districts are cocoa (*Theobroma cacao*), citrus (*Citrus spp.*), oil palm (*Elaeis guineensis*) and food crops such as maize (*Zea mays*), cassava (*Manihot esculenta*), rice (*Oryza sativa*), yam (*Dioscorea spp.*) and plantain (*Musa spp.*).

2.2 Sampling and Data Collection

The study was conducted from March to May, 2006. A sample of 300 cocoa farmers was randomly selected using the multi-stage sampling approach (Barnett, 1974; Boyd *et al.,* 2004) for individual personal interview. This sample size was determined by using the standard deviation of 16.3 years obtained from the age variable of a previous survey to achieve a precision of 0.94 (standard error of the mean) for the current study. A list of names of farmers of the Produce Buying Company Ltd (PBC) served as the sampling frame from which a sample of farmers was selected. The list of PBC farmers was considered since the company is widely represented in the cocoa farming communities. The cocoa farmers were selected from households in the 30 farming communities in some cocoa districts. This sample size was chosen due to cost consideration and to ensure a broad coverage of a representative sample of farmers. A four-stage sampling technique was used leading to the selection of a final sample of 300 farmers. All the 6 cocoa growing regions were considered in the first stage sampling in the study to ensure generalization of the conclusions over cocoa farmers in the country. In the second, third, and fourth stages, one district from each of the six regions, and a total of 30 farming communities as well as 300 farmers were respectively selected randomly using simple random sampling technique and the sampling result is presented in Table 1.

This survey involved individual interviews with selected farmers using a structured questionnaire which covered issues such as personal information, farm management practices, farm income, credit, technology adoption, constraints to cocoa production and extension. The questionnaire was pre-tested with a group of farmers to correct fundamental problems in the survey design such as difficulties in question wording, problems with leading questions and bias due to question order. Enumerators and supervisors were selected and trained in how to administer the questionnaires efficiently. The survey focused more on farmers' experience with agronomic practices (technologies), asking them of their technological choices and how they affect their cocoa production. The response rate was 100%.

2.3 Analytical Framework

Descriptive and inferential analyses of the survey data were done. The analysis was aimed at establishing the adoption rate of CRIG-recommended technologies to the farmers. This rate was measured as the proportion of farmers interviewed who had used recommended technologies. Using econometric techniques, the data were analyzed to establish whether the adoption of agronomic practices by the cocoa farmers was affected by socio-economic factors.

2.3.1 Empirical Models

Multinomial Logistic Regression Analysis of the Factors of Adoption of Cocoa Production Technologies: The multinomial logistic regression model (Hosmer & Lemeshow, 1989; Chan, 2005) was used to investigate the factors that affect the adoption behaviour of cocoa farmers relating to CRIG-recommended cocoa production

technologies. This model was chosen because it handles the case of a dependent variable with more than two categories (Salasya, Mwangi, Mwanbu & Diallo, 2007; Adekunle & Henson, 2007) as compared to the probit model which deals with only dependent variables with two categories (Chirwa, 2005; Jatoe, *et al*., 2005). The definitions of technology adopter categories are presented in Table 3. The model involves a dependent variable, the technology adoption decision variable (Y) and a set of explanatory/independent variables that might influence the final probability, P_i, of adoption of the technologies. These explanatory variables can be thought of as being in a k vector X_i and the model then takes the form

$$P_i = E\,[(Y_i/n_i) \setminus X_i]$$

The logits of the unknown binomial probabilities (that is, the logarithms of the odds) are modeled as a linear function of the X_i.

$$\text{Logit}\,(P_i) = \text{In}\,[(P_i/1\text{-}P_i)] = \beta_o + \beta_1 X_{1i} + \ldots + \beta_k X_{ki}$$

The unknown parameters β_j (j = 1, 2, 3…k) are usually estimated by Maximum Likelihood method. Five categorical dependent variables representing the individual technologies considered in the study were weeding of cocoa farm (3 categories), spraying against blackpod disease (3 categories), spraying against capsids (3 categories), applying fertilizer to the farm or not (2 categories), and the type of cocoa variety planted (3 categories).

Studies (Feder & Slade, 1984; Rahm & Huffman, 1984; Feder, Just & Zilberman, 1985; Strauss *et al*., 1991; Morris, Tripp & Dankyi, 1998; Kosarek, Garcia & Morris 2001; Doss, 2003; Jatoe, *et al*., 2005; Mazuze, 2007) have indicated that the key determinants or factors of adoption of agricultural technologies include: Farmer's educational level; time of residence in the area or community; availability and quality of extension and research; farmer's experience; farm size, soil characteristics, and cropping systems; profitability of the new technology; off-farm income; adequate provision of inputs; availability of timely credit; performance of the technology (increase productivity); transportation; functional marketing channels; and social capital (farmer associations, etc.). Although limited by the data collected, it is believed that the socio-economic factors (that is, explanatory/independent variables) which might influence the probability of adoption of CRIG technologies are those presented in Table 4. Specifically, the following empirical model is specified:

$$A = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + \beta_{13} X_{13} + e$$

Where

A = the categorical dependent variable of adoption decision of the cocoa farmers;

X_i = the ith independent variable (i = 1, 2, 3, …,13);

β_i = the parameters to be estimated;

and e = error term.

Age of cocoa farmer is predicted to have a negative impact on adoption because as the age increases, his physical strength tends to reduce and this is assumed to impact negatively on adoption of the technologies. Farmers with more experience in cocoa cultivation would be able to apply their cropping experience in the cultivation of cocoa and this would increase their ability to adopt the cocoa technologies. Educational status is assumed to influence cocoa production technologies positively because with higher level of education the farmer would be in a position to technically and economically assess the new crop or technology to clear doubts and uncertainties associated with it and enhance its adoption. Since cocoa farming is dominated by male farmers, it is expected that more male cocoa farmers would adopt technologies than their female counterparts, other things being equal. This is because women have less access to credit and land as collateral than men, as well as relying mostly on hired labour which is scarce due to migration of the rural youth to the urban areas to seek for jobs with relatively better remuneration (MASDAR, 1998). It is assumed that the more adult household members a farmer possesses, the more household labour would be available to him for farm activities in the adoption of cocoa technologies. With migration, it is expected that migrant farmers are likely to introduce the use of new technologies into the farming community and promote their adoption by the natives of the area. The number of cocoa farms owned by the farmer is assumed to have a positive impact on the adoption of cocoa technologies. A farmer having many cocoa farms could harvest more cocoa which may translate into higher income for the purchase of the relevant inputs to implement the technologies. Cocoa farm size is expected to have a positive effect on adoption since as the farmer devotes more of his total available land to cocoa cultivation, there is the likelihood that cocoa output and income would increase, enhancing the probability of technology adoption. With aging farm, there is the likelihood that the yield and income from cocoa would decline. This can discourage the

farmer from weeding and spraying the farm. However, he may apply fertilizer to increase output. It is predicted that increase in cocoa yield would have a positive impact on technology adoption because the resultant increased cocoa income can enhance the ability of the farmer to purchase the necessary inputs for the implementation of the technology. Frequent visits to the farmer by the extension agent would provide the farmer with necessary information about the availability of needed resources, market and prices as well as the profitability status of the new technology to clear any doubts and uncertainties concerning it to increase the probability of its adoption. It is predicted that attending demonstration of the technology or field day may convince the farmer to adopt the technology. Access to credit in the form of cash is predicted to have a positive influence on technology adoption since the farmer receiving credit would have the capability to purchase the necessary resources for the cultivation of cocoa.

3. Results

3.1 Profile of sample cocoa farmers

A summary of the general characteristics of cocoa farmers is presented in Table 5. The mean age of the farmers was 51.5 years. The mean working experience was 19.6 years. The average number of adults working on the farm was 3.3 people. The educational status of the farmers was low as the majority (52.0 %) had middle school education and 21.5% of them were illiterates. Considering gender, 80.0 % of the interviewed farmers were males while 20.0 % were females. The mean farm size was 3.0 ha, implying that cocoa cultivation is dominated by small-scale farmers who on average had cocoa yield of 317 kg/ha. The cocoa output variable with mean value of 797.4 kg had a bigger standard deviation or variance, which might be due to the differences in farm management practices of the cocoa farmers and varying rainfall amounts and its distribution patterns experienced over the years. The mean income from cocoa was GH¢ 717.68 with a high standard deviation of GH¢820.87, which was due to the high variation in cocoa output. Cocoa farmers also cultivated food crops (plantain, cassava, maize, cocoyam, yam, rice, banana, pineapple, okro and ginger) and other tree crops (coffee, oil palm, citrus and coconut) with respective average farm sizes of about 1 ha and 2 ha. Cocoa farmers also reared some poultry and livestock such as fowls, pigs, sheep and goats for home consumption and sale. However, the data from the survey did not allow for the estimation of income from the other crops and livestock of the farmers.

3.2 Adoption rates of cocoa production technologies

The adoption rates of the CRIG-recommended technologies such as control of capsids with insecticides, control of black pod disease with fungicides, weed control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application were 10.3%, 7.5%, 3.7%, 44.0% and 33.0%, respectively.

3.3 Multinomial Logistic Regression Analysis of the Factors of Adoption of Cocoa Production Technologies.

3.3.1 Fertilizer Application Model

The summary of the descriptive statistics of the socio-economic factors to adoption of some CRIG technologies is presented in Table 5. The results of the multinomial logistic regression analysis of fertilizer application and weeding frequency are presented in Table 6. For the fertilizer adoption model, the adopter of the technology is modeled relative to the non-adopter with respect to the adoption factors. The -2log likelihood estimate of 280.277 with a statistically significant chi-square of 37.612 ($P = 0.001$) indicated that the independent variables jointly determined the adoption decision of the cocoa farmers. The pseudo R-squared was estimated to be 0.196, implying that about 19.6 per cent of the variation in the dichotomous dependent variable (fertilizer application) was explained jointly by the predictors. The results further demonstrated that 69.3 per cent of the cases were correctly predicted by the model.

The intercept of the model was significant ($P < 0.1$). The fertilizer model indicated that the significant determinants include credit ($P < 0.1$) and number of cocoa farms ($P < 0.05$). Credit appeared less likely to affect the decision to apply fertilizer to the cocoa farm or not by the farmer. Getting credit tended to decrease the log of the odds ratio by 0.704 and decrease the odds ratio by a factor of 0.494 for a farmer applying fertilizer compared to one not applying. However, the number of cocoa farms owned by the farmer was more likely to influence fertilizer adoption. As the number of farms increased by one, the log of the odds ratio increased by 0.392 which led to an increase in the odds ratio by 1.479 times.

3.3.2 Weeding Frequency Model

In the case of weeding frequency, the adopters were compared to the partial adopters since the cocoa farmers at least weeded their farms once (Table 6). The overall model was found significant by diagnostic test, indicating a -2log likelihood estimate of 46.891 and significant chi-square of 23.988 ($P = 0.008$). The pseudo R-squared of

0.370, meaning 37.0 per cent of the variation in the weeding frequency was jointly explained by the independent variables included in the model. In addition, the model correctly predicted 97.6 per cent of the cases.

Gender of the cocoa farmer was statistically significant ($P < 0.1$) while cocoa yield variable emerged significant ($P < 0.05$). Being a male cocoa farmer compared to female was less likely to influence the decision of the farmer to weed his farm four times a year (adopter of CRIG recommendation). Being a male farmer reduced the log of the odds ratio of adopter relative to partial adopter by 1.882 and decreased the odds by a multiplicative factor of 0.152. For 1 kg/ha increase in yield, the odds in favour of the adopter was increased by a factor of 1.003. The positive sign of the yield coefficient was as expected because the increase in yield leads to an increase in cocoa income which allows the farmer to hire labour for weed control.

3.3.3 Cocoa Variety Planted

Of the cocoa seed planted by the cocoa farmers, the improved varieties (Hybrids, Amazon, and combination of the varieties) were modeled relative to the old and traditional Amelonado variety (Table 7). The diagnostic test of the three models indicated that the -2log likelihood estimate of 488.472 and a chi-square of 96.257 was statistically significant ($P = 0.001$). The pseudo R-squared was estimated to be 0.359, meaning that 35.9 per cent of the differences in improved variety planted were jointly explained by the independent variables. In addition, the analysis indicated that 56.1 per cent of the cases were correctly predicted.

3.3.3.1 Hybrid Model

The intercept, gender, educational status, and age of cocoa farm were statistically significant with $P < 0.1$, $P < 0.05$, $P < 0.01$, $P < 0.01$, respectively. The gender of the farmer emerged more likely to influence the adoption decision of the farmer to plant hybrid relative to amelonado cocoa on his/her farm. Being a male farmer increased the log of the odds ratio by 1.849 for a farmer planting hybrid and not amelonado. This result indicated that the odds ratio was increased by a factor of 6.36. Educational status of the farmer was more likely to affect the farmer's preference to plant hybrid relative to amelonado. The higher the educational level, controlling for other factors, resulted in log of the odds ratio of 3.522 for the preference of hybrid to amelonado, meaning that the odds ratio increased by 33.842 times. The result also demonstrated that the older the farmer the less likely to observe hybrid compared to amelonado on his/her farm. As age of the farmer increased by one year, the log of the odds ratio decreased by 0.123, which shows that the odds ratio decreased by 0.884 times.

3.3.3.2 Amazon Model

Age and educational status of the cocoa farmer were statistically significant at $P < 0.05$ and $P < 0.1$, respectively. The age of the farmer was less likely to affect the adoption decision of planting Amazon relative to Amelonado cocoa on his/her farm. As the cocoa farmer got older by one year, the odds of planting Amazon compared to Amelonado decreased by a factor of 0.935. However, the educational status of the farmer was more likely to influence his/her preference for planting Amazon relative to Amelonado. Being an educated farmer increased the odds of planting Amazon relative to Amelonado by 14.251 times.

3.3.3.3 Admixture Model

In this model only farmer age emerged statistically significant ($P < 0.1$). This means that age affected the likelihood of the farmer planting admixture of cocoa varieties. As the farmer got older by one year, the odds of planting admixture of varieties compared to Amelonado decreased by a factor of 0.939, controlling for the other adoption variables.

3.3.4 Capsid Sparying Frequency Model

The adoption decision of spraying frequency against capsids was modeled to reflect farmer categories of adopter, partial adopter, and non-adopter, which was the reference category (Table 8). The overall model was statistically significant as indicated by the -2log likelihood estimate of 311.761, a significant chi-square of 69.133 ($P = 0.001$). The pseudo R-squared was estimated to be 0.312 and the cases were 73.0 per cent correctly predicted.

3.3.4.1 Adopter Model

The intercept was statistically significant ($P < 0.01$), migration ($P < 0.1$), cocoa farm size ($P < 0.05$), and cocoa yield ($P < 0.01$). Migration tended to be less probable to influence the decision of a farmer to spray his/her farm against capsids four times per year (CRIG recommendation). Being a native of the place compared to a migrant/settler reduced the log of the odds ratio of being adopter relative to non-adopter of CRIG capsid control recommendation by 1.058 and the odds in favour of the adopter decreased by a factor of 0.347. Moreover, farm size had a more probable influence on the farmer's capsid control decision. As farm size increased by one hectare, the log odds ratio increased by 0.504 and the odds by a factor of 1.655 times. Yield also was recognized

to affect the probability of a farmer spraying his/her farm four times against capsids as compared to one who did not spray at all. When yield increased by 1 kg/ha, the likelihood in favour of adopters increased by a factor of 1.005.

3.3.4.2 Partial Adopter Model

Migration emerged statistically significant ($P < 0.05$), farm size ($P < 0.01$), and yield ($P < 0.05$). Migration was less probable to influence the decision of afarmer to spray his/her farm against capsids from one through three times per year (partial adopter of CRIG recommendation). Being a native of the place compared to a settler reduced the log of the odds ratio of being partial adopter relative to non-adopter of CRIG capsid control recommendation by 1.091, and the odds in favour of the partial adopter decreased by a factor of 0.336. This implies that the native farmers tended to be non-adopters whilst the migrants were partial adopters. The negative sign of migration coefficient was as expected due to the reason given for the expected signs. In addition, farm size was seen to be more probable in influencing the farmer decision of spraying partially against capsids. As farm size increased by one hectare, the log odds ratio increased by 0.567 and its odds increased by a factor of 1.763 times. Yield also was recognized to affect the probability of a farmer spraying his/her farm partially against capsids as compared to one who did not spray at all. When yield increased by 1 kg/ha, the likelihood in favour of partial adopters relative to the non-adopters increased by a factor of 1.004 times.

3.3.5 Blackpod Spraying Frequency Model

The attempt to model the adoption decision of the frequency of spraying against blackpod disease was unsuccessful because the likelihood ratio test for the overall model was not significant.

4. Discussion

The study has demonstrated that cocoa farmers have adopted CRIG-recommended cocoa production technologies to some extent. Fertilizer adoption decision is affected by access to credit and number of cocoa farms owned by the farmer. The decision on weeding frequency is also influenced by gender of the farmer and cocoa yield. The adoption of cocoa variety is affected by age of the farmer and educational status. The adoption decision on frequency of spraying against capsids tended to be influenced by migration, cocoa farm size and yield. The adoption rates of insecticide and fungicide applications to control pests and diseases were low as compared to those of hybrid variety use and fertilizer application. This might be due to the inadequate funds of the farmers to purchase the relatively expensive chemicals, scarcity of labour and the fear that, for example, herbicides would kill intercrops like cocoyam (MASDAR, 1998). The results of the adoption models are clearly consistent with the observation by Asante (1992) and World Bank/FAO (1986) that the main practice of cocoa farmers in Ghana tended to be stepwise mode of adoption of the innovations.

4.1 Fertilizer Application

For fertilizer adoption, the negative sign of credit coefficient was unexpected but possible explanation of the situation is that as fertilizer application competes with other farm activities such as pests and diseases control for the limited funds, farmers may tend to shift their loans to control weeds as well as pests and diseases instead of applying fertilizer to their cocoa farms (Aneani, *et al.*, 2007). However**,** in Kenya, Njagi (1980) observed that availability of cash, access to inputs on credit and availability of manure affected adoption of soil fertility management recommendations. Green and Ng'ong'ola (1993) reported that crop type, farming system, crop variety, credit access, off-farm income, and availability of regular labour as the main factors affecting adoption of fertilizer recommendations in Malawi. The Hitech programme might consider these findings in their activities to ensure efficient and effective fertilizer application on cocoa farms. The positive sign of the number of farms coefficient was consistent with expectation because the increase in number of farms, assuming matured and yielding, will increase the cocoa output and then the farmer's income which could be used to purchase fertilizer.

4.2 Weed Control Frequency

The high input requirements for controlling excessive weed growth is one of the most important problems with tree crop production **(**Baidoo-Addo et al., 2000). The result of this study indicated that the male farmer compared to female was less likely to weed his farm four times a year, supporting the observation by MASDAR (1998) that the weeding frequency of cocoa farms by women farmers was higher than that of men on the average. MASDAR noted that women have less access to credit than men because of having less land as collateral, and relied mostly on hired labour which is scarce and costly due to migration of the rural youth to the urban areas to seek for jobs with relatively better remuneration. The women tend to finance the employment of available hired labour using additional incomes from off-farm activities such as trading. Kamau (1980) reported that adoption of weed control recommendations was influenced by availability and cost of labour, and cash flow constraints.

Cocoa yield was more probable to affect the decision of a farmer to weed his/her farm as recommended by CRIG because the resultant increased cocoa income would enable the farmer to hire labour for weed control.

4.3 Cocoa Variety Adopted

The hybrid model suggests that age of the farmer and the educational status influence the adoption of cocoa variety. The negative coefficient of age indicated that the older the farmer the lesser his/her willingness to try new innovations or take risk. The older farmers who are used to the traditional Amelonado and Amazon varieties are more resistant to change to Hybrid seeds by replanting their old cocoa farms. In the process of growing old, a farmer's social, psychological and physical conditions change. These changes result in reduced interaction with others and declined physical energy (Odoemenem & Obinne, 2010). Al-Karablieh *et al*. (2009) reported a negative relationship between age and likelihood of barley variety adoption and attributed this to younger farmers being more likely to be willing to innovate, whereas older farmers may be less willing to adopt new varieties given the heavy labour requirement. Ntege-Nanyeenya *et al*. (1997) found level of education to have a statistically significant positive impact on a farmer's choice to adopt longe1 (a coffee variety). Farmers who received any kind of education were more likely to adopt longe1 than farmers who were illiterate. Other studies have indicated similar effects for education (Nkonya *et al*., 1997; Al-Karablieh *et al*., 2009; Odoemenem & Obinne, 2010). Generally, the low level of education of the farmers retards the adoption of innovation, especially one that is complex. Literate farmers are more disposed to understand new ideas and concepts provided by extension workers and other informants. With lack of formal education, information cannot be passed to these farmers through the print media or mass media, except through personal contact methods, personal discussion, result demonstrations, and visual aid. The implication from the hybrid model is that cocoa farmers should be educated on the benefits of growing hybrid cocoa variety as compared to the traditional Amelonado and Amazon varieties. The youth should be attracted into cocoa farming through farm mechanization by developing new labour-saving innovations since they are likely to plant hybrid cocoa.

4.4 Capsid Control Frequency

Concerning the capsid spraying frequency model, migration variable was less probable to affect the spraying decision of the farmers. The negative sign of the migration coefficient was as expected because migrant farmers are assumed to be more enterprising and prepared to increase cocoa output by adopting new technologies than the natives (MASDAR, 1998). Furthermore, the positive sign of the farm size and the yield coefficients were expected since larger farms tend to produce higher cocoa output which leads to higher income to enable the farmer to purchase insecticides for capsid control. Kalyebara (1999) indicated that farm size is a significant predictor of adoption of pesticide use; that is, the use of fungicides and insecticides. Kebede *et al*. (1990) observed that farm size has statistically significant effect on adoption of pesticide technology on Ethiopian crop production systems. The policy implication here is that the CODAPEC programme should spray both large and small farms. This is to ensure complete control of capsids because farmers are not serious in controlling capsids on relatively small farms. Also, some farmers do not adequately control capsids on their farms.

4.5 Limitation and Future Suggestions

Finally, it is expedient to point out some of the limitations and future research directions. Although the sample size on which the analysis was conducted is relatively small, the researchers think that the results portray a realistic picture of technology adoption by the Ghanaian cocoa farmers. There should be further investigation into the adoption behaviour of the cocoa farmers on the chemical control of blackpod disease since our attempt to model it failed because the overall model was statistically insignificant. Besides the set of variables used in the analysis, many other public policies might have influence on the adoption of CRIG's cocoa production technologies; for instance, the mass spraying programme (CODAPEC) and the Cocoa High Technology programme (Hi-tech). We could not incorporate the effect of those variables owing to inadequate data.

5. Conclusion

This study estimated the respective adoption rates of 10.3%, 7.5%, 3.7%, 44.0% and 33.0%, for CRIG-recommended cocoa production technologies such as control of capsids with insecticides, control of black pod disease with fungicides, weed control manually or with herbicides, planting hybrid cocoa varieties and fertilizer application. Factors such as access to credit, number of farms, gender, yield, educational status of farmer, age of farm, migration, and farm size were statistically recognized to influence the probability of adoption of CRIG-recommended technologies.

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Table 1. Profile of the Districts Selected for the Survey

	DISTRICT					
FEATURE	**Nkawie**	**Goaso**	**Enchi**	**Oda**	**Twifo/Assin Fosu**	**Hohoe**
Region	Ashanti	Brong-Ahafo	Western	Eastern	Central	Volta
District Capital	Nkawie	Goaso	Enchi	Akim Oda	Twifo Praso	Hohoe
Land Area (km^2)	894.2	1 093.7	2 638.0	1 090.0	1 199.0	1 403.0
Rainfall (mm)	1 077	1 108	1 429	1 784	1 077	1 526
Temperature (^oC)	27 - 31	23 - 33	22 - 34	25 - 27	26 - 30	22 - 34
Altitude (m)	77	305	300	61	91	890
Vegetation	Semi-deciduous rain forest	Semi-deciduous rain forest	Moist semi-deciduous rain forest	Semi-deciduous rain forest	Semi-deciduous rain forest	Moist semi-deciduous rain forest and savanna
Socio-economic activities	F and C	F and C	F, L, SSM and C	F, L, SSM, Q and C	F, L, SSM, Q and C	F and C

Note: F = Farming, C = Commerce, L = Logging, SSM = Small-scale mining, Q = Quarrying

Table 2. Farmers selected for the survey

Region	District	Number of Villages per District	Number of Cocoa Farmers
Eastern	Oda	5	50
Ashanti	Nkawie	5	50
Brong-Ahafo	Goaso	5	50
Central	Twifo Praso/Assin Fosu	5	50
Western	Enchi	5	50
Volta	Hohoe	5	50
Total		30	300

Table 3. Definitions of technology adopter categories

Farm Activity	Adopter	Partial Adopter	Non-adopter
Spraying against capsids	Farmer spraying the farm 4 times per year.	Farmer spraying the farm 1 to 3 times per year.	Farmer who has not been spraying the farm.
Spraying against blackpod	Farmer spraying the farm 6 to 9 times per year.	Farmer spraying the farm 1 to 5 times per year.	Farmer who has not been spraying the farm.
Weeding	Farmer weeding the farm 4 times per year.	Farmer weeding the farm 1 to 3 times per year.	Farmer who has not been weeding the farm.
Cocoa variety planted	Farmer who has planted only Hybrid cocoa on the farm.	Farmer who has planted a mixture of Hybrid and Amazon or Amelonado.	Farmer who has planted either Amazon or Amelonado.
Fertilizer application	Farmer who has been applying fertilizer to the farm.		Farmer who has not applied fertilizer to the farm.

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Table 4. Definitions and Assumptions of Socio-economic Factors of Adoption of some CRIG Technologies

		Apriori assumptions of the signs of the coefficients (effect).				
Code	Variable	Weeding	Blackpod spraying	Capsid spraying	Cocoa variety	Fertilizer application
X_1	Age of cocoa farmer measured in years.	-	-	-	-	-
X_2	Working experience (number of years in cocoa farming).	+	+	+	+	+
X_3	Educational level of the cocoa farmer (literate or illiterate).	+	+	+	+	+
X_4	Gender (male or female).	+	+	+	+	+
X_5	Household size.	+	+	+	+	+
X_6	Migration, (native or settler).	+	+	+	+	+
X_7	Number of cocoa farms owned by farmer.	+	+	+	+	+
X_8	Cocoa farm size measured in hectares.	+	+	+	+	+
X_9	Age of cocoa farm measured in years.	-	-	-	-	+
X_{10}	Cocoa yield measured in kilogramme per hectare (as a proxy of cocoa income).	+	+	+	+	+
X_{11}	The extent of extension visits to farmer's farm by extensionist, (no visit or at least one visit).	+	+	+	+	+
X_{12}	Attending demonstration or field day (yes or no).	+	+	+	+	+
X_{13}	Access to credit (yes or no)	+	+	+	+	+

Table 5. Descriptive Statistics of the Variables Used in the Multinomial logistic Regression Analysis

Variable	Mean	Std Dev.	Min	Max	N
Age of cocoa farmer (yrs.)	51.5	15.22	15	86	300
Working experience (yrs.)	19.61	13.65	2	65	297
Adult family labour	3.26	2.76	1	19	197
Number of cocoa farms owned by farmer.	2.1	1.5	1	8	299
Cocoa farm size (ha)	3.02	3.67	0.4	36.0	296
Age of cocoa farm (yrs.)	16.9	12.48	1	85	291
Cocoa yield (kg/ha)	329.30	219.82	104.17	1171.88	211
Cocoa production (kg)	744.77	512.68	156.25	2 375.00	206
Cocoa income (GH¢)	670.29	461.41	140.63	2 137.50	206
Educational status (literate = 21.5%, illiterate = 78.5%)					298
Gender (male = 80.0%, female = 20.0%)					300
Migration (native = 43.7%, migrant = 56.3%)					300
Extension visit (no visit = 55.3%, at least one visit = 44.7%)					293
Attending demonstration or field day (yes=31.7%, no=68.3%).					300
Access to credit (yes = 22.3%, no = 77.7%)					300

Table 6. Results of the multinomial logistic regression analysis of fertilizer application and weeding frequency

	FERTILIZER APPLICATION: Adopter				WEEDING FREQUENCY: Adopter			
VARIABLE	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)
Intercept	-2.100	0.967	0.030**		-3.803	2.692	0.158	
Age of cocoa farmer measured in years.	0.024	0.013	0.064*	1.024	-0.025	0.037	0.502	0.975
Working experience in years	-0.018	0.015	0.247	0.982	n.a	n.a	n.a	n.a
Educational level	0.382	0.390	0.327	1.466	-0.544	1.199	0.650	0.581
Gender	0.163	0.389	0.675	1.177	-1.882	0.961	0.050**	0.152
Household size.	0.054	0.031	0.083*	1.058	0.073	0.068	0.285	1.075
Migration	-0.365	0.307	0.234	0.694	-0.364	0.916	0.691	0.695
Credit	-0.704	0.336	0.036**	0.494	-0.534	0.882	0.545	0.586
Number of cocoa farms owned by farmer.	0.392	0.143	0.006***	1.479	0.290	0.278	0.298	1.336
Cocoa farm size measured in hectares.	0.014	0.039	0.721	1.014	0.024	0.165	0.884	1.024
Age of cocoa farm measured in years.	0.005	0.014	0.715	1.005	n.a	n.a	n.a	n.a
Frequency of Extension visits.	0.219	0.314	0.486	1.245	1.685	1.196	0.159	5.391
Attending demonstration or field day.	0.133	0.339	0.695	1.142	n.a	n.a	n.a	n.a
Cocoa yield (kg/ha)	0.001	0.001	0.210	1.001	0.003	0.001	0.012**	1.003
-2log likelihood:	280.277				46.891			
Chi-squared:	37.612				23.988			
Degrees of freedom:	13				10			
Sig.:	0.001***				0.008***			
Pseudo R-squared (Nagelkerke):	0.196				0.370			
% correctly predicted:	69.3%				97.6%			

Note: *$P < 0.1$, ** $P < 0.05$, *** $P < 0.01$. B = coefficient of the explanatory variables. Exp(B) = exponential value of B. n.a these variables introduced numerical problems in the model estimation.

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Table 7. Results of the multinomial logistic regression analysis of cocoa variety planted

	COCOA VARIETY PLANTED: Adopter											
	Model 1: Hybrid				Model 2: Amazon				Model 3:Admixture of cocoa varieties			
VARIABLE	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)
Intercept	4.595	2.280	0.044**		3.387	2.258	0.134		3.675	2.338	0.116	
Age of cocoa farmer measured in years.	-0.053	0.030	0.075*	0.949	-0.067	0.030	0.024**	0.935	-0.063	0.030	0.038**	0.939
Working experience in years	-0.009	0.033	0.780	0.991	0.022	0.032	0.488	1.022	0.024	0.033	0.460	1.024
Educational status	3.522	1.246	0.005***	33.842	2.657	1.236	0.032**	14.251	1.363	1.303	0.296	3.907
Gender.	1.849	0.817	0.024**	6.355	1.001	0.807	0.215	2.721	0.932	0.848	0.272	2.540
Household size.	-0.028	0.065	0.665	0.972	-0.028	0.066	0.668	0.972	-0.057	0.070	0.419	0.945
Migration.	1.124	0.733	0.125	3.078	0.796	0.730	0.275	2.217	0.945	0.745	0.205	2.572
Credit.	0.040	0.788	0.959	1.041	0.126	0.777	0.872	1.134	-0.102	0.789	0.897	0.903
Number of cocoa farms owned by farmer.	-0.030	0.335	0.928	0.970	0.396	0.323	0.219	1.486	0.200	0.336	0.552	1.221
Cocoa farm size measured in hectares.	0.152	0.103	0.140	1.165	0.105	0.100	0.293	1.111	0.044	0.102	0.663	1.045
Age of cocoa farm measured in years.	-0.123	0.030	0.000***	0.884	-0.066	0.027	0.013**	0.936	-0.016	0.023	0.498	0.984
Frequency of Extension visits.	-0.373	0.696	0.593	0.689	0.301	0.699	0.667	1.351	-0.838	0.707	0.236	0.433
Attending demonstration or field day.	-0.436	0.726	0.548	0.647	-0.125	0.720	0.863	0.883	-0.391	0.744	0.236	0.676
Cocoa yield (kg/ha)	0.002	0.002	0.316	1.002	0.001	0.002	0.569	1.001	0.001	0.002	0.437	1.001
-2log likelihood:	488.472											
Chi-squared:	96.257											
Degrees of freedom:	39											
Sig.:	0.001***											
Pseudo R-squared(Nagelkerke):	0.359											
% correctly predicted:	56.1											

Note: *$P < 0.1$, ** $P < 0.05$, *** $P < 0.01$. B = coefficient of the explanatory variables. Exp(B) = exponential value of B.

Table 8. Results of the multinomial logistic regression analysis of spraying against capsids

	SPRAYING AGAINST CAPSIDS							
	Model 1: Partial Adopters				Model 2: Adopters			
VARIABLE	B	Std. Error	Sig.	Exp(B)	B	Std. Error	Sig.	Exp(B)
Intercept	-1.387	1.533	0.366		-5.487	2.105	0.009***	
Age of cocoa farmer measured in years.	0.025	0.019	0.181	1.025	0.029	0.024	0.224	1.030
Working experience in years	0.005	0.021	0.819	1.005	-0.023	0.030	0.449	0.977
Educational level (none)	-0.773	0.547	0.157	0.462	-0.634	0.735	0.388	0.530
Gender (male)	-0.458	0.524	0.382	0.632	-0.415	0.718	0.563	0.660
Household size.	0.035	0.052	0.499	1.036	0.057	0.062	0.355	1.059
Migration# (native)	-1.091	0.438	0.013**	0.336	-.1.058	0.587	0.072*	0.347
Credit	0.136	0.541	0.802	1.145	1.102	0.787	0.161	3.010
Number of cocoa farms owned by farmer.	0.037	0.226	0.871	1.037	0.055	0.259	0.831	1.057
Cocoa farm size measured in hectares.	0.567	0.184	0.002***	1.763	0.504	0.200	0.012**	1.655
Age of cocoa farm measured in years.	-0.035	0.018	0.052*	0.965	-0.009	0.026	0.728	0.991
Frequency of Extension visits (never).	0.683	0.417	0.101	1.981	0.108	0.563	0.848	1.114
Attending demonstration or field day (Yes).	0.287	0.490	0.558	1.333	0.328	0.639	0.608	1.388
Cocoa yield (kg/ha)	0.004	0.001	0.006***	1.004	0.005	0.001	0.000***	1.005
-2log likelihood:	311.761							
Chi-squared:	69.133							
Degrees of freedom:	26							
Sig.:	0.001***							
Pseudo R-squared (Nagelkerke):	0.312							
% correctly predicted:	73.0%							

Note: *$P < 0.1$, ** $P < 0.05$, *** $P < 0.01$. B = coefficient of the explanatory variables. Exp(B) = exponential value of B.

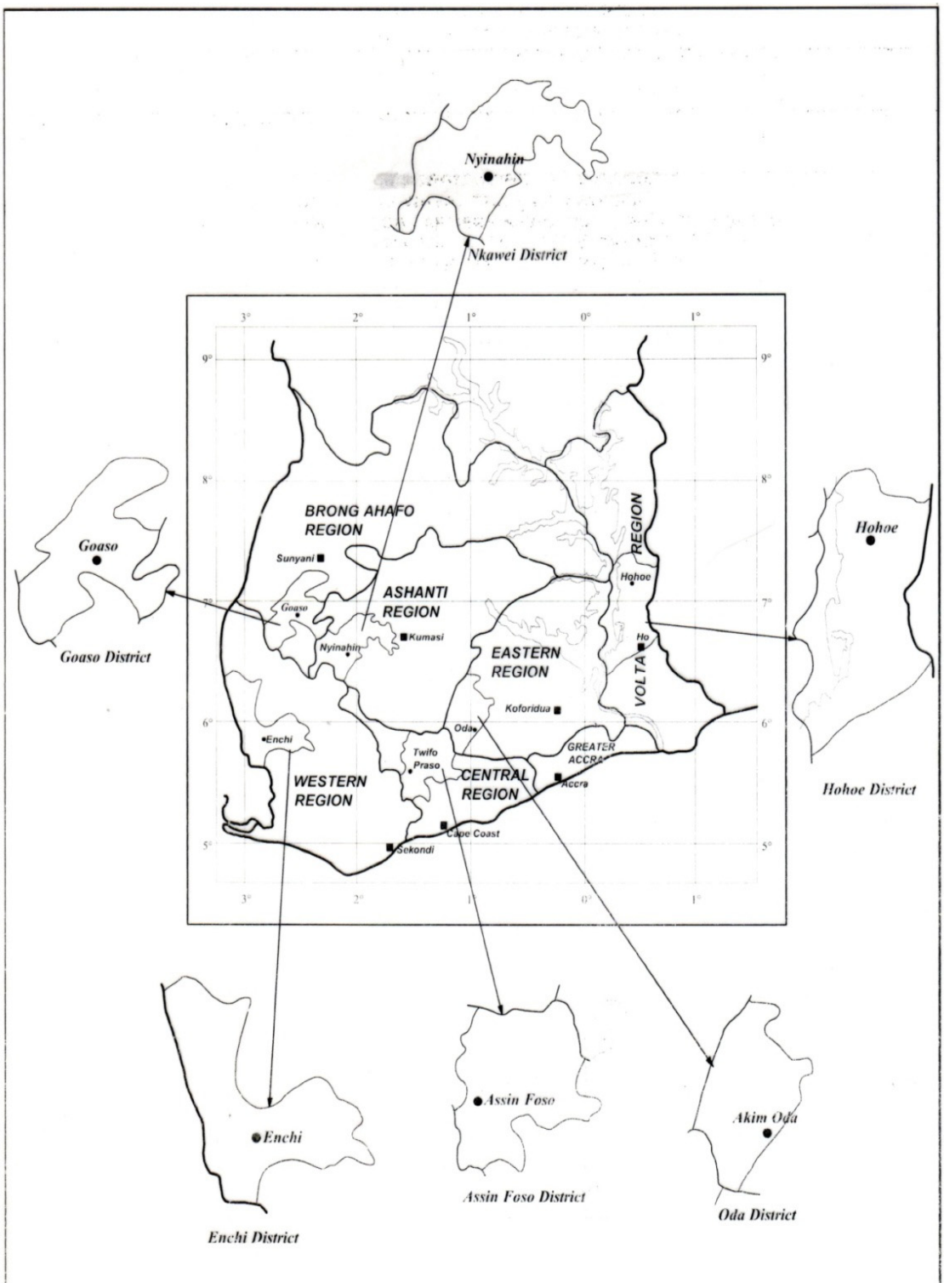

Figure 1. A map indicating the various districts where the baseline survey was conducted

Communication for Sustainable Rural and Agricultural Development in Benue State, Nigeria

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Abstract

This discourse discusses communication as a potent sociological tool for rural and agricultural development. It demystifies the concepts of communication, rural and agricultural development. It high-lights principles of communication, types of communication, communication barriers and the role of communication in a holistic and sustainable rural and agricultural development in Benue State, Nigeria. The epilogue concludes by noting that as long as there is continued imbalance in the diffusion of agricultural information and wrongful targeting of information, the possibility of harnessing the full potentials of our rural populace towards attaining sustainable and holistic national, rural and agricultural development will remain problematic and in a limbo and another political snafu. It is recommended that segmentation of the target audience based on needs, interested agro-ecological areas should be adopted by senders of agricultural messages; and decentralization of radio, and television broadcasting in local languages should be encouraged and underscored.

Keywords: Communication, Sustainable, Rural, Agricultural Development

1. Introduction

It is becoming increasingly apparent worldwide that development does not end in economics (industry) and that there can be no national development without rural and agricultural development. The new paradigm underscores local definition of developmental needs, which permits the inclusion of non-economic or non-industrial indices such as question of quality of life, equity and social participation (Okonkwor, 1987). The major issue in contention here is what aspect of development should greater emphasis be placed on? Should it be on increased agricultural productivity, better health and social conditions or development of human resources? According to Okonkwor (1987), more attention should be paid to development of endogenous skills and self-reliance. Understood this way, development involves more than modernization or urbanization. It rather evolves into a comprehensive phenomenon that comprises improvement in the totality of a people's life.

The cardinal objective of economic development upon which national development is predicated is the improvement of man himself (Okonkwo, 1987) the assumption here is that once you develop human resources, you have succeeded in creating an enabling environment for a holistic national development. To achieve this laudable objective, we must start with sensitization and mobilization of human resources towards acquisition of knowledge, skills and desired attitudinal changes. This is where communication should come in to sensitize, mobilize, persuade, engender and sustain people's interest with a view to adopting new ideas, practices or technologies that are likely to bring about holistic improvement in their well-being. What communication needs to do in this perspective is to provide an auspicious climate for rural and agricultural development which are sine qua non for a holistic and sustainable national development generally.

1.1 The Concept of Communication

Every social system consists of animate creatures that interact among themselves in their quest to survive in their social environment. Every living creature communicates. As human beings, we communicate with the whole of our body. In fact, every part of human body communicates something to others. The whole of human environment is surrounded by messages, some of which are purveyed intentionally and are consciously received and acted upon. A lot of human messages get lost en route. Most of our human problems can be traced in part to

poor communication of messages. Human communication is necessary for the survival and growth of any society.

What then is communication?

According to Udall and Udall (1979), communication is a process by which one person (or group) shares and imparts information to another person (or group) so that both people (or group) clearly understand one another. It can, also be defined as a dynamic and cyclical process by which a message or information is initiated or conceived by a source (or sender) who decodes and purveys it through certain channels to a receiver who decodes the message and, consequently, shows some effect and acts upon it by giving feed back to the sender that it has been received and understood.

Ewhrudjakpor (1989) defined communication simply as a dynamic process of sharing information between individuals. Adebayo (1997) conceptualized communication as a process of information flow by which ideas are transferred from a source to a receiver with the intent to change his/her knowledge, attitude and/or skills. Thus, for each act of communication, to Laswell model (1948), we must attempt to seek answers to the following questions:

(1) Who? (source)

(2) Says what? (message)

(3) Through what means (channel)

(4) To whom? (Receiver) and

(5) With what effect (change in the receiver's behaviour)

Communication is a key process in information dissemination in agriculture. The development of agriculture requires, among others, a timely and systematic transmission of useful and relevant agricultural information from the technology generation system (source) via various communication changes to the intended audience (receiver). It is expected that the client's changes in behaviour as a result of the message received (effect) be passed back to the source (feedback) for the communication process to be complete (Adebayo, 1997).

Age (2009) defined communication as a process in which the participants create and share information with one another in order to reach a mutual understanding. In this process, emphasis is on interactive process of information sharing overtime to the ways in which participants interpret and understand information.

1.1.1 The Major Elements of Communication

The major elements of communication include the following:

(1) Source or sender

This refers to an individual or group of individuals or an institution or agency that initiates a communication scenario. It could be the research institute or extension agency or even an individual change agent wishing to purvey relevant agricultural message to the farmers. As a purveyor of innovations, the source is expected to be knowledgeable in the subject matter. To ensure up to dateness, the source is supposed to be trained on a regular basis so that he can acquire the necessary methodologies of communication.

(2) Message

This refers to the agricultural information or idea or technology that the source whishes to purvey to the end-users and, of course, compatible with the existing practices, societal norms, belief and culture of the society before they can be widely adopted and/or confirmed. Relevance of message, connotes being technically feasible, economically affordable and socially acceptable by the generality of the people in the society.

Messages take several forms made up of several physical elements, which may be words with symbolic meaning or just ideas encoded into symbols to which meaning can be attached. Encoding connotes the changing of meanings into symbols or forms (messages) appropriate for dissemination to the receiver. When a source initiates communication scenario after conceiving what has to be communicated, he encodes or changes the meanings of the conceived message into symbols or simple understandable forms and, then, sends this message through a channel to the receiver. When the receiver receives the message, he decodes it, (that is, attaches meanings to the symbolic message) and then develops an idea of what the message is all about in his/her mind. Decoding connotes the translation of received message into interpreted meanings. As soon as the receiver decodes a message, he/she reacts to the massage by sending feedback to the source, who now becomes the receiver of feedback message.

(3) Channels

This connotes the means through which a message travels from the source to the receiver and vice versa. Communication channels can be categorized into:

(i) Physical channels, which involve direct contact. For example, visits, seminars, workshops, exhibitions, advisory village meetings, agricultural shows etc.

(ii) Non physical channels such as T.V, radio, phone calls, newspapers, magazines, and other print media channels.

(iii) Technical channels which could be physical or non-physical.

(iv) Human discipline channel, for example, dresses put on by professionals such as medical doctors, nurses, army officers, etc depict their professions

(v) Token of communication channels, which are channels in between physicals and non-physical channels. For instance, signals, gestures, idols at the shrines and other symbols.

Besides, other channels of communication are life drama such as theatre groups, audio visuals, print media, folk media such as traditional songs, dances, talking drums, village criers etc. In the communication of agricultural messages to the end-users, it is advisable to use a variety of communication channels. This is because the more senses are employed in the communication process, the most likely that communication messages will be easily understood.

(4) Receiver

A receiver is the target audience of communication, who decodes message symbols into interpreted meanings. According to Adebayo (1997), modern communication theory holds that meanings are not messages, rather they are convert responses contained within the human organism. They are learned and personal, thus, people who have similar meanings can communicate more effectively. In agricultural extension communication, it is expected that common meanings should be established between the source and the receiver.

Usually, farmers' farm families and farming communities are regarded as the end-users of agricultural extension messages. However, any member of agricultural research institutes, or extension agency, as well as policy makers who have acted as a source could, also, be a receiver, particularly of feedback communication. In order to ensure effective communication of agricultural messages to the target audience, it is expected that the communication message should be related to the goals and such messages should be designed for a specific audience in mind. It is, also, expected that segmentation of the audience should be carried out before directing such messages to them. This is because not all farmers are the specific target audience of certain agricultural messages. So, when we direct messages to all farmers without considering their needs or interest in their various agro-ecological areas, such messages will not reach their target audience. There is need, therefore, to segment or stratify the entire population based on their agro-ecological zones, needs and interests before directing agricultural messages to the target audience.

(5) Effect

Communication effect connotes the phonotypical or overt change in the receivers' behaviour, which occurs as a result of the message received. This change in behaviour could be in terms of knowledge, skills, attitude or habits. Effective communication takes place if it results in the intended behaviour of the receiver, or audience.

(6) Feedback

This refers to a response from the receiver to the source. By the concept of feedback communication, the source is, thus, viewed as a receiver. Feedback is an indispensable device that can be harnessed to measure the success or failure of communication. In fact, sending a message alone without finding out the extent of its diffusion among members of a social system and of course the effect of such a message will be a useless exercise. Effective communication can occur if and only if there is communication with feedback.

Feedback assures the source that his message has been received, understood correctly, interpreted (decoded) and acted upon. Through feedback, the source knows whether to continue or end his communication and whether or not to stop and modify his language and mode of presentation. Thus, feedback helps to guide the source through the murky waters and difficult terrain of interpersonal communication. To ignore the place of feedback in any communication scenario is to weaken communication effectiveness.

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(7) Noise

In extension parlance, noise is any interference en route transmission and reception. In other words, it is a barrier that prevents a message from getting across to the intended audience. Noise may be of three broad categories (i) physical noise, (ii) psychological noise and (iii) linguistic noise. Physical noise comes from loud conversations, side talks at meetings, sound from workmen's tools and, of course, horns from moving vehicles. Psychological noise comes via poor mental attitudes or emotional stress. Linguistic noise refers to the communicators' inability to use the language of communication accurately and appropriately. Linguistic noise is sub-divided into semantic, grammatical and phonological noise. Semantic noise results from wrong choice of words, use of unfamiliar words or use of familiar words in unfamiliar ways. Grammatically, noise may result in the form of faulty sentence structure, misapplication of the rule of correct language use. Phonological noise occurs through poor pronunciation or words. Noise may, also, come by the way of poor spelling, poor writing or even a drop of ink water, which blurs whatever is written.

1.1.2 Principles of communication

The basic principles of agricultural extension communication include the following among others:

(1) Farmers need to be informed of what is happening around them. It is when one knows what is happening around him/her that he/she will be able to function properly in his/her environment. It has been found that when human beings are deprived of information around them, they tend to become dehumanized and completely ignorant of their environment. A popular adage says "no one is an island of knowledge". It, therefore, means that for an individual person to be able to function properly in his/her environment, he/she needs some forms of information.

(2) Communication message should be designed with specific objectives in mind and should be directed to the target audience. Before starting or initiating any form of communication scenario, the source needs to determine the goals or objectives of his communication. What does he/she want to achieve at the end of his communication? The source also needs to know about the target audience of his communication. This entails knowing the socio-economic background of the audience in terms of their level of education, their level of income, occupation, social status, their needs, interests and their agro-ecological areas. It is only when audience analysis has been done by the communicator that he/she will be in a better position to segment the target audience with a view towards directing appropriate communication messages to them in order to meet their needs, interests and aspirations. There is no need directing all agricultural messages to the entire population because such broad-based messages do not reach their destinations.

(3) Message content should suit the needs and interest of the target audience, not the sponsor. In order to achieve effective communication and make positive contribution to agricultural development, the message content of communication should suit farmers' farm situation as well as their socio-cultural milieu in which they operate. The popular adage that 'he who pays the piper dictates the tune' should be ignored.

(4) There is need to use a multi-media channels of communication in purveying agricultural messages to farmers. This is because different channels appeal to different senses. According to Adebayo (1997), human senses often reinforce each other in the acquisition of knowledge and skills. Therefore, when two or more communication channels are used to share information with the audience, the end-users tend to understand the message much better than if only one channel was used.

(5) The communicator should empathize with the receivers in order to ensure effective communication. He should act at the level of the audience.

(6) The source should always be homophilious with the receivers in order to ensure effective communication.

1.1.3 Types of communication

Basically, there are three types of communication, namely:

(i) Intrapersonal communication, (ii) Interpersonal communication and (iii) Mass communication.

i. Intrapersonal communication

This refers to communication with an individual through his/her senses, which enables him/her to take decisions. It is more or less an electrochemical action of the body taking place within ourselves and it is sometimes referred to as soliloquizing. In fact, intrapersonal communication is the basis of all other forms of human communication. Without an effective system of intrapersonal communication, an organism will not be able to function properly in its environment or to be open to external forms of communication. It is this type of communication that allows an individual to take decisions based on information received through his/her senses. For example, when an

individual is watching, say, football match on T.V. or film, his eyes and ears receive information and communicate it to his brain. If what he sees and hears is interesting to him, his intrapersonal communication system will indicate that and he will continue watching that football match. If he finds it uninteresting, his brain will send a message to his muscles that will result to taking a decision either to put off the TV or to leave his room and go to the market. Another instance is this, suppose one is busy enjoying one's pounded yam with goat meat which is a delicacy in one's locality and somebody calls him from outside and just as he is about to stand up to open the door for his visitor, one's GSM hand set rings. One finds it difficult to decide whether to answer the call from outside or that of the GSM hand set. One is at a crossroad. It is one's intrapersonal communication system that will help him at this point to take decision.

If we apply these examples to Bittner's Communication Model, we than see that his eyes and ears become the sources or senders of electrochemical impulses (message) through his central nervous system, which is his medium of communication. His brain becomes the receiver of these impulses, which transmits additional electrochemical impulses in the form of feedback to his muscles, producing such physical activities as putting off the TV or answering the phone call.

From the second example above, we can see that the GSM phone call interfered in the intrapersonal communication process and, therefore, can be regarded as noise, because it encumbered decision-making process of that individual.

ii. Interpersonal Communication

Interpersonal communication, according to Soola (1993), is a two-way, two-some or dyadic communication. It is a face-to-face encounter or transactional exchange of information. This type of communication is the basic means of effecting behavioural change. It incorporates psychological processes (perception, learning and motivation) as well as language. Of relevance to interpersonal communication is listening sensitivity and non-verbal communication.

As people interact in interpersonal context, they exchange ideas, attitudes emotions and opinions. Interpersonal communication is an interaction of a conversational nature.

1.1.4 Ways of improving interpersonal communication with farmers

There are a good number of ways improving interpersonal communication with farmers. According to Obinne (1992), experts have suggested the use of traditional mass media (folk media) as credible channels of reaching the most disadvantaged audience the rural poor.

According to Soola (1993), one of the several ways in which effective interpersonal communication can be pursued, achieved and sustained is by appreciating the culture of the people. Knowing the culture of a participant in an interpersonal communication transaction serves as a significant predictor of the communication behaviour of the participant. In addition, such knowledge helps to determine the language choice that can be used for effective communication.

Another way of improving interpersonal communication is knowing the people or person involved in communication scenario. Much of our communication ab-initio is designed to provide us with information about the person and people with whom we are interacting interpersonally. Much of what goes on in the first few minutes of interpersonal communication between strangers is some form of information gathering on the part of each participant with a view to establishing a rapport, and establishing a rapport involves knowing each other. It is only when people know each other that they can communicate freely.

More so, there is need to shun dominance or control in communication and that is what is known in communication parlance as symmetrical relationship. In this kind of interpersonal communication, both participants should claim equality. Success in interpersonal communication/interaction will be better achieved better in a parallel communication relationship, in which each participant has an area of control. In an agricultural extension situation, while the extension worker is the purveyor of technical or specialized information, and should be allowed to exercise control in this area, the rural farmer is more knowledgeable about his day-to-day experiences, problems and indigenous farming practices.

Obinne (1992) stated that change agents should be homophilous in their dealing with farmers. That means that for effective interpersonal communication to take place, change agents should come down to the level of the farmers in terms of language, societal norms, beliefs or culture, level of knowledge and even behaviour, all of which are supposed to be taken into consideration. The change agent should not be boastful or arrogant but calm and humble, even to the extent of living among the clientele in the rural areas.

Generally, extension workers must show empathy and they should be able to understand and appreciate their clientele (Obinne, 1992). Empathizing with farmers helps to establish more rapport with farmers that is sine qua non for improving interpersonal communication with them. Change agents should always use simple and local languages during discussion with farmers and should only discuss matters that are of interest to the farmers without forcing their opinions on them.

Finally, interpersonal communication can be improved with farmers by recognizing the place of non-verbal communication in human communication interaction. Soola (1993) stated that one major barrier to interpersonal communication is to underplay the crucial significance of non-verbal communication. It is not often realized that, as human beings, everything about us communicates something to other people. Thus, our hairstyle, the dress we wear and our manner of wearing it, our sitting and standing postures, our facial expressions, the movement of our whole body or part thereof, our silence, all communicate without our uttering a word. Non-verbal communication transmits feelings, emotions, likings, personal meanings and preferences.

The implication of this is that action speaks louder than words. Non-verbal communication may, therefore, either be a liability (a barrier) or an asset to effective interpersonal communication, depending on whether or not we recognize its potency and exploit it with utmost care.

iii. Mass Communication

Mass communication involves sending messages through a mass medium to a large number of people. For mass communication to exist, we need an intermediate transmitter of information called a mass medium. A lot of mass media are used in mass communication such as newspapers, magazines, film, radio, television, internet, books or combination of these. Mass communication messages are directed at a group of people via mass medium. Books were the first mass media, followed by newspapers, magazines, film, radio, television and now the advent of the World Wide Web (www).

The mass media channels have distinct operational features. Some of these include;

(i) Mass medium, (ii) Impersonal (iii) Gate keeper (iv) Delayed feedback (v) Hardware and software.

1.1.5 Communication Barriers

Communication barriers refer to constraints or problems that encumber free flow of information from the source to the receiver. Some of these problems include:

Noise, incorrect message content, cognitive dissonance, information overload/fatigue, material inputs, wavering attention and, information selectivity.

Noise

This refers to anything that interferes or distorts effective communication. Noise could be physical, psychological and linguistic in nature as earlier discussed. According to Adebayo (1997), one way of reducing noise in the message is to increase redundancy through writing the same message in different forms but with similar meaning. For instance, “wash the fruits very well” or “ensure that all the dirts are removed from each fruit”. Both of these imply a thorough cleansing of the fruits. Noise can be minimized by controlling physical, psychological and linguistic factors. Physical noise can best be controlled by distancing oneself from loud sound; observing absolute silence and satisfaction of physiological needs to prevent wavering of attention, while psychological and linguistic noise can best be controlled by controlling emotional stress and correct use of grammatical rules, words and pronunciation of words, respectively.

Incorrect Message Content

Change agents who possess mastery of the subject matter as well as use appropriate teaching methods and visual aids can easily pass across their messages to the target audience. The reverse is, also, the case, especially when incorrect and irrelevant messages are disseminated by incompetent change agents to the end-users. Such change agents may lose credibility, especially if it is found out that their information is false. Even when correct information is passed on, the method of presentation may either make or mar the success of communication.

Cognitive Dissonance

This connotes negative knowledge attribute of farmers. In other words, it refers to knowledge which is inconsistent or incompatible with a farmer’s interest, attitude beliefs or culture. If a change agent fails to conduct audience analysis but goes ahead to pass on information that is not compatible with societal norms or culture or beliefs, such information may not be accepted by farmers even if it has some relative advantages.

Ethnocentrism

This refers to a tendency whereby some people see their culture as being superior to other cultures, to such an extent that any information disseminated to them by people from other cultures may be relegated to the background and, consequently, rejected subjectively. For example, a change agent from Zamfara State wishing to disseminate certain information to Ibo farmers in Imo State may not be allowed on the ground that he is coming to Islamize their state and/or introduce sharias in their state. This attitude affects communication of agricultural innovations to the end users.

Information Overload/Fatigue

Information overload means passing excess information than the carrying capacity of the receiver. This leads to the befuddlement or confusion and information fatigue. In communicating agricultural messages to farmers, there is need to first of all carryout audience analysis with a view to knowing the socio-economic characteristics of the farmers. This enables one to design messages according to their educational background and taking into consideration individual differences. Agricultural messages should, therefore, be passed on to the farmers in a piece meal and at their own pace.

Delayed Feedback/lack of Feedback

The use of gatekeepers in mass communication may cause delayed feedback and this affects timely passage of messages to farmers. In some cases, there may be no feedback at all. This is capable of causing misunderstanding which can impair communication effectiveness.

Feed Forward

This connotes either positive or negative information about the receiver, which the source has prior to initiating communication. If the source has false information about the receiver, his communication will founder even before he commences. This is true because false conception will serve as noise that is capable of distorting information or black-mailing the receiver, thus, dainting his credibility.

Shortage of Material Inputs.

Diffusion of an innovation into any social system is one side of a psychological coin and ability to adopt such an innovation is another side. Most of the farmers lack the wherewithal (capital or labour) to practice introduced innovations. In most developing countries, experience has shown that resource-rich farmers tend to adopt new farming practices much more quickly than the resource-poor farmers (Adebayo, 1997). It was earlier thought that it is the mental characteristics of the farmers that make them to adopt an innovation. It has been found, however, that most farmers will adopt new ideas only if they have the resources, and are not hampered by physical, social or organizational constraints (Adebayo, 1997).

Wavering Attention

A farmer's physiological needs may stand between him and adoption or rejection of an innovation, irrespective of its high degree of relative advantage. In other words, a farmer's attention may waver in a communication scenario simply because some of his basic or physiological needs are not satisfied. For instance, a hungry or thirsty farmer may not be attentive during method demonstration and as such may not be able to comprehend the message content or decode the message appropriately.

Information Selectivity

Farmers tend to be selective in their choice of communicated messages based on their compatibility with their existing practices, or societal norms, values or beliefs. So, when a well-thought out package of production recommendation is disseminated to them, they tend to select part of the message based on what they want to know.

Homophily Versus Heterophily in Communication

Homophily is the degree to which pairs of individuals who interact are similar in certain socio-economic attributes or characteristics such as level of education, occupation, beliefs, social status and so on. Effective communication takes place when a source-receiver pair is homophilous. The most effective change agents are those who are like their average clients on all variables with the exception of technical competence about the innovation promoted. The more nearly equal in social status, education and occupation people are, the more frequently they will interact among themselves. Age (2009) opined that communication between source and receiver is likely to be when both of them share common meanings, attitudes, beliefs and of course mutual language. According to this scholar, social relations are much closer between individuals who resemble each

other in socio-economic characteristics. This conceptual label, according to Obinne (1992), is one of the most obvious and fundamental principles of human communication, which implies that the transfer of ideas most frequently occurs between a source and a receiver who are alike (similar/homophilous)

Heterophily, on the other hand, refers to the degree to which pairs of individuals who interact are dissimilar or different in certain socio-economic attributes such as education, occupation, social status, and culture or beliefs etc. Some studies have shown that heterophilous communication leads to message distortion (ineffective communication). According to Obinne (1992), one major problem in communication of innovations is that the source is usually quite heterophilous to the receiver. According to him, some degree of heterophily is necessary because the source is expected to be more technically competent than the receiver. Generally, receivers such as smallholder farmers often seek sources that are slightly more technically competent about innovations then themselves.

In effect, most individuals would prefer to interact with people who are more or less on the part of technical propinquity. It has been found that interaction with people who are hetereophilous involves greater efforts to make communication effective. In other words, heterophilic interaction is likely to result in cognitive dissonance because the receiving unit is exposed to messages that are likely to be inconsistent with his existing beliefs, an uncomfortable psychological condition.

Heterolphilous individuals who have high empathy are, in a social psychological sense, really homophilous. Empathy connotes the ability of a person to project himself into the role of another person. If, for example, a source observes how the receiver feels,and sympathizes with him, it is possible to design a message to suit the needs, interest and condition of the receiver.

In conclusion, it should be noted that communication between heterophilous source-receiver pair is less effective than between a homophilous pair. However, complete homophily does not exist in any communication scenario, given that the source and the receiver are usually dissimilar, at least in some aspects.

2. Literature Review

2.1 Concept of Agricultural Communication

Basically, an understanding of extension communication systems in a complex chain of interaction is a major determinant of the potential success of a scientist in a research institute (Siyanbola, 1996). Sustainable development in the agricultural sector is dependent on generation of appropriate technologies and creation of effective communication strategy for dissemination of recommended techniques to end-users (Dimelu and Anyanwu, 2005).

Communication is conceptualized as a process of information flow by which ideas are transferred from a source to a receiver with the intent to change his /her knowledge, attitude and /or skill (Adebayo, 1997). It is the key process in information dissemination in agriculture. The dissemination of information from point of development to the point ultimate use is an important concept in agriculture extension delivery. For technology to be relevant, its existence must be known –a condition, which presupposes communication.

Adebayo (1997) explained that, adoption and transfer would hardly take place unless the farmers (receiver) attaches the correct and intended meaning to the technology (message) and also responds favourably as intended by the extension agent (source). It is necessary to bridge the gap between available knowledge on improved technologies and actual practices, effective information delivery since which is the missing link between the research – extension interface, and practical application of the results by the peasant farmers (Entsua-Mensail, 1993).

Agricultural communication as a branch of study in agriculture, deals with the planning and management of agricultural information and methods of effectively communicating agricultural technology in order to bring about desired changes in farmers' behaviour and their farming practices for improved living. In the context of agricultural extension services, agricultural communication is a process by which extension workers exchange attitudes, share knowledge and skills on behalf of their organizations with farm families through a medium in ways that each gain an understanding and use of the message(Agbamu,2006).Agricultural communication enhance a two-way flow of information in which farmers share information among themselves or an agricultural organization delivers message to farmers in such a way that both farmers, or the agricultural organization and the farmers establish commonality in meaning over the shared information and messages delivered with the intention of improving the knowledge, attitude and skills of farmers in given innovations.

2.2 The Concept of Development

Development is a multifaceted and normative concept meaning different things to different people (Adebayo, 1997). Development is simply a rapid and sustained rise in real output per head and an attendant change in technological, economic and demographic characteristics in a society. Yahaya (2003) described development as a trend in the technologies, organizations, activities and values of a society. According to this Scholar, the indices for measuring development are economic growth, cultural and racial prejudices, equity in income, egalitarianism (personal freedom), technology and ecology.

Majority of economists, psychologists, sociologists and political scientists have, at one time or the other focused their attention on the colossal inequalities among the world's nations (Okonkwor, 1987). According to him, the gross national product (GNP) and literacy rate are often used as indices for measuring national development. The tendency to notice a correlation between high per capita income and high literacy rate is then taken as the basis for national development. Fapohunda (1979) stated that the economic development of a country depends on the quantity and quality of its resources, the state of technology and the efficient deployment of resources in both the production and consumption processes.

The import of all these definitions is the strong emphasis on a change from an unfavourable condition to the better in both socio-economic and cultural conditions of individuals cum the entire society.

Rural development, on the other hand, can be conceptualized as a strategy designed to improve the socio-economic life of the rural poor. It involves extending the benefits of development to the poorest among those who seek a livelihood in the rural areas. Rural development includes the provision of social, physical, and institutional infrastructural facilities (such as health facilities, pipe bone water, education, electricity power supply and a host of other continuums) to a special group of people. The group includes small-scale farmers, tenants and the landless (Abe, 1991).

The rural area is the main place of abode of about 80 per cent of peasant Nigerians who subsists on agricultural production and marketing. In order to bring about national development, the rural areas should be developed. Since rural people subsist on agriculture, rural development endeavours should be shifted to agricultural development, which is the bedrock for national development.

Famoriyo (1985) defined agricultural development as a process of transforming agriculture from a predominantly subsistence level to an economy dominated by investment and market-oriented agriculture. According to Okonkwor (1987), agricultural development is a process of change not fully from the traditional and subsistence mode to more productive and commercialized enterprises but also the transformation of the people who engage in it. According to him, agricultural development depends on the availability of basic primary factors such as effective marketing system, adequate supply of farm inputs of high quality, attractive price policies, subsides, tax reliefs, efficient transportation system and continuous and effective research-extension farmer linkages.

Rural development, therefore, cannot take place without serious agricultural development. However, for agricultural development to result in a self-sustaining improvement in farming, the knowledge, skills and attitudes of the farmers must keep increasing and changing. This is where the role of the media must be recognized in the overall planning and execution of rural, agricultural and national development programmes.

2.3 The Role of Communication in National Development

Mass media channels have some distinctive operational features such as hardware, soft ware, professional managers and "gatekeepers". According to Yahaya (2003), "gatekeepers" apply to institutions wherein both people and technology interact to control the events that determine the transfer of information for the source to the receiver. Information passed by gatekeepers may be considered reliable because such messages might have compiled and edited by a team of experts such as reporters, editors, cameramen, engineers, writers etc. In this respect, gatekeepers are shapers of opinions in communication and media industry.

Mass media institutions such as newspapers, magazines, books, motion pictures, radio, TVs, internet and sound recording help in the generation and dissemination of messages that are of immediate needs to the general public. Besides, these media institutions contribute greatly towards the growth and development of knowledge as well as its preservation through documentation. Through this, researchers can gather enough research data and finally come out with workable solutions needed to solve human problems that hitherto had formed a cog in the wheel of national development.

Mass media help in sensitization of all stakeholders and beneficiaries of agricultural, rural and the overall national development programmes. Mass media channel such as radio and television are used to create

awareness in people about newly introduced programmes, projects or farming technologies with a view to adopting them.

The mass media try to persuade the beneficiaries or target audience in order to engender or kindle interest in the minds of the target audience so that they can develop favourable attitudinal changes needed for adoption of innovations or programmes.

Any development programme that is bereft of realistic objectives and has not taken into consideration social needs and interests is bound to founder. It is the responsibility of mass media to direct such developmental objectives to the target population and to ensure that such a programme meets the needs and interest of the famine.

Yahaya (2003) enumerated other functions or roles of the mass media to national development, thus:

i. **Surveillance function:** This is what makes the media "the society's watch dog, "because they facilitate the spread of political messages **(tragedies)** and shaping of information about events happening around the world.

ii. **Interpretation function:** the mass media gatekeepers try to translate messages in local and simple languages that can easily be understood by the general public to prevent distortion of information. According to Ewhrudjakpor (1989), a common language plays a vital role in communication of all the forms of social interaction. The language people speak is the most compelling and enduring source of cultural identity. Cultural identities and differences tend to follow linguistic lines. In fact, Belgium and Nigeria have been encountering continual problems of maintaining national unity because linguistic differences reinforce and accentuate cultural differences.

iii. **Cultural transmission function:** mass media help to give further information and clues about the society and, also, help in socialization process.

iv. **Entertainment function:** Mass media help in creating joy and excitement outlets, for many people.

v. **Propaganda function:** Mass media can be used to brain-wash people and to popularize specific issues of interest to political leaders.

vi. **Commercial function:** Mass media can be used for advertisement and income generation for different business outfits.

Negative Influences of the Mass Media

In spite of the numerous roles mass media have been playing to bring about national development in Nigeria, certain snags seem to influence mass media negatively.

First, majority of psychologists believe that viewing violent and immoral T.V or video programmes increases interpersonal aggression and unethical demeanours among young children.

Second, exposure to mass media programmes (T.V. or radio drama) can lead to acculturation, which is detrimental to nurturing and sustenance of African's culture. A closer look at how our educated ladies dress these days is a clear example of adulteration of African culture, which mass media have imported. This seems to be one of the imperialistic weapons the western nations are using now in their neo-imperialistic tendencies to enslave Africans indirectly. According to Ewhrudjakpor (1989), the acculturation of African countries is mainly through aggressive importation of mass media products via satellite television. These mass media expose individuals, social systems and the government to various programmes alien to our society. Good examples include the idea of gender inequality, influence on our dressing, education and even eating habits. All these lend themselves to influencing our beliefs, attitudes and behaviours either negatively or positively. For instance, the television drama on female circumcision is one effective persuasive way of stopping female genital mutilation in Cross River State, thus getting rid of strongly imbedded traditional beliefs in certain parts of Nigeria.

3. Methodology

3.1 The Study Area

Benue State is situated in the middle Belt region of Nigeria. The state is situated in the Middle Belt region of Nigeria. It is located on Longitude $6^{o}35'$E to 10^{o}E and Latitude 6^{o} 30'N to $8^{o}10'$N.

The state shares common boundaries with Nasarawa State to the North, Cross River and Enugu States to the South, Kogi and Ebonyi States to the West and Taraba State to the East. The 2006 population census puts the total population of the state at 4,219,244 (NPC 2006). The land mass spans some 34,059,244km^2 of the guinea savannah vegetation belt with temperatures ranging between 25^{o}c and 37^{o}c.

The state has distinct wet and dry seasons. The wet season starts in April to October while the dry season starts in November to March. The dry season, also called harmattan is characterized by dry and dusty North Eastern Winds. The wet and rainy season, with the mean precipitation of 1500mm has two peaks, May/June and August/September. Relative humidity during the wet season is high while during dry season is low.

Farming is the major occupation of the indigenes. Crops grown include yam, rice, sorghum, maize, millet, cassava, water yam, cocoyam, and sweet potato as well as tree crops such as citrus, mango, oil palm cashew and guava.

Administratively, the state is divided into 23 local government areas which are zoned into three senatorial zones; Zone A, B and C.

4. Conclusion

National development is the mission of all countries the world over and to attain this laudable objective, there is need to start this development at the grassroots by giving agricultural and rural development their rightful place in the scheme of things. One of the giant strides in this perspective is the development of human resources through appropriate use of mass media channels. As long as there is continued imbalance in the distribution and wrongful targeting of information, the possibility of harnessing the full potentials of our rural populace towards attaining national development will ever remain problematic and in limbo.

5. Recommendations

Mass media could be a veritable sociological tool that could be harnessed to breed national development only if all stakeholders of national development adopt the following workable strategies.

(1) Segmentation of the population in terms of needs and interest. That is to say, efforts should be made to stratify the target audience based on their developmental needs and interests or agro-ecological zones. When campaign messages are directed at the entire population at the same time without considering the needs and interest of various agricultural zones, then such messages may end up reaching nobody. For instance, a campaign about piggery farming will be of no value to Moslem communities, just like that for cattle farming will not interest people from rainforest zone, where there are a lot of tsetse flies and the entire area is too swampy. All rural farmers according to Okonkwor (1987), cannot constitute the target audience, hence there is need to first of all stratify the entire population based on needs and interest before directing campaign messages to them.

(2) There is need to relate message to the set objectives and then design messages or programmes for a particular target audience in mind. When messages are closely related to set objectives, designed with particular audience in mind and programmes are properly executed, the tendency is to achieve a successful campaign (Okonkwor, (1987).

(3) There is need to use a mixed media strategy. Traditional folk media can be integrated with modern conventional media.

(4) There is need to decentralize radio and television broadcasting using local languages; and

(5) Involvement of various social groups in video, radio and television programming and to highlight the various roles of media personnel, institutions and extensionists to avoid multiplicity of information or duplication of efforts.

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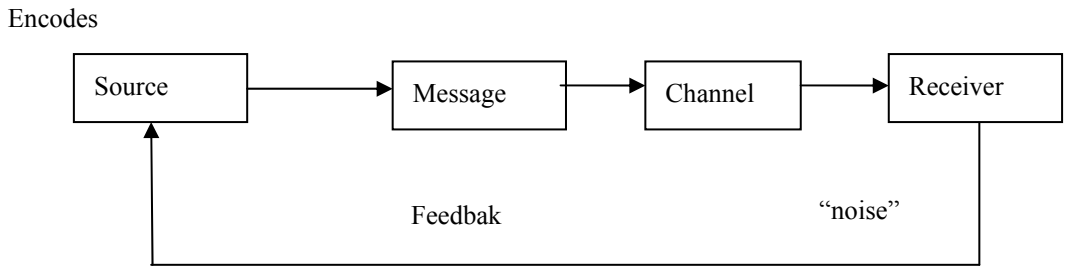

Figure 1. Communication with Feedback

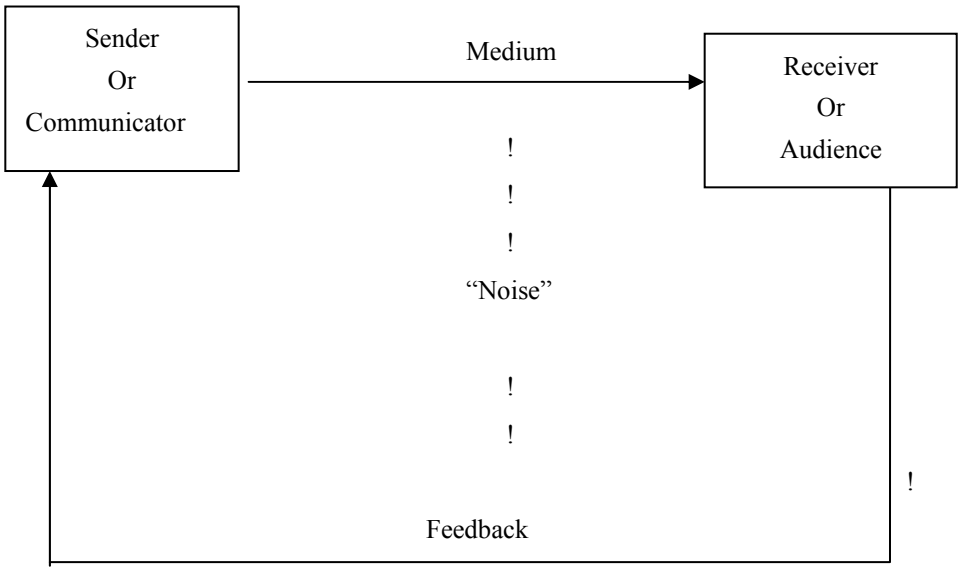

Figure 2. Bittner's Communication Model

Source: Bittner (1989)

Mapping of the Sweet Potato Value Chain Linkages between Actors, Processes and Activities in the Value Chain: A Case of "*Michembe*" and "*Matobolwa*" Products

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Abstract

The objective of the study was to map sweet potato value chain linkages between actors, processes and activities in Tanzania. The study is cross sectional in design.The study was conducted in Shinyanga rural and Mwanza urban districts. The study used individual interviews, focused group discussions; review of relevant practical documents and discussions with key informants. A total of 150 actors in the value chain participated. Data collected was summarized using Statistical Package of Social Science (SPSS) and content analysis. Analysis of data shows that "*Michembe"* and *"Matobolwa"* were two main local made value added products derived from sweet potatoes preferred by producers. In general sweet potatoes production is marked with low production and productivity. Low productivity is a result of poor agronomic practices and low level of production technology application among others. Three main marketing channels exist in the study area: Producers selling directly to consumer; producers to retailers to consumer; and producers to hawkers/village vendors to consumer. Moreover data revealed that (50.7%) of sampled producers set prices after hearing from their fellow farmers. About (44%) of the sampled producers sell their produce direct to the market. The sub sector in general faces a number of structural and technological problems that need immediate attention to revamp agricultural sector development.

Keywords: Sweet potato, *"Michembe"* and *"Matobolwa"*, Value chain, Mapping

1. Introduction and Background Information

1.1 Background to information

Sweet potato *ipomoea batatas* is a major staple food and income source in several regions of Tanzania and elsewhere in East Africa and under-exploited food crops (Ndunguru, 2003). Sweet potatoes are grown in most parts of the country, but main production zones are found in Lake Zone, Southern Highlands and Eastern Zone (URT, 2007).

Because of its versatility and adaptability, sweet potato ranks as the world's seventh most important food crop after wheat, rice, maize, potato, barley, and cassava, as it constitute a substantial source of carbohydrate and carotene (CIP, 2000; FAO, 2002). According to the Food and Agriculture Organization (FAO) statistics, world production in 2004 was 127 million tonnes of sweet potatoes majority of which came from China, with a production of 105 million tonnes**.** Nearly half of the sweet potato produced in Asia is used for animal feed, with the remainder primarily used for human consumption, either as fresh or processed products.

Cognizant, Sub-Saharan Africa produces more than seven million tonnes of sweet potatoes annually, which constitutes 5% of global production (Ewell, 2002). African's top producers of sweet potatoes are Uganda (1.7 million tonnes) and Nigeria (1.6 million tonnes) followed by Tanzania (1.3 million tonnes) (FAO, 2004). Moreover, sweet potatoes play an essential role for food security, especially in those regions prone to drought and with poor soils like Shinyanga and Kagera in Tanzania (FAO, 2004). In contrast to Asians countries, in sub-Saharan Africa, the crop is cultivated mainly for human consumption. African yields are quite low about a one third of Asian yields indicating huge potential for future growth.

Sweet potato is a co-staple in East Africa's densely populated, intensively cultivated mid-elevation farming areas and it is an important secondary crop grown for an expanding unmarked market (FAO, 2004). However its utilisation is remarkably narrow in East Africa. The crop is most often consumed boiled or roasted in the fresh form; however vines are fed to livestock particularly in areas like central Kenya where small-scale dairying in zero grazing management systems is well developed. They are also being used as starter feed and partial milk replacer for young calves (Orodho *et al.,* 1995). The limited range of ways and availability of adapted processing technologies in which sweet potato is utilized in the region seriously undermine the potential benefits of the crop to farmers and consumers and other chain actors.

In Tanzania sweet potatoes are grown mainly for survival, the average yield of sweet potatoes is approximately 5 -6 metric tons per hectare on dry weight basis, however the low yield in Tanzania is caused by many factors including susceptibility to pests and diseases, declining soil fertility, moisture stress, low level of crop husbandry and management and poor accessibility to markets (Nduguru, 2003). However in Zimbabwe the national average yield of the crop is 6 tons per hectare with wide yield variations of up to 25 tons per hectare for sweet potatoes grown under irrigation. While this compares well with Africa's yield average of 6t/ha, it is below the global average yield of 14 t/ha and a yield potential of 18 t/ha (Smith, 2004).

Total production of sweet potatoes in the Lake Zone has reached 100,000 (URT, 2004). In the lake zone Shinyanga and Mwanza Regions is by far the major sweet potatoes production area in Tanzania (*ibid*). Taking into account that Shinyanga rural district have reached around 28 428 MT (DALDO, 2010). However the crop commands both low domestic and international demand, a situation attributed to a poor marketing and distribution system (FAO, 2003). This in part can be attributed to limited consumption, processing and storage options for the crop (FAO, 2003). Moreover in the lake zone of Tanzania traditionally grows sweet potato and it appears that some indigenous post-harvest methods are also practiced. These, however, have not been comprehensively documented.

Literature on use of root and tubers like sweet potatoes value added a product is scanty. "*Michembe"* and *"Matobolwa"* are the value added products derived from sweet potato (Mpagalile *et al.,* 2007). This products looked promising in broadening market potential for wider transect of the Tanzanian community but needed improvement in processing technology, quality and sensory attributes to improve its acceptability.

1.1.1 Value chain analysis

Value chain analysis is a powerful tool for managers to identify the key activities within the firm which form the value chain for that organization, and have the potential of a sustainable competitive advantage for a company. Therein, competitive advantage of an organisation lies in its ability to perform crucial activities along the value chain better than its competitors. The value chain framework of Porter (1990) is "an interdependent system or network of activities, connected by linkages" (p. 41). When the system is managed carefully, the linkages can be a vital source of competitive advantage (Pathania, 2001). The value chain analysis essentially entails the linkage of two areas. Firstly, the value chain links the value of the organisations' activities with its main functional parts. Then the assessment of the contribution of each part in the overall added value of the business is made (Lynch, 2003).

But according to Seminar für Ländliche Entwicklung (SLE) publication series (2008) the value chain is a development concept with two main perspectives (Koenig *et al.,* 2008); Functional role; a value chain is a series of related business activities-starting with a provision of specific inputs, production processing, marketing and finally, consumption and other concept as Institutional perspective; value chain is a set of players/institutions performing function under (a) above which are linked with series of business transaction.

Similarly, Gibbon (2001) described a value chain as a chain of activities, where products pass through all activities of the chain in that order and at each activity, the product gains some value. The chain of activities gives the products more added value than the sum of added value of all activities. The author further observes that it is important not to mix the concept of value chain with the cost occurring throughout the activities. For example, careful sweet potato production, harvesting, handling, preservation, processing and storage activities by

avoiding pests, bruises, cuts may have a cost through the use of agronomical practices including use of pesticides, purchase of special processing and storage facilities but the activity relatively add much of the value of the end products, since sweet potato affected by pests with bruises or broken pieces have lower value than the wholesome ones without damage or bruises.

The ability of a company to understand its own capabilities and the needs of the customers is crucial for a competitive strategy to be successful. The profitability of a firm depends to a large extent on how effectively it manages the various activities in the value chain, such that the price that the customer is willing to pay for the company's products and services exceeds the relative costs of the value chain activities. It is important to bear in mind that while the value chain analysis may appear as simple in theory, it is quite time-consuming in practice. The logic and validity of the proven technique of value chain analysis has been rigorously tested, therefore, it does not require the user to have the same in-depth knowledge as the originator of the model (Macmillan *et al.*, 2000).

The first step in conducting the value chain analysis is to break down the key activities of the company according to the activities entailed in the framework. The next step is to assess the potential for adding value through the means of cost advantage or differentiation. Finally, it is imperative for the analyst to determine strategies that focus on those activities that would enable the company to attain sustainable competitive advantage.

Michael Porter (1990) designed the analysis to examine organizational production and support processes and their contributions towards developing greater competitive advantage. Porter argued that competitive advantage could not be understood simply by looking at a firm as a whole. It stemmed from the many discreet activities a firm performs in designing, producing, marketing, delivering and supporting its product. Over the years firms have used his framework to help them: Identify the actual activities performed by business units; Analyze the value created by these individual activities; Examine how linkages and flows to external buyers and suppliers build value as successive processes occur; Map the exchanges of flows into and out of the organization; Identify activities that are key to success of strategy a and Understand resource allocations with a view to allocating resources in accordance with the contributions of the task to strategic direction. Performing these function, value chain analysis can then be used to identify and strengthen those activities which most contribute to overall strategy while constraining resources allocated and consumed by tasks less critical.

It is fair to say that Porters initial framework adds tremendous value to our ability to understand relationships between buyers and suppliers, but as he admits it has its limitations. Porter advises against "applying value chain analysis at too high a level in an organization." He argues an industry will contain many different segments which imply the need for different processes and which involve different economic relationships and dynamics. Therefore, Porter's value chain analysis works well to assess static relationships between participants, but falls short of letting us understand the dynamics associated with high clock speed industries that continuously redefine their value chain relationships. Understanding these limitations, we set out to analyze the sweet potatoes value chain and create a framework that will allow us to formulate these economic relationships and the dynamics that drive changes within both the device and infrastructure value chain.

In order to conduct the value chain analysis, the company is split into primary and support activities (Figure 3). Primary activities are those that are related with production, while support activities are those that provide the background necessary for the effectiveness and efficiency of the firm, such as human resource management.

The primary activities (Porter, 1985) of the company include the following: Inbound logistics: These are the activities concerned with receiving the materials from suppliers, storing these externally sourced materials, and handling them within the firm. Example, seeds and pesticides from input supplies stockiest. Operations: These are the activities related to the production of products and services. This area can be split into more departments. For example, the operation in case of sweet potatoes industry includes farm preparation (ridging, planting, weeding, harvesting, handling, processing etc; Outbound logistics. These are all the activities concerned with distributing the final product and/or service to the customers. For example, in case of a sweet potatoes industry activity would entail the ways product is sold to customer, customer care costs and handling; Marketing and sales. This functional area essentially analyses the needs and wants of customers and is responsible for creating awareness among the target audience of the company about the firm's products and services. Companies make use of marketing communications tools like advertising, sales promotions etc. to attract customers to their products and Service. There is often a need to provide services like pre-system or after-sales service before or after the sale of the product or service.

Support activities of a company include the following: Procurement. This function is responsible for purchasing the materials that are necessary for the company's operations. An efficient procurement department should be

able to obtain the highest quality goods at the lowest prices. Not applicable in the household level for farming activities; Management. This is a function concerned with recruiting, training, motivating and rewarding the workforce of the company.

Human resources are increasingly becoming an important way of attaining sustainable competitive advantage; Technology Development. This is an area that is concerned with technological innovation, training and knowledge that is crucial for most companies today in order to survive. It is very important for the farmer to be equipped with modern technology in production and processing, packaging of the value added products and Firm Infrastructure. This includes planning and control systems, such as finance, accounting, and corporate strategy etc. (Lynch, 2003) .Famers should be trained on the importance of keeping records of production costs so that they can latter associate with earnings and profit accrued from that particular business. Porter used the word 'margin' for the difference between the total value and the cost of performing the value activities (Figure 3). Here, value is referred to as the price that the customer is willing to pay for a certain offering (Macmillan *et al*, 2000). Other scholars have used the word 'added value' instead of margin in order to describe the same (Lynch, 2003). The analysis entails a thorough examination of how each part might contribute towards added value in the company and how this may differ from the competition.

1.2 Problem Statement and Justification

1.2.1 Problem Statement

Sweet potato in Tanzania ranks twelveth by value and sixth by quantity (FAO, 2007). The crop provides employment and it is important in sustaining food security and livelihood for the rural poor (ibid). Sweet potato in Tanzania is grown as a subsistence crop for food security and as a cash crop (URT, 2005). Mwanza and Shinyanga region are the leading producers of sweet potatoes in the lake zone (URT, 2007). Moreover according to Shinyanga District Agricultural and Livestock Development Officer (DALDO) reported that from 2005/06 to 2009/10 (Table 13) production records show an increasing and decreasing trend (DALDO, 2010).

Like other crop famers, sweet potato farmers depend on rain fed for production and therefore produce at the same time (after the rain season), leading to a surplus of sweet potatoes soon after harvest and to a shortage in the dry season (Anon, 2003). In other words, there is lack of supply coordination between farmers in order to meet continuous market demand. Bulkiness and perishability affects post-harvest system of sweet potatoes as it has a shelf-life of little more than one week after harvesting (Abidin, 2004). Hence is both desirable and necessary to process sweet potato into storable products (Ndunguru, 2001). In other words value addition is necessary if Tanzania is to enjoy higher benefits from the crop. Sweet potatoes are mainly boiled or roasted and very little attempt has been done to make flour or crips (Ndunguru *et al.,* 2003). However what is not well known is mapping of the subsector. Many actors in the value chain are not aware of the many value addition possibilities of sweet potatoes in Tanzania. Before investing in value addition of sweet potatoes, it is important to investigate market potential for sweet potatoes value added products.

1.2.2 Justification

The study is in line with Millennium Development Goals (MDGs) Goal 1: Eradicate extreme poverty and hunger to reduce hunger and poverty. The target 1.A: Halve, between 1990 and 2015, the proportion of people whose income is less than one dollar a day.

Moreover the study is also in line with National Strategy for Growth and Reduction of Poverty (NSGPR) "MKUKUTA" programme in reducing the prevalence of income poverty in Tanzania of which according to the household budget survey of 2000/01 the proportion of population below the national basic needs such as food, shelter and water is 35.7 % (URT, 2005). Interesting the study fit in the current National program known as Comprehensive Africa Agriculture Development Plan (CAADP) signed at Maputo in 2004 by the heads African states, in the country the program will be implemented under Tanzania Agricultural Food Security Investment Plan (TAFSIP) objective is to combat the problem of food insufficiency in African countries.

1.3 Objectives

1.3.1 Overall Objective

The overall objective is to improve the welfare of the rural poor by diversification and expansion of sweet potato value added products.

1.3.2 Specific Objectives

i. To map the sweet potato value chain linkages between actors, processes and activities in the value chain.

ii. To recommend to policy makers on how to promote agricultural value added products.

1.3.3 Research Questions

i. What are the sweet potato linkages/relationship that exists between actors, processes and activities in the value chain?

1.4 Significance of the Study

The following are the significance of the study.

i. The study is important because it acts as a mirror to Tanzania as a whole on looking and assessing market potential of value added products in boosting economy of the rural people.

ii. This study will bring more influence to policy markers on how to review the existing policies for interest of all key actors in marketing of agricultural products.

2. Methodology

2.1 Research Design, Sampling Unit, Sample Size and Sampling Techniques

This study used a cross-sectional in research design. Under this design, data from household's respondents was collected at a single point of time without repetition from the representative population. The study included producers/processors, traders and consumers of sweet potatoes products with various characteristics. Generally, the study covered 150 respondents altogether. The researcher applied two types of sampling procedures namely of simple random sampling and Judgmental /purposively sampling. The sampling unit for this study was constituted of consumers, producers (farmers), processors and traders of sweet potatoes both retail and whole sellers. The sample size was 150 respondents**.** The sample size is reasonably large especially in conformity with Bailey (1994) argument that around 30 cases seems to be the bare minimum for studies in which statistical data analysis is to be done.

A multi-stage technique was used; the first stage involved the selection of wards and villages using purposively sampling technique from which producers and traders was obtained. The choice of wards and villages was based on volume of production of sweet potatoes, accessibility and communication. Selection of wards and villages was done during pre-survey. To obtain the representative sample for the study, purposively/judgmental sampling technique was used to obtain wards. This technique has been recommended in social research by Kothari (2004) as it focuses directly to the area intended to be studied. The second stage was involved selection of different categories of respondents within value added product chain. Both probability and non-probability sampling techniques were employed to select respondents.

2.2 Selection of Producers/Traders

List of potential sweet potatoes producers both small scale and medium scale were obtained from village extension officers formed the basis for selection of sample sweet potatoes producers. In the first stage involve systematic random sampling was used to select respondents from small scale category while purposively sampling was used to select medium scale producers.

2.3 Selection of Traders

Traders were purposively selected from the list of traders obtained from the heads of markets (Chairperson and Secretary) who had names of trading partners and their locations. Hence were purposively selected and interviewed at their premises. Sampling frame of hawkers and their localities was obtained from producers/processors.

2.4 Selection of Consumers

Food products produced within and around Shinyanga mainly reach the consumers through direct producer to consumer sales or via retail outlets such as local market place. This is because production of many of agricultural products depends on crop calendar. Hence random sampling was employed to obtain consumers.

2.5 Methods of data Collection

Both primary and secondary data collection methods were used to obtain sufficient and realistic information and justification to the findings. This method included questionnaires, interviews, observation and documentation. A structured and semi-structured interview was administered to producers/farmer, processors and traders and consumers.

2.6 Secondary Data

These data obtained from literature sources or data collected by other people for some other purposes. Thus secondary data provide second hand information and include both raw data and published ones (Saunders *et al.,* 2000). Secondary data was collected from the following sources; Shinyanga region and District agricultural offices, Sokoine National Agricultural Library (SNAL), Tanzania bureau of statistics, Dar-Es-Salaam university library and other sources relevant to the study and websites was explored.

2.7 Data Analysis and Interpretation

The data collected was analyzed and interpreted to enable readers to understand the results. Data analysis refers to the computation of certain measures along with searching for patterns of relationship that exist among data groups, (Kothari, 2004). The process of data analysis involved editing, coding and interpretation so as to ensure accuracy, and relevancy to the study. Both qualitative and quantitative data analysis methods were be involved. That is, the researcher used descriptions of the facts, to show the relationships of variables. The researcher used tables, graphs and some in charts for the descriptive information in order to make them understandable. Data collected from the primary sources was coded and entered in Statistical Package for Social Sciences (SPSS).

2.8 Sub-sector Mapping Analysis

Sub-sector mapping analysis was used to map the sweet potato value chain linkages between actors, processes and activities in the value chain**.** Visualize networks in order to get a better understanding of connections between actors and processes in a value chain, demonstrate interdependency between actors and processes in the value chain and create awareness of stakeholders to look beyond their own involvement in the value chain (Michael *et al.,* 2010).Qualitative data was analyzed by content/context analysis.

Sub-sector mapping analysis used to map the sweet potato value chain linkages between actors, processes and activities in the value chain. The aim is to visualize networks in order to get a better understanding of connections between actors and processes in a value chain, demonstrate interdependency between actors and processes in the value chain and create awareness of stakeholders to look beyond their own involvement in the value chain (ibid).

2.9 Ethical Contemplation

In this work, a research take into consideration the issue of confidentiality at all the time in the way that unauthorized persons were not in position to have access to the data collected and the identity of the respondents remained on the researcher knowledge, this has been done in efforts of protecting the subjects. The issuer of voluntariness was also observed as respondents participated in the research voluntary no one was forced into participation.

2.10 Data Quality

2.10.1 Reliability

The consistency with which repeated measures produce the same results across time and across observers refers as reliability (Patton, 2000).To ensure reliability, this study employed three methods of data collection namely questionnaires, documentary reviews and interviews.

2.10.2 Validity

Babie (1992) define the term validity to mean that, the extent to which the concept one wishes to measure is actually being measured by a particular scale or index; that is the extent to which an account accurately represents the social phenomena to which it refers. To ensure validity of measures, the data were gathered from various categories of respondents, including producers, processors, traders and consumers of various characteristics. Moreover date was also collected form Shinyanga region and Mwanza region and District agricultural offices, Sokoine National Agricultural Library (SNAL), Tanzania bureau of statistics, Dar-Es-Salaam university library and other sources relevant to the study and websites was explored. Primary data on specific issues of the study coincide with the secondary data.

3. Results

3.1 Introduction

This section presents the results of the study: Results are presented in various forms including percentages, statements, tables and figures. Results presented are based on the objectives of the study and study questions. Discussion follows immediately to interpret the trend shown by the results and the reasons thereof.

3.1.1 Characteristics of Sampled Sweet Potatoes Producers

The results revealed that (42%) of the sampled respondents aged was ranged from 14 years to 68 years and majority of the respondents were in between 31-40 years old (Table 1). This showed that the respondents were in active age to engage in production. Regarding to gender the data revealed that 55.3% were female and 44.7% were male, one can conclude that women engage more in sweet potato production than male (Table 2). Furthermore results in table 3 showed that majority of the household respondents were married (86%) hence married obliged to take care of their family hence participation in farming is compulsory. Regarding to education level (69.3%) spends 4-7 years in schooling (Table 4), hence attain universal primary education. This indicates that most of them were adults who can handle adult's responsibility including farming and livestock keeping for caring their family for livelihood survival.

3.2 Sweet Potato Production and Land Size

Table 5 indicated that farmers produce a minimum of 42 kg to 8 100 kg as maximum of processed sweet potato products. Moreover one bag weighed up (140 - 160 kg) in wet basis after harvesting ready for market. However when if processed can give up to 60kg of processes sweet potato. The main products produced are "*mapalage"* and "*michembe"*. However the same famers consume an average of 12 019 kg per season of processed sweet potatoes. Furthermore majority of farmers owned an average of 1 - 15 acres (85.3%) for farming of all crops hence the area seems to have no problem of land tenure (Table 6). This data appealed that that the produce is not able to sustain even for consumption purposes to lift the farmer to the next harvesting season because consumption is higher than what harvested, hence it is common that majority of household becomes food insufficiency and copping mechanism is to labour out hence they become more vulnerable. If research on sweet potato products is made more effective, perhaps sweet potato can be used to close the African food gap. In Tanzania, according to recent study the average yield of sweet potatoes in Tanzania is 6 metric tons per hectare (6 000kg) on dry weight basis (Smith, 2004). Because of poor market linkages, inadequate information and poor infrastructure, decisions concerning prices of sweet potato products are decided by few players in the value chain. The middlemen, retail traders and end users of sweet potato products control the sweet potato market.

3.3 Value Added Products Derived from Sweet Potatoes

Process flow diagram for producing dried sweet potato chips to "*michembe"* is summarized in Figure 1. Process flow diagram for producing dried sweet potato chips to "*matobolwa"* is summarized in Figure 2.

3.4 Farming Tools

Majority of the sampled respondent used rudimental farming tools especially hand hoe (80.7%) and only (19.3%) of the respondents had used oxen plough for cultivation (Table 7). Uses of traditional technologies in production retard production, efforts are needed to train famers on the use of improved agronomical practices to increase their agri-business profitably. Conversely majority of the sampled respondent used to buy local seeds for planting from their fellow farmers. Although it was noted that few famers used to grow reserved seed in their wet areas.

3.5 Common Seeds/Vines Used

Majority of the surveyed respondents/producers (99%) used a local seeds in production of sweet potato, namely *lyochi, umeme, selena, mwanamakinu, pipi, bugoi, nyahinga, kalamu ya mwinyi, mwanamke hana siri, lukuba, mwana bundala, sinia la mwanza* few to mention. These local seeds were selected for sowing based on the following options; early maturity, potential production (size of the product produces and quantity) and disease resistance. None of the farmers used improved seeds. This implies that efforts are needed to mobilize farmer on the rationale of using improved seeds to boost production.

3.6 Costs for Making Ridges

Cost for making ridges ranged from TAS 1 500 as a minimum to TAS 100 000 per acre while famers used TAS 1 000 to TAS 60 000 is used to plant one acre. Meanwhile harvesting can costs up to TAS 40 000 per acre (Table 8, 9 & 10).

3.7 Market Information

Results presented in table 11 showed that (50.7%) of interviewed sampled producers set prices after hearing form their fellow farmers. Meanwhile (44%) of the interviewed sampled producers said they visit market direct to know the price and one percent of the interviewed producers said they receive price information from NGOs like World Vision Tanzania and other sources. One may conclude that majority of producers sold their sweet potatoes products after hearing from their fellow friends or direct visit to the market.

3.8 Input Accessibility

Survey results showed that 70% of the sampled producers do not have access to or they don't need inputs and extension services for sweet potatoes production. Contrary 19.3% reported to have received extension services from extension officers and the rest from other sources (Table 12). This indicates that farmers had never received extension services from village extension officers hence more effort is needed from Local Government, NGOs and other civil society organizations to support sweet potato sub-sector in order to improve sweet potato production.

3.9 Key Players in the Value Chain

Key players of sweet potato (sweet potato-sector in particular) in Tanzania comprise a number of participants (actors).As described in the manner below.

- Producers/processors
- Small Traders
- Rural hawkers
- Processors
- Retailers
- End users
- Input suppliers
- Local Seed Stockiest

4. Discussion

4.1 Preamble

A product channel refers to route followed by products as it moves from producers to a consumer. Thus value chain analysis is intended to provide a systematic knowledge of the flow of goods and services from their origin (producer) to their final destination (consumer).This knowledge is acquired by studying the participants/key actors in the value chain i.e. those who perform physical marketing functions in order to obtain economic benefit. There are successive functions which have to be performed by market agents/intermediaries through which they achieve both personal and social goals by earnings a personal financial award. In so doing they add value to products and satisfy the consumers needs. The channels, thus, vary in their efficiency e.g. in terms of profitability to actor, quantity moved or transformed.

4.2 Sweet Potato Value Chain Analysis

The sweet potato value chain analysis involved a number of functions and institutions. It has both backward and forward integrations. Small holder farmers as growers are at the central point. Farmers are linked with input suppliers (backward integration). The inputs include sweet potato seeds, fertilizers, and chemicals. Other linkages with sweet potato growers involve oxen and tractors owners who do farm tillage operations for farmers.

After harvesting sweet potato roots (fresh), farmers process to *"Michembe*" and *"Matobolwa"*, a number of routes are involved in the forward integration. In order to reach sweet potatoes consumers, farmers may sell directly to the consumers or sell through the middlemen or village hawkers. Under this route, transporters have a function of transporting fresh sweet potato or value added products to the retailers or consumers. In Shinyanga, producers play a double role as a producer and processor in other hand, processing is done at small scale level and some few farmers do own ox-carts. The current business practice in the dried sweet potato supply chain is through spot transaction relationships between traders, middleman and farmers.

Processors who are producers also have no linkages with suppliers of machineries, utility suppliers, spare parts and packaging materials. There a number of activities involved after production of "*Michembe*", "*Matobolwa*" by processors. The activities include-transporting, retailing and distribution. In many places of Tanzania growers do process products from sweet potato for home consumption in the future use.

Sweet potato products and fresh sweet potato as products have end markets all over Tanzania and all countries around Eastern and Southern Africa (Kenya, Uganda and Burundi).The market trends for the sweet potato products is not fully utilized and local production cannot meet the demand. However in Shinyanga and Mwanza many end consumers prefer processed products. In Nigeria two primarily products were generated locally called *inginyo* and *amukeke*; it is from further processing of these that two secondary products (*amukeke* flour and *inginyo* flour) were derived (Engoru *et al*., 2005).

China is the leading potato producer followed by Uganda and Nigeria. However Tanzania ranked number 6th in the world and 3rd in Africa with production of 1.3 Million tonnes (FAO.2010). Sweet potato is grown throughout the world. However, only about one percent of production enters world trade with Canada, the United Kingdom, France and the Netherlands being the major importing countries. Conversely USA is the largest exporter of Sweet Potato accounting for 35 % of world trade (41 000 MT). Other exporters are China 16 000 MT (12%), Israel is the 3rd with capacity of exporting 12 000 MT (9%), France (7%), Indonesia (6%) and Netherlands (5%). Most of the product is used for table consumption with a small percentage going into industry uses and animal feed (FAO, 2010). Furthermore United State of America (USA) is the leading sweet potato earners with total value of more than 37 million US $ followed by France and Israel (FAO,2010). Surprisingly Tanzania earns about one million US $ from sales of sweet potatoes.

4.3 Key players and their core functions in the value chain

As said earlier in this paper according to SLE publication series (2008) the value chain is a development concept with two main perspectives; Functional role; (i) a value chain is a series of related business activities-starting with a provision of specific inputs, production processing, marketing and finally, consumption and Institutional perspective; (ii) value chain is a set of players/institutions performing function under (i) above which are linked with series of business transaction (Koenig *et al*., 2010).

Key players of sweet potato (sweet potato-sector in particular) in Tanzania comprise a number of participants (actors). As described in the manner below.

Producers: Usually producers of sweet potato sell part of their processed sweet potato to traders or fellow farmers with food shortages within the villages or nearby villages. The amount sold varies by the size of sweet potato fields, amount harvested and food requirement of household (quantities of cereals).

They sell processed sweet potato in auction each Sunday during season and off season the year depending on the household's cash needs. They sell individually in various forms including fresh sweet potato (unpeeled roots) for consumption, dried sweet potato per tin or sack ("*Michembe" and "Matobolwa")* and processed into floor.

Producers who are processors also sell processed products ("*Michembe" and "Matobolwa")* at household home or at the village-open markets (auction) every Sunday to end users consumers. Usually producers have access to marketing information on prices by direct visit to auction or hearing from their fellow friends.

Bargain is mostly on an individual basis. They do not make any pre-arrangement with vendors or traders in selling their sweet potatoes. Also, very interesting story, Producers play a dual role as a processors also, you can't separate characteristics and functions of the two actors.

Rural hawkers: Sweet potato vendors are few in numbers and not widely available in the region but they are not organized in business arena. Rural vendors/hawkers buy dried sweet potato or fresh direct from farmers. They are inadequate by capital and know where to sell. Their major transport means is bicycle and or by hiring handcart or pushcart/ox-carts

Small Traders: Practically no small traders involving in this business. The reason could be due to limited information on production and marketing of sweet potato.

Processors: They are also sweet potatoes growers per see mainly engaged in processing of fresh sweet potato to "*Michembe and Matobolwa"*. At present they have very limited technologies on processing of sweet potato as their raw materials in producing products. The work is done manually at small scale level no idea to scale up the technology. They are not aware of the benefits of the sweet potato products

Retailers: There are both urban and rural retailers involve in selling fresh and /or dried Sweet potato. Their selling points are at town markets, at village centres and along road sides. They buy from farmers or big traders in Kahama or Bukombe Districts. They manage only small quantities such as 300kg (3bags) to 10 000 kg (10bags) of fresh sweet potato per trip for up to 7 days of selling. In additional they process the product at the market place to avoid decaying of the produce due to shorter shelf life. Retailers can buy Sweet potato from farmers

End users/Consumers: Consumers from local and regional markets for the case *michembe* and *matobolwa* and byproducts as livestock feed.

Input suppliers are not vertically integrated with producers, framers normally search seeds for planting from their fellow farmers not from recognized source/agent. There is farm gate levy which producers pay fees before transporting the products to the buyers. However, suppliers of machine, spare parts and packaging materials do not interact with producers/processors at all and R&D is not vested to this crop unlike other roots crops.

Research and Development is important factor that the Tanzania needs to invest for the development of new technology. Commission for Science and Technology (COSTECH) should be capacitate to undertake this role.

5. Conclusion and Recommendation

Results of this study showed a possibility of producing other products from sweet potato. Sweet potato enterprise in Shinyanga District faced different constraints in production and marketing, which limit development and sustainability of the industry. Generally the industry plays a significant role in contributing to social economic development of the people in District. Popularization and promotion work need to target areas that use sweet potato within and outside the study districts. As a way forward in promoting sweet potato utilization, new value-added products are needed to develop newer uses of sweet potato, like "*Michembe" and "Matobolwa".*

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Table 1. Percentage distribution of the age of sampled respondents

Age	Frequency	Percent
28.10	33	22.0
29-39	42	28.0
40-50	58	38.7
51-61	10	6.7
62-72	7	4.7
Total	150	100.0

(Own survey, 2011)

Table 2. Percentage distribution of the Gender of sampled respondents

Age	Frequency	Percent
Male	67	44.7
Female	83	55.3
Total	150	100.0

(Own survey, 2011)

Table 3. Percentage distribution of the of sampled respondents by Marital status

Marital status	Frequency	Percent
Single	17	11.0
Married	129	86.0
Divorced	1	1.0
Widow/widower	3	2.0
Total	150	100.0

(Own survey, 2011)

Table 4. Percentage distribution of the of sampled respondents and Education level of sweet potatoes producers in terms of number of years in school

Number of years	Frequency	Percent
0-3	30	20.0
4-7	104	69.3
8-11	12	8.0
12-15	4	2.7
Total	150	100.0

(Own survey, 2011)

Table 5. Percentage distribution of the of sampled respondents and Amount of sweet potatoes produced, consumed and price

	N	Min	Max	Mean	Std.Dev
Amount of sweet potatoes produced (Kg)	150	42.00	8100.00	767.313	1146.75
Amount of sweet potatoes consumed (Kg)	136	2.50	60000.00	3370.42	12019.00
Price of sweet potatoes (Kg)	31	200.00	140000.0	46070.96	41654.72

(Own survey, 2011)

Table 6. Percentage distribution of the of sampled respondents and Land cultivated of the sample respondents

Land cultivated	Frequency	Percent
1-15	128	85.3
16-30	13	8.7
31-45	4	2.7
46-60	5	3.3
Total	150	100.0

(Own survey, 2011)

Table 7. Equipment/tools possessed and sampled farmers

Farming equipment/tools	Frequency	Percent
Hand hoe	121	80.7
Oxen plough	29	19.3
Total	150	100.0

(Own survey, 2011)

Table 8. Percentage distribution of the of sampled respondents and cost involved in making ridging and planting

	N	Minimum	Maximum	Mean
Cost for making ridges *matuta* per acre	118	1500.00	100000.00	28415.25
Costs of planting per acre	112	1000.00	60000.00	20053.57

(Own survey, 2011)

Table 9. Percentage distribution of the of sampled respondents and Costs of planting and weeding

	N	Minimum	Maximum	Mean	Std.Deviation
Cost of weeding	132	3000.00	60000.00	25757.57	14777.80

(Own survey, 2011)

Table 10. Percentage distribution of the of sampled respondents and Cost of harvesting

	N	Min	Max	Mean
Cost of harvesting	120	7000.00	400000.00	31091.66

(Own survey, 2011)

Table 11. Percentage distribution of the of sampled respondents and Market information

	Frequency	Percent
Direct visit to the market	67	44.7
Cross check with fellow farmers	76	50.7
Hear from friends	4	2.7
From extension officers	2	1.3
From NGO	1	0.7
Total	150	100.0

(Own survey, 2011)

Table 12. Percentage distribution of the of sampled respondents and Input accessibility

	Frequency	Percent
Village extension officer	29	19.3
NGO	2	1.3
Input supplier	14	9.3
No	105	70.0
Total	150	100.0

(Own survey, 2011)

Table 13. Estimated production of sweet potatoes (tonnes) in Shinyanga Rural

Season	Hectors under sweet potatoes	Production (Fleshed Sweet Potatoes)	Production of processed products (dried)
2005/2006	9 427	28 281	9 050
2006/2007	13 379	40 137	12 844
2007/2008	11 243	33 729	10 793
2008/2009	13 399	40 197	12 863
2009/2010	9 476	28 428	9 097

Source: District Agricultural and Livestock Officer (DALDO) office, Shinyanga Rural, 2010.

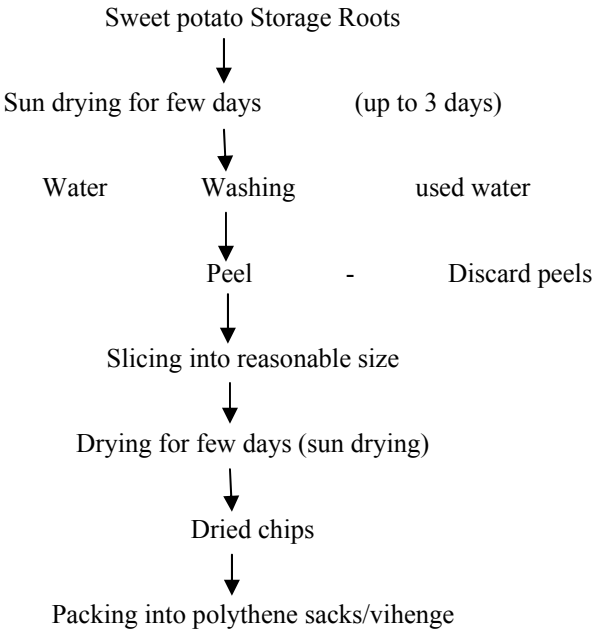

Figure 1. Process flow diagram for producing dried sweet potato chips "*michembe" or "mapalage"*

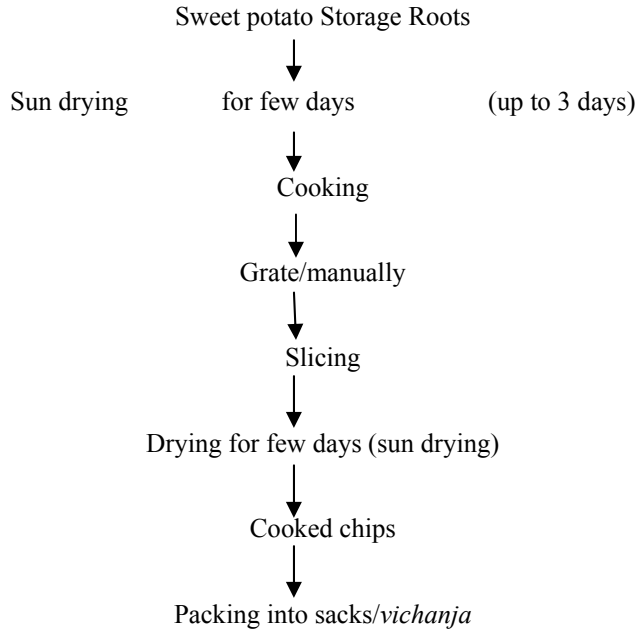

Figure 2. Process flow diagram for producing dried sweet potato chips "*Matobolwa"*

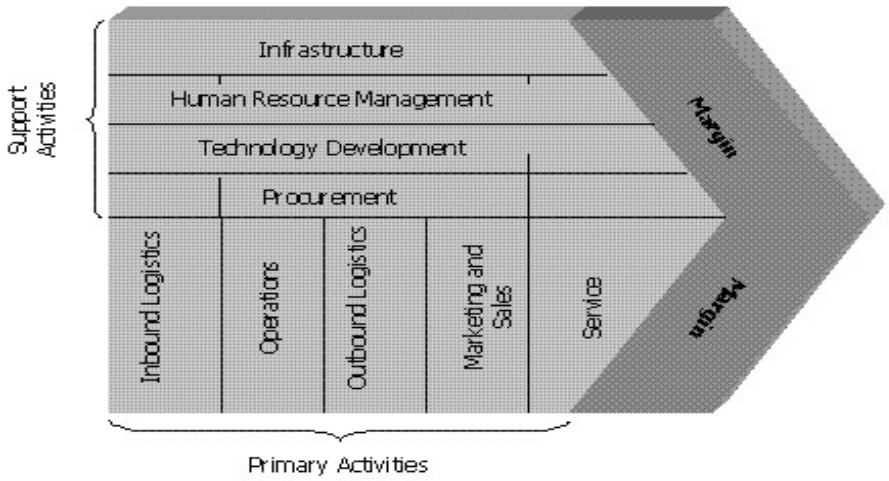

Figure 3.The Value Chain concept

Source: Porter (1985)

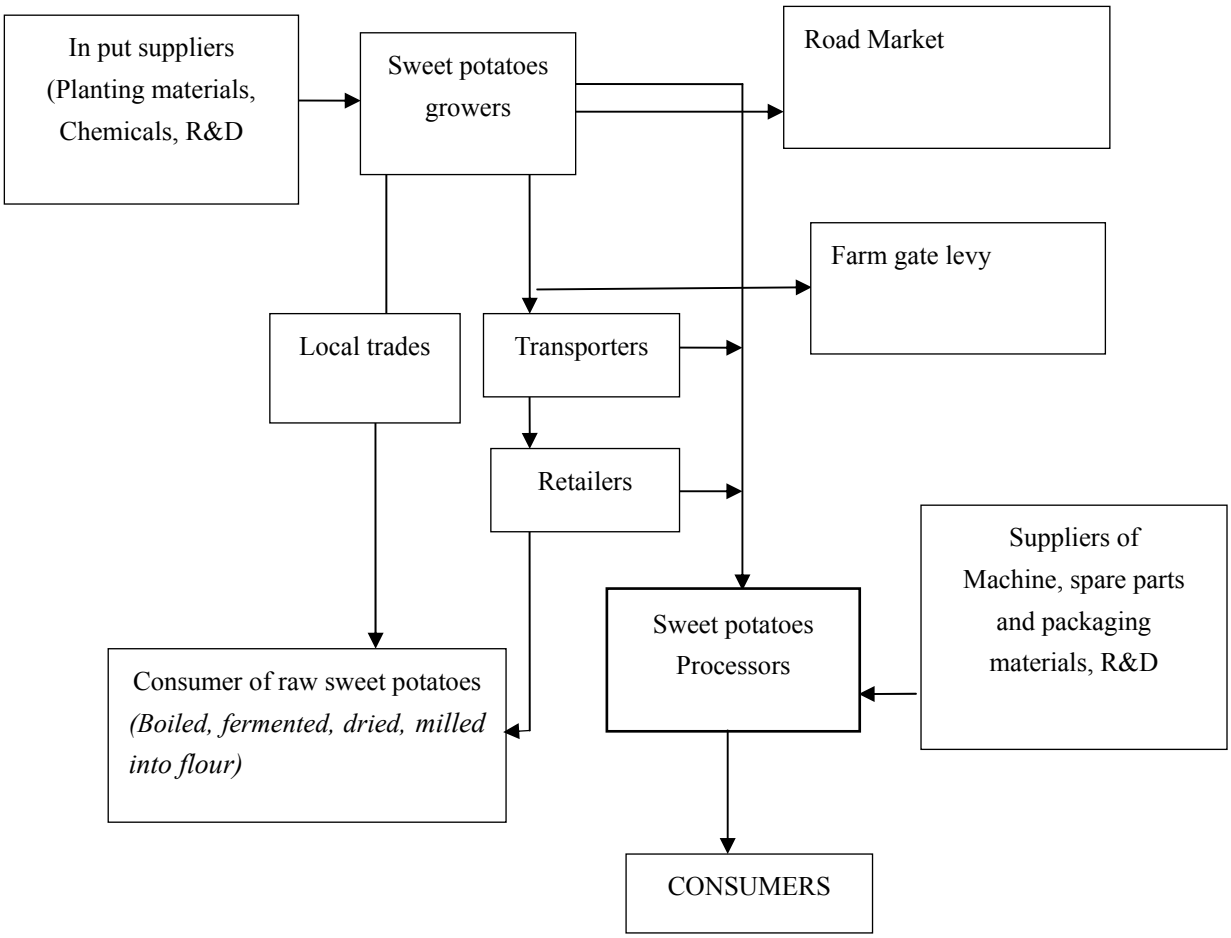

Figure 4. Conceptual framework for sweet potato value chain in Tanzania

Source: Modified from (Mpagalile *et al.,* 2008). Agribusiness Innovation Forum.

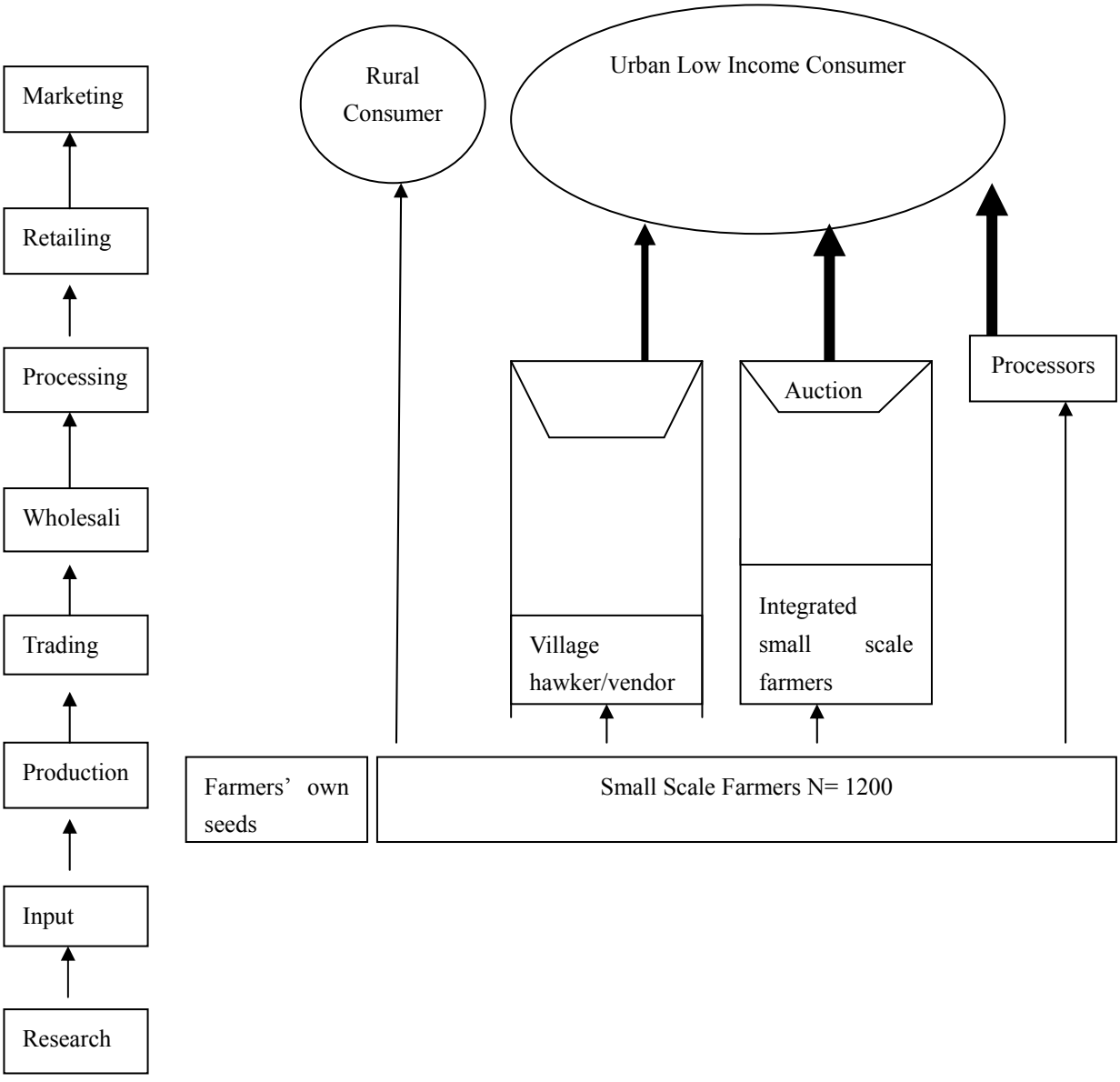

Figure 5. Sweet potato subsector dynamics

Source: Modified from SNV Tanzania. Fresh Fruits Sub sector study Final report July, 2005.

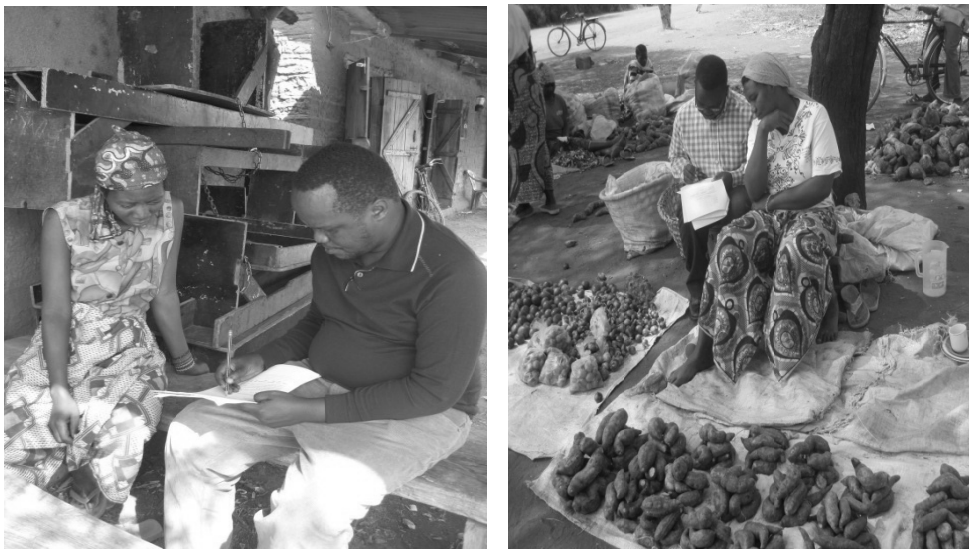

Figure 6. Principal researcher Mr. Joel. J. Mmasa conducting an interview at Iselamagazi village, Iselamagazi wards Shinyanga rural District (Left side picture). Picture in the right side shows researcher assistant Mr. Morgan Brightone conducting face to face interview with retailer at Shinyanga urban market, the picture also shows the bunch of products displayed ready for selling. The produce were sold at TAS 500 to TAS 1 000 per assortment

Figure 7. The picture above shows the woman hired by retailers to prepare “michembe” at the local market place in Shinyanga urban to increase shelf life of the produce

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Response of Broilers to Graded Levels of Distillers Dried Grain

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Abstract

A total of one hundred (100) day old broilers of mixed sexes were used to investigate the effects of graded levels of distillers dried grain on performance, nutrient utilization, and carcass evaluation. The birds were randomly allocated to five treatment groups of 20birds, and were further replicated five times. The five treatments comprised of graded levels of Distiller Dried Grain (DDG) in 0, 10, 20, 30 40% inclusion to replace maize.

Feed intake, weight gain and feed/gain ratio were significantly affected ($P<0.05$) by levels of DDG. Average daily feed intake increased with increasing levels of DDG. Birds fed 40% DDG had the highest (72.90g/bird/day) feed intake while the birds on the control diet had the lowest (68.04g/bird/day) feed intake. Weight gain was significantly affected ($P<0.05$) by dietary DDG. Birds fed 10% DDG had the highest weight gain (27.95g/bird/day). Beyond this dietary inclusion level (10%), weight gain continued to decrease. Birds fed 40% DDG had the lowest weight gain (23.10g/bird/day). Nutrient retention was significantly affected ($P<0.05$) by dietary DDG. Protein and fat retention decreased with increase in level of dietary DDG. These nutrients were retained more by broilers fed 10% dietary level of DDG. Dietary levels of DDG had no significant influence ($P<0.05$) on the relative weight of the different body parts. It was concluded that up to 10% DDG can be used in broiler starter and finisher diet.

Keywords: Broilers, Distillers Dried Grain (DDG), Diet, Nutrient digestibility

1. Introduction

Poultry production has served to meet the protein requirements of the populace through the meat and egg and also provided source of income. It is an industry that has a quick turn-over rate as the generation interval is short. Broiler chickens remain the fastest source of animal protein because of the rapid growth due to their genetic composition and ability to efficiently utilize feed. A major constraint to the industry however, is the availability and high cost of conventional feed ingredients and this has formed an incentive for the continuing search for alternative feedstuff to reduce cost of feed and animal production (Salami, 2000; Hamzat & Babatunde, 2001; Olorede & Ajayi, 2005; Oluremi *et al.*, 2007). Some industrial by-products such as barley or maize grit, Brewer´s Dried Grains (BDG), or their combinations, could serve as the alternative energy source in poultry diet at reduced cost (Olomu, 1988). These byproducts are not directly utilized by humans, they are relatively available and cheap. Barley has large numbers of by-products such as the residues of brewer and beer processing factories (Khalili *et al.*, 2011).

Distillers dried grain is a byproduct of ethanol industry and is primarily fermented grain residues that have been dried. It can be obtained from maize or sorghum. It contains all the nutrients in maize except that most of its starch has been fermented. It has TME of 2820kcal/kg, protein content vary between 20 - 23% (Spiehs *et al.*, 2002; Betal & Dale, 2003).

The present study was conducted to determine the effects of feeding varying levels of DDG as a replacement for maize on the performance of broiler chickens in the tropics.

2. Materials and Methods

A total of 100 day old broilers of mixed sexes were used for the study. The birds were weighed and randomly allocated to five treatments of 20 birds and replicated five times. The treatments consisted of diets formulated using graded levels of distiller dried grain at 0%, 10%, 20%, 30% and 40% inclusion to replace maize. During

the starter phase (4 weeks of the experimental period), the birds were fed a starter diet of 24% crude protein (Table 1) and thereafter, a finisher diet of 20% crude protein (Table 2) for the remaining 4 weeks of the experiment. The birds were housed in deep litter pens and feed and water were provided *ad libitum* throughout the experimental period. Standard management practices and vaccinations were administered.

2.1 Data Collection

Records of feed intake and weight gain were taken weekly from which feed to gain ratio was calculated. Mortality was also observed and recorded. At 7 weeks, three birds per replicate were transferred to metabolic cages, fed *ad libitum* and allowed to adjust to the cage for 4 days, after which nutrient retention trial was carried out using total collection method. Proximate compositions of feed and feacal samples were determined using the methods of A.O.A.C. (1990). At the end of the feeding trial, 4 birds were randomly selected from each treatment, weighed and slaughtered. The birds were then dissected and eviscerated for carcass evaluation.

Data collected for the various parameters were subjected to analysis of variance using the completely randomized design according to Steel and Torrie (1980). Differences between means were separated using Duncan's Multiple Range Test (Duncan, 1955).

3. Results and Discussion

Table 3 shows the results of effects of treatment on the performance and nutrient retention of broilers. Feed intake, weight gain and feed/gain ratio were significantly affected ($P<0.05$) by levels of DDG. Average daily feed intake increased with increasing levels of DDG. Birds fed 40% DDG had the highest (72.90g/bird/day) feed intake while the birds on the control diet had the lowest (68.04g/bird/day) feed intake. This trend was also observed for the feed/gain ration. DDG has been reported as a low energy feedstuff with high fibre level. High dietary fibre (feed diluents) has been reported to decrease nutrient utilization (Bolu and Balogun, 1998). In the same vein, Onifade and Babatunde (1998) reported increased feed intake with increasing levels of dietary Brewers Dried Grain (BDG). Birds have been reported to eat to satisfy their energy requirements (NRC, 1994). Birds fed 10% DDG had the best feed/gain (2.49). Lumpkin et al (2004) recommended 10 -12% dietary DDG inclusion in broiler diets since higher inclusion levels resulted in lower feed utilization. Weight gain was significantly affected ($P<0.05$) by dietary DDG. Birds fed 10% DDG had the highest weight gain (27.95g/bird/day). Beyond this dietary inclusion level (10%), weight gain continued to decrease. Birds fed 40% DDG had the lowest weight gain (23.10g/bird/day). Higher dietary fibre resulting from increasing levels of DDG may have decreased nutrient availability and consequently, weight gain. Nutrient retention was significantly affected ($P<0.05$) by dietary DDG. Protein and fat retention decreased with increase in level of dietary DDG. These nutrients had highest retentions for broilers fed 10% dietary level of DDG.

Table 4 shows the effect of treatment on carcass characteristics of birds. Dietary levels of DDG had no significant influence ($P<0.05$) on the relative weight of the different body parts and this is in agreement with Noll *et al* (2005) who reported that inclusion of DDG had no effect on meat yield of turkey.

4. Conclusion

Inclusion of DDG in the diet of broilers at10% had no negative effects on performance and nutrient digestibility of broilers. DDG is an agro-allied by-product, its use poultry diet will reduce pressure on conventional feedstuffs, cost of feed and profit accruable to production.

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Table 1. Composition of Starter Diet (g/kg)

Ingredient	**0%**	**10%**	**20%**	**30%**	**40%**
Maize	50.00	50.00	48.00	48.00	40.00
DDG	0.00	10.00	20.00	30.00	40.00
Maize bran	6.50	4.50	1.50	1.50	-
Soyabean meal	5.00	5.00	5.00	5.00	5.00
Groundnut cake	24.00	20.00	10.00	5.00	4.50
Fishmeal	9.00	5.00	10.00	5.00	5.00
Palm Oil	2.00	2.00	2.00	2.00	2.00
Bone meal	1.25	1.25	1.25	1.25	1.25
Oyster shell	1.40	1.40	1.40	1.40	1.40
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Vitamin/Mineral Premix*	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00

*Premix supplied per kg of diets; Vitamin A: $8X10^6$ IU, Vitamin D_3: 1500IU, Vitamin E: 10IU, Vitamin K_3: 1.5mg, Vitamin B_1: 1.6mg, Vitamin B_2: 4mg, Vitamin B_6: 1.5mg, Vitamin B_{12}:0.0mg, Niacin: 20mg, Pantothenic acid: 5mg, Folic acid: 0.05mg, Biotin 0.75mg, Choline Chloride: $1.75X10^4$ mg, Cobalt: 0.2mg, Copper: 0.2mg, Iodine: 1mg, Iron: 20mg, Manganese: 40mg, Selenium: 0.2mg, Zinc: 80mg, Antioxidant: 1.25mg.

Table 2. Composition of Finisher Diet (g/kg)

Ingredient	0%	10%	20%	30%	40%
Maize	50.00	50.00	48.00	48.00	45.00
DDG	0.00	10.00	20.00	30.00	40.00
Maize bran	9.50	7.50	2.50	0.50	2.00
Soyabean meal	5.00	5.00	5.00	5.00	5.00
Groundnut cake	30.00	22.00	19.00	11.00	7.50
Palm Oil	2.00	2.00	2.00	2.00	2.00
Bone meal	1.25	1.25	1.25	1.25	1.25
Oyster shell	1.40	1.40	1.40	1.40	1.40
Methionine	0.10	0.10	0.10	0.10	0.10
Lysine	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Vitamin/Mineral Premix*	0.25	0.25	0.25	0.25	0.25
Total	100.00	100.00	100.00	100.00	100.00

*Premix supplied per kg of diets; Vitamin A: $8X10^6$ IU, Vitamin D_3: 1500IU, Vitamin E: 10IU, Vitamin K_3: 1.5mg, Vitamin B_1: 1.6mg, Vitamin B_2: 4mg, Vitamin B_6: 1.5mg, Vitamin B_{12}:0.0mg, Niacin: 20mg, Pantothenic acid: 5mg, Folic acid: 0.05mg, Biotin 0.75mg, Choline Chloride: $1.75X10^4$ mg, Cobalt: 0.2mg, Copper: 0.2mg, Iodine: 1mg, Iron: 20mg, Manganese: 40mg, Selenium: 0.2mg, Zinc: 80mg, Antioxidant: 1.25mg.

Table 3. Effect of graded levels of DDG on feed intake, weight gain, feed to gain ratio and nutrient retention of broilers

DDG (%)	Feed intake (g/bird/day)	Weight gain (g/bird/day)	Feed: Gain Ratio	Fat retention (%)	Fibre retention (%)	Protein retention (%)
0	68.04^a	24.22^a	2.50^a	89.38^d	57.98^b	68.65^c
10	69.25^b	27.95^c	2.49^a	87.07^c	62.99^c	64.46^{bc}
20	71.55^c	25.74^b	2.82^b	86.63^{bc}	63.29^c	59.44^b
30	70.79^d	26.30^b	2.90^b	77.83^a	53.47^a	47.99^a
40	72.90^e	23.10^a	3.15^c	85.49^b	57.52^b	50.97^a
S.E	0.29	1.36	0.21	0.97	1.66	1.55

a,b,c,d,e: Values in the same column with different superscripts are significantly different (P<0.05)

Table 4. Effects of Graded Levels of DDG on Carcass Characteristics of Broilers (g/100g body weight)

DDG (%)	Dressed weight	Head	Back	Wings	Breast	Gizzard	Thigh	Drumstick	Liver
0	1440	49.60	252.55	148.50	211.75	36.50	181.70	171.30	33.50
10	1380	45.45	216.15	152.15	196.30	32.20	160.90	147.70	32.20
20	1340	42.85	176.75	147.60	168.85	28.45	151.70	154.80	28.45
30	1290	41.45	202.55	135.45	196.85	26.50	145.40	145.40	26.50
40	1490	51.20	253.65	153.10	244.30	36.10	193.75	170.40	36.10
S.E	0.096	3.48	19.35	15.32	30.45	4.30	16.86	18.54	12.75

Values were not significantly different (P<0.05)

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Modeling Spray Droplet Size in Order to Environmental Protection

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Abstract

Million liters of annual toxic solutions are used to combat pests and plant diseases and weeds in farms. Drift is one of the most critical problems which chemical applicators have to deal with. Wind drift would be highly controlled if the droplet size could be kept almost constant in stable atmospheric conditions.The most important factor in spraying is droplet size which is influenced by several factors including; spraying pressure, nozzle orifice diameter, the chemical viscosity and wind speed in the region. In this study factors affecting particle size have been studied using statistical methods. Nozzle orifice diameter and spraying pressure were considered as independent variables and particle size was chosen as the dependent variable. Analysis of variance showed that the effect of pressure and nozzle diameter and their interactive effect on particle volume mean diameter (VMD) were statistically significant at the 1% level. In order to compare the results estimated from regression equations and observed particle diameter chi-square test was used. Based on this test, the difference was not significant .

Keywords: Maintaining, Particle size, Pressure, Spraying

1. Introduction

Each year about 25 to 35 percent of total world agricultural crops be devastated by insects, weeds and plant pathogenic. This amounts increase to 80 percent in non-combat status(Mansourirad, 2005). Drift (toxin movement by air currents) of the distributed place may lead to contamination of nearby crops that are grown for human consumption or animal. Droplet size and distribution of pesticides are the main factors that will determine the treatment efficiency. Liquid pesticides may be contact or absorption type. With Contact pesticides, pets are disappeared. To have full effect this material is better to be distributed as fine particles at all levels. Absorbed

toxins are absorbing by the organs of the plant and move within theirs. These materials do not need to be sprayed at all levels. They are better to be in a coarse size. They are less susceptible to drift.

Use of pesticides, has improved quality and quantity of products, but the widespread use of chemical pesticides has resulted to some serious environmental issues. One of the most critical issues is movement of pesticide droplets that happens by air travelleing during or after spraying to elsewhere other than the desired location. Pesticide residues can be removed from products by surface water ,waste and air containing these substances into the environment. Problems with this issues can be reduced if pesticides are applied by controlling particle size in accordance with purpose of spraying and environmental conditions and climate while decreasing contamination to the environment. Determining and applying desired droplet spectrum for any purpose is desired. Fine particles are slower deposite than the coarse particles due to be having larger aerodynamic drag forces than the particle mass. Movement of pesticide will become even more dangerous in the future when applicators use more genetically modified crops owing to small amount of these herbicides can result serious damages on neighboring crops. (Zhu, 2005). Determining and applying the desired droplet spectrum for each targeted pest can help us to mininize the spray dirift and problems that followed by.

Droplet size spectrum has been considered as the variable that has the most influence the wind movement of spray droplets (SDTF, 1997).

Water-sensitive papers (wsp) are often used as an indicator for the presence of spray deposition Water in the spray stains the wsp and the spot size can be observed or measured (Syngenta, 2002). Womac *et al*. (1997) reported that droplet spectrum varies with every combination of tip style, size, operating pressure, and spray liquid. Some spray deposition tests use water-sensitive papers (wsp) as an indicator of the spray droplet spectrum (Matthews, 2000).

Another issue is that the smaller particles instead of depositing in the target sites may be travelling and scattering several thousands away. Also vaporized chemical active ingredients in the atmosphere may sever this happening that ultimately lead to more pollution in environment. So It is better to use the appropriate spectrum of the droplets size due to good coverage and minimize drift.

The median diameter of particles based on the number, length, surface or volume can be divided into two equal half. Usually D_{xf} be used for the median diameter. Where instead of x can be placed V for the volume, A for the area, L for the length or N for the number of drops and the f is percentage of the cumulative frequency. (VMD=$D_{V0.5}$) is the volume median diameter that means 50% of the volume of the particle diameter is less than the median and 50% of the particles is more than the median.

Farooq *et al*. (2001) studied the spray from an agricultural flat fan nozzle in a wind tunnel with a non–uniform crosswind velocity profile to examine the movement of the droplets in the wake of the spray pattern. the pressure and mean cross wind were 275 kPa and 5 km/h. The results indicate droplets <100 μm diameter were separated from large droplets and moved downwind.

Womac and Bu (2001) in order to operate with variable-rate technique designed a sample nozzle was as VFFN. Three examples of this type of spray nozzles with angles of 50, 70.90, was built and evaluated. With pressure adjusting of 138 to 414 kPa, ranges of $D_{V.5}$, $D_{V.1}$ and $D_{V.9}$ Was controlled from 190 to 58 mm, 522-141 mm and 850-300 mm respectively. Direct control of flow rate and droplet size spectrum was achieved by separately varying line pressure and control pressure.

Wolf *et al*. (2009) concluded that nozzles with smaller droplet spectra tend to have better coverage and deposition. He used water sensitive paper (wsp) for collectting spray droplets. Flow rate for Laboratory comparisons of nozzles was 0.95 L/m. Operating pressures were 193, 276 & 483 kPa. He found significant differences between all three droplet characteristics. The venturi TTI11002 at 483kPa had the largest $D_{V0.5}$ and least coverage .The XR11003 nozzle at 193 kPa had the smallest $D_{V0.5}$ and most coverage.

Zhu *et al*. (2005) has offered a computer program(DRIFTSIM) to estimate the mean drift distances of the water particles discharged from atomizers on field sprayers. The effect of various parameters like wind speed, particle diameter and height of pesticide spraying on the drift is obtained with a flow simulation program (FLUENT).

2. Materials and Method

During application it is desired to keep the particle size constant which affects drift and amount of chemical on the target In this study effect of spray pressure and nozzle orifice diameter on volume median diameter was obtained from the regression equation. No known study is available on the effect of pressure spraying and nozzle orifice diameter on spray droplet size. For this study the use of a full spraying circuit was inevitable. the primary

step in this research is design and fabrication of full spraying circuit. The system included an electropump(source of the power), specific nozzles (different in exit diameter) and the test panel.

According to previous studies, the maximum pressure spraying was considered 5 bar. Water was used as chemical application. The plastic hose was used for liquid transfer. Dynamic viscosity of water is 0.98 Mpa.s. By according to the specifications of nozzles (corresponding to the maximum pressure) maximum flow rate was achieved (Tabel 1). Profile nozzles are shown in Table 2. Three solid cone nozzles were used**.** Maximum pressure of the nozzles was 40 psi in the equivalent of 2. 785 bar. In 5 bar pressure, 5.765 liters per minute was gain as maximum flow rate. Usually there are no leaks in the new system. To ensure safety 20% of the maximum flow rate was accounted as leakage. Flow rate obtained at a pressure of 5 bar was multiplied at 1.2 to calculate the total flow rate. Reynolds number was obtained by the equation1 (Behrouzilar, 2000).

$$\mathrm{Re} = \frac{4.c'.\rho.Q}{\pi.\mu.d} \quad (1)$$

R_e: The Reynolds number

ρ ($\frac{kg}{m^3}$): Specific gravity of fluid

C': Unit conversion constant equal to 16.67

Q($\frac{L}{\min}$) : Current through the conductor

μ(mpa.s): Viscosity of the fluid dynamics

d(mm): The inner diameter of the conductor

Total length of using hose was 370 cm with 15 mm as inner diameter. The Reynolds number was gained 9993.76. because of the being the Reynolds number more than 4000 the flow was considered as turbulent. For fully turbulent flow, pressure drop was calculated from the equation 2 (behrouzilar 2000).

$$\frac{\Delta p}{L} = \frac{/0333\mu^{0/25}\rho^{0/75}Q^{1/75}}{d^{4/25}} \quad (2)$$

Δp (MPa): pressure decrease

L (m): Conductor length is equal to the pressure drop occurred in

$$\Delta p_1 = 6/424\ kPa$$

Transmission path consists of the right hose and four siphon hose. According to Hydraulic laws , equivalent length and pressure drop data for the siphon hose was obtained (Dalayeli & Madineh):

$$L_e = 154/141\ cm$$
$$\Delta p_2 = 2/675\ kPa$$

The maximum total drop pressure added pressure spraying (5 bar) to calculate the total pressure.

$$\Delta p = 6/424 + 2/675$$
$$\Delta p = 9/099\ kPa$$

Total pressure of the system was set up by:

P=50+9 /099

P=59 /099 kPa

In this device transmission was done directly from the Electro pump. A pump power was calculated by pressure spraying and the mechanical efficiency. Mechanical efficiency of pumps that can be used to estimate this power is usually considered 60-50%. The equation 3 was used for the pump power (Behrouzilar, 2000).

$$P = \frac{Q*p}{60000*\eta_m} \quad (3)$$

P = 118/198 kPa

P (kW): power

Q $(\frac{L}{\min})$: flow rate

p (kPa): pressure

η_m: Mechanical efficiency

power for the total pressure can be obtained as follows:

Power =13/628 W

The electro pump was selected with regard to Market Features and Calculations obtained (figure1).

Profile pumps are :

Maximum height (pressure) = 45 m

Max Flow = 50 (L / min)

Production capacity by electro pump was obtained by equation 4.

$$P = Q * \rho g h \quad (4)$$

P = 367 W

So the prepared Electro pump can easily privide the test operations.

After making this device, tests were performed to determine the mathematical relations between independent variables and the dependent variable (tabel 3). After preparing the test panel, nozzle hight was set in 75cm. The pressure for each treatment was created by using a flow control valve. pressure gauge were used to monitor the pressure for each treatment. The treatment solution was tap water. The exit nozzle diameter and pressure were regarded as independent variables and particle size as the dependent variable. Each factor with three levels were evaluated in a factorial experiment with five replications. Experiments were done in 24 ºC environmental temperature and 40% humidity(Accordance with the the average summer condition in East Azarbaijan in Iran). With the use of special papers (wsp) on the table, samples were collected. After all treatments and replications were completed and dried, the collection papers were placed in prelabeled-sealable bags for preservation. Data envelopes were used to organize and store the papers until analysis was complete. Water-sensitive papers were scaned with HP Scanjet 3800 scanner by 300 dpi resolution. Marcal and Cunha (2008) evaluated a fully automated method based on image processing to improve water quality and sensitive to the toxins in papers. Scan samples were tested with different resolution **.**The maximum scanning resolution was gain in 600 dpi. By consideration the scanner features and a proper speed of processing, 300 dpi resolution was chosen. SIBA software was used to analyze the papers. The software is used on the prestigious research centers such as East Azarbaijan Engineering Research Center. Output data analysis display on the Notepad page. Analysis of particle numbers, the number of pixels for each particle, particle surface area per mm^2, and the center coordinates of particle diameter is based on mm. Statistical analyses of the data were conducted with spss software Statistics 18.

3. Results and Discussion

Pressure and nozzle diameter were considered as independent factors and VMD (volume median diameter) as independed factor. Significant differences were found in volume median diameter ($D_{V0.5}$) for the three nozzles and three pressure levels. The data obtained had normally distribution in accordance Kolmogorov-Smirnov test. Kolmogorov-Smirnov test is based on the maximum absolute difference between the observed cumulative distribution functions for both samples. When this difference is significantly large, the two distributions are considered different (help of spss 18 software). The analysis of variance on pressure and nozzle orifice diameter versus VMD is shown in Table 4. Effect of each factor alone and their interaction was significant in the level 1% probability. Graph of the interaction showed the differance is the kind of change in value (figure 2).

At high pressure particles size were smaller than low pressure. Between different exit diameter of the nozzle there was a significant difference in VMD. Most VMD was obtained in the nozzle with 3.2 mm in hole diameter and its minimum was obtained in the nozzle with 1.6 mm. In hole diameter VMD range was obtained from 130 micrometer in the nozzle with 1.6 mm in hole diameter at 5 bar pressure to 885 micrometer in the nozzle with 3.6 mm in hole diameter at 4 bar pressure. VMD mean at different pressure levels and exit nozzle diameter can be seen in table 2. In this study, a linear modle express relation VMD with the nozzle exit diameter and pressure according to the treatments. Equation obtained for the mean volume diameter (Y) and pressure spraying (X1) and the nozzle diameter (X2) is:

$$Y= -95.60x (X1)+155.192x (X2)+ 518.269$$

Coefficient of determination in above equation was obtained (r^2=0.834). Standardized coefficient associated with the nozzle diameter was much greater than pressure . Thus the nozzle diameter had more effect on particle size than spraying pressure. The most amount of VMD was obtained in largest exit diameter nozzle at 4 bar spraying pressure (table 5). As evidenced in this study for a constant diameter nozzle, increasing pressure led to reduced droplets size. Difference between pressure 3 and 4 bar was significantly but between 4 and 5 bar was not dramatically different. For a constant pressure, by increasing nozzle exit diameter, particles size increased. Significant differences were found in pressure 3 and 5 bar on nozzles with 2.4 and 3.2 mm exit diameter but in pressure 4 bar there were uniformity difference among nozzles with different exit diameters. Considering the effects of each nozzle, pressure has less effect on volume mean diameter in nozzles with larger exit diameter.

Another finding of interest is that max VMD has occurred in 4 bar and the nozzle with 3.2 mm exit diameter. The results of Womac and Bu experiments showed that the volume mean diameter in the range 141-522 mm with a working pressure range 138-414 kPa was controlled. In the studies of Wolf *et al.* volume diameter was smallest of the XR 11003 nozzle with the smallest diameter of the nozzle 12 in working pressure of 483 kPa. VMD was the largest of the TTI 11002 nozzle that had the largest diameter in the rest of the nozzles at a pressure of 483 kPa. this nozzle had the minimal overlap and deposit in comparison with others. Womac and Bu achieved in the nozzles VFFN a linear relationship for the flow rate in VMD by using different working pressures. Coefficient for this equation was obtained at different pressures could be seen in Table 6.

$$D_{V0.5}=(\text{slop}).\ Q + \text{intercept}$$

As can be seen above the maximum working pressure coefficient has been obtained in maximum pressure.

After deriving the mathematical model, spraying system was adjusted based on that model and more tests were conducted to evaluate the model. In order to compare the results estimated from regression equations and observed particle diameter chi-square test was used. Based on this test, the difference was not significant. The minimum and maximum error were observed for the nozzle diameter 2.4 and 3.2 mm respectively. In nozzles with larger diameter, the error was higher due to adhesion of particles in water-sensitive cards. The results show that changing the pressure (due to the change in flow rate) particle size can be controlled. this is one of the most important issues in precise spraying. Different particle size (for any possible reason) can be diagnosed. Selecting appropriate nozzles and spraying pressure to obtain the desired particle diameter in every working conditions can prevent excess intake spraying. In addition drifting which has heavy reliance with Particle spectrum can be prevented.The diagrams obtained from the research of Zhu *et al.* showed that in particles with the range of 250-300 mm in any wind speed at 75 degrees Fahrenheit and 60% humidity environment, the drift distance was very small. Particles with a diameter of 50 mm had the maximum drift and particles with a diameter of 200 mm had the lowest drift.

4. Conclusions

Chemical pesticides had and will have a great role in the improvement of agricultural productions. By using these chemicals, quality and quantity of products are incremented. Using pesticides to control weeds have greatly reduced workforce. However, widespread use of chemical pesticides have resulted in some serious environmental issues. In order to reduce these destructive effects on the environment, some necessary actions should be carried out. Certainly, the most important issue is the control of particle size. Standardized coefficient associated with the nozzle diameter was greater than spraying pressure. So the nozzle orifice diameter had more effect on particle size.

The results of this study, considering droplet sizes, showed that nozzles with smaller exit diameter could produce smaller drolet size and higher spraying pressuretend to provide smaller droplet sizes. According to data from experiments droplets spectrums generally can be controlled by adjusting sprying pressure. This is one of the most complex issues in spraying with variable rate (VRT) that in modern agricultural is in special attention**.**

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Table 1. Pressure and flow characteristics of nozzles used in the experiment

30-DC-04	30-DC-06	30-DC-08		pressure (psi)
1/11	1/55	2/33	flow rate	20
1/36	1/89	2/73	(L/min)	30
1/59	2/20	3/18		40

Table 2. Profile of nozzles used

figure	Exit diameter nozzle	Nozzle number	Nozzle type
	3.2mm	DC- 08-30	White nozzle
	2.4mm	DC- 06-30	Yellow nozzle
	1.6mm	DC- 04-30	Red nozzle

Table 3. Different levels of experimental factors

levels	factor
P1=5 bar	Pressure spraying(P)
P2=4 bar	
P3=3 bar	
D1=1.6 mm	Nozzle diameter (D)
D2=2.4 mm	
D3=3.2 mm	

Table 4. ANOVA output pressure and nozzle diameter on a volume mean diameter

F	Mean Square	Degree of freedom	Source changes
**73.299	142214.668	2	Pressure(P)
**125.144	242804.470	2	nozzle orifice diameter (D)
**5.649	10961.058	4	P*D
	1940.195	36	Test Error

**Significant at one percent level

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Table 5. VMD mean in different levels of each factor

Average value	Factor levels	Factor
423.400	5(bar)	
486.987	4(Bar)	pressure
614.600	3 (bar)	
11.37 = LSD $_{0.05}$		
400.277	1.6(mm)	
476.227	2.4(mm)	nozzle orifice diameter
648.933	3.2(mm)	
11.37 = $_{0.05}$ LSD		

Table 6. The coefficient of the equation in different pressure obtained by Womac and Bu

pressure	slope	intercept	r^2
138	13.99	554	0.857
207	26.16	408	0.805
276	35.45	297	0.868
345	34.63	225	0.853
414	34.24	169	0.940

Figure 1. Fabricated sprayer device

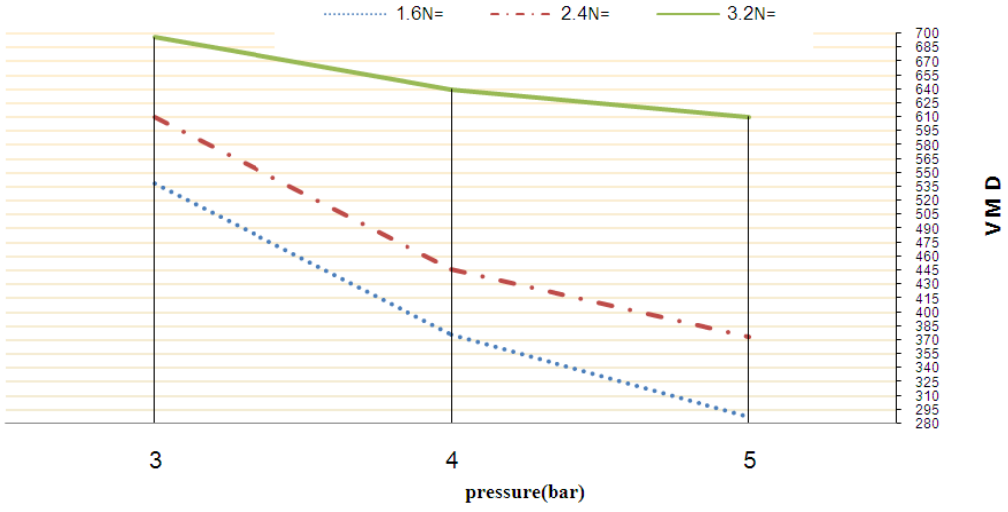

Figure 2. The effect of pressure and nozzle exit diameter on VMD

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